DEVELOPMENT AND ASSESSMENT OF AN INNOVATION AND ENTREPRENEURSHIP BOOT CAMP FOR SOPHOMORE ENGINEERING STUDENTS

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ABSTRACT

One of the main critiques of innovation and entrepreneurship programs within engineering schools is that they reach students too late in their undergraduate careers to have a profound impact. In this study, we explored the engagement of sophomore engineers in innovation and entrepreneurship through a three day, extracurricular boot camp prior to the academic year. The camp focused on developing solutions to grand challenges, as outlined on the National Academy of Engineering website. Students received instruction in innovation and entrepreneurship and participated in activities to develop these skills. Teams also pitched newly developed ideas to a panel of industry and academic professionals with entrepreneurship experience.

To assess the effectiveness of the camp, participants received pre- and post-surveys that measured their understanding of innovation and entrepreneurship concepts. Students also created process maps of the product design process both before and after the camp to assess gains in their understanding of this process.

Introduction

Recent literature has discussed the need for development of skills related to an entrepreneurial mindset among engineering students. These skills include customer empathy, the ability to persist through failure, and the capability of tackling multi-dimensional problems (Kriewall and Mekemson 2010; Byers et al. 2013). Institutions across the US have undertaken a variety of different approaches to accomplish this goal. In 2010, Shartrand et al. performed an extensive study of institutions across the US that have entrepreneurship education as part of their undergraduate engineering programs (Shartrand et al. 2010). Although they examined mostly curricular interventions, they also touched on extracurricular implementations and noted that campus offerings such as business plan competitions, entrepreneurs in residence, and projects that students can pursue outside of class are all capable of building entrepreneurial skills among undergraduate engineering students.

More recently, Yasuhara et al. (2012) published a multi-institutional analysis that specifically focused on the use of extracurricular activities to help students develop skills related to entrepreneurship. Their study found positive correlations between the development of motivation, professional skills, and problem-solving skills (a subset of skills associated with an entrepreneurial mindset) and participation in a wide range of extracurricular activities (not exclusive to innovation and entrepreneurship) ranging from student clubs to research experiences. This study demonstrates the benefit that extracurricular activities can have on entrepreneurial skill development.

Other groups at St. Louis University, San Jose State University, and the University of Ottawa have published studies describing particular extracurricular activities implemented within their institutions to foster entrepreneurial skill development (Condoor and Keogh 2012; Patel and Basu 2006; D'Amours, Lague, and Mellor 2009). For instance, the Weekly Innovation Challenges developed and implemented at St. Louis

University are hands-on activities that student teams undertake in a competitive environment. These activities have been linked to different characteristics of the entrepreneurial mindset such as creativity and innovation. Preliminary assessments done on their implementations have shown that students believe these challenges are contributing positively to their development of entrepreneurial-related skills (Condoor and Keogh 2012).

In contrast, the extracurricular activity developed at San Jose State University did not involve participation in a hands-on activity but rather demonstration of an idea for a product or concept at their "Neat Ideas Fair," which was developed to foster innovation and creativity on campus. Assessment of this extracurricular activity showed that it created an entrepreneurial-based environment and improved the awareness of this skillset. Unfortunately, however, this activity attracted mostly students who were already interested in this content area. The researchers drew the conclusion that it was only through the coupling of curricular and extracurricular programming that they could effectively build these skills among engineering undergraduate students (Patel and Basu 2006).

The Swanson School of Engineering at the University of Pittsburgh (Pitt) believes in utilizing both curricular and extracurricular activities to ensure that students are exposed to this important subject matter. In Pitt's program, students learn concepts related to customer identification, brainstorming, decision-making, prototyping, and business plan generation through design-based courses that they are required to take within their respective departments. In addition, students with a strong passion for entrepreneurship can undertake extracurricular activities to further develop their skills, which have included a boot camp, academic year challenges, and entrepreneurial student clubs.
This article will provide a review of the design, implementation, assessment, and key takeaways of the initial implementation of a sophomore innovation and entrepreneurship student boot camp in the 2013 academic year, which was built upon the technical challenge of the National Academy of Engineering's Grand Challenges.

Boot Camp Design and Implementation

The focus of the sophomore boot camp was to introduce students early in their engineering education to the concepts of innovation and entrepreneurship. To make this experience relevant to their future careers, we chose the theme of the National Academy of Engineering (NAE)'s Grand Challenges.

Students were first contacted through e-mail during the month of June with information about the boot camp and how to apply to participate. To be considered for the boot camp, students had to be entering their sophomore year in the engineering program, and they needed to complete a short application that included questions on their departmental selection and why they felt entrepreneurship was important to them and would be beneficial to their future careers. By the end of June, the application process had closed and 23 students had been selected to participate in the inaugural sophomore innovation and entrepreneurship boot camp. Out of these 23 students, ten committed to participating in the boot camp: three from Bioengineering, two from Industrial, two from Mechanical, one from Chemical, one student working toward a dual degree in Bioengineering and Electrical Engineering, and one student from Computer Engineering. Unfortunately, no Civil Engineering students applied to be a part of the inaugural student group. Of the participants, two participants were female, aligning with our female freshman engineering population of twenty-eight percent.

The boot camp was designed to be a three-day immersive experience just prior to the start of the fall semester in August. Each day started with a hands-on activity to get the students actively participating in developing their skills and to help them build community connections within the boot camp. The hands-on activities were selected from the Saint Louis University Innovation Challenges iBook (Condoor and Keogh 2012). It was possible to vary the focus of the activities each day between creativity, innovation, and entrepreneurship, as each activity within the iBook was catalogued based on these criteria.

After the hands-on activity, students were given instruction on key topics related to the product development process and the opportunity to participate in activities that would allow them to observe some of the concepts in action. For instance, students participated in a series of different games that were designed to expose them to concepts such as pre-conceived constraints and to build their teamwork skills. Table 1 provides details of our boot camp schedule and curriculum

Table 1. Schedule and Curriculum of the Boot Camp

BOOT CAMP: DAY 1		
TIME	**TOPIC**	**ADDITIONAL DETAIL**
9:00-9:30	Boot Camp Introduction	Objectives, overview of activities, pre-assessments
9:30-10:45	Creativity Innovation Challenge	
10:45-11:15	Grand Challenge videos	Six possible challenges
11:15-12:00	Brainstorming session on Grand Challenge topics	
12:00-1:00	Lunch and pitches of Grand Challenge ideas	One Grand Challenge topic is selected for product/service development
1:00-1:30	Team formation for product/service development	
1:30-2:30	"Team Building" games	Support students in working well together
2:30-3:30	"How to Develop a Product or Service with a Customer Focus"	Concepts addressed include 1) Who are potential customers? 2) Determining what is important to customers 3) Customer value propositions
3:30-3:45	Assignment of homework	*Customer Values in a World Without Oil* game
BOOT CAMP: DAY 2		
TIME	**TOPIC**	**ADDITIONAL DETAIL**
9:00-10:00	Innovation Challenge	
10:00-10:30	Homework debrief	*Customer Values in a World Without Oil* game
10:30-11:00	"Brainstorming Techniques"	Overview and methods
11:00-12:00	"Pre-Conceived Constraints" games	Explore limitations we place on problems
12:00-1:00	Lunch and Seminar	Seminar by the Office of Technology Management / Transfer
1:00-2:00	Brainstorming session product/ service development	

2:00-3:00	Lean LaunchPad webcasts & "The Value Proposition Canvas"	
3:00-3:30	Development of a Value Proposition Canvas for the chosen product/service	
3:30-3:45	Assignment of homework	*Hit the Streets* assignment
BOOT CAMP: DAY 3		
TIME	**TOPIC**	**ADDITIONAL DETAIL**
9:00-10:00	Entrepreneurship Challenge	
10:00-11:00	Homework debrief & update of the Value Proposition Canvas	*Hit the Streets* assignment
11:00-12:00	"Rapid Prototyping" and "Elevator Pitches"	
12:00-1:00	Lunch and seminar	Seminar by a noted entrepreneur
1:00-4:00	Development of prototypes and pitches for the chosen product/service	
4:00-4:45	Pitch Competition	Teams pitch their products/services to a panel of judges
4:45-5:00	Prizes and wrap-up	Post-assessments

Students were also informed about the boot camp design project. On the first day of the boot camp, students watched a shortened list of the NAE Grand Challenge videos. The topics selected were aligned with the research expertise in the Swanson School of Engineering. After watching the videos, students broke out into small groups, where they were given the chance to discuss each Grand Challenge and opportunities that might exist for new products. The students were then told to select their top three choices. Interestingly enough, the students' selection process resulted in an approximately even number of students choosing each of the Grand Challenges. During the lunch hour of the first day, each of these student groups made a pitch to the facilitators of the boot camp as to why it would be important for that challenge to be selected as the topic for the boot camp design project. The Grand Challenge topic that was ultimately selected was *Advancing Health Informatics*.

At this point, students reorganized into their design project groups, where they remained for the remainder of the boot camp. The design project required that each team propose a new product idea for *Advancing Health Informatics* and then pitch the idea to a panel that included a business school faculty member, a faculty entrepreneur, an Office of Technology Management staff member, and two members of the Pittsburgh entrepreneurial community. As part of their final pitch, students had to discuss the business aspect of their potential product and also develop a rough prototype from craft-based materials. Students had the opportunity to work on this design project between instructional modules. The boot camp curriculum gives students the opportunity to immediately apply the instruction they receive to their team's design process.

The boot camp also included "homework" assignments on both the first and second days of the camp. Each homework assignment was designed to enable students to go deeper in their development of skills related to product design. The first assignment focused on developing a customer value proposition given a specific set of products with no documented customers, and the second assignment challenged them to "hit the streets" and get customer feedback on the product ideas they had developed in response to the Grand Challenge.

Boot Camp Assessment

Two types of assessment were performed as part of the boot camp. The first evaluation involved student self-assessment of their entrepreneurial mindset and knowledge using both a pre- and post-boot camp survey. These surveys were based upon the Entrepreneurship Knowledge Inventory (EKI) for measuring self-assessed entrepreneurial knowledge (Besterfield-Sacre et al. 2012). In the second assessment exercise, students developed pre- and post-product design process maps to demonstrate any change in their understanding of this content. Given our small sample size, this boot camp assessment serves as a preliminary contribution to the literature.

Pre- and Post-Survey Analysis

The ten boot camp participants were a diverse group, as shown in the table below. Although sophomores were targeted for participation, the students represented a variety of engineering disciplines, with the largest number of students being bioengineering majors. Table 2 provides an overview of participant demographics.

Table 2. Demographics of Inaugural Boot Campers

Number of participants	10
Gender	8 Male, 2 Female
Ethnicity	6 White, 3 Black/African American, 1 Asian
Academic level in engineering studies	10 Sophomore
Engineering major	3 Bioengineering, 2 Industrial, 2 Mechanical, 1 Chemical, 1 Bio/Electrical dual, 1 Computer
Number of students aware of campus resources for translating ideas to market	1

Based on the pre-survey, only one student was aware of the availability of campus resources for translating ideas to market. This student was aware of entrepreneurship courses and clubs but not the Technology Transfer Office, and he felt that he could "definitely not" start a business at that time. Only one student attending the boot camp felt they could start a business at the time. However, eight of the ten students expressed an interest in starting a business in the next five to ten years.

Based on the pre-survey, Table 3 identifies the number of students who indicated high or very high familiarity with the various entrepreneurship concepts prior to the boot camp. "High" signified that the student could explain the concept in depth, and "very high" signified they could additionally apply the concept. The full scale also included options of "None," which signified that the student had never heard of the concept, "Low" indicating the student had heard of it but wasn't sure what it meant, and "Moderate" for students that felt they could partially explain the concept. Students most frequently indicated high to very high familiarity with the concepts of consumer needs and creativity. However, there were no students who felt highly familiar with technology transfer. Thus, our inclusion of a seminar by the Technology Transfer Office on day two was particularly relevant, given that no students felt highly familiar with this topic prior to the boot camp.

Table 3. Pre-Survey Results

HIGH TO VERY HIGH FAMILIARITY		
ENTREPRENEURSHIP CONCEPT	**NUMBER OF STUDENTS (/10)**	**EKI CATEGORY**
Consumer Needs	8	Sales and Marketing
Creativity	8	Product Ideation and Development
Business Plan	7	Becoming and Being an Entrepreneur
Entrepreneurship	6	Becoming and Being an Entrepreneur
Intellectual Property Protection	5	Product Ideation and Development
Legal agreements/ contracts	5	Product Ideation and Development
Elevator Pitch	5	Becoming and Being an Entrepreneur
Product Life Cycle	4	Sales and Marketing
Intrapreneurship	1	Becoming and Being an Entrepreneur
Technology Transfer	0	Product Ideation and Development

On the pre-survey, when asked in an open-ended question about the most important innovation and entrepreneurship skills for their future careers, students indicated the following themes, as shown in Table 4, which are listed from most to least frequent. Creativity and communications skills were given the highest importance.

Table 4. Participant Themes Emerging from the Pre-Survey

MOST IMPORTANT INNOVATION/ ENTREPRENEURSHIP SKILLS	OCCURRENCES
Creativity/thinking outside the box	6
Communications	4
Networking/relationships/likability	3
Flexibility	2
Open mindedness/accepting of other ideas	2
Sales ability/business savvy	2
Knowledge	1
Recognition of opportunities	1
Learning from mistakes	1
Leadership	1
Patience	1

On the post-survey, when asked whether any of these important skills had changed as a result of the boot camp, seven of the ten students replied "yes." The most frequent response for the particular skills that had changed centered on the customer. Specifically, three of the students stated an understanding of the importance of the customer as a skill that had changed during the camp. This was a welcome response, as our boot camp curriculum centered on the pivotal role of the customer. Changes in creativity, cooperativeness (i.e., relationships), eagerness, communications, and prototyping/product development knowledge were also noted in the data, with one response each.

On the pre-survey, when asked an open-ended question about the "muddiest points" related to innovation, entrepreneurship, or starting a business, the students indicated the following themes, which are listed from most to least frequent on Table 5. Students were most unclear about financing and funding, as well as transitioning their ideas to market.

Table 5. Muddiest Points on the Pre-Survey

MUDDIEST POINTS	OCCURRENCES
Financing/capital requirements/funding	4
Transitioning ideas to market/reality	4
Legal acumen and issues	2
Marketing	2
Regulatory requirements	1
Business acumen	1
Profitability	1
Patents	1
Business plan/model	1
Product development	1
Organizational structure	1

On the post-survey, when asked whether these muddiest points were made clearer or resolved as a result of the boot camp, nine students (90%) said "yes," while one replied "not applicable." At the close of the boot camp, all ten students intended to remain a part of our innovation and entrepreneurship community and attend at least three extracurricular challenges in the upcoming academic year.

Process Mapping Assessment

We used process flowcharting to assess pre- and post-knowledge of the product design process. We asked individual students to complete a flowchart of this process at the beginning and end of the boot camp. A process flowchart is a graphic representation of the sequence of work activities that comprise a process used to create an output (Damelio 2011). It contains symbols that depict the work steps, or operations, within the process, with the operations connected by arrows to show direction and flow (Damelio 1996). We provided the students with 15 key activities within this process, which were extracted from a larger set of activities as discussed by Golish, Besterfield-Sacre, and Shuman (2008). The activities used by the students are provided in Figure 1.

Figure 1. Design Process Activitiesñ

Choose Product Design From Alternatives		Pilot/Prototype Review
Create Product Description		Preliminary Research
Customer Needs Analysis		Product Meets Actual User Needs
Define Product's Performance Requirements		Prototype Development
Define the Product Scope/Statement of Work		Prototype Testing
Final Design Approval		Target Customer Determination
Generate Multiple Product Alternatives		Team Brainstorming
Optimization of Conceptual Design		

After providing instruction to the students on process mapping, participants arranged the 15 activities, which were provided as adhesive labels, on a blank sheet of paper to depict their understanding of the product design process. They were instructed to add comments within their maps to clarify any linkages, and were also told that it was not necessary to use all of the provided labels. All ten students developed pre- and nine post-camp maps.

Of particular interest was the "placement" of activities related to the customer within this process, as well as any changes in their placement upon completion of the boot camp. Our hope was that students would place these activities at the beginning of the product design process, especially in the post-camp maps, based on the curriculum and instruction provided during the boot camp. These customer-related activities included Target Customer Determination and Customer Needs Analysis. An expert process flowchart developed by the boot camp instructor placed these as the first and second activities, respectively, within the product design process.

To investigate this question, we began by identifying the root, or beginning, node (i.e., activity) on each student map. In addition, we identified the node immediately following the root node, as together they provided an indication of the activities at the "front" of the process. In the ten pre-camp maps, 50% had Customer Needs Analysis as the starting activity, and only one (10%) had Target Customer Determination as the starting activity. Team Brainstorming and Preliminary Research were also popular beginning activities, appearing on four and three of the pre-maps, respectively. A map could have more than one start node, as some students indicated concurrent start nodes. Unexpectedly, however, on the post-maps, Customer Needs Analysis appeared as the starting activity on only two (22%) of the maps, and Target Customer Determination did not appear as the start on any of the maps. Preliminary Research appeared as the start node on two of the post-maps. Two of the students who identified Customer Needs Analysis as the start activity on the pre-map also did so on the post-map. However, three students who identified this activity as the start node on the pre-map changed their minds on the post-map. Thus, the number of customer-related activities specified as starting nodes decreased from the pre to the post-maps.

One theory on the decrease in customer-related activities as the starting node on the post-maps was related to the time in the program at which the students completed the post-maps. The students were asked to complete them at the very end of the last day of the camp, after a culminating team competition. We feel it's possible that the students did not invest an appropriate amount of time in developing their post-maps and therefore did not place the correct emphasis on the customer in the process. Another theory is that students' process mapping reflected their experience within the boot camp curriculum, which had them brainstorming about ideas on their project prior to initiating discussions with their potential customers.

Despite the decrease in customer-related start nodes, Target Customer Determination appeared as the activity immediately following the start node on approximately one third of the post-camp maps, as did Customer Needs Analysis. Thus, although these activities did not always appear as the starting node, they were placed second in the process on approximately 33% of the post-maps. This was also the case with the pre-maps. The ending activity on the student maps was much closer to our expectations. The instructor-developed map contained Final Design Approval as the last activity. This was the case in six of the pre- and post-maps, representing 60% and 67% of these maps, respectively.

Although our process maps did not depict the desired results in relation to the curriculum and experiences provided during the boot camp, which may be due to the short timeframe associated with the boot camp, we would like to apply this method of assessment in the future using a somewhat different protocol. Specifically, we plan to change the time during the program at which the post-maps are developed by the students, so that sufficient time and effort can be devoted to this activity, including sufficient instruction on rigorous development of a process map. We also plan to more closely align the curriculum with the actual "wording" of the 15 activities to ensure that the definitions of the activities are clear. In addition, as a possible future assessment method, we will consider interviews or focus groups with the students to evaluate their understanding of the role of the customer. Data from this approach could be used in conjunction with the process maps for an overall evaluation of the impact of the boot camp. Another potential assessment we are considering is a follow-up with the 2013 boot camp participants to determine how they applied their boot camp experiences over the past year.

Conclusions

Our study described the preliminary assessment results obtained from the implementation of an extracurricular student boot camp centered on the National Academy of Engineering Grand Challenges. The boot camp took place over a three-day period in which students were exposed to a combination of lecture and active learning on material related to the product design process and the integral role the customer plays within this process. Pre- and post-survey analysis demonstrated that students who participated in the boot camp believed there were changes in their understanding of the importance of the customer within the product design process. In addition, nearly all students believed the boot camp helped them gain clarity on what they felt were their muddiest points upon starting the three-day camp.

Process mapping assessment performed by this student group showed mixed results. There was some evidence that students knew to place the customer as a key element early in the design process, but the occurrence of this actually decreased between the pre- and post-assessments. We speculated that this might have occurred due to the timing of the post-map exercise, which occurred immediately after a business pitch competition. This may have contributed to the students not spending as much time on their post-maps as they did on their pre-maps. We also believe that this type of assessment would benefit from further clarification and instruction to the students on process mapping.

Overall, our analysis shows that a three-day intensive entrepreneurship boot camp for sophomore engineering students has the ability to introduce concepts related to innovation and entrepreneurship at a relatively early point in their engineering careers. It will be important to monitor student participation in future activities to determine whether this initial exposure motivated further student participation in entrepreneurial-related activities.

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