

## Catalyzing the Adoption of Entrepreneurship Education in Engineering by Aligning Outcomes with ABET

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## Abstract

Economic trends and a changing job market for college graduates have generated significant interest in graduating more engineers who possess entrepreneurship skills and an entrepreneurial mindset. This has led to significant growth in the delivery of entrepreneurship courses to engineering students; however, research shows that such courses are typically part of minors and certificates, and not part of core engineering curriculum. The Accreditation Board for Engineering and Technology (ABET) establishes criteria for accrediting engineering programs and is a significant force in shaping the undergraduate curriculum. We propose that a more clear and concrete demonstration of the alignment of entrepreneurship education outcomes and ABET Criterion 3a-k, which involve both technical and non-technical skills, would catalyze the integration of the entrepreneurial skills and knowledge into engineering courses. Furthermore, direct assessment of entrepreneurial outcomes could aid in improving the mechanisms of achieving both ABET accreditation and the development of an entrepreneurial mindset among engineering students.

## Introduction

In recent years, the value of entrepreneurial skills and an entrepreneurial mindset to contemporary college graduates has been well documented. Global economic and workforce trends have driven the need for engineering students to possess a broader range of skills so that they can generate value and succeed in an environment where innovation and entrepreneurship are seen as the primary drivers of economic growth. This has led to increased interest in and delivery of courses and programs focused on innovation and entrepreneurship education that are accessible to engineering students. Delivering this education is achieved either by embedding innovation and entrepreneurship concepts and practice into engineering curricula, or through non-engineering based courses, minor and certificate programs to which engineering students have access (Shartrand, Weilerstein, Besterfield-Sacre, & Golding, 2010). Despite an increasing understanding of the value of entrepreneurship education to engineering graduates, research shows that actual delivery is still not yet widespread or institutionalized in the undergraduate engineering curricula (Duval-Couetil, Reed-Rhoads, & Haghghi, 2012; Shartrand et al., 2010).

Given that ABET has long been a major driver of change in engineering curricula, we propose that demonstrating the manner in which entrepreneurship education can align with ABET accreditation requirements can drive wider adoption by faculty of entrepreneurship-related knowledge and skills. Scholars have outlined challenges associated with teaching and assessing ABET Criterion 3a-k and many engineering programs are currently seeking more effective ways to meet requirements for accreditation (Felder & Brent, 2003; Shuman, Besterfield-Sacre, & McGourty, 2005). The authors have conducted preliminary research, which was supported by a small pilot grant awarded through the Stanford University Epicenter. This work consisted of: 1) developing a rationale for aligning entrepreneurship education with ABET Criterion 3a-k, and 2) conducting preliminary research which resulted in a preliminary list of 52 entrepreneurship

outcomes in 4 major categories or content areas. Results and dissemination of this work at various conferences and meetings suggest that there is significant interest and support among engineering faculty and administrators in pursuing such an approach.

### **Importance of the Problem**

A number of economic forces and workplace changes have contributed to the need to graduate engineers with both technical knowledge and an entrepreneurial mindset and skills. These changes include a slowing economy where innovation and entrepreneurship are seen as the primary drivers of economic growth, increased global competition for jobs, fewer professional opportunities in large companies, an accelerated pace of technological change, and the expansion of engineers' roles and responsibilities within work organizations (Matlay, 2006; Minniti, Bygrave, & Autio, 2006; Rover, 2005; Wei, 2005; Yurtseven, 2002). Even within organizations, the rapid expansion of the existing knowledge base required in many areas, the discovery of new applications of that knowledge, and the creation of new markets in which to apply these applications have caused a "significant shift in employment opportunities" (Creed, Suuberg, & Crawford, 2002, p. 185) for which many current engineering graduates are not adequately prepared.

As a result, the professional outlook and career path for an engineer looks very different than it did in the past. In an article about de-industrialization and its effect on engineering education, Wei (2005) remarked 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" (p.130). Today, more engineering graduates must consider work in smaller, more entrepreneurial companies, which requires "a broad range of skills and knowledge beyond a strong science and engineering background" (Creed et al., 2002, p. 185). This environment favors what Creed et al. refer to as the *entrepreneurial engineer*, who in addition to having a traditional science and technical background, is able to communicate effectively and work with small, highly focused multidisciplinary teams, including individuals from the fields of business, law, and the humanities.

The need for entrepreneurial engineers is not restricted to graduates who take positions in startup environments. Established companies are also increasingly seeking out employees, often referred to as intrapreneurs, with an entrepreneurial mindset and the skills necessary to participate in firm renewal and revitalization, which are responses to global competition and the pace of technological change (Antoncic & Hisrich, 2001; Menzel, Aaltio, & Ulijn, 2007). Renewal and revitalization for large companies can involve mergers and consolidation; spinning off subsidiaries and business units; acquiring startups, outsourcing R&D; and adopting practices to decrease product time-to-market (Creed et al., 2002). Involvement in these activities require engineers with a unique set of leadership and management skills, including individual initiative, visionary thinking, opportunity seeking, flexibility, teamwork, and network building (Menzel et al., 2007).

In response to these trends, a number of initiatives designed to infuse more entrepreneurship into undergraduate engineering programs has led more engineering faculty and administrators to

consider entrepreneurship education. One of these initiatives 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. The Epicenter offers entrepreneurship education training programs for engineering faculty, programs for students, and is conducting research on curricular models of entrepreneurship education directed at engineers. Another initiative which is bolstering awareness of entrepreneurship education in the STEM fields is the NSF Innovation Corps program (I-Corps) program. I-Corps provides NSF-funded research teams with grants and entrepreneurial training to assess the commercialization potential of their research (National Science Foundation, 2011; "NSF I-Corps Celebrates First Year Bridging University Researchers with Entrepreneurs," 2012).

### **Entrepreneurship Education in Engineering**

In the context of engineering education at U.S. universities, courses and programs that deliver entrepreneurial skills, knowledge, and experiences to students are very diverse in terms of their structure, target audience and key objectives. Some target engineering students primarily and are embedded within the engineering curriculum, while others are campus-wide and target students in a wide variety of majors. Programs can also vary in terms of how they define their desired outcomes; some focus on generating a general awareness of entrepreneurship as a potential career path, while others focus on developing innovative products and/or new business models and ventures. Some engineering schools, rather than offer a stand-alone course in entrepreneurship, integrate entrepreneurship throughout the engineering curriculum. One example is Olin College which offers an integrated approach, whereby "entrepreneurship is interwoven with mainstream engineering disciplines" (Fredholm et al., 2002).

Entrepreneurship programs that primarily target engineering or science students are generally known as "technology entrepreneurship" or "engineering entrepreneurship" programs. Researchers 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 formed with active collaboration of a business school and one or more technical schools.

Despite the growth in entrepreneurship education, studies have found that delivery to engineering students is not yet widespread or institutionalized and that such courses are typically part of minors and certificates, and not part of core engineering curriculum. A study of 341 American Association of Engineering Education (ASEE) member schools found that only 12% offered formal programs that targeted undergraduate engineering students specifically (Shartrand et al., 2010). The remainder offered either business-school based or university-wide and multi-disciplinary 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.

There is evidence that exposing engineering students to entrepreneurship has a positive impact on the intention to become an entrepreneur, entrepreneurial self-efficacy, and better prepares them for the contemporary workplace (Lüthje & Franke, 2004; Souitaris, Zerbini, & Al-Laham, 2007). Duval, Shartrand, & Reed-Rhoads (in press) found that senior-level engineering students who had taken one or more entrepreneurship courses, or who had participated in extracurricular entrepreneurship-related activities, had significantly higher entrepreneurial self-efficacy and were also more likely to get hands-on skills related to market analysis, technology commercialization, business communication, or internships within start-up companies. Miller, Walsh, Hollar, Rideout, & Pittman (2011) collected data from alumni of an entrepreneurship program embedded within engineering and found that relative to a control group, graduates were 73% more likely to have started a new company, 23% more likely to have created new products or services, and 59% more likely to have high confidence in leading a start-up.

### **Barriers to Engineering Student Participation in Entrepreneurship Education**

While many engineering students recognize the value of entrepreneurship skills to their education and careers, it appears that only a relatively small number take advantage of them -- and it is unclear whether this is due to a lack of supply or demand. A study of senior engineering students at three institutions with well-established engineering and entrepreneurship programs found that approximately 70 percent of students surveyed felt that that entrepreneurship education could broaden their career prospects and choices, however, 70 percent of all engineering students reported that they were most interested in working for a medium to large size organization after graduation. Further, less than one third of engineering students felt they were encouraged to take entrepreneurship courses, to participate in entrepreneurship-related activities, or consider starting their own companies. Similarly, less than one-third of students surveyed as part of this study felt that entrepreneurship was presented as a worthwhile career option within their engineering program or that it was being addressed by engineering faculty (Duval-Couetil et al., 2012).

There are a number of major curricular barriers to wider involvement in entrepreneurship education for engineering students and faculty. In terms of demand, many engineering students face limited space in their academic programs to participate in electives that explicitly teach entrepreneurial thinking and skills or that are perceived to be “non-engineering” curriculum (Standish-Kuon & Rice, 2002). For institutions that meet ABET requirements, academic programs are typically very structured and sequenced limiting students’ ability to enroll in elective courses or participate in extra-curricular programs, particularly if they wish to complete their programs in four years. In terms of supply, many engineering faculty do not have experience with or interest in delivering entrepreneurial concepts or activities to students. Even within the discipline of management, many institutions rely heavily on non-tenure track faculty or practitioners to teach entrepreneurship (Zappe, Hochstedt, & Kisenwether, 2012). Further, at an institutional level, there can be many complexities around who will administer and fund entrepreneurship courses, particularly across disciplines.

## ABET Accreditation

The Accreditation Board for Engineering and Technology (ABET) is a nonprofit, non-governmental organization that accredits college and university programs in the disciplines of applied science, computing, engineering, and engineering technology. ABET has long been a major driver of change in engineering curricula as it accredits over 3,100 programs at more than 670 colleges and universities in 24 countries ([www.abet.org](http://www.abet.org)). According to the ABET website, accreditation has value and matters because it is “proof that a collegiate program has met certain standards necessary to produce graduates who are ready to enter their professions.” Students who graduate from accredited programs have access to enhanced opportunities in employment; licensure, registration and certification; graduate education and global mobility.” Further, “accreditation is an assurance that the professionals who serve us have a solid educational foundation and are capable of leading the way in innovation, emerging technologies, and in anticipating the welfare and safety needs of the public.” The value of accreditation to institutions and academic departments is that it provides a structured method to develop, assess, evaluate and improve the quality of their programs.

ABET uses specific terminology as part of its accreditation process which has been described as “dense and confusing” (Felder & Brent, 2003, p. 7) and may differ from terminology used across institutions or educational programs. Some basic ABET terminology and definitions are the following (“Criteria for Accrediting Engineering Programs: 2-12-2013 Accreditation Cycle,” 2011):

- Program Educational Objectives – Broad statements that describe what graduates are expected to attain within a few years of graduation. Program educational objectives are based on the needs of the program’s constituencies.
- Student Outcomes – Describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program.
- Assessment – One or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes and program educational objectives. Effective assessment uses relevant direct, indirect, quantitative and qualitative measures as appropriate to the objective or outcome being measured.
- Evaluation – One or more processes for interpreting the data and evidence accumulated through assessment processes. Evaluation determines the extent to which student outcomes and program educational objectives are being attained. Evaluation results in decisions and actions regarding program improvement.

The ABET accreditation process requires that academic programs meet a series of criteria “intended to assure quality and to foster the systematic pursuit of improvement in the quality of engineering education that satisfies the needs of constituencies in a dynamic and competitive environment” (“Criteria for Accrediting Engineering Programs: 2-12-2013 Accreditation Cycle,” 2011, p. 2). The criteria for bachelor’s degree programs are presented in Figure 1. To simplify, these have been summarized and presented in three categories – definition of outcomes, implementation and evaluation, and resources and infrastructure.

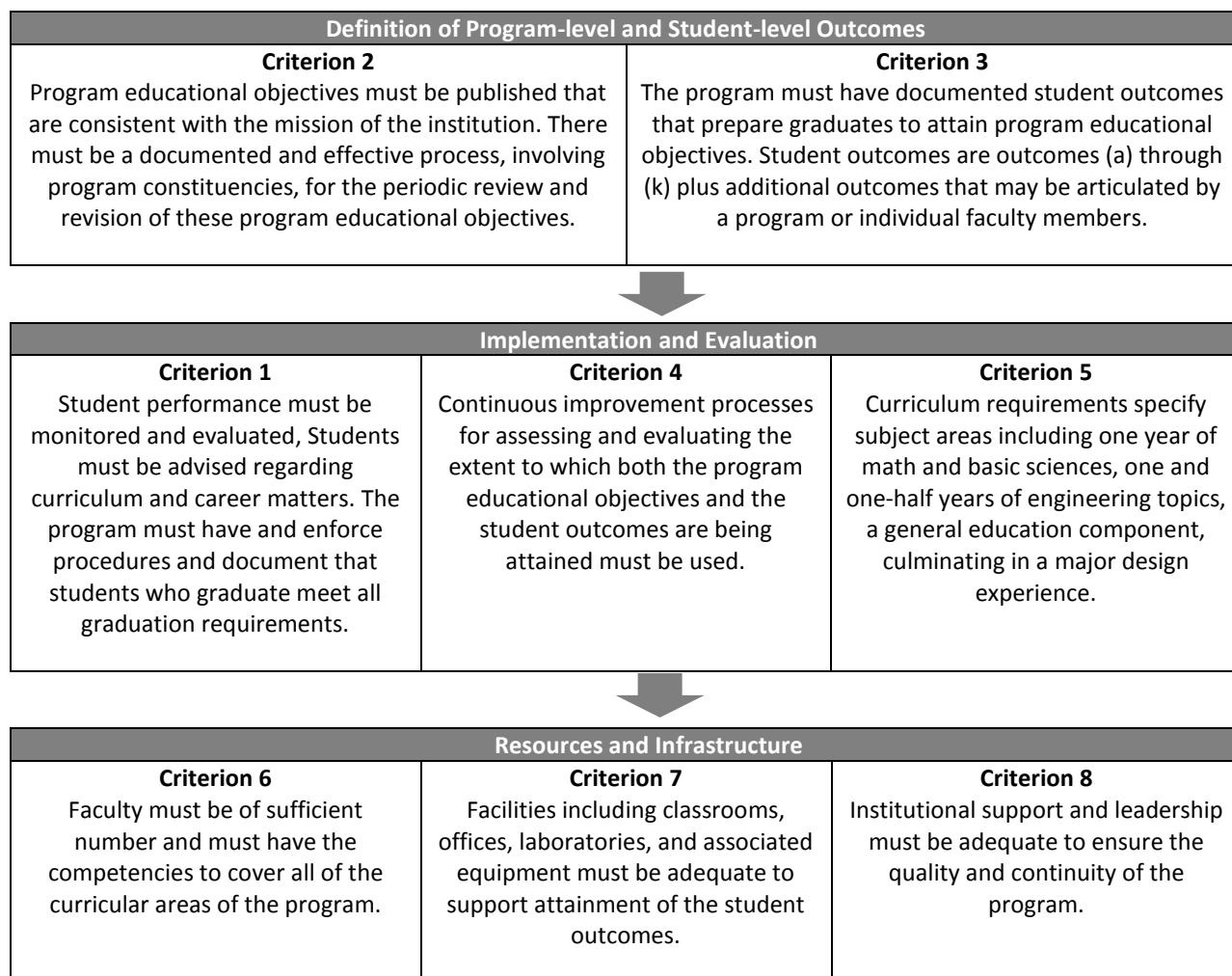


Figure 1: Summary of ABET Accreditation Criteria (adapted by authors)

Felder and Brent (2003) described the engineering criteria as constituting “an antidote to curricular chaos” (p. 8) and that “the exercise of constructing a clear program mission, broad goals that address the mission (program educational objectives) and desired attributes of the program graduates (program outcomes) required the faculty to consider seriously - possibly for the first time - what their program is and what they would like it to be” (p.8). They further add that, “if faculty members then structure their course syllabi, learning objectives, and teaching and assessment methods to address the program outcomes, the result is a coherent curriculum in which all courses have well-defined and interconnected roles in achieving the program mission” (p. 8).

Scholars have outlined challenges associated with teaching and assessing ABET Criterion 3a-k and many engineering programs are currently seeking more effective ways to meet requirements for accreditation (Felder & Brent, 2003; Shuman et al., 2005). Felder and Brent (2003) provide a comprehensive description of methods of designing, teaching, and assessing courses to satisfy the ABET engineering criteria, including a glossary of accreditation terminology as well as illustrative learning objectives and instructional methods. These guidelines are provided to help

faculty participate in the revamping of curriculum that can lead to dramatic changes in engineering education, but which depends strongly on how well engineering faculty “understand it and appreciate the extent to which their full involvement in it is crucial” (p. 7). This is because the work of equipping students with the attributes specified in program outcomes must be done at the individual course level meaning that all faculty members involved in teaching “must now understand and be involved in the accreditation process on a continuing basis” (p. 7) and not just in the months prior to an accreditation visit.

To be fully involved in curriculum transformation and assessment, faculty must have a thorough understanding of Criterion 3 which articulates course-level learning objectives that prepare graduates to attain program-level educational objectives. In the latest version of ABET accreditation standards, Criterion 3, consists of 11 student outcomes (a-k) that describe the abilities and knowledge that all students should be able to demonstrate upon completion of their degree. According to Felder and Brent (2003), Criterion 3 requires that programs seeking accreditation to formulate the following: (1) a set of program outcomes that specify the knowledge skills, and attitudes program graduates should have if the program educational objectives are achieved; (2) an assessment process for the program outcomes; (3) results from the implementation of the assessment process; and (4) evidence that the results are applied to the further development and improvement of the program.

Shuman et al. (2005) divided these 11 student outcomes into two categories—a set of five “hard” skills and a second set of “professional” skills (Table 1). The authors highlight the challenges associated with teaching and assessing these professional skills within engineering programs. First, they describe a lack of consensus about definitions, the scope by which the outcome is assessed, and the nature of the outcome itself. Second, they note that the definitions of “hard” outcomes have greater acceptance in the engineering education community and consequently, engineering educators have a greater level of confidence (and certainty) in assessing them. Third, unlike “hard” skills (e.g., thermodynamics) which are taught primarily through coursework, professional skills (e.g., ethics and teamwork) are likely to be acquired or influenced both inside and outside of the class room. In addition, their acquisition may be enhanced through experiential learning and activities such as internships, coops, service learning and study abroad programs.



Table 1: ABET Criterion 3a-k according to Shuman, Besterfield, & McGourty (2005)

Student Outcomes		
a	an ability to apply knowledge of mathematics, science, and engineering	hard
b	an ability to design and conduct experiments, as well as to analyze and interpret data	hard
c	an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	hard
d	an ability to function on multidisciplinary teams	professional
e	an ability to identify, formulate, and solve engineering problems	hard
f	an understanding of professional and ethical responsibility	professional
g	an ability to communicate effectively	professional
h	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	professional
i	a recognition of the need for, and an ability to engage in life-long learning	professional
j	a knowledge of contemporary issues	professional
k	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.(hard)	hard

### **ABET and Entrepreneurship Education**

Given the influence of ABET in shaping engineering curriculum, it is essential that entrepreneurship education be aligned with accreditation standards. Moreover, it is clear that engineering faculty must value entrepreneurship education and understand how to address it in their classes for true transformation to occur. Over the years, engineering scholars have worked to establish a pedagogical justification for including in engineering curricula both courses and material related to entrepreneurship. Nichols & Armstrong explored whether “engineering entrepreneurship” is consistent with the educational mission of an engineering college by examining the strategic plans of both the College of Engineering and the Department of Mechanical Engineering at the University of Texas Austin. They identified components of the department’s strategic plan that aligned with entrepreneurship including: creativity, novel application of fundamental engineering science, interdisciplinary activities, building a community of scholars, development of future leaders, professionalism, and excitement in discovery. They also identified ABET Criterion 3a-k as being particularly useful in making the case for entrepreneurial engineers (Nichols & Armstrong, 2003). Petersen, Jordan, & Radharamanan (2012) discussed the need to examine the outcomes for an entrepreneurial mindset as defined by the Kern Entrepreneurship Education Network (KEEN) against those of ABET in order to achieve educational transformation within academic programs. KEEN is a collaboration of U.S. universities that strive to instill an entrepreneurial mindset in undergraduate engineering and technology students.

It can be argued that ABET’s Criterion 3a-k, which address student level outcomes and reflect both “hard” and “professional” skills, can also encompass those traditionally acquired through entrepreneurship education - including the ability to address real world problems, perceive opportunities, lead others, work in multidisciplinary teams, communicate effectively, perceive

opportunities, react and adapt with flexibility in the face of uncertainty, and deal well with risk and failure. There are several published examples of how engineering courses and projects encompass entrepreneurship knowledge and competencies to meet specific ABET criteria. These are primarily conference papers that also describe activities in which students take part as a result of these experiences, including involvement in business plan competitions, executing patent applications, and providing high value to partnering companies. They also describe other benefits students derive from the study and practice of entrepreneurship, such as increased personal growth, transformative experiences, expanded career paths, excitement in serving others, appreciation for non-engineering disciplines, increased competence in work across disciplines, and a broadened understanding of business development in a global context (Davis & Rose; Hazelwood, Valdevit, & Ritter; Ochs, Lennon, Watkins, & Mitchell, 2006). A few examples of how entrepreneurship-related activities have been used within engineering courses to meet ABET outcomes are presented below:

#### Entrepreneurship Mindset and Capstone Design – Lehigh University

Ochs, Lennon, Watkins, & Mitchell (2006) described how engineering capstone design courses at Lehigh University were aligned with a campus-wide entrepreneurship minor and met or exceeded ABET requirements. Ochs provides examples of specific criterion and how they aligned with Lehigh's "Integrated Product Development Model" a five phase model for both entrepreneurial startups and established companies designed to analyze customer needs and to create wealth for the company stakeholders including owners, employees, the community and nation. The phases include: 1) opportunity scanning; 2) concept design and product planning; 3) parallel development of the product, 4) manufacturing processes and marketing; and 5) product purchase and support. The authors demonstrate how this model provides an excellent framework on which to overlay the ABET accreditation criteria and they describe how the model is used with companies the Lehigh business incubator or on with students' own venture projects.

#### Entrepreneurial Engineering Capstone Course – Washington State University

Davis & Rose (2007) described an entrepreneurial engineering design course at Washington State University offered over two semesters, which was comprised of students from engineering, science and business. The sequence was taught by a professor of bioengineering and a professor of entrepreneurial studies. Students were required to achieve and document significant progress in: 1) product development, 2) business development, and 3) personal (team and individual) development. Typically, the first semester produced a solution and tentative business plan, where students presented their plans in class and in a competition. The second term produced a design solution and business plan with testing or market data. They described course outcomes as encompassing both learner development (e.g., improving skills in engineering design, team development and productivity) and solution development outcomes (e.g., design solution that satisfies stakeholder needs and constraints, results that deliver satisfaction and value to key project stakeholders.). Assessments as part of the project were being piloted when the paper was published.

#### An Invention and Innovation Course for Engineering Students – University of Colorado at Boulder

Sullivan, Carlson & Carlson (2001) discussed an engineering course at the University of Colorado at Boulder which was described as being a team-based product design and

development course designed to teach students the processes of invention and product innovation. It is an elective course targeted at more “mature” students, many of whom either transferred into engineering later in their academic careers or who delayed taking a first year interdisciplinary projects course. It allowed students to explore the invention process through hands-on doing, while learning valuable engineering skills. The abilities include oral and written communication skills, feasibility study development, use of CAD design, and tools for exploring product invention and innovation. The course included prototyping, understanding customer needs and wants, and understanding the concepts of competitive advantage, intellectual property, manufacturing and profitability. The authors described a pervasive focus on team effectiveness which often makes students initially uncomfortable but results in higher performance teams. Course goals were mapped to specific ABET criteria and a number of assessment tools were developed. These included weekly instructor meetings, peer evaluations, pre-post skill evaluation surveys, and university required course evaluations. Actual assessments used were not provided in description.

A Model for a Biomedical Engineering Senior Design Capstone Course, with Assessment Tools to Satisfy ABET “Soft Skills” – Stevens Institute of Technology

Hazelwood, Valdevit, & Ritter (2010) described a two semester course sequence at Stevens Institute of Technology that enabled students to work with a physician to address real world clinical unmet needs and develop basic product development and project management skills while working in small teams of 3 or 4. Students were guided through exercises to assess clinical and market needs, technical feasibility, the development of a “proof of concept” prototype, and the development of patent applications. Teams practiced oral and written communicational skills through collaborative proposals, reports, and presentations. The authors reported that the course had resulted in a startup company, in numerous awards including the top entrepreneurship prizes among senior design teams and elevator pitch competitions. Alumni and employers who hired alumni provided very positive feedback regarding their personal confidence the feeling of preparedness for their employment as a result of the experience. The authors stated that this model readily allowed for the quantitative assessment (grades on oral and written reports) of some of the harder to assess course and program outcomes required in the ABET accreditation process, in particular Criterion 3a-k. The authors provided specific examples of assessment questions (Table 2) that were used in connection with the ten course assignments and deliverables required which included: a problem definition, market assessment, preliminary intellectual property review, mission statement, practice proposal presentation, mid semester formal proposal, confidential team assessments, project review meeting presentations, draft invention disclosure and a formal execution plan.

Table 2: Assessment questions used in conjunction with course assignments

<b>Assessment Semester 1</b>	ABET Criterion 3a-k
For a given clinical problem, I can identify the unmet medical need in terms of technical, clinical and market needs	d, h, i, j
I can present my project effectively, including a concise mission statement that explains how my project will save/improve lives and provide entrepreneurial opportunities (or save costs)	h, j
I can develop a project strategy that takes these aspects into consideration: Intellectual Property, FDA/ Regulatory, Resource availability	c
I can schedule a project in accordance with the industry accepted methods, including the Critical Path Method or a Gantt chart	c
I can apply engineering and physiology training, as well as use standard resources to design a solution to a clinical problem (i.e. write a project proposal)	g
In a collaborative manner with medical and/or industry professionals, I can design a simple and effective “proof of concept” model to address an unmet clinical need	d
<b>Assessment Semester 2</b>	
I can function as a productive member of a team to execute my project	d
I am comfortable explaining my project in various oral formats such as project review meetings, student forums and research	f, g
I understand how my project may be applied to solve a medical need in society	h, i, j
I understand how to write an invention disclosure	g

These course examples demonstrate the variety of ways that entrepreneurship education has been used within engineering education courses to meet both entrepreneurship and ABET outcomes. These curricular initiatives highlight the ABET criterion that appear to be most commonly aligned with entrepreneurship education, including:

- c. Ability to design a system, components, or a process to meet desired needs with realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability,
- d. Ability to function on multidisciplinary teams
- f. An understanding of professional and ethical responsibility
- g. An ability to communicate effectively;
- h. The broad education necessary to understand the impact of engineering solutions in a global economic, environmental, and social context
- j. A knowledge of contemporary issues

This review of the literature shows that despite some examples of entrepreneurship education being addressed within core engineering courses and the manner in which they align with ABET, they remain anecdotal. To our knowledge, there are no articles describing the manner in which entrepreneurship pedagogy or assessments have been formally integrated into or scaled across courses or programs. Further, it appears that little research has sought to formally explore entrepreneurship education’s relationship to ABET outcomes. Given that ABET standards are often viewed as driving the outcomes and content of core courses, demonstrating the manner in

which innovation and entrepreneurship curriculum, activities, and assessment can be used to meet ABET outcomes is imperative if wider option within engineering education programs is to occur. Providing faculty with resources and tools that point define practical activities mapped to ABET Criterion 3a-k and entrepreneurship outcomes that they can use and assess in the classroom can reduce barriers to adoption .

## Future Work

As stated at the start of this manuscript, the authors have conducted a pilot project which has sought to 1) began to develop a rationale for aligning entrepreneurship education with ABET Criterion 3a-k, and 2) identify a preliminary list of 52 entrepreneurship outcomes in 4 major categories or content areas that are relevant to engineering education. This work was presented as a poster at the 2013 National Collegiate Inventors and Innovators Alliance (NCIIA) annual conference, as a work-in-progress paper presented at the ASEE Frontiers in Education Conference in Oklahoma City in October 2013, and as a workshop at the 2014 NCIIA Annual Conference. The categories and content areas are provided below in Figure 3 and the full list of 52 outcomes are provided in Appendix A.

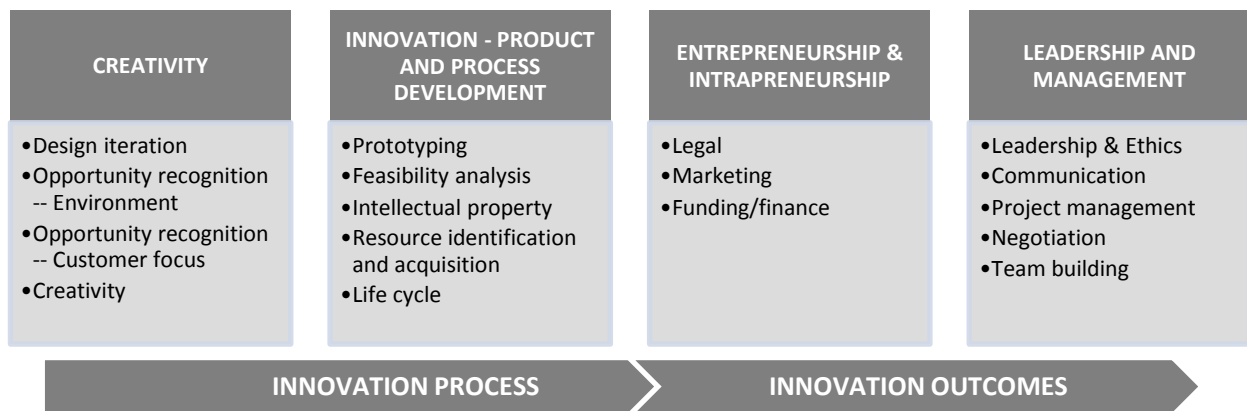


Figure 2: Categories and Content Areas for Engineering Entrepreneurship Learning Outcomes

These outcomes were generated based on discussions with a small working group of engineering entrepreneurship educators, a review of the literature, and the experience of the authors. They were organized into categories along what is described as an *entrepreneurship education continuum*, which ranges from the topic of creativity on one end, to entrepreneurship and management on the other (Duval-Couetil & Dyrenfurth, 2012). This framework allows us to distinguish between outcomes that are aligned with the *innovation process* which is comprised of creativity and product and process development, and those aligned with *innovation outcomes* which are comprised of entrepreneurship/intrapreneurship and technology management/business development. While these concepts often overlap and are iterative, this framework was useful to understand the emphases and desired learning outcomes associated with entrepreneurship programs directed at engineering students.

The next phase of this work will consist of refining and validating this list of outcomes and mapping them to ABET Criterion 3a-k. Refining and validating this list of outcomes will be accomplished by conducting qualitative and quantitative studies with engineering/entrepreneurship

thought leaders and engineering faculty. The mapping will consist of creating matrices that demonstrate the degree of alignment with ABET Criterion 3a-k. Ultimately, the goal is provide engineering faculty with examples of curricular activities and assessments that will help them meet these criterion (Figure 2). Preliminary work and dissemination suggests that there is significant interest and support among engineering faculty and administrators in pursuing such an approach.

## **Conclusion**

There are several factors, particular to engineering programs and engineering faculty, that limit accessibility to and adoption of entrepreneurship education that should be addressed in future research and curriculum development efforts. These include: 1) the limited space available in academic programs to integrate what might be perceived by faculty as “non-engineering” curriculum; 2) the reality that many engineering faculty may not have had exposure to, experience with, or interest in entrepreneurship education; and 3) the reluctance on the part of engineering programs to modify curriculum that, without entrepreneurship education, meets ABET accreditation outcomes. Given these barriers, embedding more entrepreneurship-related knowledge and skills into the core of the engineering curriculum could be an effective way to deliver entrepreneurship education to engineering students, and meets the ABET goal of setting high educational standards for all engineering students.

For engineering students, the array of knowledge and skills that can potentially inform the creation of new enterprises can be even broader and deeper than for those in other disciplines due to their involvement in product and process innovation. The field of engineering faces many of the same curricular challenges faced by business school-based and multidisciplinary programs, including a lack of consensus on definitions and learning outcomes associated with entrepreneurship education. As a result, there are relatively few examples of curricular models or validated assessment instruments being used across programs.

This paper shows a number of examples of how entrepreneurship education has been aligned with the professional skills outcomes associated with ABET accreditation standards. It also demonstrates that for true curricular change to occur, faculty must have a thorough understanding of course-level learning objectives that prepare graduates to attain program-level educational objectives. A more refined body of knowledge for entrepreneurship education, particular to engineering students, would be useful to understand and assess what particular curricular activities can have an impact on developing entrepreneurial skills and mindset. Conducting research to examine the overlap with ABET criteria, as well its operationalization, can be an effective means to catalyze wider adoption of entrepreneurship education by engineering faculty.

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# Appendix A

## ENTREPRENEURSHIP-RELATED OUTCOMES PERTINENT TO ENGINEERING STUDENTS BY CONTENT AREA

### CREATIVITY - THEORIES AND TECHNIQUES

**Design iteration**  
Employ frequent iteration to improve a design  
Understand that failure is learning  
Extract learning from design iteration failures and successes  
**Opportunity recognition – Environment**  
Understand how changes in science industry and economic forces create opportunities  
Evaluate current and future trends and their impact on new venture opportunities  
Compare/contrast the different opportunities and how they create value  
**Opportunity recognition – Customer focus**  
Identify methods used to capture customer needs  
Detect latent or explicit unmet needs among customers  
Formulate needs into engineering problem statements  
**Creativity**  
Use ideation techniques to generate ideas and opportunities  
Understand the environments, practices, and processes that foster creativity

### INNOVATION - PRODUCT AND PROCESS DEVELOPMENT

**Prototyping**  
Develop specifications for usability and functionality testing  
Identify resources and techniques for prototype development  
Produce working, testable prototypes of the product/service  
**Feasibility analysis**  
Evaluate the feasibility of moving from prototype to commercial product  
Perform market research to quantify market demand  
Conduct financial analysis of opportunity by developing budgets and pro-forma financial statements  
Relate industry and regulatory laws and standards to a design concept  
**Intellectual property**  
Perform a comprehensive patent search for a design concept  
Justify the appropriate legal protection for a design concept  
Generate documentation necessary to file for a provisional patent  
**Resource acquisition/identification**  
Identify potential partners for sourcing, manufacturing, and production  
Assess human capital needs  
Identify physical capital needs  
**Life cycle**  
Analyze current product life cycles to anticipate future needs  
Demonstrate consideration of product life cycle in design decisions  
Demonstrate awareness of sustainability issues

### ENTREPRENEURSHIP AND INTRAPRENEURSHIP

**Legal**  
Select most appropriate legal entity for new business venture  
Understand the use of non-disclosure agreements  
Understand the process and costs associated with IP protection  
**Marketing**  
Identify sources of, and methods to obtain, primary and secondary market research  
Perform competitive analysis to develop a value proposition  
Use market segmentation to develop a marketing plan and budget  
**Funding/finance**  
Determine financial requirements for a new venture at various stages of development  
Understand the process and requirements for obtaining funding from different sources  
Identify the pros and cons of various funding sources  
Understand business valuation

### LEADERSHIP AND MANAGEMENT

**Leadership & Ethics**  
Develop and clearly communicate a vision for the venture/organization  
Translate vision into goals and metrics  
Delegate tasks and organize work groups effectively  
**Communication**  
Convey accurate and appropriate information tailored to stakeholder needs  
Create and give persuasive presentations and reports on status  
Collect and synthesize information from multiple sources  
**Project management**  
Select and use appropriate project management tools and methods  
Give team members clear assignments and feedback  
Create a process for measure and reporting on progress and performance  
**Negotiation**  
Understand and express the positions of various stakeholders  
Apply of the principles, strategies, and tactics of effective negotiation  
Identify and negotiate solutions that are satisfactory to all stakeholders (win-win)  
**Team building**  
Identify talents and styles of individuals within a team  
Assemble work teams that make best use of members' skills and knowledge  
Implement guidelines for managing and evaluating team performance