AC 2012-3954: RELATIONSHIP BETWEEN STUDENT CAPSTONE DESIGN PROJECT AND ENTREPRENEURIAL MINDSET

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Relationship between Student Capstone Design Project and the Entrepreneurial Mindset

Abstract

This paper provides an analysis of student perceptions of the application of the entrepreneurial mindset in regards to participation in capstone design projects. The goal of the analysis is to examine the relationship between these activities and building the entrepreneurial mindset in engineering education. Student capstone design projects have been and continue to be an integral part the engineering curriculum. Cross disciplinary and inter-disciplinary teams are formed in various projects in engineering programs. These projects can have great impact in team building skills, self-confidence, technological knowledge, and linking theory and practice. The study for this paper involves surveys from team members of those projects in four Kern Entrepreneurial Education Network (KEEN) schools. These surveys aid in identifying the relationship between student senior design projects and the entrepreneurial mindset within the engineering discipline. Based on the results of the survey, student's perceptions were positive in various elements of the entrepreneurial mindset; however, as the projects relate to entrepreneurship (as opposed to the entrepreneurial mindset), results were not as positive. Some explanation and recommendations are given based on the results.

Introduction

What is the best vehicle and/or approach to fostering the entrepreneurial mindset within the engineering discipline? Perhaps there is not a single approach, but participation in senior design projects may provide one of the opportunities to experience entrepreneurial thinking. Some schools have actively and purposefully involved entrepreneurial aspects into the senior project.^{1,2,3} Others have inadvertently incorporated entrepreneurial aspects for their engineering students.^{4, 5} While senior design project activities vary from school to school, in most instances, this experience provides an opportunity for students to use his/her classroom learning in a “real-world” environment. Although senior design projects have been integral part of the engineering

curriculum, historically, they have not been associated with fostering the entrepreneurial mindset. This paper provides a closer look at senior projects and how they add value to the entrepreneurial learning experience. In particular, based on student perceptions, the paper studies and discusses the relationship between student participation in a capstone senior design project teams and the entrepreneurial mindset. Furthermore, the paper seeks to determine if this activity, by its direct and indirect variables will create entrepreneurial learning experiences within the engineering discipline.

Entrepreneurial Mindset: Our Approach

The entrepreneurial mindset is not about creating a business venture, although that can be an aspect. The foundational elements of entrepreneurship include creating an awareness of the importance of managing risk while experiencing failure and ambiguity. In addition, there are many other elements in the entrepreneurial mindset including; communication, teamwork, leadership, opportunity recognition, persistence, creativity, innovation, critical thinking, and business skills (including marketing, financial analysis, and strategic planning).⁶ Entrepreneurial thinking is important for individuals who may create a business as well as for those who will work in larger organization as “Corporate Entrepreneurs” or “Intrapreneurs.” According to Morris et al., “Corporate Entrepreneurship” is a term used to describe entrepreneurial behavior inside established mid-sized and large organizations.⁷ The term “Intrapreneur” was first introduced by Pinchot in 1985 as any dreamers who take hands-on responsibility for creating innovation of any kind within an organization.⁸ Based on these terms, it appears that entrepreneurial thinking could therefore be an important aspect in a successful senior project.⁹ Consider that the entrepreneurial mind creates inventive solutions to complex problems. The entrepreneurial mind also recognizes the importance of identifying entrepreneurial opportunities.

Lawrence Technological University (the authors’ institution) has a strong commitment of fostering the entrepreneurial mindset. The College of Engineering has taken a leadership position in implementing the University’s vision of developing students with a global view and an entrepreneurial spirit. The curriculum includes eight courses with entrepreneurial content (as laid forth in the *Lawrence Tech 2010 Strategic Plan*). The College of Engineering offers a

Certificate in Entrepreneurial Studies. In addition, Lawrence Tech is part of the Kern Entrepreneurial Education Network (KEEN) which is funded by the Kern Family Foundation. KEEN consists of twenty private universities (with small to mid-sized engineering colleges) from around the U.S. The primary focus of KEEN is engineering entrepreneurial education and the development of the entrepreneurial mindset. This includes a focus on entrepreneurship and intrapreneurship.

With the support of the Kern Family Foundation grant, Lawrence Tech has been modifying a minimum of 30 courses in the College of Engineering and the College of Arts and Sciences. The University has established Kern Innovative Teaching faculty which consists of selected faculty members who are developing and teaching the modified courses focusing on problem-based learning, active collaborative learning and entrepreneurial learning. The KEEN grant has allowed development of a new Entrepreneurial Studio at Lawrence Tech. This unique facility provides space for the entrepreneurial student teams to create their product ideas and build prototypes. In addition, Lawrence Tech students have an opportunity to hear from entrepreneurial alumni. Select alumni's personal entrepreneurial journey is featured in the monthly Entrepreneurial Lecture Series (ELS). All of the ELS are archived in the Lawrence Tech Digital Entrepreneurial Library. The students have access to these entrepreneurial alumni through The Legends, an organization of entrepreneurial alumni. Lawrence Tech has an active chapter of the Collegiate Entrepreneurs' Organization where students experience and practice the entrepreneurial mindset. Another component of the KEEN grant allows Lawrence Tech the opportunity to develop the Entrepreneurial Internship Program for students which enables them to interact with entrepreneurs that own and manage their businesses. The KEEN grant also provides for an "Engineering Entrepreneur in Residence." This position brings an experienced entrepreneurial engineer to the campus to support the student entrepreneurial activity and provide advice and counsel to an individual or team. The KEEN grant activity in the College of Engineering and the College of Arts and Sciences is coordinated through a 14 member campus-wide committee. Finally, the University's Leadership Curriculum, required of all undergraduate students, is an integral part of the Kern/KEEN campus activity.^{4,5,11}

Entrepreneurial Mindset: An Experience in Experiential Learning

Students who participate in experiential learning are better prepared to enter the world of the entrepreneur. Entrepreneurial curricula now include experiential learning as an integral part of exposing the student to the entrepreneurial mindset. Lawrence Tech has created an entrepreneurial curriculum that integrates experiential learning in senior projects, community outreach programs, plant tours, E-Teams, and laboratory environments.^{3, 10} As mentioned above, Lawrence Tech is now working on integrating entrepreneurial content through active collaborative learning into a minimum of 30 existing courses. This initiative includes the opportunity to link “theory and practice” through the integration of experiential learning into the engineering, arts, and science curricula. As a final component of experiential learning, the new entrepreneurial internship and co-op programs provide an opportunity for Lawrence Tech students to work directly with entrepreneurs in their companies. The Legends of Lawrence Tech, the alumni entrepreneurial organization, is participating in this program.

Senior Capstone Design Projects and the Entrepreneurial Mindset – Student Surveys

In a recent survey of student experiences in a senior capstone design activity/project, students at KEEN schools were asked about their understanding and awareness of the entrepreneurial mindset. Students gave their perceptions to help determine if their participation contributed to their understanding of the entrepreneurial mindset. The following ten questions were used for the survey:

1. How significantly did your experience in this senior capstone design project relate to enhancing your leadership skills?
2. As a result of your experience, to what extent did you have an opportunity to improve your problem-solving skills?
3. How much did your experience contribute to improving your team building skills?
4. To what extent did your experience in your project team provide an opportunity to sell your ideas to others (both inside and outside of your team)?
5. What was the extent of your experience in preparing a business plan in your senior design team?

6. As a result of your experience in the senior design project, to what extent did you employ innovative techniques and develop innovative ideas?
7. To what extent did you experience uncertainty as part of your participation in the design team?
8. As a result of your senior design team participation, to what extent were you involved in developing a budget and/or financing the project?
9. To what extent do you consider your participation on the senior design team to be entrepreneurial?
10. To what extent did you or members of your team experience risk (pertaining to design decisions and finances) during your project activities?

The full questionnaire is included in the appendix of this paper. The respondent has the option of answering each question on a 5-point Likert scale. Responding with a one indicates none, least involvement, least significant, least relevant or least applicable. Responding with a five indicates maximum, most involvement, most significant, most relevant or most applicable. There is also an option to provide written comments for each question. This survey was sent to selected KEEN schools and conducted electronically. Forty-seven students responded. A school-to-school comparison is not included for this paper; only composite results are given.

Review and Analysis of Survey Data

The analysis of the data collected provides the foundation for this paper. The feedback from the questionnaire indicates that the capstone senior design activities provide a foundation for exposing students to different elements of the entrepreneurial mindset. Recall that some of these elements include: leadership, problem solving skills, uncertainty, team building skills, marketing and financial processes. Most of the responses for these elements resulted in positive entrepreneurial skill development; however, the survey response specific to “entrepreneurial participation” was less positive. Table 1 includes the questions with the responses from students at four KEEN schools. Table 2 shows means and standards deviations from the student survey.

Table1: Summary of Survey Responses on Entrepreneurial Skills in Capstone Senior Design Projects

TOTAL	1	2	3	4	5
1. How significantly did your experience in this senior capstone design project relate to enhancing your leadership skills?	1	4	17	18	7
2. As a result of your experience, to what extent did you have an opportunity to improve your problem-solving skills?	0	2	16	21	8
3. How much did your experience contribute to improving your team building skills?	0	1	11	28	7
4. To what extent did your experience in your project team provide an opportunity to sell your ideas to others (both inside and outside of your team)?	6	3	15	15	6
5. What was the extent of your experience in preparing a business plan in your senior design team?	10	14	14	7	2
6. As a result of your experience in the senior design project, to what extent did you employ innovative techniques and develop innovative ideas?	4	4	14	20	5
7. To what extent did you experience uncertainty as part of your participation in the design team?	3	4	11	17	11
8. As a result of your senior design team participation, to what extent were you involved in developing a budget and/or financing the project?	11	7	10	12	6
9. To what extent do you consider your participation on the senior design team to be entrepreneurial?	8	11	19	6	2
10. To what extent did you or members of your team experience risk (pertaining to design decisions and finances) during your project activities?	3	6	20	14	4

Table 2. Survey Means and Standard Deviations

Question	Mean	Standard Deviation
1. How significantly did your experience in this senior capstone design project relate to enhancing your leadership skills?	3.553	0.928
2. As a result of your experience, to what extent did you have an opportunity to improve your problem-solving skills?	3.744	0.793
3. How much did your experience contribute to improving your team building skills?	3.872	0.679
4. To what extent did your experience in your project team provide an opportunity to sell your ideas to others (both inside and outside of your team)?	3.266	1.195
5. What was the extent of your experience in preparing a business plan in your senior design team?	2.510	1.120
6. As a result of your experience in the senior design project, to what extent did you employ innovative techniques and develop innovative ideas?	3.382	1.074
7. To what extent did you experience uncertainty as part of your participation in the design team?	3.630	1.142
8. As a result of your senior design team participation, to what extent were you involved in developing a budget and/or financing the project?	2.891	1.386
9. To what extent do you consider your participation on the senior design team to be entrepreneurial?	2.630	1.061
10. To what extent did you or members of your team experience risk (pertaining to design decisions and finances) during your project activities?	3.212	0.998

Based on the data collected from the survey of four schools, Figure 1 appears to be an indication that leadership skills have been experienced in the senior design course, and the degree of development of leadership skills is above average. This data indicates a positive trend toward leadership skill development.

Figure 1: Enhancing leadership skills

Figure 2 indicates that participating in senior design projects allow for student improvement of problem solving skills. This experience provides a “hands-on” interactive activity that is engaging and challenging. As a result, most students are directly involved in problem solving processes.

Figure 2: Opportunity to improve problem-solving skills

Figure 3 indicates that students have experienced team building skill development in their capstone experience. The student experiences as well as their team experiences provide the foundation for team building skills. As result of individual experiences in a team environment students share in completing various tasks and interact with other students to learn valuable lessons in working with others from various disciplines.

Figure 3: Improving team building skills

Figure 4 indicates that some of the students did not have an opportunity to sell their ideas, but a majority of the students had significant experience selling their ideas. Some of this activity was driven by the nature of the senior design project itself. The faculty advisor often has a strong influence on the creation of an environment that fosters the selling of ideas and innovation. The student team leaders are also responsible for promoting the importance of idea generation and selling those ideas among all team members. Student leaders often have a strong influence over their peers.

Figure 4: Opportunity to sell your ideas to others (both inside and outside of your team)

Figure 5 indicates that the majority of students participating in the senior design project did not actively participate in the business planning process. Partially this is the result of the structure of some projects as one student commented, “Most of our project was planned out for us.” In other cases, students may not have been exposed to the relative importance of developing a “road map” that clearly defines the overall broader view and impact of the total project. Therefore, Figure 5 may demonstrate the limitation in understanding the broader sense of the senior design project. The importance of engaging key stakeholders throughout each of the project phases is a key element to the overall learning process. Exposure to marketing, financing, manufacturing, business strategy and other elements of the business plan development become essential in the senior project design activity.

Figure 5: Preparing a business plan

Figure 6 indicates that students do employ innovative thinking and techniques as an integral part of their senior design project activity. However, often the innovation that occurs in senior design activity is incremental and is barely noticed by the students. One student reinforced this by stating, “This aspect of engineering has little room for innovation, because standards, codes, and regulations have been developed that must be followed. For example, there are only so many ways that one may design and construct a road for a client and any innovative techniques have most likely already been tried before.” Conversely, students are incorporating innovative ideas and techniques in the project development and implementation. Their use of innovative thinking is a key factor in the entrepreneurial mindset. One student stated, “By inspecting the facilities at our project site, we came up with a new solution that our client hadn't previously considered; this new design can have savings in the millions of dollars.”

Figure 6: Innovative techniques and develop innovative ideas

Figure 7 appears to indicate that students who participate in senior design projects experience elements of uncertainty. However, the degree to which students experience uncertainty varies. The element of uncertainty is an important factor in the entrepreneurial mindset. How students manage uncertainty is an integral part of learning experience in senior design project activities. One student noted, “As part of the learning process, there was a large degree of uncertainty. I feel that this was beneficial, because it allowed us to explore what we needed to do and how we were going to accomplish our goals in a safe, school environment.” Both uncertainty and ambiguity are challenging and sometimes difficult to recognize ahead of time. A student stated, “Things went wrong, we were uncertain how to proceed until we fixed them.”

Figure 7: Experience uncertainty

Figure 8 indicates that students were involved in the development of a budget and/or financial plan in various degrees. Some of the students were engaged extensively, while others had moderate to no involvement in the financial aspect of the project. The various level of engagement in financial processes may indicate that only certain members of the team were involved in the finances. One student confirmed this by stating, “It was kind of a one-person job, and I wasn’t responsible for that part.” Actually, some project students may steer away from financial aspects because of a lack of knowledge or fear of this business function. Other project teams just were not at a point yet to develop financial aspects, as seen from the comment, “haven’t gotten there yet.” Finally, some senior projects may not require a detailed financial plan at all. Three students’ comments confirm this: “The budget is very informal. We talked to our company, but there was no set budget and we did not set a defined budget outright, only a guess at the cost. (mostly because our project won’t cost too much money).” “Liaisons and faculty member did it for us.” “We have had to write up tentative budgets based on items we have chosen to use but have had sort of a blank check for the project and have not had to worry about financial constraints.”

Figure 8: Developing a budget and/or financing

Based on the students' perceptions, Figure 9 appears to indicate that students do not consider their experience with a senior design project to be entrepreneurial. Interestingly, these low results of question 9 contradict the evidence from the above average results from many of the previous survey questions, all of which pertain to entrepreneurial traits. In other words, the students' actions display that they are being entrepreneurial, but they perceive that the senior project is not entrepreneurial. Or put a third way, senior design projects have many entrepreneurial components; however, students may not recognize these as entrepreneurial. Therefore, it is likely that students do not have an awareness or understanding of the definition of "entrepreneurial." First many students may not think about their senior design project as a business venture. For others it is clearly a business venture as related in the following student comment: "The end goal for our project is to have a product that our liaisons can sell on the market so we have had to consider market feasibility throughout the project. This included cost vs. savings analyses and pay back period calculations." Second, the students may confuse "entrepreneurial" with "entrepreneurship." In other words, the students may interpret "entrepreneurial" as the creation of a new business based on some new product. Two student comments support this: "Our project is pretty much rebuild something that was developed in the 1960s. Nothing innovative about that." and "We are a research team more than a design team." In reality, "entrepreneurship" is more the practice of being an entrepreneur, while

“entrepreneurial” is using the traits of a successful entrepreneur. As a final note to survey question 9 represented in Figure 9, the other two elements of the entrepreneurial mindset that were rated below average are business plan development and finance/budget development (survey questions 5 and 8). Both of these elements are often closely linked by the students to entrepreneurship and perhaps not so much the entrepreneurial mindset.

Figure 9: Participation on the senior design team to be entrepreneurial

Figure 10 indicates that students in senior project activity believe they have experienced some exposure to risk. Students should be aware of the risks involved in the project and the consequences of the risks. Risk can be controllable and uncontrollable. Each has its own characteristics and must be effectively managed. The perception of risk becomes a key factor in understanding how risk can impact the outcome. Experiencing risk is a key element of the entrepreneurial mindset.

Figure 10: Experience risk (pertaining to design decisions and finances)

Figure 11 is a comparison of four different KEEN schools indicating exposure to the enhancement of leadership skills by participating in senior design project activity. Most of the schools trend toward positive impact in developing effective leadership skills. These leadership skills can be utilized in creating entrepreneurial organizations and entrepreneurial thinking. However, strong leadership skills may not necessarily result in venture creation. Leadership skills are a key ingredient in building the entrepreneurial mindset.

Figure 11: Comparison of student leadership skills senior capstone design project in a select group of KEEN schools

Figure 12 represents another comparison of four KEEN schools and illustrates the extent to which students perceive their senior project to be an entrepreneurial experience. As with Figure 9, the survey results indicate that many students did not view their senior design project experiences as entrepreneurial. Almost all four KEEN schools are showing similar results with schools C and D trending the highest. As mentioned earlier, the term and/or definition of entrepreneurship and/or entrepreneurial mindset may not be understood by students who are engaged in senior design projects, and in fact may be disseminated differently at each school. The variation of responses among the four KEEN schools could be due to the different demographics and the processes each school used in the implementation of the senior design project. We could not provide specific details due to lack of demographic and process information. In the future, we may analyze it through the expansion of the study.

Figure 12: Comparison of student entrepreneurial experiences in senior design teams by schools

Summary and Recommendations

Over the years, the senior project experience has provided a value to the students' professionalism as engineers. This experience is obtained through "hands-on" interactive learning within a "real-world" team environment. Via student survey, this paper explored the student perceptions of the entrepreneurial mindset within the context of the senior design project experience. Four KEEN schools participated in the survey. The responses received were mixed.

Most of the key elements of the entrepreneurial mindset received a positive response. Two elements that were below average included business plan development and budget/finance development. When asked specifically about the senior project as an entrepreneurial experience, students did not respond positively. Understanding of the term and/or definitions of “entrepreneurship” and “entrepreneurial” may have contributed to lower responses. Interestingly, business plan and financial development are often closely linked to entrepreneurship and perhaps not so much the entrepreneurial mindset. A relatively small sample size of 47 was obtained for this study. The future plan is to increase the sample size as well as the number of schools participating in the survey. This will include more demographic comparison.

Based on this study of the relationship between student capstone design project and the entrepreneurial mindset, the following recommendations have been developed:

- Students should have a clear understanding of the terminology, definition, and characteristics of the entrepreneur, corporate entrepreneur, entrepreneurship, and the entrepreneurial mindset.
- Create an Entrepreneurial Orientation Seminar for students (and perhaps faculty advisors) who participate in the senior capstone project.
- Faculty advisors of projects should closely monitor student activity for entrepreneurial content.
- All entrepreneurial characteristics should be clearly identified as such prior to the senior capstone project activity taking place.
- Encourage students to provide feedback on their individual entrepreneurial experiences during the project activity.
- Identify entrepreneurial alumni who may serve as mentors for students who participate in the senior capstone activity.
- Student should be encouraged to talk with industry professionals to create a better understanding of short and long term perspective of the impact of the project.
- Students should be encouraged to take entrepreneurial courses prior to senior capstone activity.

- Although each student will be charged with a specific task, they should be aware of and understand the “big picture” of the project and its entrepreneurial content.

The above recommendations reflect the findings of the data and the analysis of the information gathered from students in the surveyed schools.

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Appendix: Survey Questions

Relationship between Student Capstone Design Projects and the Entrepreneurial Mindset

Student Questionnaire: The Entrepreneurial Mindset

The Entrepreneurial Mindset is not about creating a business venture, although that can be an aspect. The foundational elements of entrepreneurship include creating an awareness of the importance of managing risk while experiencing failure and ambiguity. In addition, there are many elements in the entrepreneurial mindset including; communication, teamwork, leadership, opportunity recognition, persistence, creativity, innovation, critical thinking, and business skills (including marketing, financial analysis, and strategic planning). Entrepreneurial thinking is important for individuals who may create a business as well as for those who will work in larger organization as “Corporate Entrepreneurs” or “Intrapreneurs.” The entrepreneurial mind solves problems using creativity and inventive approaches.

Your recent experience in a senior capstone design activity/project could contribute to your understanding and awareness of some aspects of the entrepreneurial mindset. The completion of this questionnaire will help us quantify the extent that your capstone experience may have contributed to your understanding of entrepreneurship. Please note that your participation in this survey is completely voluntary. Your responses will remain confidential. The results are used purely for assessment and may be included in a paper being prepared for the American Society of Engineering Education and for a proposal submission to National Science Foundation (NSF). There are no right or wrong answers, only honest ones. Thank you for participating in this survey.

Legend

1	2	3	4	5
None Least None				Maximum Most Significantly

1. How significantly did your experience in this senior capstone design project relate to enhancing your leadership skills?

1 2 3 4 5

2. As a result of your experience, to what extent did you have an opportunity to improve your problem-solving skills?

1 2 3 4 5

3. How much did your experience contribute to improving your team building skills?

1 2 3 4 5

4. To what extent did your experience in your project team provide an opportunity to sell your ideas to others (both inside and outside of your team)?

1 2 3 4 5

5. What was the extent of your experience in preparing a business plan in your senior design team?

1 2 3 4 5

6. As a result of your experience in the senior design project, to what extent did you employ innovative techniques and develop innovative ideas?

1 2 3 4 5

7. To what extent did you experience uncertainty as part of your participation in the design team?

1 2 3 4 5

8. As a result of your senior design team participation, to what extent were you involved in developing a budget and/or financing the project?

1 2 3 4 5

9. To what extent do you consider your participation on the senior design team to be entrepreneurial?

1 2 3 4 5

10. To what extent did you or members of your team experience risk (pertaining to design decisions and finances) during your project activities?

1 2 3 4 5