AC 2011-215: ENHANCING THE ENTREPRENEURIAL MINDSET OF FRESHMAN ENGINEERS

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Enhancing the Entrepreneurial Mindset of Freshman Engineers

Abstract:

On page 1 of *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* cites the most critical task of engineering educators: “first and foremost, engineering education must produce technically excellent and innovative graduates.” This report further states “it is agreed that innovation is the key and engineering is essential to the task of helping the United States maintain its economic leadership and its share of high technology jobs.” The goal of our research is to benchmark and identify creativity and innovation skill sets in first-year engineering students, which are included among necessary entrepreneurial skill sets, and understand how and why these skill sets change over their undergraduate matriculation.

Our research will report on an initial study of the impact of first-year engineering courses on the changes in entrepreneurial mindsets of first year engineering students. Entrepreneurial mindset in our study is operationally defined as a more growth orientated mindset versus a fixed orientated mindset. This operational definition and the accompanying mindset measurement instrument was developed and validated by Carol Dweck of Stanford University. Based on Dweck’s research results we assume a growth mindset is a reasonable surrogate for a student engineer’s creative and innovative or entrepreneurial skills.

Mindset of student engineers are benchmarked at the beginning of the freshman year and then again at the end of the freshman year, soon after completion of a team based poverty alleviation freshman capstone project. Two pre and post control samples of freshman engineer mindsets are being collected from similar sized engineering programs at comparable colleges in our geographic vicinity. Initial beginning-of-year testing results indicate a statistically significant tilt toward a fixed mindset in freshman engineering students compared to a growth mindset observed in an opportunity sample of freshman business students. We are tracking engineering students both at the group and at the individual level, by major and by other statistically significant demographic attributes.

Our long-term principal research goal is to determine how and why engineering course assignments affect a student engineer’s entrepreneurial skill set. We hypothesize that a student engineer’s innovation skills are a learned behavior that is influenced by the student engineer‘s learning experiences and course assignments. In order to study this phenomenon we must first establish a baseline of how student engineer mindsets change over time. Once we have established this baseline of mindset data, we can then alter interventions to evaluate their differentiated impact on mindset changes.

If entrepreneurial skill is critical to the future economic success of our country then enhancing this skill set is a critical component in engineering education.

Background:

Training engineers as entrepreneurs and innovators has been a hot topic in the popular and academic press for at least the past decade. It is a generally held societal belief that an understanding of business principles by engineers along with enhancing entrepreneurial tendencies will lead to a greater number and more successful technical innovations for a company[1] or country [2-4]. It is expected that such innovations will lead to economic wealth and job creation, vital concerns of all societies. As many as 47 US universities now offer entrepreneurship courses to engineers [5]. This belief in the value of engineering entrepreneurship is not limited to the United States and is used to justify teaching business principles and entrepreneurship to engineers all over the world [6-9]. Competitions, as in the ITP, Innovation-to-Product Competition, [10], networks of universities emphasizing entrepreneurship training for engineers, as funded by the Kern Family Foundation, [11], and curriculum changes [12-17] have all been created based in part on this deeply held belief. In addition substantial capital investments are regularly made in student engineers or teams of student engineers who demonstrate the ability to be entrepreneurial and innovative as a part of their academic activities. These investments include initial entrepreneurial successes [18, 19]. The myths surrounding the efficacy of engineering entrepreneurship training are also in the words of Scott Berglund, the author of the The Myths of Innovation cleared away when you examine the lives of some of the greatest innovators of all time, e.g., Edison, VanGogh, or Tesla, "they were not experts [fixed mindset], they just got to work trying to solve important problems and learned along the way [growth mindset]."[20]

To date little has been reported on how student engineers receiving entrepreneurial training as a group have had their cognitive abilities, aptitudes or attitudes changed by their entrepreneurial training and any associated experiential education. Prior research includes investigations into engineering student experiences from playing a business game. The results indicate that students who participate in a business market game have significantly better perceptions of engineering entrepreneurship than those students who execute regular engineering project assignments. [21]. Yemini also found increased interest in entrepreneurship and improved self esteem by participants in an engineering entrepreneurship program in Israel [22]. Many published case studies also discuss the success of student engineering teams participating in entrepreneurial design competitions and experiential team project activities [18, 23]. However the analysis and reporting focus tends to be on the significant entrepreneurial successes not the impact of the training on individual engineers.

Bergland did find differences in the way engineers versus business students responded to entrepreneurial training as engineers were thinking more incrementally and business students were more market focused after receiving the entrepreneurial training [24]. Wise also suggested methods for measuring the success of an entrepreneurship minor program for engineers [25]. Some authors maintain that entrepreneurial behavior as evidenced by the ability for students to raise funds for design projects is proof of learned entrepreneurial skills. [26].

Entrepreneurial Interventions:

Our approach to measuring the impact of our interventions however is based upon measuring whether the mindset of our students is changed or altered by the entrepreneurial interventions that we incorporate into the freshmen engineering experience. These interventions occur throughout the first year of study in engineering.

In the engineering students' first quarter, a one class introduction to the definitions and concepts of entrepreneurship is conducted. A particular emphasis is placed on the excitement and risks associated with starting something new and the need to overcome the fear of failure, demonstrated in '*Failure: The Secret to Success*', a film produced by Honda. A discussion of the societal role of entrepreneurs underscored by playing The Acton Institute video, '*The Call of the Entrepreneur'* (ref: http://www.youtube.com/watch?v=pem0ZSsMQVA).[27] An inspirational call to consider entrepreneurial ventures closed by playing the Grasshopper video: '*Entrepreneurs Can Change the World*.' (ref: http://www.youtube.com/watch?v=T6MhAwQ64c0).[28]

A team based exercise emphasizing creative thinking, thinking-outside-the-box and teamwork creativity is conducted in the second quarter. The DeBono Six-Hat teamwork creativity technique and lateral thinking idea has been used successfully in this second step (ref: http://www.youtube.com/watch?v=UjSjZOjNIJg&feature=related)[29]. The DeBono 6 Hat lateral thinking technique has important perspectives that assist the engineer in a cross functional team in drawing upon the creative resources of the whole group. Each member of the group assumes a role within the team designated by the appropriate 'hat'. These 6 Hat process steps as named by DeBono as: The White Hat, emphasizing facts and figures; The Yellow Hat, emphasizing advantages; The Black Hat, emphasizing conservative points of view; The Green Hat, emphasizing creative ideas; The Red Hat, emphasizing emotions; and The Blue Hat, responsible for organizing the meeting and discussion (ref: http://www.youtube.com/watch?v=cjVxSk1MqO4&feature=related). [29, 30]

A final team based exercise in which students design a device to alleviate some effect of poverty within a specified population is assigned during the final quarter. This project requires teams to investigate their assigned population to identify potential projects that would be beneficial. Once the team proposes a design, they progress through the complete design cycle to design, prototype, test and present results of their design [31-33], The inspiration for this approach was the 2008 ASEE Distinguish Lecture presentation by Dr. Paul Polak [34]. In his presentation, Dr. Polak described how engineering faculties are starting to focus on design-affordable products for the poor. While his emphasis was on senior- and graduate-level design projects, the advantages to incorporating this concept into the first year of study were apparent, allowing students experience how an engineer can effect positive change by designing for those who are impoverished by presenting real world examples where realistic constraints listed in ABET EAC Criterion 3c (ref: www.abet.org) must be considered.

A sample Request for Proposals is shown in Figure 1.

Request for Proposals:
Design of Poverty-Alleviating Devices

Summary

The Other 90 Design, Inc. (TO9D), is a not-for-profit multinational corporation that has as its mission to develop products that will benefit the 90% percent of people on Earth who are poor by helping them out of "absolute poverty", which was defined by the World Bank in 1990 as the earning of an equivalent income of $2 a day or less. TO9D attempts to accomplish this goal through focusing development efforts on products that either allows people to earn their way out of poverty or allow people to spend less time, money and/or effort on the necessities for life. Among the products developed to date are:

- Solar-powered flashlight for nighttime illumination (replacing kerosene lamps)
- Low-cost drip irrigation and water storage systems (for locations with both rainy and dry seasons)
- Donkey carts (for material deliveries in roadless areas)

TO9D is now accepting proposals for new products designed for alleviating poverty in one or more impoverished countries.

Specifications

The proposal must identify a real world poverty situation in a specific nation where at least 40% of the population earns less than $2 a day…

Figure 1. Summary of Request for Proposals.

Entrepreneurial mindset:

In evaluating the impact of our interventions we have chosen to look at the mindset of our students toward risk and intelligence and how we might encourage them to be more entrepreneurial (defined as creative and inventive) in executing their projects and as they develop into engineers. The measure of mindset we are using has been developed by Carol Dweck of Stanford and is based on two key ideas or states of mind. The fixed mindset is a mindset where the individual believes that the abilities or intelligence they have is all they will ever possess and cannot be changed, while a growth mindset is one where the individual believes intelligence and intellectual ability is affected by life experience; thus individuals have a chance to intellectually learn and grow, and not necessarily discouraged or stopped by failure. [35, 36].

A critical aspect of the mindset approach to instilling entrepreneurial behavior in engineers relates to pedagogical instruction in the classroom. In order to develop an individual's growth mindset, it is necessary to praise an individual's process of learning rather than their intelligence. Praise of their intelligence simply encourages students not to take more risks or learn from their failures. [37-39]. In this context we are assuming that a change to a more growth orientated mindset means the student engineer is potentially more entrepreneurial.

Method

The Dweck mindset measurement instrument was administered to first-year engineering students three times during their first year of study; prior to an introduction to entrepreneurship concepts, after an initial entrepreneurial intervention focused on creativity and innovation, then at the end of the first year. As an attempt of benchmarking of college student entrepreneurial mindsets, the same Dweck mindset measurement instrument was administered to a group of freshmen business majors. The data from this measurement is compared to the engineering student mindset measurements at the beginning of their first year of study. This data is analyzed to determine significant differences in mindset between students choosing engineering versus those choosing business as an initial major. Differences between students beginning their studies in these majors, as well as changes over the course of the first year in engineering student mindsets may provide insights into changes in mindset. Differences in both fixed mindset and growth mindset are investigated.

Statistical significance was determined using a Mann-Whitney nonparametric test of comparison, using SAS (version 9), *proc npar1way* with *wilcoxon* option. Nonparametric tests were selected to avoid a required assumption of data normality.

Statistical significance of differences is influenced by sample size, and a statistically significant difference does not *necessarily* imply a meaningful or important difference – only that a true difference most likely exists. The effect size, or Cohen's *d*, is a measure of the magnitude of the effect or the importance of the difference [40, 41] Cohen's d is found by:

$$d = \frac{(M_1 - M_2)}{\sigma_{pooled}} \quad (1)$$

where M1 and M2 are the means of the male and female population. The pooled standard deviation, σ_{pooled}, is the root-mean-square of the standard deviations of the two populations (Cohen, 1988). That is, the pooled standard deviation is:

$$\sigma_{pooled} = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}} \quad (2)$$

When the two standard deviations are similar (as is typically the case), the root mean square differs very little from the simple average of the two variances.

While Cohen originally defined ranges for effect sizes as small: $d = 0.2$, medium, $d = 0.5$; and large, $d = 0.8$, the suggested ranges of effect size were adjusted for different applications shortly after publication of these initial estimates. Hyde [42] defined the ranges as part of the Gender Similarity Hypothesis as: near-zero, $d \leq 0.10$; small, $0.11 < d \leq 0.35$; moderate, $0.36 < d \leq 0.65$; large, $0.66 < d \leq 1.0$; and very large, $d > 1.0$; based on subsequent exploration of effect sizes as they apply to research in the social sciences.

Results:

Initial results showed a significant difference at the $\alpha = 0.05$ level between business students and first-year engineering students at the beginning of their first year of study in both growth mindset ($p = 0.048$) and the fixed mindset ($p = 0.0355$). The value of Cohen's *d* shows a moderate effect size between the two populations (business $n = 64$, engineering $n=84$), meaning the difference is both statistically significant and meaningful (see Table 1).

These results show that first-year engineering students and first-year business students begin with differences in both growth and fixed mindset. While this is interesting, the goal is to capture the change over the first year.

The data also show that engineering students show a slight difference between the beginning and end of their first year of study through values of effect size ($d = -0.1348$ for fixed mindset, $d = 0.1131$ for growth mindset); while the difference is not statistically significant, the data does show that engineering students tended toward a more fixed mindset and away from a growth mindset over the course of their first year.

Table 1: Differences between engineering and business student mindset, with changes in engineering mindset over time

Mindset Changes	Fixed Mindset			Growth Mindset		
	mean	Chron d		mean	Chron d	
Engr 1 > Engr 3	2.74 vs 2.83	**-0.1348** (small)	$\chi^2 = 1.242$ $p = 0.265$	3.36 vs 3.28	**0.1131** (small)	$\chi^2 = 1.157$ $p = 0.282$
Engr 1 > Engr 2	2.74 vs 2.77	-0.0528	$\chi^2 = .1104$ $p = 0.740$	3.36 vs 3.21	**0.1852** (small)	$\chi^2 = .977$ $p = 0.323$
Engr 2 > Engr 3	2.77 vs 2.83	-0.0528	$\chi^2 = .7504$ $p = 0.386$	3.21 vs 3.28	-0.0792	$\chi^2 = .010$ $p = 0.920$
Engr 1 > Business	2.74 vs 2.52	**0.3116** (moderate)	$\chi^2 = 4.422$ $p = 0.036$	3.36 vs 3.60	**-0.3201** (moderate)	$\chi^2 = 3.99$ $p = 0.046$

While the trend toward fixed mindset over the first year of study, while not surprising, is not ideal. The coursework found in the first year of engineering study does not necessarily foster the ideal of a growth mindset; physics, calculus, and chemistry, for example, do not offer much room for creativity or innovation.

Discussion and Future Plans:

The question of any effect of the entrepreneurial interventions remains: did the interventions themselves have an effect on the changes in fixed or growth mindset of first-year engineering students?

To investigate this, two comparison populations are participating in the survey at the beginning and end of the academic year. The two populations will serve as control groups, in that they will not receive an intentional entrepreneurial intervention in their first year of study. All freshmen engineers in comparison samples A and B will be sampled with the validated Dweck mindset instrument at the beginning and end of their freshmen year.

The first comparison sample, school A, is a college in the upper Northeast with about 2000 total students and undergraduate engineering majors in Bioengineering, Computer Engineering, Electrical Engineering, and Mechanical Engineering. The second comparative sample, sample B, is a college in the Midwest with about 2000 total students and undergraduate engineering majors in Chemical and Bioprocess Engineering, Civil Engineering, Computer Engineering, Computer Science ,Design, Engineering Technology, Electrical Engineering, Mechanical Engineering, and General Engineering. All three institutions are similar in size and geographical location. Differences in students at the beginning and end of the year will be measured, and differences in the magnitude and direction of changes will be measured.

Conclusion:

It is theorized that the introduction of entrepreneurial interventions into the first year of an engineering curriculum will help students move toward a more growth oriented mindset (where their intelligence and learning ability can improve), rather than a fixed mindset (where an individual's intelligence is thought to be fixed). This study showed that engineering students enter their first year of study with a much more fixed mindset than first year business students. Further, there is a change in mindset over the first year of study, although not in the desired direction.

These results lead to further questions: do the interventions themselves perhaps slow or decrease the shift toward a fixed mindset? To answer this question, studies are currently underway to assess differences between institutions where entrepreneurial interventions exist and where they do not.

Regardless of the value of the interventions toward changes in mindset, the interventions are seen as very valuable in increasing creativity and innovation in projects completed in the first year. As such, the interventions are planned as permanent components within the first year curriculum.

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