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Developing Entrepreneurial Mindset in Industrial Engineering Classes: A Case Study

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Abstract

Instilling entrepreneurial mindset among engineering students is one of the challenges in engineering education. This paper presents the efforts to improve a core undergraduate industrial engineering course, Designing Value in Supply Chain, to infuse entrepreneurial thinking among students using an internally funded grant by Kern Entrepreneurial Engineering Network (KEEN). For this purpose, three new course modules are designed and their effectiveness on student learning is evaluated. This course is ideal for establishing entrepreneurially minded learning (EML) as a systematic approach is required for managing the chain of supply, especially since the impacts of the decisions are not isolated and will be spread out through the entire chain. In addition, creative multidisciplinary knowledge is required to address most of the supply chain challenges. The proposed modules are expected to promote students' creative thinking, curiosity, collaboration and communication skills, and enable them to identify the opportunities where they can apply their technical skills to create value in the community based on customers' expectations. These factors are key pillars of EML as proposed by KEEN.

In the first course module, students propose a new product to be released to the market (idea generation). They complete this module as the product moves toward the end user in the supply chain following the concepts they learn during the term. This module enables the students to observe the domino impact of the decisions they make in the initial stages of supply chain and enhances structured learning experience by linking different concepts. In the second module, in order to expose the students to real life applications of the course content, wireless consumption data provided by students is used to practice different demand forecasting methods. Students also need to provide some economic analysis to choose the best solution alternative regarding their forecasted values. This module makes the learning process more meaningful as the learners observe a real life application of the subject. In the third module, students practice energy management in order to minimize energy waste as one of the most important types of waste in lean production systems. In this module, they are expected to determine several sources of energy waste on campus and propose action plans, and estimate the economic impact of their solution. As a result of this project, students learn how to create value and communicate an engineering solution in terms of economic benefits. Students provide a report for each module which is graded based on designed rubrics. All these modules are performed in teams which in turn improves students' team work and collaboration skills. This paper elaborates the details of each module and learning outcomes, and presents the student evaluation results, and at the end discusses the lessons learned.

1. Introduction

In the past few years the attitude that considers engineers as sole reactive specialists has evolved to team player entrepreneurs. This fact is critical while designing the contents for engineering courses. In order to promote entrepreneurial thinking in engineering programs, some schools offer entrepreneurship courses, administered by business departments, for engineering students. These courses are more concerned about the creation of a new business. However, entrepreneurial mindset training for engineering students is a broader concept than just establishing a new business [1]. The contrast between entrepreneurship and entrepreneurially minded engineer is explained by Kriewall and Mekemson [2]: Entrepreneurship is more toward self-employment via establishing a new business; whereas, an entrepreneurially minded engineer is an engineer with the ability to identify the unmet customers' expectations and bring them before design, incorporate the emerging technology and engineering skillsets to fill in this gap, and create positive cash flow for the enterprise. In this new paradigm, the significance of understanding of non-technical human-based factors and principles of business acumen are integrated into classic technical engineering courses. The ultimate goal of this re-engineered pedagogy is to prepare the students to be influential team players and entrepreneurial engineers with great communication skills.

There are several studies in the literature that investigate the impact of the entrepreneurship training on engineering and science students. In a study by Souitaris, Zerbinati, and Al-Laham [1] it was shown that entrepreneurship program raised the entrepreneurial attitude and intention, but expectedly the effectiveness of these efforts cannot be assessed in practice due to the time lag between action and attitude. A new course design with industry participation is discussed by Creed, Suuberg, and Crawford [3], where students collaborated with industry to propose a business plan and prototype product. Student reflections were very positive about the learning outcomes of the course. The impact of student's exposure to entrepreneurial aspects of engineering on freshman engineering students and their perception of professional engineering skills is examined through a simulation game by Dabbagh and Menasce [4]. Their analysis showed that students' perception of engineering improved significantly as a result of this exposure.

Transforming students' mindset, i.e. the way they think about their surroundings is a challenging task for faculty in higher education, and Entrepreneurial Minded Learning (EML) is an effective tool for this purpose. There are different pedagogical strategies ranging from Subject-Based Learning (SBL) to more learner-oriented methods. Active Collaborative Learning (ACL) and Problem-Based Learning (PBL) are more recent approaches that concentrate on teaching with respect to applications and guided student participation. EML embraces these two methods, and in addition has the ultimate goal of value creation and opportunity identification in connection with the society. The EML approach aims at promoting student curiosity and their ability to be

proactive, instead of being passive or reactive. In Kern Entrepreneurship Education Network (KEEN) approach, engineering education is being transformed to support the future societal needs via a cultural transformation and is based on three C's of Communication, Curiosity and Creating value [2,5]. In this new pedagogy, students are trained to fix problems and create value using technical fundamentals through practicing more realistic and challenging problems.

The traditional methods of engineering education focus on presenting theory to students and solving some hypothetical or numerical examples. In addition, most of the concepts taught in different courses look like different pieces of a puzzle with no connection. However, exposing engineering students to multi-disciplinary real-life applications to intrigue their curiosity where they can integrate information from different sources (connection), and persuading them to explore unexpected opportunities to contribute and create value can make the learning process more organized and meaningful. An overview of the utilization of KEEN-based entrepreneurial minded learning toolset along with PBL and ACL approaches in the First Year Engineering Program is presented by Riofrio et al. [6]. In their study, the effectiveness of EML on students' perceived knowledge was assessed through pre and post surveys. The results indicated a significant increase in student scores, when they were exposed to EML-based modules.

In this study, an industrial engineering course, Designing Value in the Supply Chain, is reinforced using the KEEN approach. The objective is to infuse entrepreneurial mindset and promote EML in undergraduate engineering students. As a result of the course update, three course modules are presented and their effectiveness on students' perception of knowledge, along with the lessons learned from pedagogical perspective is discussed.

The rest of the paper is organized as follows. In section 2, a summary of course information is provided and section 3 elaborates the proposed modules. Section 4 discusses the results of student surveys, and in section 5 the concluding remarks and the lessons learned are presented.

2. Course information

This study is aimed at reinforcing the "Designing Value in the Supply Chain" course. In supply chain management, technical skills are utilized at each stage; however, a broad systemic approach is required to provide a coherent and integrated structure. Therefore, it is very important for the engineering students to be exposed to some real-life challenges in supply chain courses and understand the domino impact of the decisions they make at each stage on the overall success or failure of a supply network. This course mainly focuses on the planning stage of the supply chain. Planning phase includes functions such as market analysis, demand planning and pricing, integrated production planning, and inventory management decisions.

Reviewing the literature proves that supply chain management plays a key role in determining failure or success of a practice [7, 8]. Walmart and Kmart case studies are well-known examples of success and failure. Therefore significant efforts are required to ensure the learner acquire enough education in this area. In order to promote student learning in this course, three EML-based modules are proposed and adopted in the Designing Value in the Supply Chain course during spring 2015 semester. Through these modules students consolidate their knowledge in different areas to create value, solve a real problem and communicate their decisions via teamwork.

3. Course modules

This section presents three course modules designed for the course of interest. The main goals of these modules are to cultivate entrepreneurial mindset, increase student curiosity via connecting to real life challenges, and enhance material retention. Before introducing the course modules to the class, an introductory supportive module was designed to enhance students' knowledge about their role as future entrepreneurs. Raising the awareness about the necessity of entrepreneurial mindset training is provided extensively via different workshops, publications and conferences at local or national level. However, these trainings mostly target faculty to educate them on how they can upgrade their course contents to instill entrepreneurial mindset in their engineering students. Educating students about the future expectations of the changing world is also very critical and can facilitate the learning and adapting process. This fact necessitates increasing students' knowledge about the power of entrepreneurial mindset and the required skills. For this purpose, a short tutorial course module was presented to clarify the impact of having entrepreneurial mindset and the associated skills on future career of engineering students. Students mostly consider the projects and case studies just as part of their course load; however, increasing their awareness about the motivation behind the designated activities can facilitate the achievement of EML goals. Once the students understand the significance of the relationship between the course assignments and EML-oriented skills that they are expected to develop, the training procedure will be more meaningful and motivating.

3.1. Module I: Demand forecasting module

In the first module, once students learned about demand forecasting techniques, they were required to review their wireless (cellular) minutes and cellular data consumption information over the previous two years (if possible, otherwise over the last 6 months) to forecast their future data and minutes requirements. Thereafter, they were asked to conduct economic analysis in order to select the most cost effective wireless plan. This process resembles the supplier selection problem, which is a very common problem in supply chain management. Students recognized that they might require considering other factors, such as network coverage, number of line required, and their desirability and previous satisfaction history while selecting the best provider.

This process is called Multiple Criteria Decision Making (MCDM) [9], and via this module students practiced the concept using a real life problem.

As the assignment is a group project, students should come to an agreement in choosing the person who provides the data. In this practice students learn how to implement demand forecasting techniques on real data, and explain possible sources of variations and irregularities observed in the consumption pattern. The teams submitted a report which was evaluated based on a rubric. The learning outcomes of this module are as follows:

- Advancing problem solving skills and the ability to analyze real data
- Promoting the ability to communicate a solution in economic terms
- Demonstrating the ability to make a connection between technical skills and potential applications in day-to-day activities in order to create value
- Enhancing teamwork and leadership skills by working in teams
- Learning various forecasting methods and comparison techniques to select the best method
- Integrating a mix of industrial engineering tools such as demand forecasting, economic comparison and decision making to address a real-life problem

3.2. Module II: Course map module

In the second module, student groups propose a new product/ service to be released to the market (idea generation). In this project, they have to justify their product/service from different perspectives, explain the benefit of the product/service, study the market, identify potential customers and their expectations, and translate the customer values and needs into product/service design features. This module mainly focuses on the introduction phase of the product life cycle, from design to production. Student also decided on their production system control mechanism and the module is completed at this point. Students completed the project as the course evolves, i.e., in different stages of this module, they utilized different tools relating to the course content, such as market analysis, demand forecasting, quality function deployment and production system planning.

Groups were required to submit a report which was evaluated based on a rubric. As a result of this module, students are able to think out of the box and determine the opportunities where they could create value. In addition, it helps the student to make a clear logical connection among various concepts, hence making their learning more structured and organized. The learning outcomes of this module are summarized as follows:

- Promoting innovative and higher order thinking via identifying potential opportunities in the market prior to product development

- Enhancing teamwork and leadership skills by working in teams
- Improving active learning via identifying the areas that students can apply their technical skills
- Promoting structured learning and enhancing the retention of the material
- Instilling entrepreneurial mindset via engineering thought and actions
- Integrating a mix of industrial engineering tools to analyze real life problems, and practicing different course concepts with the goal of creating value for the society
- Evaluating the impact of various design concepts in different stages of the product's life cycle
- Enabling students to identify customer needs and values and translate them into product/service requirements and design

3.3. Module III: Energy management module

In module three, which was an individual activity, the students experienced energy management practices in order to minimize energy waste, as one of the important types of waste in lean production systems. In the lean culture, waste is referred to whatever is using resources but not creating value for the customers. In order to enhance students' knowledge on environmental sustainability and energy efficiency, a two-step module was designed. In the first step, students walked across the campus in search of three sources of energy waste. Energy waste could be observed in the offices, labs, classrooms, stairs, and restroom areas. Thereafter, they were required to propose energy saving solutions for the specified areas in the buildings they audited.

In the second phase, a real dataset from a manufacturing facility was provided by the instructor and the goal was to calculate energy and financial savings resulted from occupancy sensor installation at various locations of the plant. For this purpose, students proposed their action plans for implementing the solution, such as collecting and analyzing data, feasibility analysis, getting quotes from different suppliers, estimating implementation cost and calculating energy savings. Accordingly, they estimated the associated financial saving and payback period. Each student submitted a report to show the details of his/her work. The learning outcomes of this module are:

- Advancing problem solving skills and the ability to work and analyze the real data
- Enabling the students to assess the feasibility of engineering solutions
- Promoting the ability to communicate engineering solutions in economic terms
- Promoting active learning via identifying the areas that students can apply their technical skills
- Connecting to real life applications and create value
- Increasing students' knowledge about environmental sustainability

4. Assessment

A detailed rubric was designed for evaluating student reports and guiding them through their progress. Modules I, II and III constitute 10%, 15%, and 5% of the overall grade, respectively. At the end of the term, a voluntary unanimous assessment survey was distributed to gather student feedback and their evaluation of the effectiveness of each module. In addition, students were asked to evaluate the significance of each module in developing skills in different pillars of entrepreneurial training framework as proposed by KEEN. Among the enrolled students, 15 completed the survey entirely (See Appendix). This section summarizes the analysis of the collected data.

As shown in Figure 1, Module 2, Course Map, is the most effective project in student learning from their perspective. Students found this module to be very helpful as it assisted them in making connection between various concepts. Based on the responses to the question "How could Module 2 help you in better understanding the course material or enhancing your knowledge in supply chain and operations management field?", it is concluded that students believed that this module strengthened their learning via a structured process and provided a coherent organization in presentation of concepts. One student reported that this module made him/her "think of the box", which is one of the key objectives of this module.

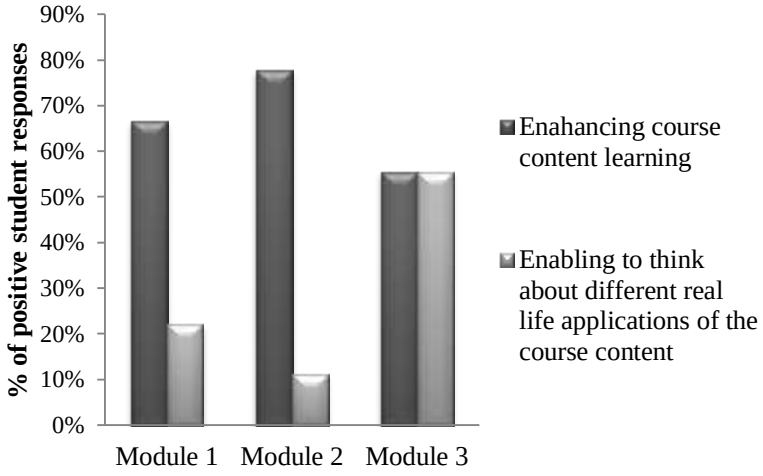

Figure 1. Modules' impacts on students learning and application demonstration

Evaluating the effectiveness of the modules on representing real life applications shows that students found Module 3 (Energy Management Module) to be very effective in demonstrating the applicability of technical skills in real life problems. The course map module was the least real-life type project from students' viewpoints.

As explained earlier, in the KEEN approach, an entrepreneurially minded engineer develops abilities in business acumen, understanding customer needs and societal values and possesses technical depth [2]. In the survey, the students were asked to assess the effectiveness of each of the proposed modules based on 7 complementary skills extracted from KEEN pillars. These skills are as follows:

a) Market study and investigation
b) Opportunity identification
c) Assessment and evaluation of solutions for technical feasibility, and societal and economic benefits
d) Communicate engineering solutions in economic terms
e) Collaboration and team building skills
f) Curiosity and motivation enhancement about changing world
g) Value creation for yourself and/or or society

According to the student feedback, as shown in Figure 2, modules 1 and 2 are the most effective modules in developing *e* and *d* skills. Module 3 was an individual activity and did not have any contribution toward developing team work skills. Generally, it seems that module 2, Course Map, is dominantly addressing all the above skills from student perspective. Module 3 is successful in illustrating value creation as it deals with energy consumption concept, and students are well-familiar with its benefits.

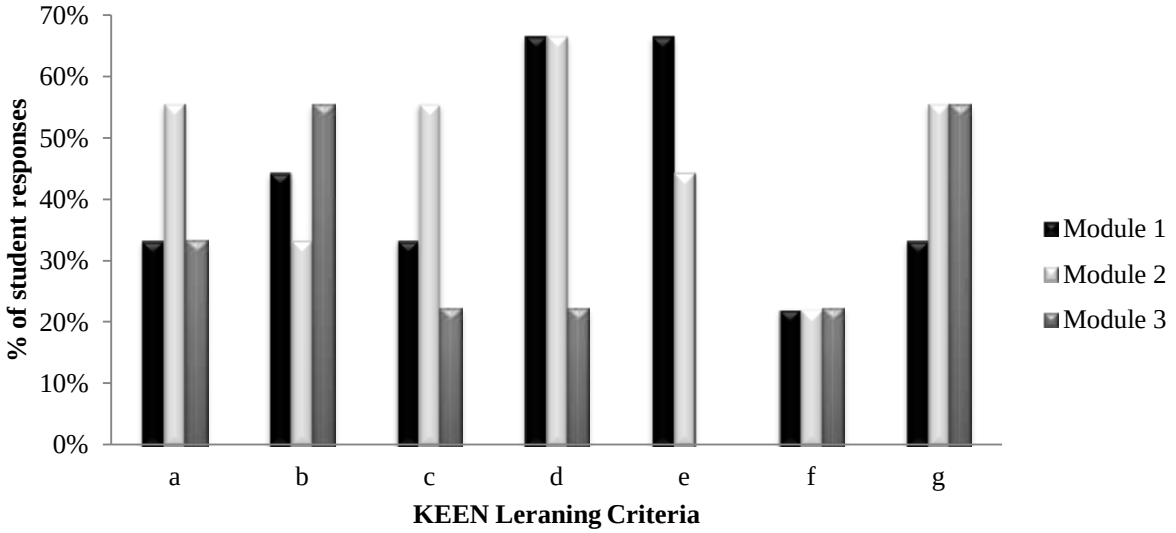

Figure 2. Modules assessment based on KEEN criteria

Comparing student performance using their standardized grades in each module did not reveal any statistically significant difference (*P-Value*=0.13>α=0.05). In other words, the students

performed equally in different modules, although they observed the Module 3 to be the most interesting and effective module for value creation.

5. Concluding remarks and lessons learned

This paper presents the efforts to support developing entrepreneurially minded learning in an industrial engineering course via three modules. These modules were designed in accordance with different course contents, and assessment surveys collected student feedback on the effectiveness of these modules. The survey results confirmed the effectiveness of the modules in satisfying the entrepreneurial mindset training goals as proposed by KEEN.

This practice has been conducted over one term, and some students expressed concern about the amount of time they had to spend on these modules, especially module II. They also believed that the grading structure (10%, 15% and 5%) for these modules was not proportionate to the level of the work they were required. Some adjustment is planned for the modules, especially module II, to fine-tune the course load and make it more manageable for the students. This experiment will be implemented in future classes to collect more data on student feedback and have a more firm conclusion about the effectiveness of the modules. In addition, as part of the future research work, we would like to consider a control group where the students are not exposed to these modules and compare their performance with treatment group.

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Appendix: Sample Questionnaire

1- Do you think "Module 1" enhanced your understanding of the course material or developed a new area of knowledge?

Yes No

2- Do you think "Module 2" enhanced your understanding of the course material or developed a new area of knowledge?

Yes No

3- Do you think "Module 3" enhanced your understanding of the course material or developed a new area of knowledge?

Yes No

4- Did any of the performed projects make you think about different real life applications of the concepts you have learned in this course?

Yes No If yes, which project?.....

5- Do you think including these projects/modules extended your vision about the application of some of the concepts you learned in this course?

Yes No

6- Was the Module 1 able to address any of the following factors? Please circle the ones that apply to this module.

a) Market study
b) Opportunity identification
c) Assessment and evaluation from technical feasibility standpoint, customer or social value and/or economic viability perspectives
d) Communicate an engineering solution in economic terms
e) Collaboration skills
f) Curiosity
g) Value creation for you, people, or society

7- Was the Module 2 able to address any of the following factors? Please circle the ones that apply to this module.

h) Market study
i) Opportunity identification
j) Assessment and evaluation from technical feasibility standpoint, customer or social value and/or economic viability perspectives

k) Communicate an engineering solution in economic terms
l) Collaboration skills
m) Curiosity
n) Value creation for you, people, or society

8- Was the Module 3 able to address any of the following factors? Please circle the ones that apply to this project.

a) Market study
b) Opportunity identification
c) Assessment and evaluation from technical feasibility standpoint, customer or social value and/or economic viability perspectives
d) Communicate an engineering solution in economic terms
e) Collaboration skills
f) Curiosity
g) Value creation for you, people, or society

9- Can you please evaluate the overall effectiveness of Module 1, having 1 as the lowest score and 5 as the highest?

1 2 3 4 5

10- Can you please evaluate the overall effectiveness of Module 2, having 1 as the lowest score and 5 as the highest?

1 2 3 4 5

11- Can you please evaluate the overall effectiveness of Module 3, having 1 as the lowest score and 5 as the highest?

1 2 3 4 5

12- How could “Module 1” help you in better understanding of the course material or enhancing your knowledge in supply chain and operations management field?

13- How could “Module 2” help you in better understanding of the course material or enhancing your knowledge in supply chain and operations management field?

14- How could “Module 3” help you in better understanding of the course material or enhancing your knowledge in supply chain and operations management field?