Project-Based Learning in a Simulation Course to Develop an Entrepreneurial Mindset

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Abstract
Having an entrepreneurial mindset is often a characteristic of highly successful engineers. This mindset can be cultivated through engineering curriculum and educational methods. This work presents a case study in which project-based learning is utilized in a simulation course to foster the development of an entrepreneurial mindset in engineering students. The activity involves utilizing simulation to design a full-scale production system given an assembly system prototype. In addition to the traditional technical engineering objectives, the project engages the key elements of the entrepreneurial mindset including curiosity, connections, and creating value. Both the project outcomes and results of a student survey support the benefits of this approach.

1. Introduction

The concept of the entrepreneurial mindset is described by Bosman and Fernhaber [1] as "the inclination to discover, evaluate, and exploit opportunities." All engineers need to have technical engineering skills to perform their daily jobs, however, those engineers that are highly successful look beyond the calculations, part specifications, process parameters, etc. and seek out opportunities and solutions that will have a positive impact on society.

In engineering education, the idea of including elements in courses that will help to foster an entrepreneurial mindset in engineering students has gained momentum. One of the leading proponents and sources of educational material related to developing an entrepreneurial mindset in engineers is the Kern Entrepreneurial Engineering Network (KEEN) [2]. KEEN has developed a framework that summarized the skills associated with an entrepreneurial mindset which includes *curiosity, connections*, and *creating value*. There is a growing list of educators that are developing and integrating entrepreneurial mindset activities in courses. Korach and Gargac [3] use active learning in a first year engineering course to introduce students to the entrepreneurial mindset concept. Kuhl [4] develops an exercise to promote the recognition of value creation and curiosity by exploring simulation applications. Bosman et al. [5] utilize on-line discussions, Bellotti et al. [6] use serious gaming, and Vignola et al. [7] use project-based learning as ways to develop the entrepreneurial mindset in courses.

In this work, we present a case study in which project-based learning is utilized in a simulation course to foster the development of an entrepreneurial mindset in engineering students. The activity involves utilizing simulation to design a full-scale production system given an assembly system prototype. In addition to the traditional technical engineering objectives, the project engages the key elements of the entrepreneurial mindset. The intention of this activity is not to teach what the entrepreneurial mindset is, but rather to provide students with an opportunity to exercise these qualities and concepts in a meaningful way.

The remainder of the paper is organized as follows. In section 2, we discuss the motivation for integrating entrepreneurial mindset concepts in a systems simulation course. In section 3, we describe the project-based learning activity. The outcomes and assessment of a pilot study are described in section 4. We conclude in section 5 with some insights and observations.

2. Motivation for Entrepreneurial Mindset Activities in Simulation

Simulation is an engineering tool used by companies for system design and analysis. Applications of simulation span a wide range of areas including manufacturing, healthcare, supply chain, logistics, military, and theme parks, among others. Simulations courses often focus on model building and the statistical analysis of results. The design and analysis of alternative system configurations typically emphasize system optimization in terms of maximizing productivity and efficiency. As such, the broader impacts and opportunities that simulation provides in terms of economic, social, and environmental benefits (the triple bottom line) are often given little attention.

We have developed a project-based learning activity to be administered as a term project for a simulation course which emphasizes value creation, connections, and curiosity in addition to the technical and statistical aspects of simulation. The project involves the design of a full scale production system given a process prototype. This is a scenario often encountered in industry. The project provides a goal of meeting weekly demand for a product, but the project team is open to exploring innovative ways to do so. Then using simulation, various production system alternatives are compared considering the boarder impacts to determine their recommendation.

2.1 Why Production System Design?

An application of simulation to an industrial case study is the motivation behind utilizing production system design for this project-based learning activity. In particular, Garbers et al. [8] conduct a simulation-based production system design study for Sanatela, a medical solutions company. A research team developed a new biomedical process for a product called *Matrix*, a gauze-like, biological tissue made from a substance in human umbilical cords known as Wharton's Jelly. Matrix is a product with promising medical applications including the diagnosis and treatment of cancers such as leukemia and the promotion of the growth of stem cells. Having the prototype of the process for producing the Matrix product in a lab, the company tasked our team with the design of an efficient full scale production system that would be ready to go upon implementation.

Upon reflection of the process that our team went through in the design of the production system for this biomedical product, we noticed how many of the elements correlated to and could not have been accomplished without an entrepreneurial mindset. The most obvious element of the entrepreneurial mindset is creating value. Beyond the economic value that the production system would bring to the company, our team needed to consider robustness of the time-sensitive biomedical process, the management and control of the process, and the minimization of potential waste. Furthermore, we see the value that the product itself could bring to society through the treatment of disease and medical research. In terms of the value of applying simulation, we see how various system alternatives can be designed and compared without experimenting with the actual system (potentially wasting valuable resources) and doing so before the system is built. In terms of connections, there is so much that went into the production system design from other area including the application of lean principles (e.g., production flow, eliminating waste, visual production management, etc.), biomedical processing standards, clean room standards and processes, among others. In addition, the project would not have been successful without the team's curiosity from learning about processes (e.g., decellurization, homogenization, lyophilization, etc.) to questioning why particular process steps were performed as they were in the current lab environment and to investigate alternatives.

Brining all of these things together, we recognize the need take into consideration all of the various aspects of the production systems design project that extend well beyond the output performance measures obtained from the simulation model. This motivated the question - how can we bring this type of experience to the simulation courses to give each student the opportunity to engage in a project that will develop not only their simulation skills but also their entrepreneurial mindset? In the next section, we describe a project-based learning activity with this in mind.

3. Project-Based Learning Activity: Production System Design

The project-based learning activity centers on the design of a full scale production system based on a prototype production process set up in a lab environment. We present our pilot study on skateboard production, however, this activity could be applied to the production of any available product. This is a team based project designed for groups of three or four students. The students received the following scenario.

A skateboard company is committed to enabling the development of future skateboard Olympians in their quest for gold! The task of the team is to design a full scale skateboard production system capable of producing skateboards to meet weekly demand based on the components and prototype assembly process developed in the RIT Toyota Production Systems Lab (Figure 1). The teams use simulation to compare alternative system designs and to demonstrate the performance capabilities and limitations of the system.

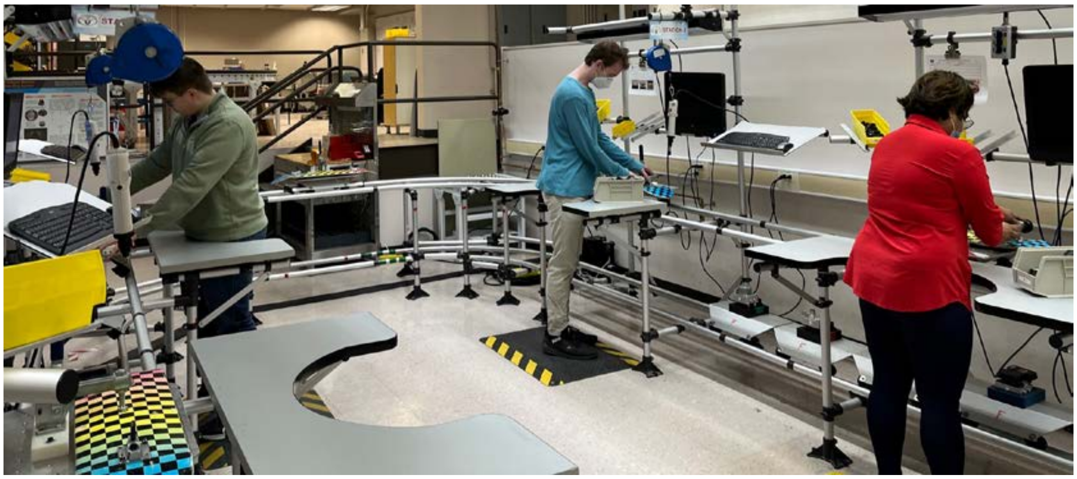

Figure 1. Production system prototype developed in the RIT Toyota Production Systems Lab.

We provide the teams with a description of the manual prototype skateboard assembly process, and the teams set up and run the assembly system to collect process times for the various steps. Some of the assembly steps are shown in Figure 2.

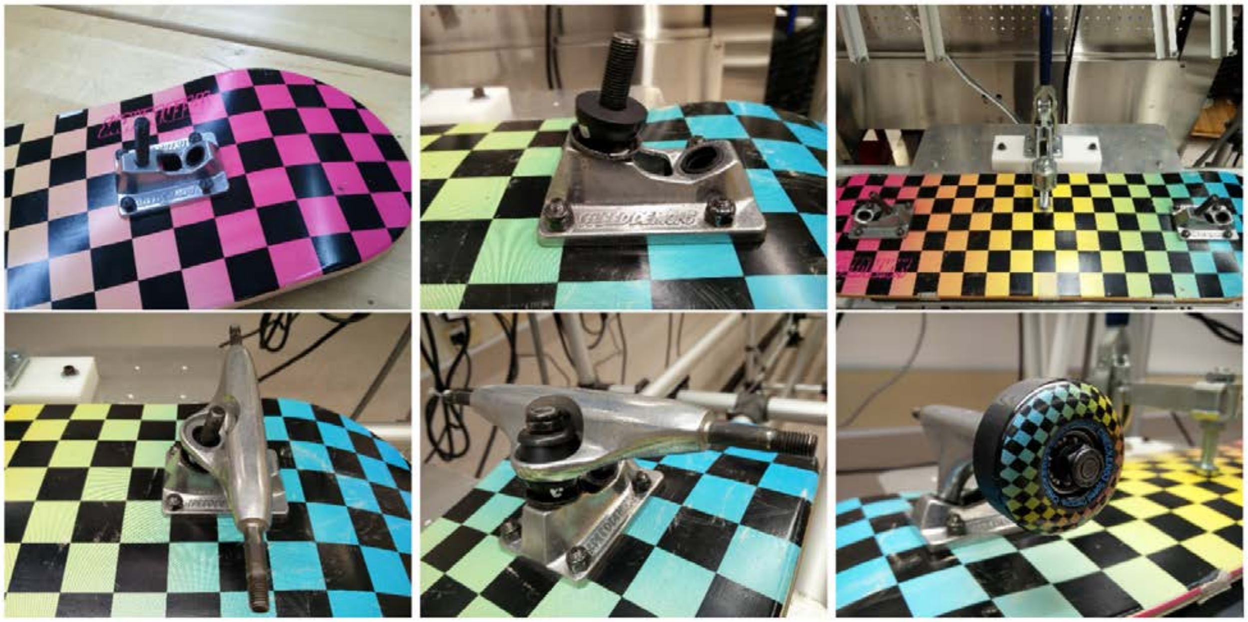

Figure 2. Examples of skateboard assembly steps.

In addition to the skateboard assembly process itself, the team are given additional information regarding the requirements of the full scale system, including:

- The assembled skateboard is put into a box, and then placed on a pallet. A pallet holds 48 skateboards (6 boxes on each level, 8 levels high);
- A forktruck is used to move the pallet to the warehouse;
- Weekly demand forecasts for a one year are provided which are accurate to within ± 10%;
- Demand is met (skateboards are shipped) on Friday each week;
- Skateboards are shipped in full pallets only; and
- Unmet demand results in lost sales (no backorders).

In terms of costs, the following information is given:

- Assembly worker cost is $25 per hour;
- A skateboard sells for $150;
- Material/component costs are $50 per skateboard;
- A one-arm assembly robot cost is $100,000 and has a life expectancy of 5 years;
- Inventory holding costs are $5 per pallet per week; and
- Other costs of system components should be reasonably estimated via Internet search (provide sources). DO NOT call or request cost information/quotes from companies!

The key performance indicators and information of interest includes:

- Production system configuration and methods;
- Weekly planned production schedule;

- Projected weekly inventory;
- Number of workers and schedules for assembly;
- Number of forktrucks/drivers;
- System cost and skateboard profit; and
- Triple Bottom Line: Social, environmental, and economic impacts of system designs.

The project deliverables include an executive summary with supporting documentation providing recommendations, modeling approach, experimentation/statistical analysis, and trade-offs among alternatives. In addition, the teams submit the simulation models of current lab assembly process and alternative full scale production system configurations. Finally, the team gives a ten-minute class presentation.

4. Outcomes and Assessment of Pilot Study

We implemented a pilot study of the project-based learning activity as a term project during the fall semester of the 2021-2022 academic year. Two groups, consisting of four students, each worked on the project independently. The students formed their own groups. The duration of the project was approximately seven weeks. Our objective is to evaluate the extent to which students engaged in the three aspects of an entrepreneurial mindset – curiosity, connections, and creating value. To evaluate the level of engagement, we employ a direct measurement using part of the project rubric and a reflection using a post-project survey.

A grading rubric was provided to the students at the start of the project. The rubric includes the following grading categories: (a) executive summary; (b) modeling; (c) analysis; (d) boarder impact/triple bottom line; and (e) recommendations and conclusions. The rubric provides the expectations for achieving a grade level of excellent, good, fair, or poor for each part. Part (d) related to the boarder impacts/triple bottom line, serves as the primary direct measurement of how well the students were able to recognize the value of their design alternatives from multiple perspectives. In this pilot study, both groups earned a grade level of excellent for their analysis and discussion related to part (d). Examples of points discussed by the students included the economic value, the environmental impact of their designs, and the impact of their design on workers, stakeholders, and customers.

At the conclusion of the project, students completed a project survey specifically designed to assess the effectiveness of the project-based learning in utilizing skills and actions associated with an entrepreneurial mindset. The students were asked to complete the ten-question survey by indicating the extent to which they agree or disagree with each statement. The survey utilize a five-point Likert scale with the following responses (weights): Strongly Agree (5); Agree (4); Neutral (3); Disagree (2); and Strongly Disagree (1). The project survey questions along with a summary of the responses is provided in Table 1. Each students completed the survey independently for a total of n=8 survey responses. The average and standard deviation of the Likert score is provided for each question. The values of the responses for each survey question indicates that the project provided opportunities for the students to apply entrepreneurial mindset related concepts and skills that resulted in action as they proceeded through their project.

Table 1: Project survey questions and response summary.

Project Survey Questions [5-Strongly Agree; 4-Agree; 3-Neutral; 2-Disagree; 1-Strongly Disagree]	**Response Average (Std. Dev.)**
1) The project prompted me to formulate and ask questions.	4.75 (0.43)
2) The project prompted me to gather data/information to support my ideas.	5.00 (0.00)
3) I took ownership of, and expressed interest in the project.	4.63 (0.48)
4) I was able to connect my previous experiences with the content of the project.	4.25 (0.97)
5) The project prompted me to consider, why the analysis/recommendations adds values from multiple perspectives (e.g., economic, societal, etc.)	3.75 (0.83)
6) I created solutions to meet customer needs.	4.63 (0.48)
7) I created a compelling value proposition for the project stakeholders.	4.38 (0.70)
8) I integrated monetary and non-monetary factors into a triple bottom line assessment.	4.75 (0.43)
9) I applied technical skill/knowledge to the development of a technology/product/process.	4.88 (0.33)
10) The project prompted me to present technical information effectively using charts, graphs, tables, etc.	4.25 (0.66)

Although this pilot study with a small number of participants cannot conclude decisively that this project-based learning activity significantly impacts or improves the entrepreneurial mindset of students over traditional approaches, the empirical evidence does seem to indicate that we are moving in the right direction.

5. Conclusion

In conclusion, we presented a project-based learning activity intended to serve as a term project for a simulation course. The structure and grading of the project is designed to engage students in the concepts of value creation, connections, and curiosity in an effort to develop an entrepreneurial mindset. Both the project outcomes and results of a student survey support the benefits of this approach. Our future work in this area is to expand the project to other products for which we have production process prototypes including the assembly of automotive products, and to expand our analysis to a larger set of students to better determine the impact of this approach.

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