EML Projects and Performance of Students

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Abstract

Entrepreneurial-minded learning (EML) projects are commonly used in the curriculum to increase the entrepreneurial characteristics of students on curiosity, connection, and value creation. They also improve students' understanding, teamwork, and problem-solving skills. The current paper investigates the performance of students in two different classes: structural analysis and steel design. The project in the steel design course focused on the design of a balcony. The project in the structural analysis class was on a balsa wood bridge truss competition. The performance of students in each class was compared to another group who was not exposed to any project. The results of an anonymous survey revealed that EML projects effectively strengthen both the technical and entrepreneurial skills of students.

Keywords

EML, Civil Engineering

Introduction

Problem-based learning (PBL) and project-based learning (PjBL) have been widely used in engineering education. In PBL, which is a student-centered approach, an open-ended, ill-structured, and real-world problem is assigned to students. The students identify the learning needs and find a viable solution while the instructors act as facilitators in the learning process[1,2]. PjBL is similar to PBL but involves an assignment with one or more tasks that leads to a final product such as a design, a model, a device, or a computer simulation that can be used in the real world. Work goes on for a considerable amount of time and a written and/or oral report summarizes the procedure and presents the outcome. PjBL covers a broader scope and may include several problems. The focus of PjBL is applying or integrating previous knowledge while the emphasis of PBL is the acquisition of new knowledge[2,3]. Several studies have shown the effectiveness and benefits of PjBL such as motivating students, taking ownership, learning more material, retaining the information longer, and promoting critical and proactive learning[4,5,6].

Currently, different institutions are utilizing entrepreneurial-mindset learning (EML). EML enables students to complete an assignment in a fashion that creates value. Engineers equipped with an entrepreneurial mindset (EM) can make personal, economic, and societal value through their work in the workplace. They understand the bigger picture, recognize opportunities, evaluate markets, and learn from mistakes to create values for themselves and others[7,8,9]. EML course modulus can be created by incorporating behavioral or complementary skills into student-centered pedagogy. Examples of such skills are demonstrating constant curiosity, exploring a contrarian view of accepted solutions, assessing and managing risk, evaluating economic drivers, examining societal and individual needs, understanding the motivations and perspectives of others, and conveying engineering solutions in economic terms. Particularly, EML builds upon active pedagogies such as PBL by integrating curiosity, identifying an opportunity, and creating value[10]. Gerhart and Melton applied EML within the context of PBL and presented a framework to demonstrate how to incorporate stakeholders, opportunity identification, and value creation in a fluid mechanics course[10]. EML is being promoted by Kern Entrepreneurship Education Network (KEEN) and implemented at many institutions. The key elements of the entrepreneurial framework are defined by 3C's:

1. Curiosity. Students are encouraged to demonstrate constant curiosity about our world and explore different solutions, which empowers them to investigate the rapidly changing world and motivates them to become life-long learners.

2. Connections. Students integrate information from many sources to gain insight, assess, and reveal innovative solutions.

3. Creating value. Students get to create value for themselves and others by identifying unexpected opportunities and learning from failure to meet the needs and demands of stakeholders in a changing world[10, 11, 12].

The main objective of the current paper was to investigate whether EML projects could improve the performance of students and their understanding of the course content. The projects were implemented in a structural analysis course and a steel design course. A brief description of the projects, assessment criteria, and observations of the instructor are presented in the paper.

Description of Structural Analysis Project

The project was given as a month-long project in the form of a competition. The project involved forming a team, identifying alternative bridge trusses, analyzing them using the commercial software, selecting the superior truss, and constructing it using balsa wood. To increase the motivation of students, the competition was defined as a task from the Ohio Department of Transportation (ODOT): ODOT has funded a timber truss bridge to be constructed over the Maumee River in 2025. During the preliminary design stage, Ohio Northern University is to investigate different possible prototype truss bridge systems to make a recommendation on the appropriate truss type based on cost, constructability, aesthetics, and strength. The design constraints on the overall dimension of the model, length and cross-sectional dimensions of balsa wood sticks, and connections were defined.

Description of Steel Design Project

The project used in the steel design course was a two-week-long project. The students in the course had the opportunity to visit the new engineering steel building, which was under construction at the time, to get more familiar with the common elements of a steel building. Based on the author's experience, beam design is one of the most challenging topics of the course for students to grasp. Therefore, it was felt that assigning a simple real-world project on the new engineering building would be beneficial. The following hook statement was utilized to increase the motivation of students: Prof. Yoder, the dean of the college of engineering at Ohio Northern University, has asked the architect to add a balcony to the second floor of the new engineering building. Due to time and financial constraints, the dean and architect have decided to hire a group of internal experts on steel design to evaluate and identify the most cost-effective and constructible framing plan. The structural drawings of the buildings and the requirements on the location, the width of the balcony, and shapes and yield strength of the beams were shared with students. The students were expected to calculate the loading per ASCE7.

Deliverables

1- Team Charter: The students were asked to organize into groups of two or three for the steel design course (22 students) and four to five for the structural analysis course (26 students). Each group was to represent a fictitious startup company to bring its consulting service to the market. The students had to select a name for their company and list the set of rules and expectations for the team. The purpose of the rules was effective teamwork and communication among group members as well as a reminder of how to avoid the common pitfalls. The team charter contributed to 5% of the project.

Stimulating the curiosity of students is one of the most important goals of any educator. If successful, the student will be motivated to continue to learn and explore the course material outside of the classroom and find connections with other information or applications. To stimulate the curiosity of students, the Question Formulation Technique (QFT) was utilized. The QFT Process starts with a prompt (called a Question Focus or QFocus for short) that promotes lots of questions (divergent thinking). Then, improve and prioritize the questions are improved and prioritized (convergent thinking). The QFT enables students to generate technical questions, which makes the process of problem-solving easier and helps them to take ownership of materials and become self-directed learners. A student needs to be aware of what they do not know and be able to articulate it in the form of a question[13,14]. Thus, each company was asked to submit a list of questions. The instructor served as the client for both projects.

2- Written Proposal: The proposal must include problem description, constraints, alternative solutions that meet the constraints outlined in the problem statement, selection of superior design through Need-Approach-Benefits-Competition (NABC) approach, and conclusions. The written proposal contributed to 70% of the project and was evaluated through rubrics.

Exploring multiple solutions further stimulates the curiosity of the students. The alternative designs were to be considered as competing solutions to the problem. The selection of the final design should be based on the NABC approach. NABC framework developed by Stanford Research International to teach engineering students how to articulate value propositions. The framework highlights the market needs, solution approach, solution benefits, and competition dimensions of any created solution. The objective is to create a solution that delivers the customer's value and need and is greater than the competition's. The NABC framework starts with a clear articulation of the underlying Need the idea addresses. What are the important customer and stakeholder needs?[15, 16]. Then, the Approach to meet the need is described. What is the unique approach and compelling solution for addressing the specific client need? This should be drawn or simulated to help convey the vision required. As the approach develops through iterations, it becomes a full proposal or business plan, which can include cost, staffing, deliverables, a timetable, etc. [15, 16]. The Benefits of the approach to the specific stakeholders must be highlighted and should demonstrate a favorable benefit to cost ratio. Each approach to a client's need results in unique client benefits, such as low cost, high performance, or quick response. Success requires that the benefits be quantitative and substantially better - not just different[15, 16]. Finally, the Competition should be analyzed to show how the idea improves upon the competing solutions[15, 16]. Everyone has alternatives. We must be able to tell our client why our solution represents the best value. To do this, we must clearly understand our competition and their value proposition and our client's alternatives[15]. Since students may not be familiar with the method, it is beneficial to show a video introducing the framework[17] and share an example of applying the method. A good example might be video-on-demand, which was pitched to a cable broadcast company, circa 2006. The Need was a $5 billion business opportunity for movie rentals, which the company did not have any market share at the time. Furthermore, customers do not like picking up and returning rentals as well as late fees. The Approach was developing a system for the company to provide the customers with videos on demand using the cable. This enables people to have access to all movies by using one of the unused channels with the same price as video store rental, which means there will be no change to the system and no capital needed to be invested by the company. Benefits were a market share of 20% and receiving $5 revenue per rental. Besides, the customers were not worried about late fees and could have the same experience as VCR/DVD without the need to return. The competition was online rentals, but they do not provide the customers with spontaneous rentals, and sending videos back is not convenient[15]. In the structural analysis project, Need was given with a well-defined problem. The problem was to build a prototype bridge. The Approach was limited through the design requirements such as the length and width of the truss, material, etc. The Competition was limited by requiring students to design alternative viable solutions and using alternative solutions as the Competition. Each member of the group had to investigate a unique bridge truss. Finally, the Benefits were to be articulated through evaluation metrics considered in the design such as cost, aesthetics, strength, and ease of construction. While the aesthetics and ease of construction would be subjective, the cost and strength aspects could be quantified. Students were able to estimate the strength and cost of each bridge system via the Bridge Designer and SAP2000 software. Similarly, in the steel design project, the Need was to add a balcony to the second floor of the new engineering building. The Approach was limited through project requirements such as shape, yield strength, location, and the width of the balcony. Each member of the group had to investigate and design a unique framing plan as an alternative solution or Competition. The students had to assess the Benefits through evaluation metrics considered in the design such as cost and constructability.

3- Peer Evaluation: Team members were asked to evaluate their peers through a rubric on different skills such as working with others, attitude, time management, quality of work, contributions, and problem-solving. The students were asked to submit their peer evaluation twice, one in the middle and the other at the end of the project. The peer evaluation contributed to 10% of the project.
4- Bridge Competition/Presentation: In the structural analysis project, the students were given a week to construct their superior bridge model. The company with the highest strength to weight ratio was recognized as the winner of the competition. In the steel design project, each team had to give a 5- minute presentation on the constraints of the design, NABC value proposition including a concise review of alternative solutions, evaluation metrics used, and the superior design. The bridge construction/presentation contributed to 15% of the project grade.

Results

To evaluate the effectiveness of the projects, the students were surveyed anonymously. 22 out of 26 students in the structural analysis course and 20 out of 22 students in the steel design course submitted their responses. The survey asked students to rate each question on a scale of 1 (strongly disagree/none at all) to 5 (strongly agree/throughout most of the project). Table 1 shows the average of the results from the survey for the structural analysis project. The overall average rating was 4.3. For the entrepreneurial dimension, questions two, five, and six target creating value. Question 4 is related to curiosity and questions 1 and 3 target making connections. Questions 10 and 11 target the communications skills on the technical aspect of the project.

Table 1. Survey results for the structural analysis project

Dimension	No	Survey Question	Average Rating
Entrepreneurial	1	The real-world application motivated me to do my best work	4.3
	2	Create value for a customer or stakeholder	3.7
	3	Integrate information from many sources to gain insight	4.1
	4	Apply critical thinking to ambiguous problems	4.4
	5	Examine a customer’s needs	4.4
	6	Convey engineering solutions in economic terms	4.4
Technical	7	Identifying the components of a bridge truss	4.5
	8	Analyzing truss systems by SAP2000	4.4
	9	Drawing the influence line for a truss member	3.9
	10	Reporting the solution to a customer	4.4
	11	Work with your team	4.9

Figure 1 displays the relative frequency for each survey question. For question 1, more than 80% agreed that the real-world application of the project motivated them while 14% were neutral and 5% disagreed. The project goal of creating value for a customer was successful as over half of the students (64%) agreed, 23% were neutral, and 14% disagreed. 41% of students strongly agreed and 36% agreed that they could integrate information from multiple sources to gain insight. 18% were neutral and 5% disagreed. Survey question 4 asked whether students applied critical thinking throughout the project. As shown in Figure 1, more than 90% agreed and 9% were neutral. Students overwhelmingly (81%) reported integrating information from many sources while 19% were neutral and none disagreed. According to the results for survey question 6, over 80% of students agreed that they were able to convey engineering solutions in economic terms throughout the project. 14% were neutral. Students strongly (52% strongly agreed and 43% agreed) agreed that they improved their skills on identifying the components of a bridge truss (question 7) while 5% were neutral. 90% of students found that the project improved their skills in analyzing truss systems by SAP2000 (question 8) and 10% were neutral. The project successfully improved students' skills on drawing the influence line for a truss member (question 9) as 24% strongly agreed and 52% agreed. 10% were neutral and 14% disagreed. Questions 10 and 11 evaluated communications skills. Over 90% agreed that the project successfully enhanced their skills in writing effective reports and reporting the solution to the customer while 10% were neutral and 5% disagreed. Similarly, 91% strongly and 9% agreed that the project helped them to improve their skill in working with their peers.

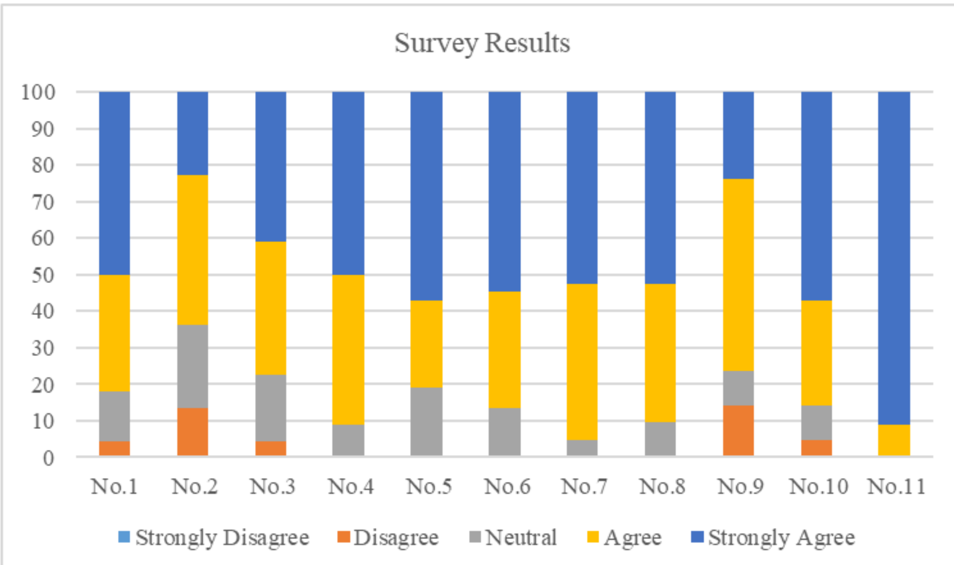

Figure 1. Relative frequency for each survey question for the structural analysis project

The average of the results from the survey for the steel design project is shown in Table 2. The overall average rating was 4.4. Figure 2 displays the relative frequency for each survey question. For question 1, more than 90% agreed that the real-world application of the project motivated them while 5% were neutral. The project goal of creating value for a customer was successful as over half of the students (55%) agreed, 40% were neutral, and only 5% disagreed. 40% of students strongly agreed and 15% agreed that they could integrate information from multiple sources to gain insight. 25% were neutral. 15% disagreed and 5% strongly disagreed. Survey question 4 asked whether students applied critical thinking throughout the project. As seen in Figure 2, 30% strongly agreed, 45% agreed, 15% were neutral, and 10% disagreed. Students overwhelmingly (90%) reported integrating information from many sources while 5% were neutral and only 5% disagreed. According to the results for survey question 6, over 80% of students agreed that they were able to convey engineering solutions in economic terms throughout the project. One-fifth were neutral. Students strongly (65% strongly agreed and 35% agreed) agreed that they improved their skills on identifying the components of a typical balcony (question 7) as well as determining the beam sizes for various framing plans (question 9). The project successfully improved students' skills in determining loads (question 8) as 50% strongly agreed and 50% agreed. Based on the results for survey question 10, 65% strongly agreed and 30% agreed that the project improved their skills in choosing an actual framing plan that meets the design requirements. 5% were neutral and none disagreed.

Table 2. Survey results for the steel design project

Dimension	No	Survey Question	Average Rating
Entrepreneurial	1	The real-world application motivated me to do my best work	4.6
	2	Create value for a customer or stakeholder	3.8
	3	Integrate information from many sources to gain insight	3.7
	4	Apply critical thinking to ambiguous problems	4.0
	5	Examine a customer's needs	4.4
	6	Convey engineering solutions in economic terms	4.3
Technical	7	Identify the components of a typical balcony	4.7
	8	Determine loadings	4.5
	9	Determine the beam sizes for various framing plans	4.7
	10	Choose an actual framing plan that meets the design requirements	4.6
	11	Report the solution to a customer	4.3
	12	Work with your team	4.6

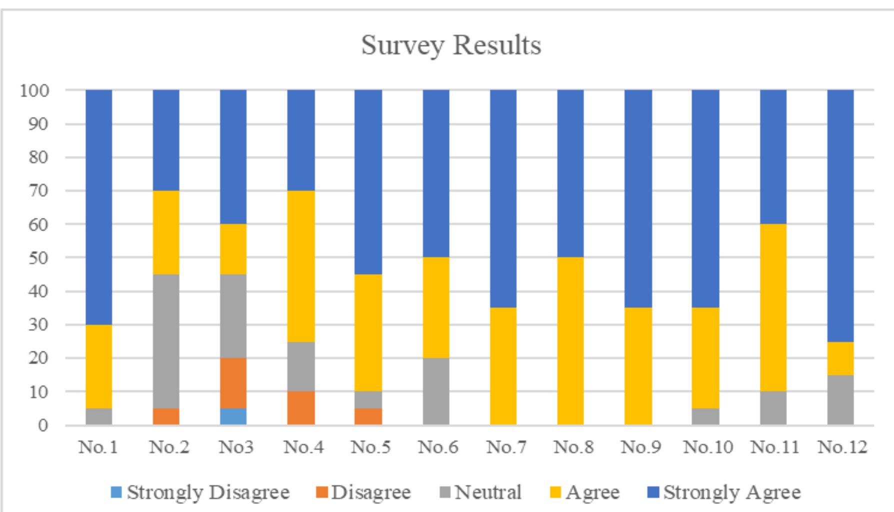

Figure 2. Relative frequency for each survey question for the steel design project

As seen in the tables and figures, the projects were successful in targeting both the technical and entrepreneurial skills of students and were well received by them. Students overwhelmingly agreed that the project motivated them and gave them a better understanding of addressing customer's needs and using critical thinking skills to find solutions. Students found that they improved a myriad of skills including analyzing truss systems by SAP2000, drawing influence lines, creating framing plans, load calculation, beam design, report writing, and overall communication, not only with each other but with their client.

To see whether the projects were helpful for students to understand the importance of influence line and how to apply the concept in the design of bridges in the structural analysis course or beam design in the steel design course, the results of these groups of students were compared to students from the previous year who were not exposed to any project. This was done by giving a similar influence line problem for the structural analysis course and beam design for the steel design course on the final exam. Figures 3 and 4 display the comparison of the groups for the structural analysis and steel design course, respectively. Both groups had the same instructor, curriculum, and approximately similar average scores on midterm exams. Blue is corresponding to the scoring of 90% or better, orange 75% to 90%, grey 60% to 75%, and yellow below 60% of the total points.

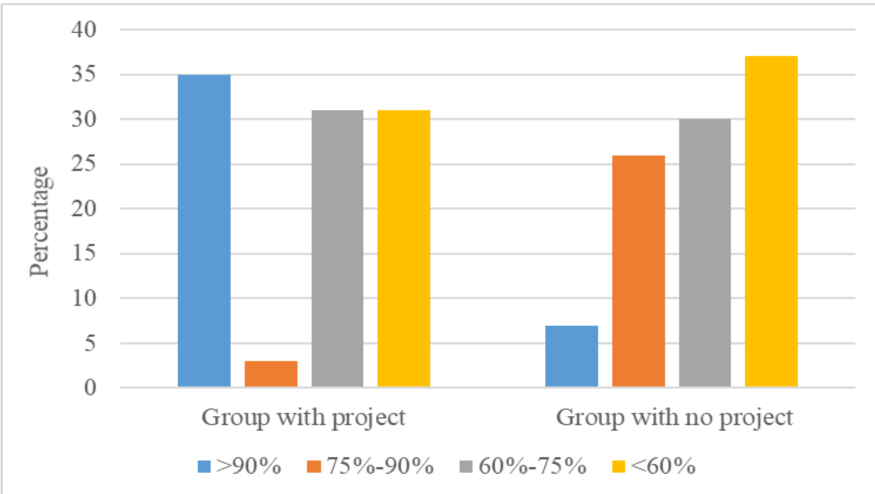

Figure 3. Comparison of the two groups of students for the structural analysis course

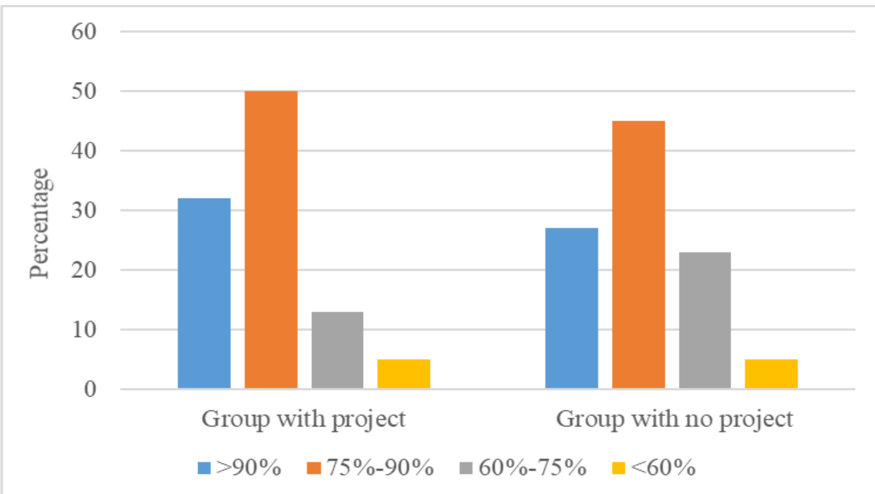

Figure 4. Comparison of the two groups of students for the steel design course

As seen in Figure 3, 35% of the group with the project scored 90% or more while 7% of the other group scored the same. For the group with the project, 3% of the students scored 75% to 90%. The percentage for the other group was 26%. This shows that the project was most beneficial to the students scoring at least 75%. It seems that these students were able to take ownership of the project and understand the concept very well to improve their score. 30% of the students with no project scored 60% to 75% while 31% of the other group scored within the same range. For below 60%, the percentage for the group with the project and the other group were 31% and 37%, respectively. This shows that these students were able to learn more from their peers and improve their performance. Also, the average score on this problem and overall for the group with the project was 16% and 5% higher, respectively.

Per Figure 4, 32% of the group with the project scored 90% or more while 27% of the other group scored the same. For the group with the project, 50% of the students scored 75% to 90%. The percentage for the other group was 45%. As seen, a lower number of students with the project scored 75% or less. 23% of the students with no project scored 60% to 75% while 13% of the other group scored within the same range. This indicates that the project was most beneficial to the students scoring between 60% and 75%. It seems that the students were able to take ownership of the project and learn from their peers. 5% of the students of each group scored below 60%. Besides, the average score on this problem and overall for the group with the project was 3% and 10% higher, respectively.

Further Observations

Based on the results of the open-ended feedback portion of the survey, students in the structural analysis course found the project competition as a fun and creative way to learn about trusses and were excited about the competition to test their design. They also liked the hands-on experience and being able to learn how to analyze the trusses in Bridge Designer and SAP2000 and apply what had learned to an actual design. The students enjoyed the real-world application and appreciated the opportunity for creativity. The students in the steel design course enjoyed the real-world aspect of the project and liked using the actual drawings of the building. Furthermore, they liked the open-ended and simple, yet challenging nature of the project. The fact that students had to look back at old materials from other courses and apply them to newly learned materials was also appreciated by them.

Conclusions

Based on students' feedback and observation of the instructor, the following conclusions were made:

- Implementing projects using the framework discussed herein can expose students to EML effectively and target both their technical and entrepreneurial skills.

- EML projects improve the performance of students.

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