"The Odd Couple" of Engineering and Entrepreneurship: Playing at a University Near You

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Abstract **- Engineering is a meticulous and methodical neat freak, frowning on anything short of success. To Engineering, failure is not an option. Engineering was not always like that, but the decade long relationship with Quality Improvement left him in knots. Entrepreneurship is a compulsive gambler who thrives on trying new and untested things. To Entrepreneurship, failure is mark of progress. Engineering lived happily in a crowded but fastidiously kept curriculum. That all changed when Entrepreneurship moved in and started unpacking. This is the story of how the two have gotten along and how they are able to share the same space. This paper gives a map of a prototypical mechanical engineering curriculum and overlays it with various entrepreneurship educational elements. This paper includes a basic review of some of the various tools and techniques used to weave in the entrepreneurial engineering elements including one such technique developed at the University of Detroit Mercy: The technical entrepreneurship multimedia case study.**

Index Terms - Entrepreneurship, Case studies, Entrepreneurial mindset.

INTRODUCTION

In a special report on entrepreneurship, The Economist magazine quoted Victor Hugo's remark that "you can resist an invading army; you cannot resist an idea whose time has come." That same article followed by stating that "today entrepreneurship is such an idea" [1]. The entrepreneurial economy [2] and the associated small businesses are widely acknowledged to be a significant driving force behind this country's economic growth and prosperity. The recent realization of the importance of entrepreneurship coupled with the traditionally central role that technology plays in the US economy have conspired to bring these two disciplines together in engineering colleges throughout the US.

Calls for more and better entrepreneurship training in undergraduate engineering curriculums are coming from sources with the highest levels of credibility (National Science Board) [3] and the "development of entrepreneurial behavior" has been identified as one element in preparing "engineers to meet the needs of the changing economy and society" (National Science Foundation) [4]. The Grand Challenges Scholars Program of the National Academy of Engineering has one of its goals to "enhance student interest in engineering, science and technology entrepreneurship" [5].

The value of entrepreneurship in engineering education goes far beyond the economic windfall resulting from the potential of business creation. The engineers who are created through entrepreneurship training possess a mindset and a skill set that are highly valued and encouraged [3]. The entrepreneurial skill set maps very well to the ABET outcomes [6-7], especially those that are deemed most difficult to assess i.e. outcomes *d, f, g, h, i* and *j*. Also, entrepreneurship programs have been found to positively affect GPA and retention of students [8].

This article starts by defining the entrepreneurial mindset and by making the case for its value to the practicing engineer. It then seeks to illustrate the distinction between an *entrepreneurial engineer* and an *engineering entrepreneur* and make the case for the former. The authors then use a parody of the odd couple to illustrate the difficulty of bringing together these two disciplines. The article then discusses the prevailing and common techniques to inculcate the entrepreneurial mindset in the engineering curriculum and concludes with a description of a series of short technical entrepreneurship video case studies that can be used for that purpose.

THE ENTREPRENEURIAL MINDSET

Entrepreneurship is primarily a mindset. Drucker associates entrepreneurship with learned behavior and not personality trait or intuition [9]. In reality, entrepreneurship education consists of two components; the entrepreneurship mindset and the entrepreneurship skill set. The entrepreneurship skill set consists of soft skills (teamwork, communications, etc…) as well as hard skills involving the requisite business and technical knowhow. The entrepreneurship mindset on the other hand is fairly different. The mindset is the strategic part of entrepreneurship (i.e. the thinking and habit of entrepreneurship) while the skill set is the tactical part (i.e. the part of entrepreneurship that involves communication and quantitative analyses).

While the entrepreneurship skill set is necessary for an entrepreneur to be successful, it alone does not make an entrepreneur. The authors would argue that if an entrepreneurial mindset exists, then an engineer would likely seek to acquire the necessary skills in order to maximize his/her chances for success, most likely by taking business and continuous learning courses.

According to McGrath and MacMillan [10], the entrepreneurial mindset involves five characteristics. Habitual entrepreneurs passionately seek new opportunities, pursue those opportunities with discipline, are selective about which opportunity to pursue, focus on "adaptive execution" and form teams of people with the needed expertise. Goldberg discusses a set of ten competencies of the entrepreneurial engineer [11]. These are a mix of skills and a mindset, although a majority of them are ingredients for general success in any endeavor and/or field. He makes the case that strong technical skills are not enough and that engineers should have an ability to communicate effectively, sell ideas, manage time, and recognize and properly evaluate opportunities. Drucker gives an extensive treatment on managing oneself and one's career (a quintessential entrepreneurship trait) for success in the "knowledge economy" and takes into account various learning and thinking styles [12]. Timmons and Spinelli discuss what they term as "six themes of desirable and acquirable attitudes and behaviors," which are 1) commitment and determination, 2) leadership, 3) opportunity obsession, 4) tolerance of risk, ambiguity and uncertainty, 5) creativity, self reliance and adaptability and 6) motivation to excel [13].

It is not hard to make the case that these entrepreneurial traits are great assets to an engineer whether working in small or large company.

ENGINEERING ENTREPRENEURS OR ENTREPRENEURIAL ENGINEERS

The higher educational engineering community is still sorting out the ways to better support the entrepreneurial economy and one of the many open questions remaining is whether to target the educational models to produce *engineering entrepreneurs* or *entrepreneurial engineers*. The difference is more than simple wording. The first implies educating entrepreneurs who have an engineering/technical background versus a business background. This involves giving the engineering student the significant arsenal of business skills that form the entrepreneurial skill set. The second implies educating engineers with an entrepreneurial mindset versus an "employee mindset" [14]. There is a need for both and the contrast is one of depth versus breadth. If one measures success as the degree of contribution to the economy, then a successful engineering entrepreneur would most likely make a bigger impact than an entrepreneurial engineer who is operating from within an existing company. However, if one is able to imbue the entrepreneurial mindset in the large engineering population, in effect creating an army of entrepreneurial engineers, then their collective contributions from within medium and large businesses would be very significant.

THE ODD COUPLE

If engineering and entrepreneurship were embodied as human beings, they would form a veritable "odd couple." This reference is a parody of the famous original play *The Odd Couple* [15] where two men are driven by circumstance to share the same apartment. In the play, the main characters are named Felix and Oscar. Felix is meticulously organized, polished and proper. Conversely, Oscar is quite comfortable in a chaotic environment, he is disheveled and undisciplined. Conflict between the characters is unavoidable. Likewise, Engineering and Entrepreneurship are forced to live together with similar results. The reader is asked to forgive the authors' indulgence in the informal style in some sections of this paper.

In this story, Engineering is a meticulous and methodical neat freak, frowning on anything short of success. Failure is not an option. Engineering was not always like that, but the decade long relationship with Quality Improvement left him in knots. The unlikely roommate, Entrepreneurship, is a compulsive gambler that thrives on trying new and untested things. Failure is mark of progress. Let the show begin.

ACT 1: ENGINEERING AND ENTREPRENEURSHIP MEET FOR THE FIRST TIME

The setting is the engineering curriculum which is very crowded but very structured and extremely well kept.

Engineering: Hello Entrepreneurship, welcome to my home. I'm told that you will show me the new world order, but as you can clearly see, I have everything pretty well under control. I've made a bit of room for you, but it's already a crowded curriculum.

Entrepreneurship: You gotta' be kidding me. The business world doesn't follow your neat tidy little schedule. It's messy, it changes every day and it's unpredictable!

Engineering: Unpredictable? (Gasp)

Entrepreneurship: Ya, you're a betting man aren't you? Ready to roll the dice with me? Let the games begin, it's great fun!

Engineering: (Faints)

Humor aside, integrating entrepreneurship into an engineering curriculum is not an easy task. The difficulties stems primarily from the fact that the engineering curriculum is very crowded with few if any free electives. This is especially true at universities with large and unyielding core curricula. The University of Detroit Mercy has a very elaborate and rigid general education curriculum with defined choices. Adding credit hours to such an already crowded curriculum is a non-starter and including classes on entrepreneurship in the core curriculum is nearly impossible given the number of colleges and departments that would be involved in such decisions.

ACT 2: ENGINEERING AND ENTREPRENEURSHIP FACE FAILURE

The setting is following an initial presentation to a prospective customer, where the customer vehemently rejected the proposal.

Engineering: Well Entrepreneurship, I hope you're happy. Maybe if you were a little more like me, this wouldn't happen. You would have done more analysis before embarrassing us both!

Entrepreneurship: If anyone should change, it should be you Engineering! You're right about one thing, this would have never happened because we would have never made it this far. Ever heard of "analysis paralysis"?

Engineering: You're a loose cannon!

Entrepreneurship: You're a nerd!

There are considerable difficulties in reconciling the definition and management of failure for these two disciplines. Engineering failures are of a physical nature and are highly technical and well-defined. While in entrepreneurship, failure is more strategic in nature, is not very technical and can occur at a number of potential points. Because of the broad number of potential failure points, entrepreneurs are trained to get the product in front of customers at the earliest possible time in order to get feedback, correct for any strategic errors and attempt to contain any damage. Engineers, on the other hand, are trained to work procedurally and comprehensively in order to avoid failure and thus develop a tendency to want to get the product in a very good condition with all features and options developed and tested before releasing it to be seen by the customer. If the engineer and entrepreneur are one and the same, then these opposing tendencies must be reconciled.

ACT 3: ENGINEERING AND ENTREPRENEURSHIP FIRST SUCCESS

The setting is at the end of their first long, protracted project together. The project was successful but both characters are exhausted.

Engineering: Well, Entrepreneurship that was quite a project. I can see now that we have to work together. It's clear that we have to think like each other. We have to integrate our approaches.

Entrepreneurship: Integrate? We don't need to integrate, we need to divide and conquer! Some days you have to lead and other days I need to take the lead.

Engineering: Can't you ever just agree with me? (Sigh)

Entrepreneurship: I don't think so.

There are numerous issues that engineers and entrepreneurs will find very difficult to integrate. One example is how to make decisions in the absence of accurate and actionable information or data. While the ability to make decisions in the face of ambiguity is a principal trait of a successful entrepreneur, an engineer cannot make an engineering decision without good data and without employing proper statistics to understand and mitigate risk. The data that an entrepreneur must deal with comes from surveys and market analyses as well as future projections of the legal and cultural landscape. While this is considered empirical data for the most part, it is a far cry from the test data that engineers are used to. It is thus imperative that an engineer learns to differentiate between the two situations.

ACT 4: ENGINEERING AND ENTREPRENEURSHIP …

The setting is following the completion of many projects together. Our characters reflect on their experiences.

Engineering: Entrepreneurship, I wish I knew way back then what I know now.

Entrepreneurship: You're right Engineering, now that we've had some success, it's sure easier to see how important we are to each other. Like the old saying goes, "hindsight is 20-20".

Engineering: Did you say I was right?

Entrepreneurship: Don't let it go to your head.

In the end, the best outcome is to have engineering graduates who have a business owner's perspective of their professional lives. That take charge approach will make these engineers better employees who will contribute positively to their own success as well as the success of their employer.

INTEGRATIVE VERSUS SUPPLEMENTAL APPROACH

Introducing elements of the entrepreneurship mindset into the engineering curriculum ultimately is a question of *how* and *where*. There are two basic approaches that one can use depending on the circumstances. A supplemental approach could be used which involves entrepreneurship courses being offered as part of a minor or a certificate. This is the predominant model in place today as indicated by the burgeoning number of engineering colleges with a minor in entrepreneurship. Large research universities are breeding grounds of entrepreneurship with their technology parks and high-tech start-up incubators that are contributing positively to the US, both in number of businesses and economic output. While this model is extremely productive, it does require engineering students to self-select into it and thus typically reaches only a small fraction of the student body. Another supplemental approach is to offer entrepreneurship courses in place of free electives. This is very difficult as free electives are in very short supply in many engineering curricula and universities tend to have very structured core-curricula.

An integrative approach involves integrating entrepreneurial elements throughout the curriculum inside various courses. The benefits of such an approach are that the experiences are being reinforced repeatedly and that it requires no structural modifications to the curriculum. This is fairly easy in project based courses (i.e. Introduction to Design in the first year and the Capstone Design course for the graduating class). In a typical engineering curriculum, shown in Table I, these types of classes exist in the first half of the first year and in the fourth year. Courses in the second and third years with an emphasis on engineering sciences and analysis do not lend themselves to the seamless inclusion of entrepreneurial content. Yet, this constitutes over half of the curriculum and a time when engineering

students undergo phenomenal growth. One technique that has been used to great positive effect is a short, one lecture long, technical entrepreneurship case study that can be integrated into second and third year courses.

TABLE I
A TYPICAL ENGINEERING CURRICULUM

General topic	Year 1	Year 2	Year 3	Year 4
Engineering	Introduction to engineering and basic skills	Engineering Science	Analysis, Design and advanced skills	Design, practicum and technical electives
Mathematics	Calculus, differential equations and statistics			
Science	Physics and Chemistry			
Humanities	Electives			
Communications	College/technical writing and speech			

THE TECHNICAL ENTREPRENEURSHIP CASE STUDY

The technical entrepreneurship mini-case study was developed as the venue to inculcate the entrepreneurial mindset into all UDM engineering undergraduates. These case studies illustrate how a successful entrepreneur capitalized on his/her knowledge of specific technical or scientific topics to create a successful business venture. The short case studies are made part of the relevant engineering or science courses. This approach required minimal alteration to the existing curriculum.

There is much benefit to having entrepreneurs speak and lecture to the students [16] but the logistics become unmanageable. The mini-case studies rely on video recording of personal interviews with an entrepreneur as s/he speaks about his/her venture. Other than mere convenience, the video format resonates far more with today's YouTube generation and videos are easy to archive and share. With a planned podcast format, they will be disseminated on the internet and can be virtually within anyone's reach. There are pedagogical bases for this type of instruction technique and an example is a self-directed course that is offered by the Cisco Entrepreneur Institute on Entrepreneurial Mindset [17]. The following is an excerpt from the course description: "The Entrepreneurial Mindset course is specifically designed to explore the mindset of successful entrepreneurs. Rather than focus on business plans and balance sheets, you'll examine the world through the eyes of real-world entrepreneurs who will tell you how they think, how they are able to recognize opportunities, and the mindset that enabled them to transform those opportunities into successful new ventures. Through their stories we will unravel the mysteries and explore the realities of what it really takes to start and grow a successful new business."

The state of the art on either the case studies in entrepreneurship or the videos on entrepreneurship has been established long ago. The Harvard Business School (HBS) maintains a long list of business case studies that can be purchased. Stanford has a fairly extensive list as well that one can get directly through that university's website or through HBS. There are a couple of sources overseas and in particular from India.

A large number of entrepreneurship videos can be found on the Stanford Technology Ventures Program (STVP) E-corner website http://ecorner.stanford.edu/index.html and on the E-Clips website at Cornell University http://eclips.cornell.edu/homepage.do. Both websites contain over 1200 video clips each and they are generally of the highest quality and featuring some of the best and most renowned experts and entrepreneurs. E-Clips actually serves as a repository of videos gathered by the NCIIA, Harvard, RPI and others. Most of the STVP videos can be seen on the Academic Earth website at http://www.academicearth.org/subjects/entrepreneurship.

In both cases, STVP's E-Corner or Cornell's E-Clips, the videos are fairly short and provided in segments ranging between two and ten minutes. The investigators have spent a significant amount of time viewing these videos and found them to be enjoyable and intellectually stimulating and rewarding. As a matter of fact, one can easily gather a collection of these videos and create a course on entrepreneurship where the students will hear from actual entrepreneur who have a great deal of credibility and are very well-spoken.

There is a fair amount of overlap in style and substance between what the investigators are proposing here and the video clips from E-Corner and E-Clips. However, the intended audience and educational outcomes are quite different and as a result, these case studies fill an unmet need. These case studies are designed with the undergraduate STEM student audience in mind and are targeted to individual technical courses. The mini-case studies are designed to take up a single lecture and to leave the students with elements of the entrepreneurial mindset and a useful bit of the corresponding technical content to motivate their studies. The E-Corner and E-Clips videos are primarily aimed at entrepreneurship/business student audiences and hardly touch on the technical subject.

The basic premises of the entrepreneurship case studies [18-20] are as follows:

- Relatively short (thirty to forty-five minutes or so) entrepreneurship case studies integrated into existing technical courses.
- Cases that illustrate how an entrepreneur has capitalized on his/her knowledge of specific technical/engineering topics covered in the course.
- Besides illustrating the practical relevance of the subject matter, each case study focuses on few key aspects of entrepreneurship. Collectively, the cases are structured to provide as broad an exposure as possible with minimal duplication of content/topics.

- The aim is to provide routine exposure to successful engineering entrepreneurs and principles of entrepreneurship throughout the curriculum.
- The cases are centered on a videotaped interview with the entrepreneur with illustrations and voice-over when needed.
- To strengthen the tie to the course, a relevant in-class exercise, lab, or homework assignment accompanies each case study.

The student, upon completion of their undergraduate studies, and after viewing a comprehensive set of these case studies as well as the follow-up discussions will be able to:

- Appreciate the value of entrepreneurship to their person as well as to society.
- Appreciate the economic value of the entrepreneurial society.
- Tolerate ambiguity and make decisions using incomplete information.
- Tolerate risk in decision-making and properly assess and mitigate its effects.
- Embrace the entrepreneurial habits of seeking new opportunities and pursuing and executing on them.
- Have a clear image of the steps needed to create a successful new venture.

To strengthen the tie to the course, a relevant in-class exercise, lab, or homework assignment accompanies each case study. These case studies are freely available at http://weaverjm.faculty.udmercy.edu/udmkeencases.html.

Full assessment of the effectiveness of these case studies is still undergoing but initial results are very promising [20].

CONCLUSIONS

The last few decades have witnessed tectonic changes in the economy and those changes have significantly affected the engineering profession. The entrepreneurship mindset is widely viewed as empowering engineers to see and act on opportunities driven by these changes. The mindset also empowers engineers to take a business owner's perspective of their careers which helps inoculate them against the adverse effects of globalization. There are numerous successful models for providing entrepreneurship mindset training to engineering students, but mostly consist of intensive course experiences (minors, concentrations, capstone courses) and/or co/extra-curricular activities. The drawbacks of these approaches are that they are supplemental and that students have to self-select into them. An integrative approach is one that directly relates entrepreneurship to the subject matter of technical course. Such an approach reaches the entire student population by using a series of hour long positive exposures to technology and entrepreneurship interspersed throughout the curriculum. A dozen technical entrepreneurship video case studies were developed for that purpose at the University of Detroit Mercy and have been used successfully to positively affect the entrepreneurial mindset.

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