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Implementing Entrepreneurial Mindset Learning Activities in Several Engineering Courses

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Implementing Entrepreneurial Mindset Learning Activities in Several Engineering Courses

The entrepreneurial mindset is characterized by the Kern Entrepreneurial Engineering Network (KEEN)'s 3C's, which are curiosity, connections and creating value. Entrepreneurially Minded Learning (EML) activities are designed to inspire curiosity and teach students to integrate information from many sources to gain insight and encourage them to create value by identifying opportunities and working in a team. To foster an entrepreneurial mindset at The Citadel, EML is integrated in an Engineering Probability and Statistics course, in an Introduction to Geotechnical Engineering course, and in a first-year seminar course via problem-based learning, geotechnical failure analysis, and several case studies, respectively. EML is incorporated into junior and senior level Materials classes via a problem-solving studio approach, directing students to actively connect what information is given, what assumptions can be made, and what additional information is needed. This approach is applied to foundational concepts in Materials including atomic packing, material density, phase diagrams, and material processing. Additionally, EML is incorporated into junior level Engineering Design courses by emphasizing connections and creating value for the stakeholders in the development of a new product.

Introduction

An active, productive technology and entrepreneur community can benefit the economy in a variety of ways, including the development of new innovative products, job creation, and economic growth [1]. Recognizing this, members of the business and education community began developing methods for teaching key habits and attitudes of successful entrepreneurs long ago, giving rise to Entrepreneurship Education (EE) in the 1980s [2]. During the early years of EE, resources mainly taught skills and concepts that aided in identifying business opportunities and building self-confidence [3], as well as developing the ability to think about problems that require innovation and risk-taking [4]. A small shift in EE's focus and pedagogy occurred as educators and researchers acknowledged that entrepreneurship is not limited to starting and managing a business but is, instead, a broader concept that encompasses innovative thinking, creativity, adaptability, and resilience. Over the past decades, EE has now evolved to Entrepreneurially Minded Learning (EML), which is an educational framework that seeks to develop an inquisitive approach through active, experiential, and problem-based learning that emphasizes innovation and creating value. EML aims to prepare learners to go beyond just thinking like an entrepreneur to, instead, identify opportunities, take calculated risks, and proactively solve problems. Organizations, such as the Network for Teaching Entrepreneurship (www.nfte.com) have developed curricula for students and teachers, while organizations like KEEN (https://engineeringunleashed.com/mindset) have created a community of college faculty who develop and share teaching tools with other faculty.

The KEEN framework blends engineering skills with an entrepreneurial mindset. The KEEN mission is "to graduate engineers with an entrepreneurial mindset who can create personal, economic, and societal value through meaningful work [5]." The overall KEEN framework encourages students to be Curious, to Connect information, and to Create value for others—that is, the three Cs emphasized by KEEN. By encouraging students to explore diverse areas of knowledge, EML fosters a holistic and integrated approach to problem-solving while working successfully as a team. EML also focuses on developing other vital skills such as resilience and creativity.

EM pedagogy emphasizes active learning, engaging students in hands-on, interdisciplinary experiences such as creating and developing innovative business ideas, solving complex problems, and collaboration. Numerous ASEE presentations and conference proceedings have detailed the unique ways that faculty have incorporated EM into their engineering classrooms and their methods for assessing effectiveness. Some EM learning activities have utilized synchronous or online asynchronous e-modules [6], [7] others utilized global design challenges [8], yet others developed an integrated curriculum that spread content and EM learning outcomes throughout multiple college semesters [9], [10].

This paper details a few of the ways in which the authors have incorporated EML in various courses at The Citadel. These activities could be incorporated into other courses and classrooms with small modifications.

EML Example 1: Engineering Probability and Statistics

Engineering Probability and Statistics is a required course for Civil, Construction and Electrical Engineering majors at The Citadel. Topics of the course include data collection and presentation, descriptive statistics, probability, sampling distributions, confidence intervals, hypothesis testing, regression and correlation, and analysis of variance. Usually, the course is offered based on the traditional textbook approach. The material in the textbook is presented in the class and students are required to work on problems in the textbook as part of the course assignments. These textbook problems are typically well-defined, have only one solution method, and provide all information necessary for a solution.

To help students apply the course concepts to real-world applications, as well as to improve their entrepreneurial mindset learning (EML), a comprehensive semester-long problem was developed. EML activities were designed to inspire student's curiosity about the world around them and teach them to integrate information from several sources. In addition, these activities encouraged students to create value by identifying opportunities and working collaboratively with fellow students. To promote student engagement and deeper conceptual understanding and to develop statistical problem-solving, M&M's® candies were used to illustrate topics such as data collection, identifying categorical and numerical variables, distribution of a numerical variable, data analysis, probability, simple linear regression model, and inference. Students demonstrated curiosity by exploring a contrarian view of accepted solutions, demonstrated connections by integrating information to gain insight, and created value by composing technical reports documenting the findings of their analysis.

The assignment is presented to the students through the following letter from a client regarding the semester-long problem: "I am writing to inform you that the statisticians in this course have been asked to investigate several claims made by Mars, Inc. regarding the color distributions of M&M's®. Mars, Inc. claims that (1) the proportions of blue, orange, green, yellow, red, and brown in plain packet is 24%, 20%, 16%, 14%, 13%, 13%, respectively and (2) the packets of various types of M&M's® have same color distribution and regardless of type, the number of M&M's® in each packet is the same. We request that you perform the appropriate analyses to investigate the distribution of colors, descriptive statistics, probability distributions, confidence intervals, hypothesis testing, correlation and regression, and chi-square and one-way analysis of variance. Please send Customer Protection Agency the interim reports 1-3 containing your findings and recommendations by each due date."

The students completed an in-class activity which involved using plain, peanut, and peanut butter M&M's® packets. The primary goal of this class activity was to trigger students' curiosity about various statistical concepts and their application in real life. The data that was collectively generated was used to prepare follow up reports that required them to use various data organization and analysis tools to characterize the population of interest. As a hook, a packet of M&M's® was shown to the students and the following prompts were used to facilitate class discussions: what type of data is encountered when you open the bags, how to estimate the percentage of M&M's®, how to identify categorical and numerical variables, how to identify discrete and continuous variables, how to distinguish parameters from statistics, how to record the data, how to analyze the data using graphical tools, and how to determine the variation in the data.

An unpopulated spreadsheet was prepared to record the data from the students (Table 1). The purpose of this step was to give the students experience in how to structure their data collection and to facilitate analysis. Three types of individually sized packets of M&M's® (plain, peanut, and peanut butter) were distributed to each student. Students were instructed to count the total number of M&M's® in their packet, as well as to sort them by color to count the number of each color. Finally, students used a scale to determine the gross weight and net weight of each packet. Students were asked not to eat the "data" until the conclusion of the data collection process. Students reported their values, and the spreadsheet was completely populated. Important statistics concepts were tied to the dataset.

Students used the collected data to investigate the distribution of colors, descriptive statistics, probability distributions, confidence intervals for mean and proportion, hypothesis testing, correlation, regression, chi-square goodness-of-fit test, and one-way analysis of variance test. They created value by composing three technical reports that addressed all the client's concerns regarding various claims made by Mars, Inc.

The semester-long problem aimed to trigger students' curiosity about statistical concepts and their applications in real life. The intent of the questions was to help them see the relationship between value and variation and what each of these terms means from the customer and manufacturer perspective.

Table 1. Unpopulated spreadsheet and example collected data for plain M&M's®.

Student	Total	Blue	Brown	Green	Orange	Red	Yellow	Check	Weight (g)	Net W

Student	Total	Blue	Brown	Green	Orange	Red	Yellow	Check	Weight (g)	Net W
	53	9	4	16	10	11	3	0	47.83	46.79
	55	6	10	16	10	9	4	0	49.41	48.37
	56	14	4	16	9	9	4	0	49.7	48.72
	56	9	10	14	6	11	6	0	50.36	49.38
	59	16	11	13	4	11	4	0	52.94	51.97
	57	8	4	23	8	10	4	0	50.85	49.84
	56	9	7	17	9	12	2	0	50.12	49.14
	54	9	5	17	8	11	4	0	48.56	47.53
	52	7	6	16	7	10	6	0	46.75	45.79
	55	8	3	20	11	8	5	0	49.09	48.06
	55	13	3	20	3	13	3	0	49.1	48
	54	13	7	12	8	12	2	0	48.51	47.45
	53	8	11	9	12	11	2	0	47.83	46.85
	57	4	8	10	12	18	5	0	51.77	50.66
	57	7	8	19	6	14	3	0	50.97	50
	55	14	6	16	6	9	4	0	49.36	48.36
	55	11	7	16	8	11	2	0	49.12	48.14
	57	10	5	17	6	12	7	0	51.11	50.09
	58	8	10	13	9	11	7	0	51.39	50.4
	54	13	6	16	6	11	2	0	48.66	47.67
	58	8	8	15	8	15	4	0	52	51.01
	56	11	7	12	11	12	3	0	50.34	49.34
	56	9	7	16	8	10	6	0	50.3	49.35
	54	12	10	16	2	7	7	0	48.39	47.42
	56	7	4	23	4	17	1	0	50.35	49.35

EML Example 2: Introduction to Geotechnical Engineering

As a requirement for graduation, Civil Engineering majors must take Introduction to Geotechnical Engineering in their senior year at The Citadel. The Introduction to Geotechnical Engineering course is offered in the fall semester. The course focuses on basic principles of soil mechanics (i.e., engineering uses of soils; laboratory and field determination of soil properties; determination of phase relationships; engineering soil classification; soil-water interaction; stress effects of loading on soils at depth; and consolidation, compaction, shear strength, and bearing capacity theory).

An activity was developed to help students connect the class content with real-world applications. To deepen their understanding of the geotechnical concepts, students were asked to select a geotechnical failure that is commensurate with their level of understanding of soil mechanics and conduct an in-depth study of why the failure occurred through the exploration of journal articles and textbooks. Students were also required to explain the mechanism(s) of failure using the concepts learned in the course and compose a technical report documenting the findings of the analysis.

Objectives of this activity were three-fold: (1) address curiosity by taking ownership of, and expressing interest in the topic; recognize and explore knowledge gaps, (2) connect concepts learned in the course with independent research on a particular geotechnical failure to explain how the failure occurred, including the mechanism(s) of the failure; connect life experiences with class content; identify and evaluate sources of information. (3) create value by composing a technical report documenting the findings of their in-depth failure analysis, as well as presenting findings to peers. These objectives overlap with the KEEN three Cs.

Students enjoyed the connection between what they learned in class with the real-world application of these concepts. Some students creatively selected their topics which required in-depth understating of the topic and provided great justifications.

EML Example 3: First-Year Seminar Course

As a requirement for graduation, students at The Citadel must take a First-year Seminar course in their first year. One such course is Environmental Hazards, which is offered by the Civil Engineering department. Two, seven-week modules have been developed that integrate EML into the course. The first module focuses on curiosity and connection via introduction to EML, environmental justice, case studies (Love Canal, "A Civil Action", and Flint water crisis), and superfund and brownfield sites. The second module focuses on all three Cs of the EML via a project. The Flint water crisis EML activity is described below.

To create connections, the Flint, MI water crisis case study was used in this course. Students were asked to identify and discuss several connecting factors related to the community that played a role in the water crisis in Flint. Students were required to examine and discuss multiple issues of water, including human rights; the role of governments on ecological resources and utilities, infrastructure; citizen action; and health related to economic development. Teams of students debated questions such as:

- How did science play a role in diagnosing the problem?
- How do you think racial discrimination played a role in the crisis?
- How did politics affect health?
- What social factors in Flint are not directly about health that nonetheless harmed children's health?
- How did poverty increase Flint children's risk of exposure to lead in the water?
- How did changes in industry and employment affect economic security?
- What was the role of national safety in the crisis?
- How are legal policy, environmental policy, and health policy factors in this crisis?
- How important were the voices of parents in identifying the Flint water crisis and pushing for national attention and change?
- How was public safety compromised in the Flint water crisis?
- How did public awareness of health issues influence this crisis?
- What is the connection between poverty and health care?

Students concluded that seeking a solution to Flint's water crisis required coordinated collaboration across diverse sectors of society as well as governments.

EML Example 4: Engineering Materials and Advanced Materials

Engineering Materials is a required junior-level course and Advanced Materials is an elective senior-level course for Mechanical Engineering majors at The Citadel. Topics of the required Engineering Materials course include the properties of major material groups, fundamental atomic and microstructural concepts that impact material selection, effect of processing on material properties, and an introduction to important material failure modes. Topics of the elective senior year Advanced Materials course include an introduction to specialty materials and their uses, as well as an in-depth treatment of failure mechanisms of various materials during real-world usage. Usually, these courses are taught using textbook reading, in-class lectures, and textbook-like problems both in-class and as homework.

To engage students in applying the course material, activities that bring together multiple open-ended, hypothetical problems are introduced. These activities are based on a KEEN problem-solving studio (PSS) approach, directing students to actively question what information is given, what assumptions can be made, and what additional information is needed. This approach is applied to foundational concepts in Materials including atomic packing, material density, phase diagrams, and material processing. These activities provide real-world context that builds curiosity, requires questioning and synthesis of concepts that establish connection, and address a need that can create value for a customer. That is, these activities apply the three Cs in the KEEN framework.

For the junior year Engineering Materials course, examples of problem-solving studio (PSS) problems include determining atomic packing, validating that a customer's required material properties could be obtained from a material with a specific composition, and resolving if a given material processing could create the desired material properties.

An example PSS exercise from this class developed because students often find it challenging to calculate how atoms are packed together and how they efficiently fill the space in the cubic atomic arrangements that metals adopt. There seem to be two main barriers to solving this sort of atomic packing factor problems: the scale is on the nanometer rather than the centimeter scale and it has been some years since the students have done the basic geometry calculations and they don't remember the equations for volume. To make atomic packing more tangible, the PSS approach is implemented so that minimal information is provided, and they must ask questions and retrieve the relevant equations. The scenarios used involve an outlandish scenario where beach balls or bowling balls are packed into a room and then the room is filled with water. The students are entertained to picture this outlandish scene and to calculate the amount of water that is in the room. They quickly figure out that they need to ask questions to find out the size of the room, the size of the beach balls, the arrangement of the balls in the room, the equations for volume of a cube and the volume of a sphere. With this information, they work through the calculation. After they have done this calculation, the correlation to the atomic scale arrangement of atoms is made. The students perform much better in future calculations related to atomic packing in different crystal structures with their unique packing of atoms.

This class also introduces the concept of heat and cooling a piece of metal (heat treatment), with small changes resulting in significantly different atomic arrangements and the resulting changes in material properties. It can be challenging to understand and resolve the interlaced effects when the basics of the Fe-C phase diagram have just been learned. To put those individual pieces of knowledge into practice, student teams are challenged to use steel composition charts and phase diagrams to design a material selection and heat treatment that would produce a material that has specific properties. The teams ask many questions to hone in on their solutions as there are many ways to satisfy the constraints. Additional challenges, such as cost and machinability, are added as challenges while the teams are working. The teams then present their solutions to the class; classmates then verify that the proposed solution is acceptable. Outcomes from this PSS is that students process the complexity of material selection, appreciate that there is not just a single correct solution to a problem, and respond to constraints.

For the senior year Advanced Materials course, examples of problem-solving studio prompts include proposing the loading and environmental exposure history of a structural part given an observed failure mode and isolating factors that are design challenges for complex, real-world mechanical systems, such as wind turbines and electric vehicles. Given a real-world failure of a bridge or wind turbine, the usage conditions often include corrosion and fatigue as well as sudden shifting loads, resulting in failure. In many engineering classes, the students are asked to compute the stress in a structural member or to compute a factor of safety. Students might even be given examples of how environmental conditions and loading variations can contribute to corrosion and fatigue crack growth. However, it can be unfamiliar to them to be given an example of real-world failure and be asked to consider these confounding effects to determine which factors are likely contributors to failure. For example, the students are given the following scenario: there is a bridge in Charleston, SC on which a load-bearing member has failed. The bridge is a pre-cast concrete box girder bridge with the load being supported by post-tensioning cables. While the design life is 50 years, the cables have failed after less than 30 years. The bridge deck is 155 feet above the river below and carries approximately 75,000 vehicles per day. The students are asked to ask for further information (i.e. What were the cables made from? The cables were made of 19-strand steel cables encased in concrete grout). They then must state their assumptions and all the possible sources of damage before detailing the degradation mechanisms and making estimates on the progression of damage that led to failure.

EML Example 5: Mechanical Engineering System Design

Mechanical Engineering System Design is a required course for Mechanical Engineering majors at The Citadel. This course is taken in preparation for the senior year capstone design project. Components of this course include approaches to design, teamwork, project definition, project planning, understanding the customer, product specifications, concept generation, and presentation skills. Usually, class time is split between instructor-led teaching of concepts, in-class individual and small group exercises, and a semester-long team design project.

To increase connections to the needs of a customer and to focus creativity and design choices on creating value-added products, open-ended in-class activities are conducted throughout the semester. Students are presented with hypothetical situations with constrained design choices, unique customer requirements, and a limited supply list. These are generally presented as MacGyver-like challenges. Student teams create solutions to the challenge and then communicate the motivation for their design choices and the value of their solution through a brief but persuasive presentation to the class.

Conclusions and Research Next Steps

This paper describes the implementation of several EML activities in multiple engineering and engineering-related courses. Preparing the students for engineering evaluations that complement real-world applications is an important outcome that can be achieved through the methods of instructions discussed in this paper. It is important to note that although these EML activities were designed for the specific stated courses, they could also be successfully used for other courses with minimal alteration.

As this research continues, quantitative and qualitative data will be collected from all three courses in the form of graded assessments, evaluation of ABET outcomes, and student surveys. It is anticipated that the analysis of the data collected would give meaningful insight into the effectiveness of the methods used in these courses.

References

[1] P. F. Drucker, *Innovation and entrepreneurship: practice and principles*. New York: Harper & Row, 1985.

[2] A. Barucic and B. Umihanic, Entrepreneurship education as a factor of entrepreneurial opportunity recognition for starting a new business. *Management*, 21(2), pp. 27–44, 2016

[3] F. Almahry, A. Sarea, A. Hamdan, and M. Al Mubarak, “The Impact of Entrepreneurship Education on Entrepreneurs’ Skills,” *Entrepreneurial Innovation and Economic Development in Dubai and Comparisons to Its Sister Cities*, pp. 183–197, 2020

[4] A Thomas and S. Mueller, “A Case for Comparative Entrepreneurship: Assessing the Relevance of Culture,” *Journal of International Business Studies*, vol. 31, no. 2, pp. 287–301, 2000 http://www.jstor.org/stable/155638

[5] D. Rae and D. Melton, “Developing an entrepreneurial mindset in US engineering education: an international view of the KEEN project,” *Journal of Engineering Entrepreneurship*, vol. 7, pp. 1-6, Feb. 2017

[6] R. Aadtiyasinh, “Direct Assessment of Entrepreneurial Minded Learning Through Integrated E-Learning Modules“ Master's Theses. 152. (2019) https://digitalcommons.newhaven.edu/masterstheses/15

[7] R. Harichandran, N. Erdil, M. Carnasciali, J. Nocito-Gobel, C. Li, “Developing an Entrepreneurial Mindset in Engineering Students Using Integrated E-Learning Modules,” *Advances in Engineering Education*, ASEE publication, vol. 7, no. 1, pp. 1-6, Fall 2018

[8] J. DeWaters and B. Kotla, “Growing the Entrepreneurial Mindset in First Year Engineering Students Using Sociotechnical Design Challenges,” *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 7, pp. 24–49, Oct. 2023 http://dx.doi.org/10.3991/ijep.v13i7.41667

[9] J. Gorlewicz and S. Jayaram, “Instilling Curiosity, Connections, and Creating Value in Entrepreneurial Minded Engineering: Concepts for a Course Sequence in Dynamics and Controls,” *Entrepreneurship Education and Pedagogy*, vol. 3, no. 1, pp. 60–85, Nov. 2019 https://doi.org/10.1177/2515127419879469

[10] L. B. Bosman and M. Phillips, “Integrating the Entrepreneurial Mindset Into the Engineering Classroom,” *IEEE Transactions on Education*, pp. 1–6, 2021 https://doi.org/10.1109/te.2021.3101360