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ENTREPRENEURIAL MINDSET LEARNING (EML) IN SIMULATION EDUCATION

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ABSTRACT

An entrepreneurial mindset is associated with recognizing and seeking opportunity that can result in societal benefits. Entrepreneurial mindset learning (EML) is a pedagogy that has gained increasing attention in science, technology, engineering, and math education. In this paper, we present a set of examples to illustrate how EML methods can be applied in simulation courses to foster the development of the entrepreneurial mindset of students. In addition, we discuss some of the opportunities and challenges for adoption of EML in simulation education.

1 INTRODUCTION

Companies frequently utilize simulation to evaluate alternative system designs. In particular, simulation is employed to aid in making decisions that have significant economic or social impacts. (Examples include, the design of hospital emergency departments, public policy decisions, etc.) The generation of high impact solutions requires not only simulation analysts with strong modeling and analysis capabilities but individuals that seek to discover and test innovative alternatives. Simulation courses typically focus on the technical and statistical aspects of model building and statistical analysis focused on operational performance of metrics that can be collected within the simulation itself. To complement these technical simulation aspects, it is important for students to understand the full context of the decision under consideration and boarder impacts of the alternative solutions.

In this work, we present an approach to foster the development of an entrepreneurial mindset (EM) in simulation education. The entrepreneurial mindset concept is described by Bosman and Fernhaber (2018) as "the inclination to discover, evaluate, and exploit opportunities." Furthermore, entrepreneurial mindset learning (EML) is a pedagogy that has gained increasing attention in science, technology, engineering, and math (STEM) education to help students develop EM traits. We present as set of examples to illustrate how EML methods can be applied in simulation courses. The intention of these EML activities is to provide students with opportunities to exercise EM qualities in a meaningful way resulting not only students with better retention and understanding of simulation technical knowledge but better problem solving abilities as well.

The remainder of the paper is organized as follows. In section 2, we present some background and related work on EML. In section 3, we give an overview of the design of EML activities for simulation courses as well as a set of examples. We provide a discussion of some of the opportunities and challenges for implementing EML activities in section 4. Finally, in section 5 we present our conclusions and future work.

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2 BACKGROUND AND RELATED WORK

The need for understanding the methods and results of simulation modeling and analysis in the broader context of the decisions under consideration have been recognized in the literature. Goodwin and Franklin (1994) discuss the use of the popular "Beer Game" to integrate the concept of systems thinking to improve the learning of simulation concepts. Furthermore, active game-based learning has been used to improve the engagement of students in teaching simulation concepts resulting in improved students learning outcomes (Padilla, Lynch, Diallo, Gore, Barraco, Kavak, and Jenkins 2016).

The idea of an entrepreneurial mindset is often associated only with individuals that create start-up companies (entrepreneurs). However, these characteristics and thought processes can be developed and applied in all walks of life. In their book, "Teaching the Entrepreneurial Mindset to Engineers", Bosman and Fernhaber (2018) provide a thorough discussion of the origins of EM and how engineers can learn and benefit from developing EM.

In addition, the Kern Entrepreneurial Engineering Network (KEEN) is one of the leading proponents and sources of educational material related to developing an entrepreneurial mindset in engineers (Kern Entrepreneurial Engineering Network (KEEN) 2023). KEEN has developed a framework that summarized the skills associated with an entrepreneurial mindset. These skills include curiosity, connections, and creating value (also known as the 3Cs). Curiosity involves being inquisitive about the changing world and exploring contrarian views. Connections involves integrating information from multiple sources to gain insight. Creating value involves the ability to identify opportunity for creating extraordinary value. The intersection of these characteristics form the basis for an entrepreneurial mindset (Figure 1).

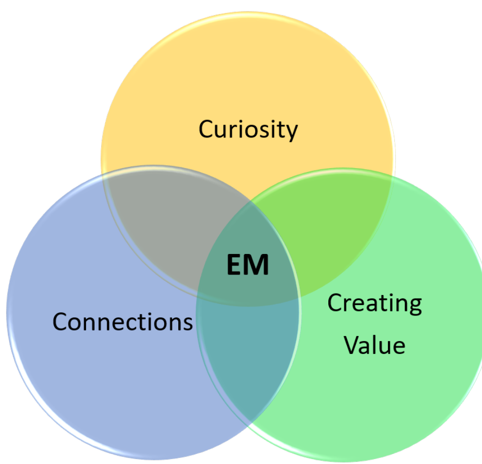

Figure 1: Characteristics of an engineering mindset (EM): Curiosity, Connections, and Creating Value.

There is a growing list of educators that are developing and integrating entrepreneurial mindset activities in courses. Examples include: using active learning in a first year engineering course to introduce students to the entrepreneurial mindset concept (Korach and Gargac 2019); utilizing on-line discussions to develop EM characteristics (Bosman et al. 2019); using serious games (Bellotti et al. 2014); and using project-based learning to develop the entrepreneurial mindset in statistics courses (Vignola et al. 2017).

To address the development of EM characteristics in simulation courses, we present a set of EML modules. In particular, the goal of these modules is to help students see how simulation can be used in system design to create value and facilitate innovation.

3 IMPLEMENTING EML ACTIVITIES IN SIMULATION COURSES

In this section, we present several EML activities that have been successfully implemented in an undergraduate engineering course in systems simulation. The goals of these simulation activities are multifaceted. Each activity has a goal of learning about simulation modeling and analysis but doing so in a way that will help to promote the student's curiosity about simulation, facilitate the process of making connections between simulation and other experiences, and uncovering the value created by the use of simulation. The following three activities are just an example of the type of EML that can be used in teaching simulation.

The materials supporting each of the EML activities are available through the *Engineering Unleashed* website portal (Kern Entrepreneurial Engineering Network (KEEN) 2023). Access to the material is freely available to faculty by registering/creating of a portal account.

3.1 Exploring Simulation Applications

At the start of a simulation course there is an opportunity to engage students in an EML activity that will demonstrate how simulation can be used to solve significant problems as well as stimulate student curiosity about simulation. This activity is used to expose students to the vast array of diverse applications of simulation (Kuhl 2020). This activity is conducted in two parts (individual and group assignments) in order to accommodate large classes and give students exposure to a wide range of applications.

The individual assignment is to search for a published simulation application paper that is of interest to them. As the premier international conference on discrete-event and continuous simulation, the Winter Simulation Conference (WSC) (Winter Simulation Conference 2023) has a proceedings archive that contains a wide array of simulation applications papers (hundreds of papers per year for 50+ years). The WSC Archive (INFORMS Simulation Society 2023) is readily accessible and serves as the primary resource for this activity, however, students may use other publications as well. The assignment is to read the paper and write a one paragraph summary that includes that application and problem; how simulation was used; the results/outcomes; and the broader impacts (social, economic, environmental, etc.) Students are given one week to complete this individual portion of the assignment.

For the group portion of the assignment, students are assigned to groups of 3-4 students. The students are asked to meet with their group to discuss their selected applications. Each group then selects one of the applications to share with the class. The group creates one visual-aid slide and one person selected by the group will give a 90 second summary presentation of the application to the class.

For a class of 40 students in groups of four, each student will be exposed to a minimum 13 applications of simulation that are of interest to them and their peers. Additionally, the students encounter other applications during their search and communicate with one other about the applications during and after the project activity. We have observed that this activity, promotes curiosity about simulation and its wide range of applications. By investigating applications that are of interest to the student, they are able to make connections with their own experiences. Finally, student are able to identify the value that can be created through the use of simulation and the broader impacts. As a side note, from an instructor perspective as this activity is conducted near the start of the course, insight can be gained about the interests of the class that can be used to help relate concepts later in the course.

Additional details about this EML activity including the activity narrative, an example, and rubrics are available from KEEN Card 1351, *Simulation Everywhere!!!*, (see Kuhl 2022c).

3.2 EML Open-Ended, Team Simulation Activity

In this second simulation activity, students utilize EML to propose and evaluate the performance of a transportation system to move guests between lands within a theme park (Kuhl 2020). As an alternative to specifying all of the details in a written problem description, this team-based activity enables students to generate their own design alternatives for a theme park – an application that most students are familiar with. In particular, the objective of this open-ended activity is for students to generate a transportation alternative for moving guests between lands within the park. Student are provided only a minimal amount of information with regard to the park and the design requirements for the transportation system. These include,

- The configuration of the theme park: four themed land located around the perimeter of a lake having a radius of one mile;
- The hours of operation: daily, 9 am - 9 pm;
- Average demand: 400 guest per hour that leave each land and want to travel to one of the other lands (destinations are equally likely);
- The mix of group sizes traveling together: groups of size 1-6 and their respective likelihoods;
- The target date of operation: one year; and
- Evaluation: assess the total value of the transportation alternative (including but not limited to initial cost, operational costs, operational performance, guest experience, and other factors.

Recognizing that efficient transportation is only one (and perhaps not the most important) aspect of the theme park's decision, students simulate their transportation system alternative and evaluate system performance while considering entertainment value, ability to accommodate a diverse set of individuals (ages, physical abilities, etc.), and costs, among other considerations.

This activity has been used in the course a midterm project. At this point, students have a sufficient amount of modeling and analysis knowledge to enable them to successfully model a transportation system. However, this problem requires the students to consider the stakeholders including the users of the system. We have observed how students make connections between the simulation modeling and their experiences with visiting theme parks, waiting in line, wanting a fun experience, etc. In addition, as the student generated alternative will inevitably have some aspect that was not covered explicitly in the class, their curiosity is sparked to discover the appropriate modeling technique to use. Finally, students recognize how simulation can play a key role in value creation when designing a systems and evaluating them from multiple perspectives.

Additional details about this open-ended, EML activity including the activity narrative and rubrics are available from KEEN Card 3438, *Theme Park Transportation System: Simulating Alternative Designs* (see Kuhl 2022d).

3.3 Project-Based Learning Activity

This team-based project uses EML in the design and analysis of a full scale production system based on a lab prototype assembly process using simulation (see Figure 2) (Kuhl 2022b). This project-based learning activity encourages curiosity, connection, and value creation in term of the broader impacts that simulation provides in terms of economic, social, and environmental benefits (the triple bottom line). This activity is administered as a term project for a simulation course, typically over the last 6-7 weeks of the semester.

The design of a full scale production system given a process prototype is a scenario often encountered in industry. The motivation for this activity originated from an industry project involving the design of a biomedical production system for an innovative new product that can be used for diagnosing disease and for stem cell growth (Garbers et al. 2020). Working with students to design this production system using

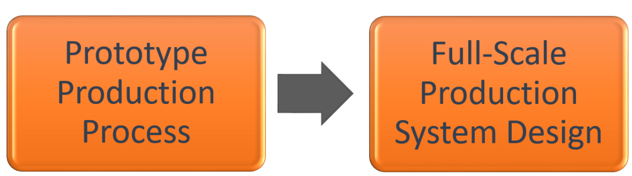

Figure 2: Project-based learning activity: Using simulation to design a full scale production process from a production process prototype.

simulation and seeing the EM qualities and engagement of the students, our goal was to bring this type of experience to the simulation class.

The project focuses on the design of a production system for a new product (in this case skateboards although any product could be used). We chose skateboards for several reasons: (a) student can connect with riding skateboard; (b) the skateboards were readily accessible in our production systems laboratory and are used for teaching line balancing and K-12 outreach activities; and (c) skateboarding has gained attention as a new summer Olympic sport.

The task of the team is to design a full scale skateboard production system capable of producing skateboards to meet weekly demand. Based on a prototype assembly process developed in a production systems lab, the team collects data, performs input analysis, constructs a simulation model, and analyzes the prototype system. Then the team uses simulation to design and compare full scale system alternatives.

The teams are provided some minimal information about the full scale production system including:

- Packaging and palletizing information;
- Weekly demand forecasts for one year which are assumed to be accurate to withing $\pm 10\%$;
- Unmet demand results in lost sales; and
- Cost information (wages, material cost, holding cost, etc.)

In addition, teams are told that the information and performance measures of interest to the company include:

- Production system configuration and methods;
- Weekly planned production schedule;
- Projected weekly inventory;
- System cost and skateboard profit; and
- Triple Bottom Line: Social, environmental, and economic impacts of system designs.

The project deliverable include the simulation models, report, and class presentation.

For this EML activity we were able to observe the desired outcomes of increased curiosity, connections, and creating value. Furthermore, we administered a student survey to evaluate these project in terms of the perceived level of EM development opportunity. Although a small sample size, the results of the survey indicate were positive in general.

Additional details about this project-based, EML activity including the activity narrative and rubrics are available from KEEN Card 2969, *Go for the Gold! Design and Simulation Analysis of a Skateboard Production System* (see Kuhl 2022a).

4 OPPORTUNITIES AND CHALLENGES

In the previous section, we outlined several examples of EML activities that can be implemented in simulation courses. These are only a few of the vast array of potential opportunities for engaging students to develop an entrepreneurial mindset. The challenge is shifting the way in which instructors think about (and teach students to think about) simulation concepts and methods.

Hopefully, the EML activities presented in the previous section are relatable and appear as natural candidates for implementation. However, with some effort these same EML concepts could be applied to any simulation course topic. For example, one could consider how a standard classroom lecture on random number and random variate generation involving derivations and numerical examples could be transformed into an activity where students learn the importance (value) of random number/variate generators, spark their interest in what makes a good generator (curiosity), and relates to their interests and experiences (connections) both within the context of simulation analysis and real-world applications/decisions.

Although there are many opportunities for integrating EML activities in a simulation course, there are also challenges including assessment, class time management, and striking the appropriate balance of constraints and open-ended aspects of the activities.

In terms of assessment, there are several issues that can arise. First is the assessment of the level of technical simulation knowledge gained by students versus the assessment of the entrepreneurial mindset aspects gained from the activity. In the projects presented in this paper, a rubric is applied where a portion of the grade is attributed to EM outcomes. However, if the EM methods are indeed promoting learning, the technical knowledge portion should also reflect this. Second is the ability to assess the EML activity itself. Although there are methods available for addressing teaching pedagogy, understanding and measuring the impact of activities outside of a controlled experiment is difficult.

Class time management can be another challenge, particularly when trying to start an effort toward EML. Fortunately, there are some great resources available through Engineering Unleashed and elsewhere that can help an instructor to get started. One suggestion is to start small with a single activity in a class. Find out what works and does not work for you and build on your successes. In addition, we have observed the need carefully consider which aspects of the activities we conduct in class and which aspects should be done by students outside of class in order to use the in-class time most efficiently.

Finally, for the EM activities striking the appropriate balance between constraints and open-ended aspects can be challenging. For traditional approaches of providing simulation assignments where most (if not all) aspects of the problem and required analysis are given, the instructor can generate an expected solution and predict areas where student may struggle. However, open-ended problems sometime lead to unexpected solutions and modeling approaches. In some cases, give too much liberty, students can make assumptions that over simplify or over complicate the intended problem. To address this, it is important to interact with the students early on and continue interaction throughout the project activity to guide the students to the desired simulation learning outcomes.

5 CONCLUSIONS

In conclusion, in this paper we have presented an entrepreneurial mindset learning approach for simulation courses. In addition, we have provided some examples of EML activities that have been successfully applied in undergraduate engineering courses in systems simulation. Finally, we have presented some opportunities and challenges associated with EML. Based on our experience, these activities can help to develop an entrepreneurial mindset that students will be able to take with them beyond the simulation class. As mentioned previously, Engineering Unleashed can be a great resource to get started in applying EML in courses, and a platform for sharing EML activities with colleagues. One of our next undertakings is to develop an EML activity for simulation verification and validation.

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