Early Incorporation of Entrepreneurship Mindset in An Engineering Curriculum

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Abstract

In the study herein aimed at incorporating the entrepreneurship mindset early on in the engineering curriculum of undergraduate students via a final project of an introductory programming course with MATLAB. Students were asked to find a need on campus, in the society, or in the market with a business potential and write a standalone application to solve that problem. Prior to the start of project, students were required to study an online module developed by KEEN on generating new ideas in which they learned the definitions and differences between an idea and an opportunity, and different methods of recognizing business opportunities, followed by online quizzes. The study found that students were interested in learning about entrepreneurship and using the technical skills learned in class to solve a real-world problem with potential business opportunities; they enjoyed the course material more and it reinforced their learning of previous topics; and more importantly, it attracted students' attentions toward self-employment. Pre- and post-assessment of creative thinking using standard AACU rubrics also showed a significant increase in the levels of students' creative thinking skills due to participation in this project.

Keywords: entrepreneurship mindset, market need, business potential, engineering curriculum, generating new ideas, programming, standalone application

1. Introduction

In the competitive technology markets of the 21st century, it is no longer sufficient to educate engineering students with merely technical skills. An evidence to this claim is the large number of startups with apparently promising futures that have gone out of business early due to lack of entrepreneurial skills of the founders. A recent study by Duke and HARVARD Universities over 500 technology companies revealed that only 37% of their leaders even have engineering backgrounds (Zwilling). If any country wants to have a sustained economic growth, educating engineers with entrepreneurial mindsets is absolutely necessary, specifically during the times of volatile economy (Jarrar, 2016). According to the report in 2012 by the World Intellectual Property Organization (INSEAD, 2012), the U.S. dropped to 10th on a global innovation scale. That's why implementing entrepreneurship in engineering education of American universities has grown by more than 400% during the last few decades (Byres, 2013) to alleviate unemployment and create new ventures (Da Silva, 2015). Currently, entrepreneurship education is embedded in more than 400 engineering schools in the United States (Luryi, 2007). Another evidence to this in United States is the abundance of federal and private institutions that have invested in engineering entrepreneurship programs, including National Science Foundation (NSF) Epicenter and I-Corps programs, Kern Entrepreneurial Engineering Network (KEEN), VentureWell (formerly known as NCIIA), Accel Roundtable on Entrepreneurship Education (REE), and American Society of Engineering Education (ASEE) Entrepreneurship and Innovation Division program (Weilerstein, 2016). In addition to the United States, universities around the world, including, in Europe (Bonnet, 2006; Huber, 2014), Malaysia (Rahman, 2012), and Africa (Gerba, 2012), have reported entrepreneurship incorporation in their engineering curricula.

Depending on their desired outcomes, some engineering programs focus more on generating awareness of entrepreneurship and/or creating an entrepreneurial mindset, while others focus on developing innovative products and technologies and/or new business models and ventures (Duval-Couetil, 2016). In this study, the goal was to combine both of these objectives: improving students' awareness by learning from an online module and incorporating an entrepreneurship mindset via developing products and software applications that have business values.

In an engineering curriculum, students typically encounter financial limitations of the design process and the importance of product marketing and project sponsorship during their capstone projects. Some recent publications have also implemented entrepreneurship in junior and senior-year engineering courses (Liu, 2015; Pech, 2016; Wang, 2001). Working with all groups of undergraduate engineering students, some engineering educators (Tryggvason, 2010) believe that incorporating the entrepreneurial mindset has to start from the first year in the undergraduate curriculum. The introductory course to programming is one of the first opportunities for undergraduate engineering students to write programs that can solve a societal need or a market gap that has business values. As expected, the students under this study proposed interesting topics, which had both business potentials and were an essential need of the campus or the society. Some of these topics worked in groups of 3 students were: 1) a remotely-activated switch via Bluetooth connection for old devices that cannot be turned on/off remotely; 2) a personal security application that allows the student to press a button for sending a help signal and the location GPS coordinates to the campus security office if felt threatened while walking on campus at night in areas with no emergency call box; 3) a hiking application which provides a list of dangerous animals and edible and dangerous plants for a given location as well as pertaining pictures and first-aid actions; 4) a campus navigation map that finds the path from one building to another building on campus by entering the buildings' names, as well as total distance, travel directions, and estimated travel time in addition to a picture of the destination for recognition purposes; 5) an application for autonomously detecting failures in a 3d printer, including running out of filament, spool entanglement, and peeling, using computer vision and sending a warning to the operator to stop the print and avoid wasting the filament; and 6) a roommate finding application that enables users to create a profile and enter their personal information and preferences for a roommate in order to build a database which can then be searched for an optimal roommate.

The author believes that every hands-on experience should be proceeded with proper theoretical training. So, in this study, in order to enhance the effects of this hands-on experience on students' entrepreneurial skills, they were asked to study an online module developed by KEEN on generating new ideas, followed by online quizzes. It should be mentioned that not only KEEN partners with universities as an intellectual leader providing training on entrepreneurship implementation in engineering courses and curriculum via its online modules (KEEN), conferences, and workshops, it also sponsors many of these educational endeavors, and this is reflected in many recent publications in this field referring to KEEN (London, 2018; Weaver, 2010; Kriewall, 2010).

Prior researches on engineering education have shown that implementing entrepreneurship in engineering courses can lead to higher student satisfaction, longer-term professional careers, self-directed learning, teamwork skills, GPA, understanding depth of the material, changing attitude toward engineering challenges, improved creativity, and starting new business ventures and self-employment (Duval-Couetil, 2010; Täks, 2014; Besterfield-Sacre, 2016). This study confirmed the success of early incorporation of entrepreneurship in an engineering curriculum via standard AACU rubrics and a customized questionnaire showing that it led to increased creative thinking skills, higher interest in learning about programming and entrepreneurship, reinforcement and further enjoyment of the class material, and changing the student perspectives toward real-life problems and seeking business opportunities in them.

2. Implementation Method

Students were initially required to study an e-Learning module on "Generating New Ideas" created by University of New Haven and funded by KEEN with the following learning outcomes:

a) Differentiating between an idea and an opportunity

b) Describing how to identify new business opportunities by observing social and environmental trends

c) Recognizing how to find business opportunities through identifying needs and offering viable potential solutions

d) Explaining how identifying gaps in the marketplace can lead to finding viable business opportunities

e) Describing a variety of techniques that can generate ideas of value

This online module provided students with a variety of case studies and learning resources. After studying the module, students were asked to take online quizzes to ensure their learning about definitions and differences between an idea and an opportunity, and different methods of recognizing business opportunities, including observing trends, solving a problem, and finding gaps in the marketplace.

Then, they were asked to find a real-world problem with business potential and write a standalone application for it using the programming methods they learned in class.

Participants of this study were mostly freshman engineering students at Embry-Riddle Aeronautical University in Prescott, Arizona, USA, who enrolled in the introductory programming course. They worked in groups of 3 as an effort to also enhance their teamwork skills and were given 2 weeks to identify the problem. Then, they presented the topic to the instructor and their classmates in a preliminary design review session, where they received feedback about the feasibility of fulfilling the undertaking in one semester and the business potentials of the problem.

Before starting the project, they were asked to fill a pre-project questionnaire about creative thinking skills adopted from AACU rubrics that can be seen in Figure 1, which allows students to self-evaluate their creative thinking skills of acquiring competencies, taking risks, solving problems, embracing contradictions, innovative thinking, and connecting, synthesizing, transforming on a level of 1 to 4 where 1 represents the basic level and 4 is the highest achievable level.

The hypothesis was that being involved in this study can have significant effects on the students' creative thinking skills. At the end of the project, students filled the same questionnaire again and a paired t-test was conducted to measure the significance of changes in their skillsets.

Furthermore, a customized complementary questionnaire about some of the study objectives that were not covered by the questions in the AACU rubric was also filled at the end of project. as can be seen in Figure 2. Students answered to these questions with responses of "Strongly Agree", "Agree", "Neutral", "Disagree", and "Strongly Disagree", which counted as 1, 2, 3, 4, and 5, respectively. Several of these questions were utilized in

	Capstone 4	Milestones 3	2	Benchmark 1
Acquiring Competencies	Reflect: Evaluates creative process and product using domain-appropriate criteria.	Create: Creates an entirely new object, solution or idea that is appropriate to the domain.	Adapt: Successfully adapts an appropriate exemplar to his/her own specifications.	Model: Successfully reproduces an appropriate exemplar.
Taking Risks	Actively seeks out and follows through on untested and potentially risky directions or approaches to the assignment in the final product.	Incorporates new directions or approaches to the assignment in the final product.	Considers new directions or approaches without going beyond the guidelines of the assignment.	Stays strictly within the guidelines of the assignment.
Solving Problems	Not only develops a logical, consistent plan to solve problem, but recognizes consequences of solution and can articulate reason for choosing solution.	Having selected from among alternatives, develops a logical, consistent plan to solve the problem.	Considers and rejects less acceptable approaches to solving problem.	Only a single approach is considered and is used to solve the problem.
Embracing Contradictions	Integrates alternate, divergent, or contradictory perspectives or ideas fully.	Incorporates alternate, divergent, or contradictory perspectives or ideas in a exploratory way.	Includes (recognizes the value of) alternate, divergent, or contradictory perspectives or ideas in a small way.	Acknowledges (mentions in passing) alternate, divergent, or contradictory perspectives or ideas.
Innovative Thinking	Extends a novel or unique idea, question, format, or product to create new knowledge or knowledge that crosses boundaries.	Creates a novel or unique idea, question, format, or product.	Experiments with creating a novel or unique idea, question, format, or product.	Reformulates a collection of available ideas.
Connecting, Synthesizing, Transforming	Transforms ideas or solutions into entirely new forms.	Synthesizes ideas or solutions into a coherent whole.	Connects ideas or solutions in novel ways.	Recognizes existing connections among ideas or solutions.

Figure 1. AACU Rubric for Assessment of Creative Thinking Skills

	Description
Q1	Doing this project made me realize that I want to develop my own business.
Q2	I believe that the application we developed has a business value.
Q3	I believe that combination of learning about capabilities of MATLAB to solve real-world problems and learning about methods to recognize a business opportunity made me look at engineering problems and societal needs from an entrepreneurial perspective and consider them as a business opportunity.
Q4	I would like to know more about entrepreneurship in engineering after this project.
Q5	The online material about methods of recognizing business opportunities was valuable to me.
Q6	Writing a program that can solve a real-life problem helped me appreciate the value of programming and enjoy the class more.
Q7	I think the need to use programming for the final project reinforced what I learned in class about MATLAB coding.
Q8	The project was challenging since it required learning new material on my own that was not covered in the syllabus.
Q9	This project helped me improve my teamwork skills.
Q10	I think entrepreneurial training and projects should be added to a larger number of engineering courses.

Figure 2. Questions of the Customized Project Questionnaire

3. Results and Discussion

In this section, first, students' projects are described and then, effects of implementing entrepreneurship in the course (hypothesis testing results) will be discussed. Some projects created in this class were:

1) The first project was aimed at creating a remotely activated switch using an Arduino microcontroller, relays, and Bluetooth controlled by a standalone application developed in MATLAB. The goal was to design this switch for old devices without remotes to be turned on and off and apply a timer to these devices. The switch and the application are shown in Figure 3.

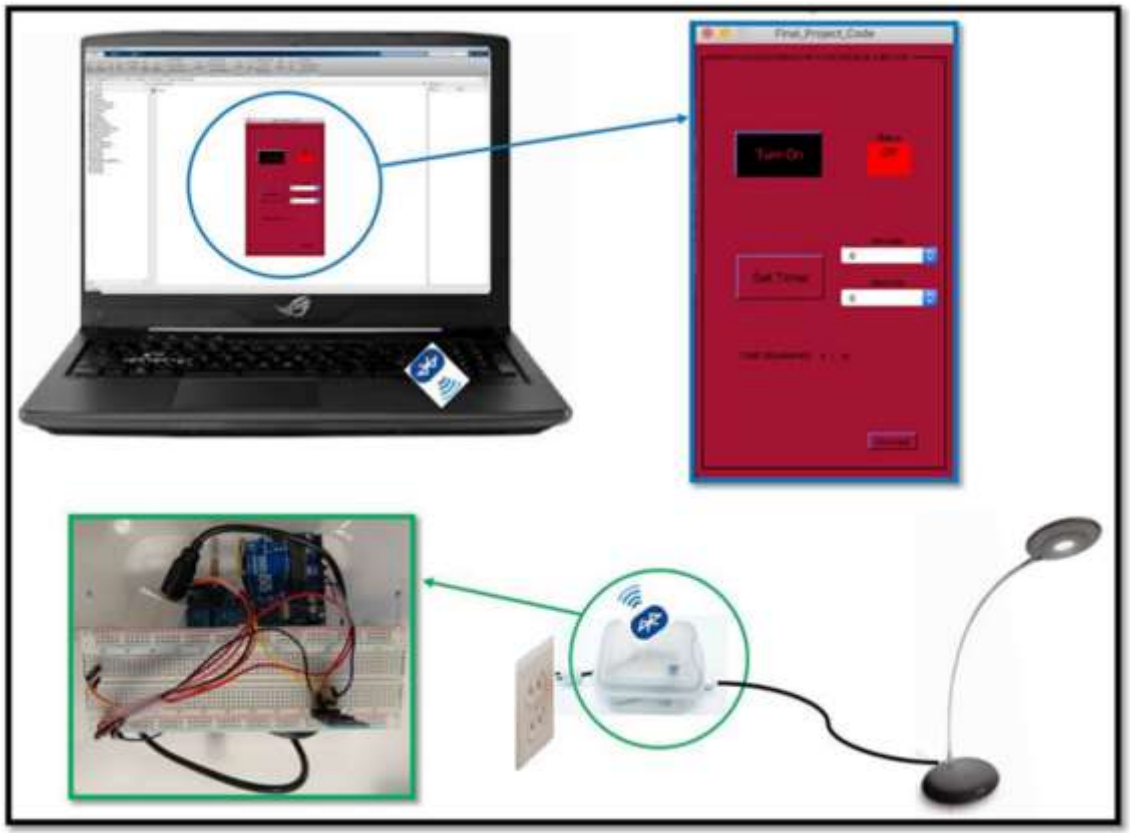

Figure 3. Remotely Activated Switch and Its Standalone Application

This device is currently being optimized and miniaturized and will enter the market to compete with similar commercial products. The students who developed this application are currently working on the device under the author's supervision in an undergraduate research project deploying the application from a laptop to a cellphone, designing printed circuit board for the device, and learn about marketing aspects of the project.

2) The second project was to design a campus navigation map for freshman students and visitors currently missing in Embry-Riddle Aeronautical University apps package that takes the name of the current location on campus and the name of the destination, as well as the mode of transport and returns a path to the destination through campus sidewalks, directions and distances to travel, the total estimated time of travel, and a picture of the destination in order to recognize it while navigating. This application can be seen in Figure 4. It has to be mentioned that the author has provided the path planning algorithm to the freshman students and help them understand its algorithm (Rapidly Exploring Random Tree, RRT) as it was beyond the scope of this class.

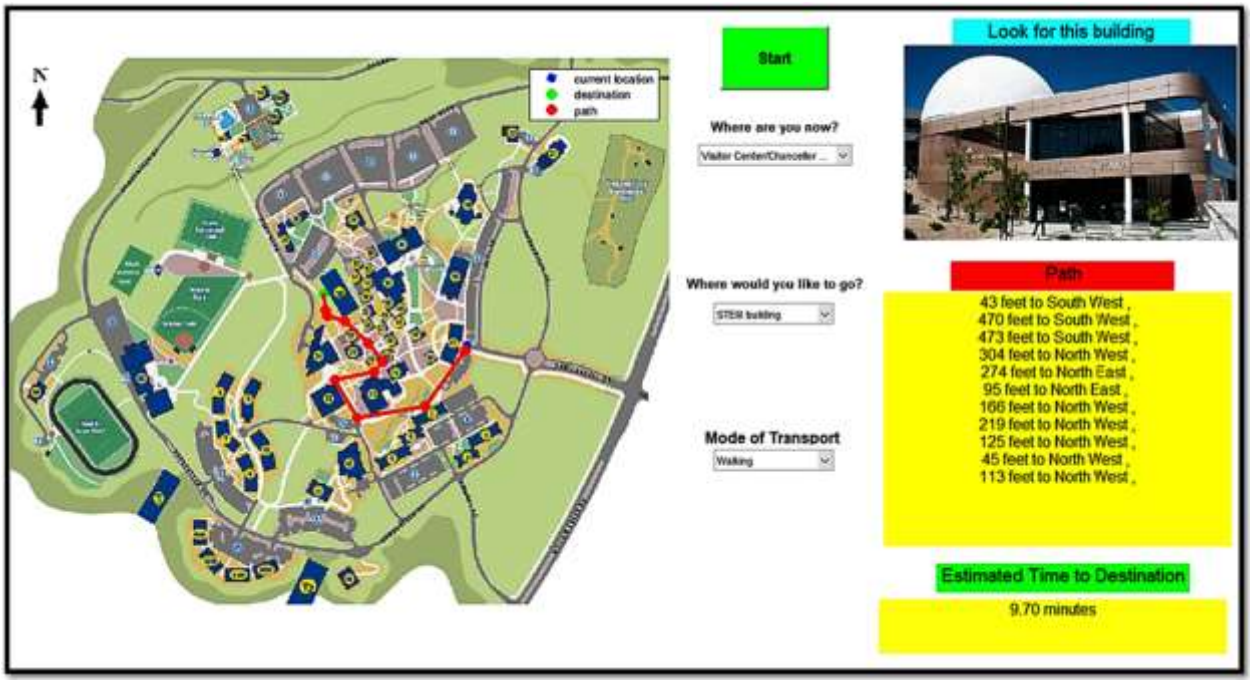

Figure 4. Campus Navigation Application

3) The third application was a hiking aid that can provide a list of animals and edible and dangerous plants for a given trail in a local area as well as their pictures, exposure risks, and first aids as can be seen in Figure 5. Considering the fact that Prescott, Arizona has an abundance of hiking trails, this application can really benefit local hikers, but it can also be expanded to larger areas, and gather its required information from contributors and online resources.

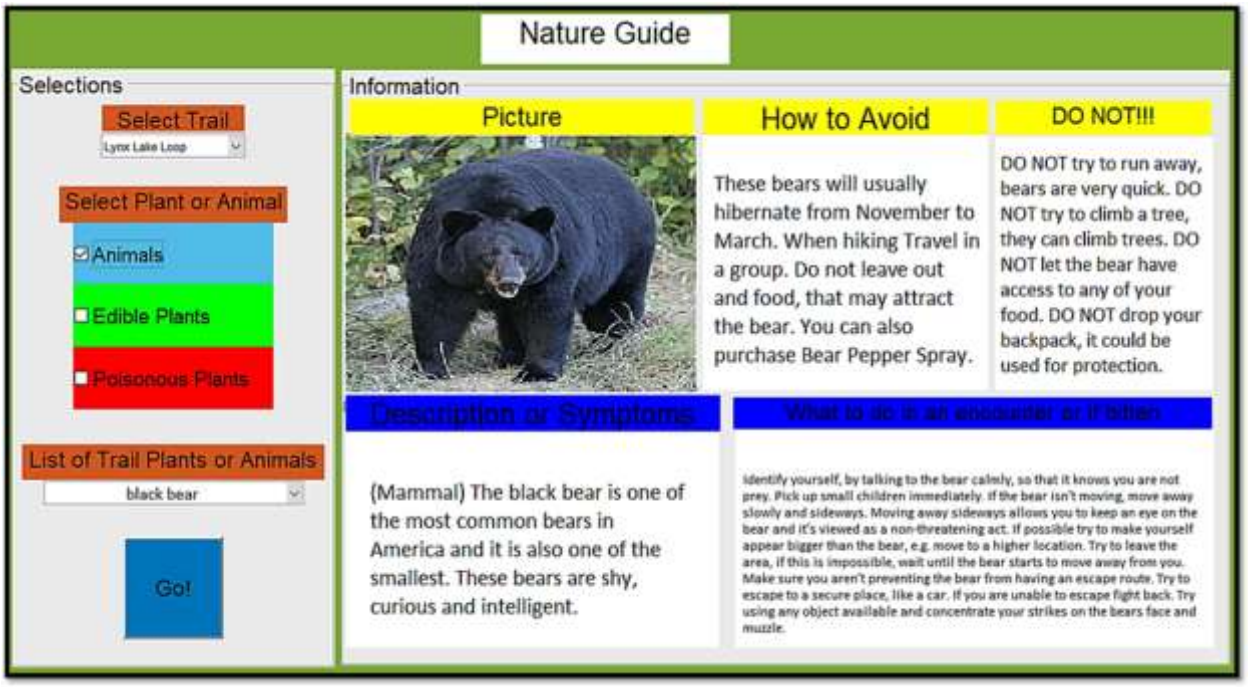

Figure 5. Hiking Application

4) The fourth application designed to help students was a security app that can send a message to the campus security office by push of a button containing the GPS location of the person if the he/she

   feels threatened while walking on campus in areas with no emergency call box. It has to be mentioned that currently, if a student faces any threat, such as being stalked at night on campus where no emergency call box or any other person is around, he/she needs to take off cellphone, call the security office or 911, and then provides information about his/her location which can either not be properly done under stress or even provoke the stalker further. Instead, this application uses the GPS sensor on the cellphone and by a simple push of a button, its calls the security office and send relevant information without attracting the attention of the stalker.

5) The fifth project introduced here was an application aimed at detecting failures that can occur during 3d printing using computer vision, such as peeling, nozzle clogging, missing filament, or spools entanglement which sends a warning signal to the operator for stopping the print to avoid wasting the print material. Since this project was beyond the scope of the class, it is currently being continued as an undergraduate research project supervised by the author, where participating students keep learning about topics they did not have the chance to learn in class, such as image processing and machine learning in MATLAB. The initial setup of the system can be seen in Figure 6.

6) The last project is a roommate finding application which creates a personal profile for users by gathering their personal information and roommate matching preferences, then, adding the information to its database and finding the best potential roommate based on its matching criteria. This application can be seen in Figure 7.

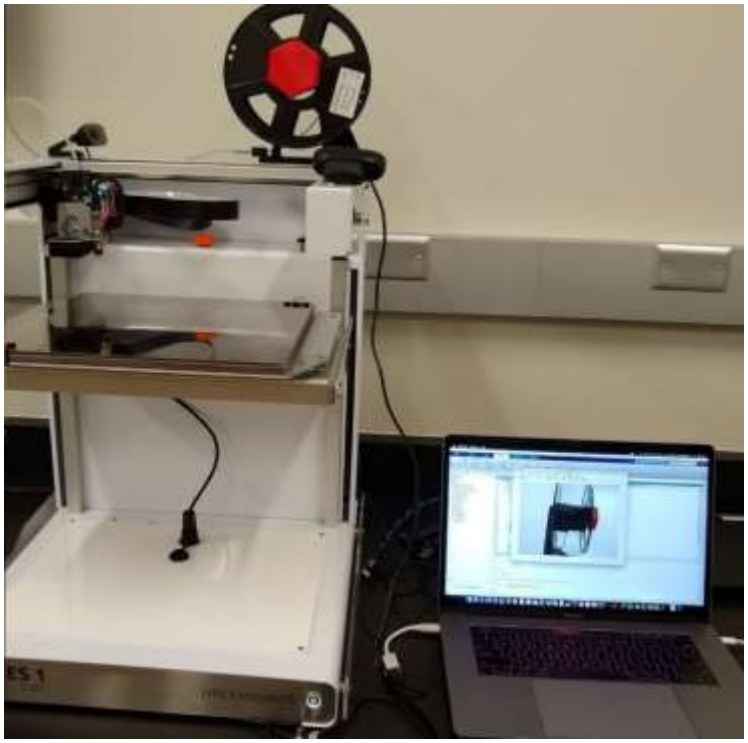

Figure 6. Printer Monitoring Application

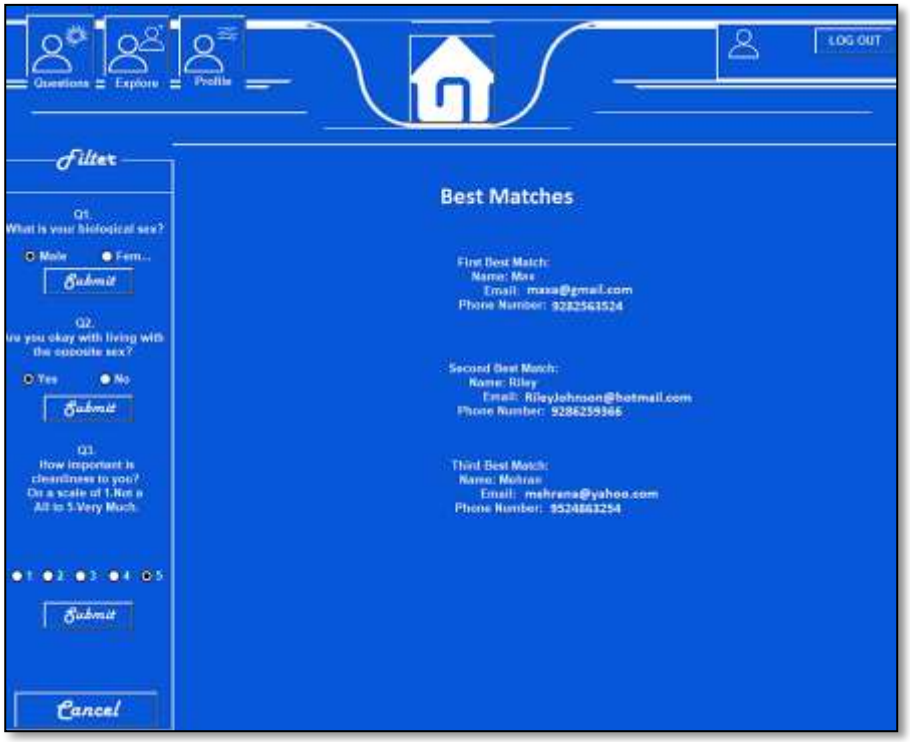

Figure 7. Roommate Finding Application

To evaluate the effects of entrepreneurship education in engineering courses, several assessment tools and surveys have been proposed in the literature, including the Engineering Entrepreneurship Survey (Duval-Couetil, 2011; Duval-Couetil, 2010), that evaluates five categories of attitudes and awareness, behaviors, knowledge and skills, self-efficacy, and perception pf programs and faculty by students.

In this study, we have used standard AACU rubrics shown in Figure 1 for assessment of creative thinking skills in order to test our hypothesis: "Incorporating an entrepreneurship mindset to this course led to a significant increase in the creative thinking capabilities of the students". A paired t-test with a significance level of $\alpha = 0.01$ was conducted between the pre- and post-project ratings by the students of their skill levels for creative. To ensure that the t-test was appropriate for the hypothesis testing, normality of the data was examined using Q-Q plots, skewness, kurtosis, and data histogram, and normality of data was confirmed. As can be seen in Table 1, P values show a significant difference in all skill sets and so the hypothesis can be confirmed.

Among the 6 skillsets identified by AACU rubric for creative thinking, the most significant change was observed in the skillset of "taking risks". An engineering entrepreneur can be defined as "One who organizes, manages, and assumes the risk of an engineering business or enterprise" (Nichols, 2003). Typically, in freshman engineering courses, the learning assessment is mostly based on assignments, quizzes and exams, and barely a final project which spans over the entire semester is defined. Even, if such project is embedded in the syllabus, it is not an open-ended project and it has rigid guidelines and deliverables. Allowing students to identify a real-life problem for which the they are not even sure if/how to write a code and develop and application and possibly a physical device, and it worth 20% of their total course grade, can be considered risk taking early on in their engineering education. For some groups (Bluetooth-activated switch and printer failure monitoring) that had to also build a physical device, it went further than grade as they aimed at patenting their devices and selling their products.

Table 1. Effects of Adding Entrepreneurship on Creative Thinking Skills Defined by Rubric in Figure 1

Skills	**P Value of the Paired t-Test ($\alpha = 0.01$)**
Acquiring Competencies	< 0.01
Taking Risks	< 0.01
Solving Problems	< 0.01
Embracing Contradictions	< 0.01
Innovative Thinking	< 0.01
Connecting, Synthesizing, Transforming	< 0.01

Students' ratings in response to 10 customized questions about the project (as shown in Figure 2) are provided in Table 2, with numbers 1 to 5 being used for "strongly disagree", "disagree", "neutral", "agree", and "strongly agree", respectively. Questions 1, 3, 4, and 10 in this questionnaire were introduced in other publications too (Duval-Couetil, 2012). As can be seen in Table 2, students welcomed the incorporation of entrepreneurship in their class and asked for further training on this topic; they enjoyed the class more; being involved in the project reinforced the course material they learned previously and changed their perspective about solving real-world engineering problems from a pure technical side to a business opportunity aspect.

4. Conclusion

In this study, it was attempted to raise awareness and knowledge of entrepreneurship and to incorporate an entrepreneurship mindset in engineering students during their first year in an undergraduate curriculum by exposing them to the basic definitions and methods of generating new ideas with business potentials that solve a societal problem or fill a market gap. Working in groups, students under the study could find such problems, propose solutions for them, and implement the solutions that can be marketed. It worth mentioning that initial ideas proposed by the students were examined and improved by the author and students were guided toward a more marketable and feasible solution from their initial raw and ambitious ideas.

Using standard and customized questions in pre- and post-projects surveys and a standard statistical paired t-test, this study provided evidences on the effectiveness of incorporating entrepreneurship in engineering curricula early on by showing that it can encourage students to think creatively, recognize business opportunities in engineering problems, motivate students to take risks, makes it possible for the students to enjoy and appreciate their courses more by observing their usefulness in solving real-world requirements, and leading to undergraduate research projects that can be continued beyond the course time limits.

Table 2. Results of the Customized Project Questionnaire in Figure 2

Questions	Average Response
1. Doing this project made me realize that I want to develop my own business.	3.42
2. I believe that the application we developed has a business value.	**4.21**
3. I believe that combination of learning about capabilities of MATLAB to solve real-world problems and learning about methods to recognize a business opportunity made me look at engineering problems and societal needs from an entrepreneurial perspective and consider them as a business opportunity.	**4.05**
4. I would like to know more about entrepreneurship in engineering after this project.	**4.09**
5. The online material about methods of recognizing business opportunities was valuable to me.	3.63
6. Writing a program that can solve a real-life problem helped me appreciate the value of programming and enjoy the class more.	**4.16**
7. I think the need to use programming for the final project reinforced what I learned in class about MATLAB coding.	**4.42**
8. The project was challenging since it required learning new material on my own that was not covered in the syllabus.	**4.47**
9. This project helped me improve my teamwork skills.	3.79
10. I think entrepreneurial training and projects should be added to a larger number of engineering courses.	**4.06**

5. Future Works

Students could create standalone applications on laptops, but these applications must finally be deployed to cellphones. It could not be achieved during one semester due to its complicated process and has been considered for future works.

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