Investigating the Entrepreneurial Mindset of Engineering and Computer Science Students

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Introduction

In recent years, numerous engineering programs around the country have introduced curricular revisions and co-curricular activities to develop entrepreneurial skills in students. The primary motivation of these efforts is to graduate engineering students who can rapidly contribute to the economic growth of the nation through entrepreneurship and innovation. A precursor to launching startups or creating new products or services is the development of an entrepreneurial mindset. Efforts focused on developing an entrepreneurial mindset in engineering students through curricular and co-curricular activities are emerging from the many partner institutions of the Kern Entrepreneurial Engineering Network (KEEN) [1]. As these efforts strengthen, approaches to assess the entrepreneurial mindset have also been developed. A popular approach is the use of survey instruments. Lichtenstein and Zappe [2] reviewed 22 instruments developed to assess entrepreneurial mindset.

We have developed a rigorously validated assessment instrument to explore the entrepreneurial mindset of engineering and computer science students [3], [4]. This instrument was developed based on a framework in which an entrepreneurially minded engineer is defined as one who possesses *curiosity* about our changing world, habitually makes *connections* to gain insight from many sources of information, and focuses on *creating value* for others. The italicized words, referred to as the 3C's, form the core of this framework which was developed by the Kern Entrepreneurial Engineering Network (KEEN) [1]. The instrument consists of 50 questions loaded on 14 factors that are associated with learning outcomes based on the 3C's [4].

The instrument was administered to first-year and senior engineering students in two consecutive years and 394 valid samples were collected. A set of two sample t-tests were performed to answer the following research questions:

1. How diversified is the entrepreneurial mindset of first-year students when they enter the university?
2. How diversified is the entrepreneurial mindset of seniors when they complete their program?
3. How does the entrepreneurial mindset of students evolve through traditional engineering and computer science undergraduate experiences?
4. Are there differences in the entrepreneurial mindset between male and female students?
5. How does family background influence the entrepreneurial mindset?

By investigating the answers to these research questions, we hope to answer the broader question: How can engineering and computer science undergraduate programs be revised to enhance entrepreneurial mindset growth as we strive to meet the challenges of "Educating the Engineer of 2020"?

Instrument Development

In the initial design stage, we developed an assessment instrument based on the definition of the engineering entrepreneurial mindset proposed by KEEN [3]. Two broad sets of items were generated in this instrument. The first set contained 12 items that were designed to measure general entrepreneurial characteristics such as curiosity and interest in entrepreneurship. The second set included 25 items that were designed to measure acquisition of entrepreneurial knowledge. This design resulted in a survey questionnaire with 37 items loaded on 15 theoretical factors [3]. This questionnaire was administered to first-year engineering students at the University of New Haven. 227 students participated in the study and the survey results were used to test the validity of the instrument. After applying exploratory factor analysis (EFA) to the collected data [4], a model with 27 items loaded on 10 factors was extracted. Reliability analysis based on Cronbach's α for this 10-factor model suggested that the number of items on factors with low internal consistency should be reduced, and the number of items for factors with low reliability should be increased.

Based on the EFA result for the first design, a revised 14-factor model was proposed in the second design stage [4]. There were 50 items in the instrument, with 49 items loaded on 14 factors and 1 item designed as a comparison indicator. The interpretation of the factors is listed in Table 1. The detailed items and their associated latent constructs are presented in Table 2 (note that is not exactly the format of the survey questionnaire used for data collection).

Table 1. Interpretations of Factors

Number	Factor Names	Abbreviation
1	Problem Solving/Logical Thinking	PS
2	Engaging Stakeholders	ES
3	Value Creation	VC
4	Risk Management	RM
5	Career Plan	CP
6	Ability to Learn	AL
7	Analyze Market Conditions	MC
8	Systems Thinking	ST
9	Team Building	TB
10	Exposure to Entrepreneurship	EE
11	Ability to Anticipate Technical Development	AT
12	Intrinsic Curiosity	IC
13	Ability to Assess Financial Value	AF
14	Data Driven Decision Making	DM

Data Collection and Analysis

To answer the proposed research questions using the survey instrument, we invited both first-year and senior engineering students from the University of New Haven to participate in the study. First-year students took the questionnaire during the engineering orientation in fall 2016 and fall 2017. Seniors took the questionnaire at the time when they completed exit surveys in spring 2016 and spring 2017. In all cases a paper-based survey was used. The data was coded in MS Excel. Of

Table 2. Engineering Entrepreneurship Mindset Instrument

	Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	I am able to act effectively and creatively in difficult situations	1													
2	I am able to identify potential stakeholders for a new product or service		2												
3	Business value creation is the company owner's concern			3											
4	Business risk assessment is the business manager's responsibility				4										
5	I like to learn about entrepreneurship					comparison									
6	Every time I fail a task, I reflect on why I failed so that I can learn how to do better in the future						6								
7	I understand why a monopolistic market is usually not favorable to consumers							7							
8	I consider how multiple changes affect each other								8						
9	I am confident in leading a team to work on a project									9					
10	I have had exposure to entrepreneurship concepts before entering college										10				
11	I have the ability to anticipate technical developments by interpreting surrounding social trends											11			
12	When I see a piece of machinery, I always like to find out how it works												12		
13	I am able to communicate an engineering solution in economic terms													13	
14	I am able to substantiate claims with data and facts														14
15	I have a clear plan for my professional development					5									
16	I am able to use the means at my disposal to handle situations effectively	1													
17	I am able to address stakeholder interests in a business plan		2												
18	Whenever I work on a project, I think about what value it will deliver			3											
19	I thought about potential risks related to my past jobs and tried to actively manage them				4										
20	The ability to cope with failure can be improved through training						6								
21	I understand why a free market economy is generally favorable to consumers							7							
22	I am able to see the big picture as well as the details when I am working on a problem								8						
23	I always try to maintain a good interpersonal relationship in a team									9					
24	There is/are entrepreneur(s) among my relatives										10				
25	I like to speculate how new technology can be used for the future											11			
26	I always actively seek as much information as I can in a new situation												12		
27	I am able to assess the economic viability of a new product or service													13	
28	I am able to use data and facts to identify an opportunity														14
29	I want to become a good engineer as well as a successful entrepreneur					5									
30	I am able to apply logical thinking to gathering and analyzing information	1													
31	Stakeholders have a strong influence on company business activities		2												
32	When I read about a new innovation, I try to understand the value that it will create			3											
33	Most employees of a company do not need to worry about managing risk				4										
34	Creative thinking skills can be acquired through training						6								
35	I know how to take advantage of market conditions when developing a product or service							7							
36	Understanding how events affecting each other occur is crucial in solving complex problems								8						
37	I always try to complete assigned tasks when working in a team									9					
38	I have the ability to anticipate technical developments by looking at existing technology											11			
39	I consider myself to be a person who takes action when I'm curious about something												12		
40	I am able to make decisions based on economic value													13	
41	I am able to make data driven decisions														14
42	I plan to start up my own business in the future					5									
43	I am able to apply logical thinking to designing and solving problems	1													
44	All stakeholders carry equal weight in company decisions and activities		2												
45	I welcome new ideas on how to accomplish tasks differently						6								
46	Considering a problem in relation to the whole results in a better solution								8						
47	I am able to leverage the personality traits of individuals to make a team perform well									9					
48	I have the ability to anticipate technical developments by interpreting surrounding economic trends											11			
49	I find myself being curious about a lot of things and people I encounter in life												12		
50	I think allowing supply and demand to determine price is good for customers													13	

the total 394 valid responses received, 55.1% were freshmen, and 44.9% were seniors; 16.1% were women, 83.6% were men, and 0.3% indicated "other."

The items in the survey questionnaire were formatted based on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In order to avoid biased answers in case a student did not understand a question, the additional choice "I don't understand" was provided in the questionnaire. During data coding, "I don't understand" was treated as missing data. Since the data sample was relatively small, we did not apply listwise or pairwise deletion. To minimize information loss, we replaced the missing data with the means. Data analysis was performed using the MS Excel Analysis Tool.

Research Question 1: How diversified is the entrepreneurial mindset of first-year students when they enter the university?

To answer this question, we calculated the mean value for each factor. Table 3 shows the factors ordered from the lowest mean to the highest based on first-year student responses. The means vary from 3.09 to 4.10 across all factors, which indicates that when entering college engineering students possess a neutral to strong entrepreneurial mindset. They believe they are strong in the following traits: F12-Intrinsic Curiosity (mean = 4.10), F9-Team Building (mean = 4.09), F6-Ability to Learn (mean = 4.06), and F8-Systems Thinking (mean = 4.06). These appear to be distinctively strong characteristics possessed by traditional engineering students. Table 3 also shows that first-year students think they are not strong (mean < 3.50) in the following areas: F4-Risk Management (mean = 3.09), F2-Engaging Stakeholders (mean = 3.19), and F13-Ability to Assess Financial Value (mean = 3.45). These weaknesses appear reasonable since recent high school graduates are typically not expected to have strong ability in risk management, assessing financial value, or understanding how to engage stakeholders.

The items with low mean values provide direction on what educational elements should be brought into engineering curricula for the purpose of educating engineering students to have a holistic entrepreneurial mindset.

Table 3. First-Year Student Responses Ordered by Factor Means

Factor #	Factor Name	Mean Value
12	Intrinsic Curiosity	4.10
9	Team Building	4.09
6	Ability to Learn	4.06
8	Systems Thinking	4.04
1	Problem Solving/Logical Thinking	3.98
14	Data Driven Decision Making	3.74
7	Analyze Market Conditions	3.65
5	Career Plan	3.64
3	Value Creation	3.63
11	Ability to Anticipate Technical Development	3.54
13	Ability to Assess Financial Value	3.45
2	Engaging Stakeholders	3.19
4	Risk Management	3.09

Research Question 2: How diversified is the entrepreneurial mindset of seniors when they complete their program?

Table 4 shows the mean for each factor based on responses by seniors. The means vary from 3.37 to 4.25 across all factors, which again indicates that as they finish their programs seniors possess a neutral to strong entrepreneurial mindset. On average, the means are higher for seniors compared to first-year students. The four traits with the highest means for seniors are: F9-Team Building (mean = 4.25), F1-Problem Solving/Logical Thinking (mean = 4.22), F8-Systems Thinking (mean = 4.16), and F12-Intrinsic Curiosity (mean = 4.15). Compared to first-year students, the means for two more factors are above 4.00 for seniors. They are F1-Problem Solving/Logical Thinking (mean = 4.22), and F14-Data Driven Decision Making (mean = 4.01). The noticeable increase in the mean value from first-year students to seniors indicates that the intrinsic entrepreneurial mindset of engineering students is strengthened and broadened during their undergraduate programs.

The weakest traits (mean < 3.50) in the seniors are F4-Risk Management (mean = 3.37), followed by F2-Engaging Stakeholders (mean = 3.76). These were also the two weakest factors in the responses of first-year students, although the mean scores increased from the first to the last year. These results indicate that perhaps more emphasis should be placed on risk management and engaging stakeholders in undergraduate engineering curricula to develop entrepreneurial engineers.

Table 4. Senior Student Responses Ordered by Factor Means

Factor #	Factor Name	Mean Value Freshman	Mean Value Senior
12	Intrinsic Curiosity	4.10	4.15
9	Team Building	4.09	4.25
6	Ability to Learn	4.06	4.07
8	Systems Thinking	4.04	4.16
1	Problem Solving/Logical Thinking	3.98	4.22
14	Data Driven Decision Making	3.74	4.01
7	Analyze Market Conditions	3.65	3.82
5	Career Plan	3.64	3.84
3	Value Creation	3.63	3.90
11	Ability to Anticipate Technical Development	3.54	3.87
13	Ability to Assess Financial Value	3.45	3.87
2	Engaging Stakeholders	3.19	3.76
4	Risk Management	3.09	3.37

Research Question 3: How does the entrepreneurial mindset of students evolve through traditional engineering and computer science undergraduate experiences?

At the University of New Haven, the primary curricular component for developing an entrepreneurial mindset in students is the integration of short e-learning modules on entrepreneurial topics into existing engineering and computer science courses [6]. When the development of the e-learning modules is complete, there will be a total of 18 modules that

students will complete. However, at the time the data analyzed in this study were collected, seniors had only completed 1 to 3 e-learning modules during their time at the university. These modules included:

- Building, Sustaining and Leading Effective Teams and Establishing Performance Goals
- Applying Systems Thinking to Complex Problems
- The Elevator Pitch: Advocating for Your Good Ideas

Since these seniors received very limited exposure to entrepreneurial topics, we can assume that the programs they completed were rather traditional ones. Therefore, the differences in the responses between the first-year students and seniors originate primarily from their maturity, and the training they received from conventional engineering and computer science curricula.

We compared the responses of first-year students and seniors to all questions in the survey instrument to assess how their entrepreneurial mindset evolved through their educational experiences. First, we compared their abilities in understanding the questions using the number of "I don't understand the question" responses. In 14 out of 50 questions, the percentage of seniors who understood the question was at least 5% larger than the percentage of first-year students who understood the questions, and in 8 out of these 14 questions the percentage difference was 10%. For the remaining questions, the difference in the percentage of students who understood the question did not change significantly between first-year students and seniors. First-year students seemed to understand two of the questions more than seniors, but the difference in the percentage was less than 2% and is considered a result of measurement noise. The questions for which the difference in the percentage of seniors and first-year students who understood the question was at least 10% are listed in Table 5. It is interesting to note that all of these items are loaded on factors associated with marketing and financial aspects of entrepreneurship. In particular, all questions related to Factor 2 (Engaging Stakeholders) were in this set, despite this aspect not being formally introduced in the curricula when the data were collected. This result seems to indicate that students naturally develop their understanding and ability in these areas due to influences from society and/or as a result of their maturation.

Table 5. Factors for which the Difference in the Mean Percentage of Seniors and First-Year Students who Understood the Question was at Least 10%

Factors	Questions
2. Engaging Stakeholders (all items)	2. I am able to identify potential stakeholders for a new product or service
	17. I am able to address stakeholder interests in a business plan
	31. Stakeholders have a strong influence on company business activities
	44. All stakeholders carry equal weight in company decisions and activities
3. Value Creation	3. Business value creation is the company owner's concern
7. Analyze Market Conditions	7. I understand why a monopolistic market is usually not favorable to consumers
	21. I understand why a free market economy is generally favorable to consumers
13. Ability to Assess Financial Value	27. I am able to assess the economic viability of a new product or service

Next, we determined the differences in the means for all 50 questions between the two groups of students. In 30 questions, seniors show a statistically significant improvement in their responses, whereas there is a statistically significant decline for 3 questions. For the remainder of the 17 questions, the mean differences across the two groups are not statistically significant. The analysis results are summarized in Table 6. We find that all items loaded on Factors 1, 2, 3, 11 and 14, and some items loaded on Factors 4, 7, 8, and 13 show statistically significant improvement from first-year students to seniors. A particular result to note is that F2-Engaging Stakeholders is the only factor in which seniors demonstrate both an improvement in understanding and stronger answers to *all* questions. It may be that this improvement is a result of senior design projects, many of which are sponsored by industry and have industry stakeholders and other activities where stakeholders may be involved.

Table 6. Factors in which Seniors Show Significant Improvement

Number	Factor Names	Abbreviation	Improvement
1	Problem Solving/Logical Thinking	PS	All Items
2	Engaging Stakeholders	ES	All Items + Understanding
3	Value Creation	VC	All Items
4	Risk Management	RM	Some Items
5	Career Plan	CP	Improved + Declined
6	Ability to Learn	AL	Improved + Declined
7	Analyze Market Conditions	MC	Some Items
8	System Thinking	ST	Some Items
9	Team Building	TB	Improved + Declined
10	Exposure to Entrepreneurship	EE	No Items
11	Ability to Anticipate Technical Development	AT	All Items
12	Intrinsic Curiosity	IC	No Items
13	Ability to Assess Financial Value	AF	Some Items
14	Data Driven Decision Making	DM	All Items

Another result is that there is one item in each of Factors 5, 6 and 9 that shows statistically significant lower means in the response of seniors compared to the response of first-year students. These are Q29/F5-I want to become a good engineer as well as a successful entrepreneur, Q20/F6-The ability to cope with failure can be improved through training, and Q37/F9-I always try to complete assigned tasks when I work in a team. We make the following speculations as to the decline in the mean responses:

- Q29: Technically focused engineering curricula may be steering students away from entrepreneurship.
- Q20: No formal instruction is given related to coping with failure and any optimism that first-year students might have had perhaps diminish over their undergraduate years.
- Q37: The college experience may be revealing the reality that students don't always complete their tasks when working in a team.

These observations indicate that there is potential for improving the entrepreneurial mindset of students through curricular and co-curricular interventions.

Finally, we find that there is no statistically significant difference between the mean responses of first-year students and seniors for *all* items loaded on Factors 10 and 12. We can expect no difference in F10-Exposure to Entrepreneurship, since it is related to students' exposure to entrepreneurship before entering college. However, F12-Intrinsic Curiosity is related to their level of curiosity, and no change in the mean from the first to the last year in undergraduate programs confirms the general notion that highly technical education stifles creativity. Curricular and co-curricular interventions that stimulate students' creativity should therefore be very valuable within engineering and computer science curricula.

Research Question 4: Are there differences in the entrepreneurial mindset between male and female students?

First we compare the differences between how well male and female students understood the questions. The results show that more female students selected the "I don't understand (the question)" response than male students. Out of the 50 questions, in the 5 questions that are shown in Table 7, the difference between the means of the percentage of male and female students who did not understand the question was more than 10%. Furthermore, in 9 questions, this difference was more than 5%. On the contrary, the mean percentage of male students who did not understand the question exceeded that of female students in only in 3 questions, and the difference was less than 2.6%. At first blush, it might appear that in general more female students did not understand the questions in this instrument compared to male students. However, the differences in means may also be indicative of stereotypical gender behavior, whereby more males than females do not like to admit that they "don't understand."

Table 7. Questions in which the Difference between the Mean Percentages of Males and Females who Understood the Question was at Least 10%

Factors	Questions
2. Engaging stakeholders	17. I am able to address stakeholder interests in a business plan
	31. Stakeholders have a strong influence on company business activities
3. Value Creation	3. Business value creation is the company owner's concern
7. Analyze Market Conditions	7. I understand why a monopolistic market is usually not favorable to consumers
13. Ability to Assess Financial Value	27. I am able to assess the economic viability of a new product or service

Even though the above results seem to indicate that more female students have difficulty in understanding the questions, the differences in the mean responses by male and female students for all the questions show that both groups demonstrate similar performance. Among the 50 questions, there are only 4 questions in which the mean response of male students was statistically higher than that of females, and in 2 questions the mean responses of females were higher than that of males. It is interesting to note that only 1 of the 4 questions in which the mean response of males was higher than that of females belongs to the pool of 5 questions in Table 7, for which mean response of male students who understood the question was significantly higher than that of female students. Thus, while more male students felt that they understood the questions, they did not necessarily provide affirmative responses for the specific questions. On the whole, we

conclude that there is no significant difference between the entrepreneurial mindset of male and female students.

Among the 4 questions for which the higher mean response of male students compared to female students is statistically significant, two questions are noteworthy: Q5-I like to learn about entrepreneurship, and Q42-I plan to start up my own business in the future. We included these items in the instrument to ascertain students' interests in entrepreneurship. Based on our measurement results, the evidence indicates that male students show a statistically stronger trait in this aspect. More male students are keener to become entrepreneurs than female students.

Research Question 5. How does family background influence the entrepreneurial mindset?

Students' exposure to entrepreneurship through relatives was determined through the question Q24-There is/are entrepreneur(s) among my relatives. Since a 5-point Likert scale was used for measurement, students' responses range from 1 (strongly disagree) to 5 (strongly agree). We interpreted a response of 1 to mean that no relatives of the student were entrepreneurs, a response of 5 to mean that the student had an entrepreneur within his or her immediate family, and responses from 2 to 4 to mean something in between. When conducting data analysis, students who selected 1 and 5 were clustered into Group 1 and Group 5, respectively. The responses of 2, 3 and 4 were not used in the analysis since they fall along the continuum from "no influence" to "very strong influence." Depending on how a student interpreted "relatives," there might be some overlap between the responses of 2, 3 and 4. Analysis based on Groups 1 and 5 only will avoid distortions and be more reliable.

The analysis results show that for 17 of the 50 items (i.e., 34% of the total traits measured), the means for students in Group 5 (assumed to be those that have an entrepreneur within the immediate family) are statistically higher than the means for Group 1 students. On the other hand, there are no items for which the mean for students in Group 1 (assumed to be those that have no entrepreneur among relatives) is statistically higher than the mean for Group 5 students. Of the 50 items, Group 5 has 31 items for which the mean exceeded 4.0, while Group 1 has only 21 items for which the mean exceeded 4.0. Therefore, we conclude that having an entrepreneur within the immediate family has a very strong influence on students developing an entrepreneurial mindset.

It is very interesting to note that even though an entrepreneurial family exerts a strong influence in the development of an entrepreneurial mindset, students from such families do not appear to have a stronger desire to start a new business. The mean of Q42-*I plan to start up my own business in future* is only 3.85 for Group 5. In fact, the question that has the highest mean response in Group 5 is Q29-*I want to become a good engineer as well as a successful entrepreneur* (mean = 4.68). It is worthwhile to further explore why students from families having entrepreneurs are less interested in starting up a new business than becoming an engineer as well as an entrepreneur.

Conclusions

The responses by first-year students and seniors in engineering and computers science undergraduate programs at the University of New Haven to a 50-item survey instrument designed to assess their entrepreneurial mindset yielded the following interesting results: 1) Engineering and computer science students enter college with a neutral to strong entrepreneurial mindset. Particular strengths that they identify include intrinsic curiosity, team building, an ability to learn and systems thinking. Their particular weaknesses include risk management, engaging stakeholders and the ability to assess financial value. 2) The entrepreneurial mindset of students

who pursue traditional engineering and computer science programs shows some improvement from first year to senior year, especially in team building, problem solving/logical thinking, systems thinking, intrinsic curiosity, the ability to learn, and data driven decision making. Seniors who followed these traditional programs showed weaknesses in risk management and engaging stakeholders. 3) There is no significant difference in the entrepreneurial mindset of male and female students. However, a greater proportion of male students are interested in becoming entrepreneurs compared to female students. 4) Students who have close relatives that are entrepreneurs have a stronger entrepreneurial mindset. However, these students do not have a stronger desire to start a new business compared to other students.

The above findings seem to indicate that traditional technically focused curricula may be steering students away from entrepreneurship, do not enhance students' ability to cope with failures, and may be stifling their intrinsic curiosity. Therefore curricular and co-curricular interventions in these areas should be emphasized. The findings also show that for the purpose of educating engineering students to have a holistic entrepreneurial mindset, programs should be revised to focus more on risk management, assessing financial value, and engaging stakeholders.

This paper reports current progress on a continuing effort to investigate the entrepreneurial mindset of engineering and computer science students. The seniors who participated in this study were exposed to very few of the 18 e-learning modules on entrepreneurial topics that are being integrated into programs. Even though their exposure to entrepreneurial education was limited, the data is mildly "contaminated" by this exposure. In a future study, we will measure the difference in entrepreneurial mindset between freshmen and seniors from programs at other colleges with very traditional curricula and compare the change in those students to change in our students. We also plan to extend the investigation to compare the entrepreneurial mindsets of students in the U.S. and students in Asian countries. Finally, and most importantly, we intend to measure student learning of entrepreneurial concepts when they complete all 18 of the e-learning modules that we will deploy. These studies will extend over the next few years.

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