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Integrating the Entrepreneurial Mindset into the Engineering Classroom

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Abstract –

CONTRIBUTION: This paper highlights one approach to fostering the entrepreneurial mindset in the engineering classroom.

BACKGROUND: Entrepreneurship and innovation are currently trending topics in engineering education and will continue developing for the foreseeable future.

INTENDED OUTCOMES: The guiding research question is: How can an entrepreneurial mindset focused learning experience improve student self-regulation, seeing value, and lifelong learning through metacognitive reflections?

APPLICATION DESIGN: The study is implemented within a five-week module focused on developing the entrepreneurial mindset as part of a required course on supply chain management technology. The supporting pedagogical interventions include authentic learning, information literacy, a mix of low stakes and high stakes assessment, and parallel scaffold and collaborative learning. The module is assessed through a metacognitive reflection centered around self-regulated learning, seeing value, and lifelong learning.

FINDINGS: First, the metacognitive reflections showed ~50% of participants would approach their work differently (e.g., make changes to management and scheduling, using credible sources, obtaining writing assistance through the university writing lab). Second, participants were able to articulate soft skill development and/or subject matter expertise as benefits as it relates to entering the workforce. Third, participants were able to express opportunities for extending their knowledge in the future.

Index Terms **– undergraduate, entrepreneurship, metacognition, reflections, information literacy**

I. INTRODUCTION

The increased use of technology in industry, as a strategic value-added approach, has resulted in greater opportunities to connect the theoretical classroom to real-world examples. In particular, this growth has laid the foundation for improving lifelong learning through creating educational environments fostering innovation and entrepreneurship. This paper contributes to the field of engineering education by highlighting one approach to integrating the entrepreneurial mindset into an engineering course, supply chain management technology, to improve not only lifelong learning but also seeing value and self-regulated learning. Specifically, the study is implemented within a five-week module with a focus on developing the entrepreneurial mindset in a course required of all industrial engineering technology majors. The main assessment for this module is a metacognitive assignment. The guiding research question is as follows: *How can an entrepreneurial mindset focused learning experience improve student self-regulation, seeing value, and lifelong learning through metacognitive reflections?*

II. LITERATURE REVIEW

The goal of this study was to assess how integrating the entrepreneurial mindset into an undergraduate industrial engineering technology course on supply chain management technology can improve metacognitive abilities including self-regulation, seeing value, and lifelong learning. This section provides a brief overview of the entrepreneurial mindset, metacognitive reflections, and general best teaching practices which were intentionally incorporated into the study design.

A. Entrepreneurial Mindset

There are many definitions and interpretations of the phrase “entrepreneurial mindset” in the literature, which creates challenges for curriculum integration and assessment [1]. The authors of this paper use Bosman and Fernhaber’s definition: “inclination to discover, evaluate, and exploit opportunities” [2]. In addition, this teaching invention is in alignment with Bosman and Fernhaber’s four intentions for teaching the entrepreneurial mindset to engineers [2]:

(1) Intention 1: The learning activity should provide an experience to discover, evaluate, and/or exploit opportunities. Opportunities that create the most value should be aimed at customer desirability, technology feasibility, and business viability.
(2) Intention 2: The learning activity should provide an experience to develop professional skills (collaboration and communication).

(3) Intention 3: The learning activity should provide an experience for continued practice, reflection and feedback.
(4) Intention 4: The learning activity should be aligned with and reinforce the learning goals, learning objectives, and learning assessment.

B. Metacognitive Reflections

Metacognition in learning focuses on students' abilities to understand, monitor, and regulate their own knowledge [3]. Metacognition has been tied to entrepreneurship [4] and shown to improve student learning [5] in engineering education.

C. Best Teaching Practices

The entrepreneurial-minded learning module applies the following pedagogical approaches: (1) authentic learning, (2) information literacy, (3) repetitive mix of low stakes and high stakes assessment, and (4) parallel scaffold and collaborative learning. Each of these is further explored in this section.

Authentic learning strives to align higher education teaching and learning environments with real-world approaches to learning [6]. Multiple researchers [7], [8] have integrated authentic learning and entrepreneurship into first year engineering education courses.

Information literacy encompasses the knowledge, skills and abilities needed to find, access, evaluate, use, manage, share and create information [9], which are vital for academic and lifelong success. ABET's Engineering Accreditation Commission (EAC) recognizes the need for information literacy in their accreditation criteria, most explicitly in Criterion 3, Student Outcome 7, "an ability to acquire and apply new knowledge as needed, using appropriate learning strategies" [10]. Librarians and instructors partner to integrate information literacy into engineering curricula to support student entrepreneurial mindset development [11].

In general, the stake value of an assessment is related to the overall impact of student performance on that assessment [12]. For example, 'low stakes' approaches (e.g., optional quizzes, in-class work) are associated with formative, in-process learning and student performance on them has little impact on course grades or future opportunities. This is in contrast to 'high stakes' approaches typically associated with summative assessments, such as midterms and final exams, that have a significant effect on student grades and next steps. Engineering courses utilize a mix of low [13] and high stakes [14] assessments.

Scaffolding involves an expert (e.g. instructor, more advanced peer) intentionally supporting novices through the learning process to be able to make achievements they would not have been able to independently, at least initially [15]. Collaborative learning requires that students work in groups to jointly accomplish a goal, and learning occurs and is furthered by the group's social interactions [16]. Parallel scaffold and collaborative learning approaches have been previously integrated into engineering education courses with success [17].

III. METHODS

A. Participants

The study was conducted at a research-intensive university in the Midwest United States. Participants included 72 sophomore-level students enrolled in a three-credit course called Supply Chain Management Technology. The course is required for students enrolled in the Industrial Engineering Technology (IET) bachelor's degree program, and also serves as an elective for non-IET majors. The course description includes topics such as supply chain design, supply chain strategy, supply chain process mapping, and supply chain decision making with the use of technology, data analysis, and performance metrics.

B. Study Design

Participants completed a five-week teaching intervention including five key learning experiences, as summarized in Fig. *1*. Focal pedagogical approaches include (1) authentic learning, (2) information literacy, (3) repetitive mix of low stakes and high stakes assessment, (4) parallel scaffold and collaborative learning, and (5) lifelong learning metacognitive reflections.

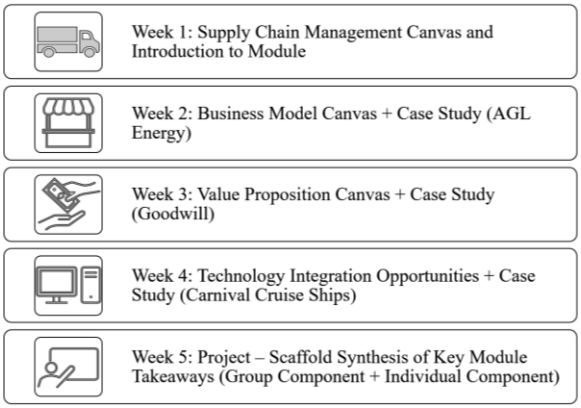

Fig. 1. Module Overview- Five Key Learning Experiences

The first four weeks of the module were repetitive in nature, following the same flow for the in-class lecture, in-class group work, and out-of-class individual homework. This allowed for a series of low stakes formative assessment opportunities before completing the module project (e.g., summative assessment). During the in-class lecture, students were introduced to the theoretical topic. Then, for the in-class group work, students worked in groups of 4-5 students to apply learning using a case study. They used Google Docs to record findings and respond to the case study questions. Finally, for the out-of-class individual homework, students used the learning management system's online discussion platform to respond to a second set of questions related to a different company. During the fifth week of the module, students were required to complete a project with two major components, including a group component and individual component. Upon completion of the module (via submission of the module project), students were directed to complete the metacognitive assignment. Details are presented in the next section.

C. Data Collection

Data collection includes student grade performance for the Module 1 (which culminated with Project 1), which includes grades for quizzes, in-class assignments, and online discussions. In addition, students completed a metacognitive reflection (including three questions) after submitting Project 1. All three reflection questions are related to metacognition, the act of thinking about one's own thought process in an attempt to build understanding and regulation over one's own thinking [18]: Q1) Post-Assessment: After completing Project 1, identify what you learned and insights you gained. In the future, how might you approach an assignment like this again? Q2) Why this Matters: Identify what type of job or career you might like to have in the future. Why are assignments (like those completed in this module) important in preparing you for entering the workforce? Why are the concepts, skills, and prior knowledge required for assignments like these important to future employers? Q3) Lifelong Learning: In the future, how might you extend your knowledge related to Project 1? Be specific in identifying a minimum of 5 diverse resources.

D. Data Analysis

This study followed a mixed methods approach. First, qualitative analysis was conducted to identify themes. Second, quantitative analysis was conducted to analyze the statistical relationship, if any, between the themes and quantity of applicants.

The qualitative analysis was done using thematic analysis. According to Braun and Clark [19], a thematic analysis is a foundational qualitative method for discovering patterns within the data. It should be conducted using a step by step process. The NVivo 12 qualitative analysis software was used to code the reflections. The researchers first become thoroughly familiar with the data to generate initial codes. Then, the researchers reviewed and analyzed the documents several times. Upon the completion of coding, themes were generated. As a final step, the researchers revised the themes and wrote the report. Due to the qualitative nature of the research, the goal of the analysis was to explore potential themes within the data. The researchers debated the strengths and weaknesses between strictly conceptualizing themes without quotes and heavily using quotes to provide readers with evidence. It was decided to merge the two philosophies and meet in the middle. Quotes were drawn from the data to allow readers to make their own judgements on credibility, accuracy, and fairness [20].

As a second step, coding of the qualitative data allowed quantification and prioritization of the themes through basic statistical analysis [21]. SPSS software was used to quantitatively analyze the coded themes with respect to module grades. Descriptive statistics and correlation analysis were applied.

IV. RESULTS AND DISCUSSION

The researchers completed qualitative and quantitative analysis for each individual reflection question (e.g., Post-Assessment, Summary of Why this Matters, and Lifelong Learning). Results are provided within this section for each individual reflection question.

A. Student Performance

This section provides a summary of the student performance for Module 1, which was a precursor to completing Project 1, which was completed within the first five weeks of the semester. The grade performance includes quizzes, in-class assignments, and online discussions. A histogram of the student grades is provided in Fig. *2*. The histogram shows about one-third of the students are on track and have kept up with the high expectations of the course requirements. Overall, the average student grade performance is 91.52 (out of 100) with a standard deviation of 8.9. These results are typical for the beginning of the semester.

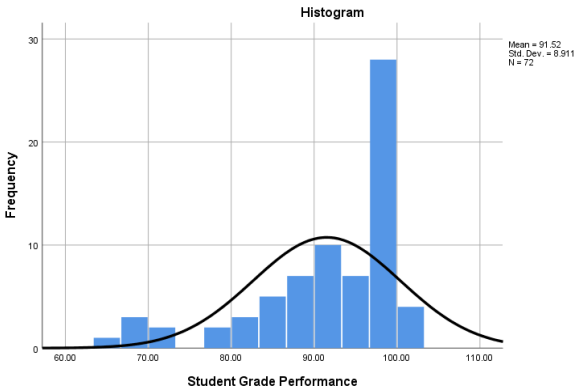

Fig. 2. Student Grade Performance for Module 1 - Histogram

B. Post-Assessment

The Post-Assessment reflection prompt was as follows: After completing Project 1, identify what you learned and insights you gained. In the future, how might you approach an assignment like this again? In general, students responded with their approach to Project 1 and concluded either (1) they would not do things differently or (2) they would do things differently. All participant responses were coded as one of these two categories for the purpose of conducting quantitative analysis. Examples of coded quotes are shown below.

Example Coded Quotes: (1) Do Things the Same Next Time

- "We worked on the assignment a week before and did it efficiently as I separated each role to each student. I think this is adequate and we would approach it the same way next time."
- "I believe that having three days to work on the assignment was substantial for us because we all have advanced documentation skills that are needed in order to complete the objectives for the project. In the future, I believe that I would approach the assignment in a similar fashion that I did during this first project."
- "I finished my assignment almost a week before it was due and sent it to the writing lab. I plan to use the same approach next time."

Example Coded Quotes: (2) Do Things Differently Next Time

- "The next time I get an assignment like this I want to build better communication with my work group. I'd like to see us meet at least once midway through the assignment to go over things and to make sure everyone is progressing as they should be."
- "In the future, I may start on the project even sooner and pay more attention in class instead of having to do so much researching at the end."
- "I started working on this assignment a few days after it was assigned. I worked on it sporadically at first, but worked very disciplined during the second week. In the future, I will make a project timeline to meet deliverables."

The quantitative summary for the Post-Assessment reflection prompt is shown in TABLE 1 and TABLE 2. The TABLE 1 report provides the average grade performance for students coded as a (1) do things the same versus (2) do things differently. A total of 32 students were coded as (1) and this group's average grade performance was 91.0 (standard deviation of 9.8); a total of 40 students were coded as (2) and this group's average grade performance was 91.9 (standard deviation of 8.2). The TABLE 2 ANOVA table provides an analysis of variance to test for statistically significant differences between the two Post-Assessment groups (1 versus 2). A p-value of 0.690 implies there are no statistically significant differences between the two groups. However, because the results from TABLE 1 show more students identified what they would do differently next time (n=40 vs n=32) and the mean grade for (2) do things differently was higher than for (1) do things the same, the researchers are optimistic about the findings.

TABLE 1. Coding Analysis: Post-Assessment & Student Grade Performance

Post-Assessment	Mean	N	Std. Deviation
(1) Do Things the Same	91.0	32	9.8
(2) Do Things Differently	91.9	40	8.2
Total	91.5	72	8.9

TABLE 2. ANOVA: Post-Assessment & Student Grade Performance

		Sum of Squares	df	Mean Square	F	Sig.
Student Grade Performance * Post-Assessment	Between Groups (Combined)	12.875	1	12.875	.160	.690
	Within Groups	5624.556	70	80.351		
	Total	5637.431	71			

C. Why This Matters

The Why This Matters reflection prompt was as follows: Identify what type of job or career you might like to have in the future. Why are assignments (like those completed in this module) important in preparing you for entering the workforce? Why are the concepts, skills, and prior knowledge required for assignments like these important to future employers? In general, students responded by highlighting the

Project 1 benefits as it connects to the real-world in one of three ways: (1) soft skill development (e.g., collaboration, research skills, technical writing, etc…), (2) subject matter expertise development (e.g., business and entrepreneurship skill applications), or (3) soft skill AND subject matter expertise development (e.g., both). All participant responses were coded as one of these three categories for the purpose of conducting quantitative analysis. Examples of coded quotes are shown below.

Example Coded Quotes: (1) Soft skill (SS) Development

- "As mentioned before, these kinds of projects prepare me for my career field by improving my research and reading skills. These projects help me learn overall, and will enhance my ability to critically think and analyze information and thinking outside of the box."
- "Project 1 is important for any job because it makes you work and research as a group. These projects are important in preparing you for the workforce because it makes you interact with others to meet a deadline."
- "These assignments are important because it teaches you to apply what you have learned, how to work in a group, how to compile research papers, and much more. These skills are important to employers because they show you are able to perform assigned jobs and apply learned methods to real life situations."

Example Coded Quotes: (2) Subject Matter Expertise (SME) Development

- "I might like to have a Supply Chain based management position in the future. This assignment helped me realize the importance of each canvas factor for every business. These assignments get me ready to write reports to people on what we need to improve. These skills are important for understanding how businesses flow."
- "My intended career would be an international supply chain manager. Project 1 helps me to dig into a certain company's supply chain networks and overall logistics strategy more deeply. I can understand how the company operates and the reason why it's successful in the market really helps me to develop the skills and learn the concepts that enhance me to best fit the position I wanted in the company."
- "I plan to have a job which is in manufacturing consumer goods. I will be in an engineering role so it will be good to have the background that I will know in supply chain continuous improvement."

Example Coded Quotes: (3) SS + SME Development

- "This project helps me prepare for my future by making sure that I understand the structure of my business, the supply chain and knowing what my customers want. Some skills that will be important for future employees include good communication, time management, leadership and problem-solving skills."
- "A job that I wish to have in the future is a project manager. Project 1 helped me understand the supply chain of a big company. These assignments are important for preparation of the work force because they do a great job of requiring a student to put their best foot forward towards a project that needs to be completed, much like the real world. Future employers value these transferable skills because they can be used in almost any industry."
- "It will be helpful to understand technology that businesses could use that could improve customer experiences and having prior knowledge of these processes will help tremendously. These assignments I feel are important as they mimic projects that we may complete for internships and projects that our employers will ask of us when we enter the labor force. The skills we used in this assignment are common everyday skills such as communication that employees are struggling to find."

The quantitative summary for the Why This Matters reflection prompt is shown in TABLE 3 and TABLE 4. The TABLE 3 report provides average grade performance for students coded as (1) soft skill (SS) development, (2) subject matter expertise (SME) development, and (3) SS + SME development. A total of 18 students were coded as (1) and this group's average grade performance was 90.2 (standard deviation of 10.8); a total of 40 students were coded as (2) and this group's average grade performance was 91.4 (standard deviation of 8.9); a total of 14 students were coded as (3) and this group's average grade performance was 93.7 (standard deviation of 5.9). The TABLE 4 ANOVA results provide an analysis of variance to test for statistically significant differences between the three Why This Matters groups (1 versus 2 versus 3). A p-value of 0.534 implies there are no statistically significant differences between the three groups. However, because the results from TABLE 3 show an increase, the researchers are optimistic about the findings.

TABLE 3. Coding Analysis: Why This Matters & Student Grade Performance

Why This Matters	Mean	N	Std. Deviation
(1) Soft skill (SS) development	90.2	18	10.8
(2) Subject matter expertise (SME) development	91.4	40	8.9
(3) SS + SME development	93.7	14	5.9
Total	91.5	72	8.9

TABLE 4. ANOVA: Why This Matters & Student Grade Performance

		Sum of Squares	df	Mean Square	F	Sig.
Student Grade Performance * Why This Matters	Between Groups (Combined)	101.520	2	50.760	.633	.534
	Within Groups	5535.911	69	80.231		
	Total	5637.431	71			

D. Lifelong Learning

The Lifelong Learning reflection prompt was as follows: In the future, how might you extend your knowledge related to Project 1? Be specific in identifying a minimum of 5 diverse resources. In general, students responded with resources across four different categories: (1) popular media - documentaries, magazines, books, movies, YouTube, company websites; (2) events - conferences, workshops, seminars, on-the-job training; (3) people - networking, industry professionals, specific people, peers, government agencies; and (4) academic resources - journal articles, case studies, additional coursework, textbooks, professors, librarians. All participant responses were coded to one of these four categories for the purpose of conducting quantitative analysis. Examples of coded quotes are shown below.

Example Coded Quotes: (1) Popular Media

- "I might extend it by focusing on reading a few supply chain-related movies, subscribing to monthly business magazines, and watching fun documentaries related to this area of business."
- "In the future I would extend my knowledge mostly through the internet. The internet is my preferred choice because there are dozens of articles available that will show an unbiased opinion if you fact check one article against the other. I could also expand my knowledge through documentaries and magazines."
- "In the future, the way that I will extend my knowledge related to Project 1 is to make myself acquainted with major executives in any company that I come across. Another way is to keep up on any major news about the company that I could find in magazines or newspapers. I can also learn about the importance of a company by watching any documentary about it."

Example Coded Quotes: (2) Events

- "I will extend my knowledge in any business internship or experience by better understanding how to evaluate supply chains. I will extend my knowledge of working with others when I enter the workplace after graduation to understand how to optimize team efficiency when all teammates have different timelines or leadership styles."
- "Ways that I can extend my knowledge from project 1 include attending a seminar or conference about developing a business."
- "I plan to expand my knowledge in the aspects of project 1 by using the supply chain knowledge and processes that I developed and implement them into my daily work life."

Example Coded Quotes: (3) People

- "In the future, I plan to extend my knowledge by networking with many companies and learning what companies they partner with. Along with that, I plan to talk with many other people and seeing how manufacturing is being utilized in construction. People make mistakes and it's important to try and learn from them."
- "I would ask entrepreneurs what they are doing and get some other ideas for running a business."
- "I can also talk to people - specifically professionals - to learn more about supply chain processes."

Example Coded Quotes: (4) Academic Resources

- "I would extend my research knowledge by using more of [University X] Libraries. I only used the web at home. Using books and [University X] Libraries would have given me more information to complete the project."
- "I could research academic articles on supply chain management, ask professors for their knowledge on the subject, and read textbooks dedicated to it."
- "Textbooks are a good reference, more recent text material will be more precise. Librarians sometimes offer the best options for my research, they are skillful and give me advice on how to obtain certain skills. Other education institutions, in my case online learning through educational websites allows me to gain knowledge in a short amount of time while maintaining my status at [University X]."

The quantitative summary for the Lifelong Learning reflection prompt is shown in TABLE 5. The table quantifies the student count (e.g., how many students listed at least one resource related to the theme area), sum (e.g., total resources listed per each theme), and average per student (e.g., mean quantity of resources per all 72 student participants). Popular media and academic resources were the most common resources listed; this isn't surprising given an undergraduate student's circle of influence at this point in their educational journey.

TABLE 5. Lifelong Learning Reflection Prompt - Quantitative Coding

Theme	Student Count	Sum	Average
(1) Popular media	58	113	1.9
(2) Events	28	31	1.1
(3) People	37	42	1.1
(4) Academic resources	56	93	1.7

V. CONCLUSION

A. Summary of Practical Implications

This study responded to the following research question: *How can an entrepreneurial mindset focused learning experience improve student self-regulation, seeing value, and lifelong learning through metacognitive reflections?*

Three critical practical implications are summarized here. First, with respect to the Post-Assessment reflection responses, about half of the participants would approach their work differently and about half of the participants would approach their work in the same way. From an educator perspective, the hope was that the vast majority of students would recognize the opportunity for improvement (because there is always opportunity for improvement). To assist students in better assessing and regulating their thinking, future modules will have a short discussion outlining student success factors including time management and scheduling, using credible sources, obtaining writing assistance through the university writing lab, and teamwork skills.

Second, with respect to the Why This Matters reflection responses, 25% of student responses centered around soft skill development only, 55% centered around subject matter expertise only, and 20% centered around development of both soft skills and subject matter expertise. From an educator perspective, the hope was that the vast majority of students would recognize both the soft skill and subject matter expertise connections to the real-world working environment. To assist students in better connecting the course concepts to the real-world, future courses will have students complete a pre-course survey where students identify in advance their desired job and industry. This will aid in finding and using examples relevant to the student interest areas.

Third, with respect to the Lifelong Learning reflection responses, popular media and academic resources were the most common resources listed. It's important to note this isn't surprising given an undergraduate student's circle of influence at this point in their educational journey. To assist students in developing awareness of practical and easy to access resources, future courses will include a short overview from an academic librarian, covering a gamut of informal and formal information resources (including events and people), in addition to popular media and academic resources [22].

B. Limitations and Future Research

This manuscript has a few limitations and recommendations for future research which are mentioned here. Most notably, this study only evaluated participants from one engineering course (n = 72) at one educational institution. Future studies should consider increasing the generalizability through replication in other courses and at other institutions; as the sample size increases, so does the potential for statistical significance. Also, this study used the qualitative assessment of reflection (which was coded quantitively). Future studies would benefit from a mixed methods approach using alternative assessments. In addition, the study was conducted using a five-week module. Future studies should consider a longitudinal approach to better understand the long-term implications. Although the focus was on designing and evaluating an entrepreneurial minded module for an industrial engineering course, the researchers are confident that similar modules would likely be successful in a variety of courses both inside and outside of engineering.

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