The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center ASEE
Portland, OR . June 23 - 26, 2024
Paper ID #41693

Using Video Creation to Develop the Entrepreneurial Mindset of Engineering Students

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Using Video Creation to Develop the Entrepreneurial Mindset of Engineering Students

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Abstract

Engineering professionals are expected to conduct various methods of communication when they enter the workforce. Video presentations are emerging as a preferred mode of communication for marketing and employment processes. However, such communication is uncommon for project-based learning (PBL) assignments in engineering education. Engineering professionals are expected to bring some level of entrepreneurial-minded learning (EML) skills to solve social or cultural problems with responses rather than solutions. Moreover, the latest industry trend shows the incorporation of video presentations to showcase and pitch entrepreneurial endeavors. However, such communication assignments are uncommon in engineering education. The purpose of this study is to showcase a pedagogical intervention within an engineering course to develop an EML-based project using video creation in mechanical engineering curricula to help facilitate student learning experience and enhance professional communication skills. Students were given EML-based PBL assignments, including three asynchronous video presentations. Students were surveyed on their experience of EML-based PBL assignments using digital video communication. The survey results show slight improvement in digital technical communication skills as the students are less confident about their technical communication. Moreover, a high number of students (over 70% of students) are confident in their technical analytical skills. They have high confidence level (over 60% of students) in their abilities related to curiosity and creating value for relevant EML outcomes. The results show that engineering students can perform certain tasks needed for an open-ended video project using an entrepreneurial mindset while they continue to have the room to build on their skills to communicate in a digital environment effectively.

1. Introduction

1.1 Problem Identification

Professionals from the engineering industry have called for the need to increase entrepreneurial-minded learning (EML) skills for engineering students since they see a lack of skills and ability to solve critical problems (social or cultural problems with responses rather than solutions, multiple stakeholders and no conclusive formulation) or the ability to communicate in a digital environment [1, 2]. Moreover, project-based learning (PBL) has been gaining more traction in engineering programs to facilitate student learning experience and professional development. Although design courses including capstone design have PBL with components of EML, entrepreneurial mindset based PBL is quite uncommon in many engineering courses that are not design courses [3]. Traditional engineering course projects involve a relatively close-ended problem where instructions and information about the project specifications are provided. This can be due to engineering instructors lack of access to curriculum that focuses on problem solving with open ended questions, and this problem is only exacerbated when considering the need to communicate the problem solution in a digital environment including video and audio format. Moreover, the current approach doesn't address other modes of communication, which is used industry and other academic fields, but rarely in engineering education. The digital mode of communication through videos can enhance EML in non-design courses to demonstrate the students' ability to develop breadth by extending into other fields.

1.2 Current Approaches to the Problem and Gaps in Current Approaches

Several works and studies have previously shown approaches to incorporating entrepreneurial-minded learning (EML) into various engineering courses to assist instructors and implement in courses for student learning. For the first approach, there is a Center for Excellence in Teaching and Learning at many universities that is a valuable resource for faculty to get assistance with developing customized curricula [4]. However, not all universities have these centers. Moreover, the staff often lacks a background in STEM at these centers [4].

The second approach involves of Kern Entrepreneurial Engineering Network (KEEN) (and Engineering Unleashed), which is a great resource for faculty to observe and learn to incorporate EML into courses and curriculum [1, 5]. However, recruitment and marketing are limited to network schools, and a limited curriculum has an EML-based PBL with a digital communication assessment. An example of the use of some of Kern Entrepreneurial Engineering Network (KEEN) goals as course outcomes can be observed for a specific system dynamics project that specifies stakeholders and customers for which the student group must formulate questions to be able to develop specifications and requirements [3]. The PBL approach in this course doesn't allow students to formulate the need and solution as the instructor still provides the specific project need of interest and does not incorporate a digital communication assessment.

The third approach is faculty using books that are available to help develop a course project that incorporates EML. However, the book options are limited in general and even more so limited for engineering educators and professionals [6].

For the fourth approach, a center for entrepreneurship can exist at many universities for students to gain EML outside of the classroom [7, 8]. However, this requires students to invest time in extracurricular activities outside the classroom. Thus, this can be an obstacle to many engineering students, including those with a rigorous coursework load and/or personal and financial obligations. Thus, it will not be a practical option for many students.

A fifth approach for students is to enroll in entrepreneurship-focused minors and advanced degrees, which now exist at several universities. However, this also requires students to spend additional time, money, and resources to enroll in such programs outside of their engineering degree of interest.

For the sixth approach, EML is making its way into traditional design courses and even introduction to engineering courses [9, 10, 11]. Although this helps students enhance their learning experience as they are likely to take the first and last engineering courses in their degree programs, there is a lack of additional experience in the rest of the engineering courses, which are mostly non-design courses. There are a handful of non-design courses, such as thermodynamics and system dynamics, that incorporate EM into their courses to enhance student engagement and learning experience at different educational levels [3, 12, 13, 14, 15]. Similarly, more such learning experiences could be explored for other non-design courses, including technical elective courses in the academic topic of control theory, to add and create value for students, including widening technical communication skills. The current approaches can expand and enhance the student learning experience to develop EML but can be improved to allow students to formulate the need and solution in a digital environment as the instructor still provides instruction through typically writing communication.

1.3 Proposed Solution

This exploratory study investigates a novel approach to an EML design project (implemented in a non-design course) using digital communication as the assessment. A completely open-ended asynchronous video-based project that the students explore to identify a need by acquiring and applying skills using EML in a topic to develop breadth in the control and automation industry, including process control.

The curiosity and creativity of students can be further demonstrated by allowing students to explore and choose a topic and system of their interest to provide stronger motivation to solve the need. The asynchronous video report for communication allows students to learn about other communication tools and techniques to convey their concepts and ideas in a different format and platform than they are used to in other courses (written reports and live oral presentations). This can allow students to connect with a potentially wider audience in a more innovative way that is not constrained to location and word count.

2. Background

2.1 PBL

Project-based learning (PBL) is an increasingly common feature in many engineering courses, including introduction to engineering courses and senior design projects across universities in the United States [16]. PBL is of significant impact practices in teaching and learning [13]. Such a learning experience can be of benefit to students by consisting of these components relevant to engineering education:

1. making clear the PBL goals for knowledge, understanding, and skills,
2. providing engaging problems at a suitable level of challenge and open-endedness to motivate students,
3. allowing for sufficient time to for students to explore and learn new topics in terms of breadth and depth,
4. motivating students by relating to real-world problems to allow for authentic learning,
5. providing mentorship, not supervising, as students choose objectives, methods, and testing and assessment process of their project,
6. enabling students to reflect on what they learned from their projects and how these projects relate to the real world through survey and open discussions,
7. having consistent follow-up through scaffolded PBL assignments, as well as providing formative feedback for improvement, and
8. making project prepared and presented for external audience to motivate student accomplishment [16].

Although PBL activities have been employed in courses to help students quickly learn new concepts as well as prepare students with skills such as leadership, team building, ethical behavior, creativity, critical thinking, and problem solving, there is still room to enhance the PBL experience through developing the innovative mindset for opportunity recognition and being resourceful [12].

2.2 Entrepreneurial minded learning in PBL

Entrepreneurial elements can be described as any innovative actionable element that, through an organized system of human relationships and the combination of resources, is directed towards the achievement of a specific objective [17]. To encompass these elements, the EML can be represented by the "three C's" conveyed through KEEN: curiosity, connections, and creating value [9]. The concept of curiosity can be elaborated to be "students will demonstrate constant curiosity about our changing world and explore a contrarian view of accepted solutions." The concept of connections includes "students will integrate information from many sources to gain insight and access and manage risk." The concept of creating value: "students will identify unexpected opportunities to create extraordinary value and persist through and learn from failure" [9].

The objective of these concepts is to promote entrepreneurial-minded pedagogy within engineering courses and programs [12]. Thus, a student, who graduates to become an engineer in the field, can be equipped with an entrepreneurially minded perspective to be able to address unmet client needs and specifications as well as consider the benefits and impact of their designs in addition to their technical details [9]. Over the last several years, many engineering educators have recognized the significance of including EML through various courses, and several have even improved courses and programs to incorporate such an approach for students to employ an entrepreneurial mindset [9]. Thus, more universities are starting to introduce entrepreneurial-minded learning (EML) or entrepreneurial elements as stand-alone courses or incorporation into courses [3].

2.3 Technical communication in EML and PBL

Communication is an important part of PBL and EML so engineers can not only develop, but also communicate their concepts and ideas effectively. As part of their EML integrated course, Dahm et al incorporated writing instruction that is contextualized such that engineering instruction is included to clarifies the importance of writing in engineering practice [18]. Students are only expected to communicate using written technical reports and real-time presentations in the classroom. There is a case to make for improving learning experience and increasing student engagement by assigning students the task of actively creating video content, through PBL [19, 20, 21, 22]. Taylor et al. suggests having value co-creation to boost student engagement with audience, which is currently lacking in engineering education including PBL [20]. Students need to connect differently and even effectively with the changing age of the audience.

An area of improvement in EML-based PBL has been in connection or technical communication to ensure the other concepts come through to an audience including other students, faculty, and clients. Technical communication is vital to properly convey the outcome and results of a project or task. The different types of technical communication typically employed in the field and the classroom include written and oral communication. Written communications can range from memorandums and emails to technical reports and manuals, while oral communications can range from unstructured discussions during meetings to formal oral presentations with slides and even to video and audio-recorded platforms such as those used in social media.

McNeil et al found from a survey that engineering graduates in the workplace, on average, spend a third of their time in written communication, while almost another third is spent on various oral communications [16]. Although it has become an important skill for engineering graduates to have that has been known by engineering faculty and professionals, it is one of several professional skills that are required for engineering graduates that pose difficulties for engineering educators[16, 23]. Thus, there has been an emphasis on technical reports and live presentations in several courses across different engineering programs.

The industry has been producing a large number of videos as a communication method for marketing and even requiring videos as part of the employment process in some fields of industry [24]. Moreover, current college students are accustomed to documenting and sharing their experiences through text, photo, and video, thanks to the ready availability of all of these through personal portable devices [25]. Thus, other disciplines cover other types of communication as technology and client expectations evolve. In Business schools, there have been incorporated of student driven videos to enhance student engagement [19, 26, 20]. There seems to be success in such disciplines of use of video for student communications. Presentation of video content as an instructional aid in the classroom is commonplace, but the production of student created video in engineering and engineering technology courses is apparently uncommon [27].

From the limited literature related to student created video assignments, Schmitz et. al. presents an example of a biomedical engineering class at Stanford University that aimed to help develop students' ability to communicate to a non-technical audience [28]. They implemented a service-learning project whereby students produced tutorial videos that demonstrated how to construct an inexpensive paper microscope developed [28]. Another example involves an electrical engineering project where students are required to integrate knowledge from three courses to evaluate the design of a cell phone. Students were required to produce short video presentations to demonstrate their abilities in integrating the knowledge and the ability to communicate through a video presentation [23]. Such communication is beneficial to incorporate into courses across various engineering programs including mechanical engineering to promote digital communication of course assignments. Although the literature can be found on student created video assignments for teaching and learning in non-design courses, there is virtually no open-ended EML-based projects presented through digital communication in non-design engineering courses especially in mechanical engineering. This gap in digital communication of EML-based project in mechanical engineering curriculum needs to be explored to facilitate the student learning experience and to enhance professional communication for the industry.

3. Methods

3.1 Study Design

Study was conducted via indirect assessments over the course of the semester. The indirect assessment was to gauge the students' familiarity and confidence through the completion of the open-ended EML based project. The project involved three asynchronous video reports in a scaffolded manner. The students also had a couple of discussion assignments to inquire and clarify about the project expectations and guidelines. The students were expected to choose a topic related to the course for their project: Thermal fluid energy dynamic system such as temperature control of energy conversion (e.g. fuel cell/Electrolyzer) systems or thermal fluid system. For the first video report with an 8-minute limit, they submitted project title, names, and draft outline along with motivation and likely objectives of their proposed project. Moreover, they can ask relevant and meaningful questions to clients, which in this case was the instructor, to learn about specifications and requirements as well as help determine assumptions and other information from literature. They were also assessed not only on technical content, but also on organization and logical Coherence of the video presentation, presentation skills, and visual aids and format.

In the 2nd video report with a 10-minute limit, the student group developed their system model based on the feedback from the 1st report. The model was developed by hand and then using MATLAB and Simulink/Simscape® to determine the system performance behavior. They also started strategizing based on the estimated performance under different operating conditions to design control the system such as simulate how and what to do to maintain a given temperature. They could also identify unexpected opportunities to create value beyond what is expected by proposing to come up with a different concept or approach. In the third and final video report with time limit of 12 minutes, the student groups incorporated previous reports' feedback and completed the project to recommend a control system based on specifications and requirements such as the system with controller had less than 5% of overshoot, less than 10% of settling time and less than 2% of steady-state error compared to the open loop system. The student group's responsibility included not only to create a control system solution to meet client needs, but also to determine a solution based on monetary and non-monetary constraints.

For indirect assessment, a voluntary anonymous survey was completed by students in relation to project-based learning and the addition of entrepreneurial elements. The survey was created by the author in Qualtrics where the questions used a Likert scale for quantitative analysis while the comments were provided for qualitative analysis. Students were asked to rate the agreeability of their abilities after the completion of the project. The survey was distributed during the fifth and sixth weeks, and the last two weeks of classes in the Spring 2022 semester, after being approved through the standard Institutional Review Board process.

3.2 Participation Information

The course offered in Spring 2022 is Process Control, which is a technical elective course for mechanical engineering students during which the study was conducted. Two sections were offered with a total of 31 students. The course was taught at two different locations in a combined mode of instruction – simultaneously online synchronous to the rural location (Tyler) and face-to-face in the urban location (Houston). There were different underrepresented groups in the combined sections including about 10% of the students were women, about 7% of the students were considered to have disabilities or ADA, and about 39% of the students were Hispanic. The face-to-face section in an urban setting, which also had an online synchronous option during the semester to accommodate for Covid guidelines per university policy, had 20 students, who were 100% transfer students. The online synchronous only section, which was in a rural setting, had 11 students.

3.3 Data Collection

Indirect assessments using a Qualtrics survey that was distributed at the start and the end of the semester. The survey includes five sets of questions related to course outcome, PBL, and EML including communication skills. A sample copy of the survey can be found in the Appendix. The survey starts off inquiring about the location of the student for instruction. The first three sets of questions were asked for agreement with statements provided and rated based on a 5-point Likert scale. The last two sets of questions ask students to provide comments related to their PBL and digital communication experience.

The first set of questions inquires about the agreeability of the student to be able to meet outcomes such as utilizing computational tools to design and analyze different types of control systems and relate the use of control systems to real-world problems. These outcomes are not only related to the course but can also relate to adding or creating value for the student about EML.

The second set of questions inquires about the agreeability of the student to be able to employ problem-solving and critical thinking skills, such as identifying unexpected opportunities to create extraordinary value and creating solutions that meet customer needs [3]. These responses relate to the 1st C of the 3 C's: curiosity and creativity in relation to EML.

The third set of questions inquires about the agreeability of the student to be able to develop video reports such as developing introduction and background sections, meeting spelling and grammar as well as formatting expectations, and developing results and discussion sections with appropriate figures and tables. These questions relate to the 2nd C of the 3 C's in relation to EML: connection where communication to a broad audience through a virtual platform is assessed. The last two sets of questions inquire about the students' feedback on PBL, where the students provide written comments of a minimum of 100 words. Such questions include what will be or are benefits to participating in project-based learning (PBL) with entrepreneurial elements and describe professional skills you will or did learn (e.g., communication, collaboration, etc.) through PBL.

3.4 Data Analysis

All data were compiled into Microsoft Excel® and analyzed using MATLAB®. For the data analysis, the pre- and post-course project survey results of Process Control course were obtained. Likert-type rating scales were converted to numerical values (1 to 5) according to a predetermined response to estimate means and standard deviation for each question or statement. Statements were grouped into categories aligned with the 3 C's. Student responses based on the pre- and post-surveys were compared using unpaired two-sample Student t-test.

4. Results

A total of 22 students participated in the pre- EML based PBL assignment survey. There were 14 student responses from the urban location while 8 responses were from the rural location. A total of 17 students participated in the post- EML based PBL assignment survey. There were 9 student responses from the urban location while 8 responses were from the rural location.

Figures 1 to 6 present the survey results that relate to technical skills, communication skills and problem solving and critical thinking skills. Figure 1 and Figure 2 show results of survey-based questions related to communication skills on a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Figure 3 and Figure 4 show the survey results on a Likert scale of 1 (strongly disagree) to 5 (strongly agree) for some of the EML outcomes related to curiosity and creating value. Figure 5 and Figure 6 show the survey results on a Likert scale of 1 (strongly disagree) to 5 (strongly agree) for the technical aspect related to the course and project outcomes. Table 1 shows the results of pre- and post-EML based PBL assignment survey categorized based on EML outcomes related to the 3 C's – curiosity, connection and creating value.

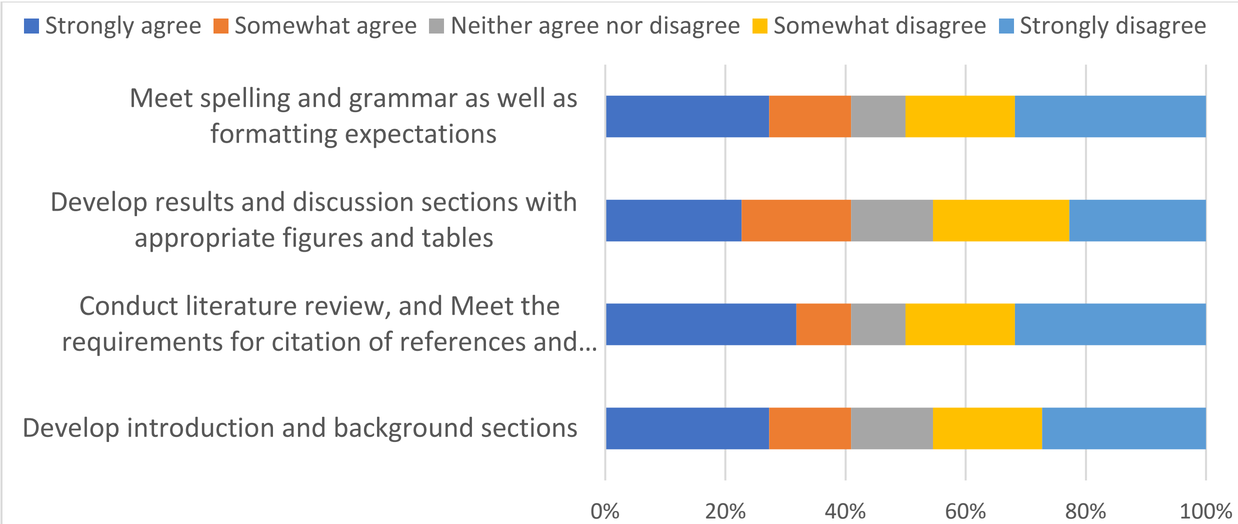

Figure 1. Survey results of communication related to EML outcome of connections from pre-EML based PBL assignments.

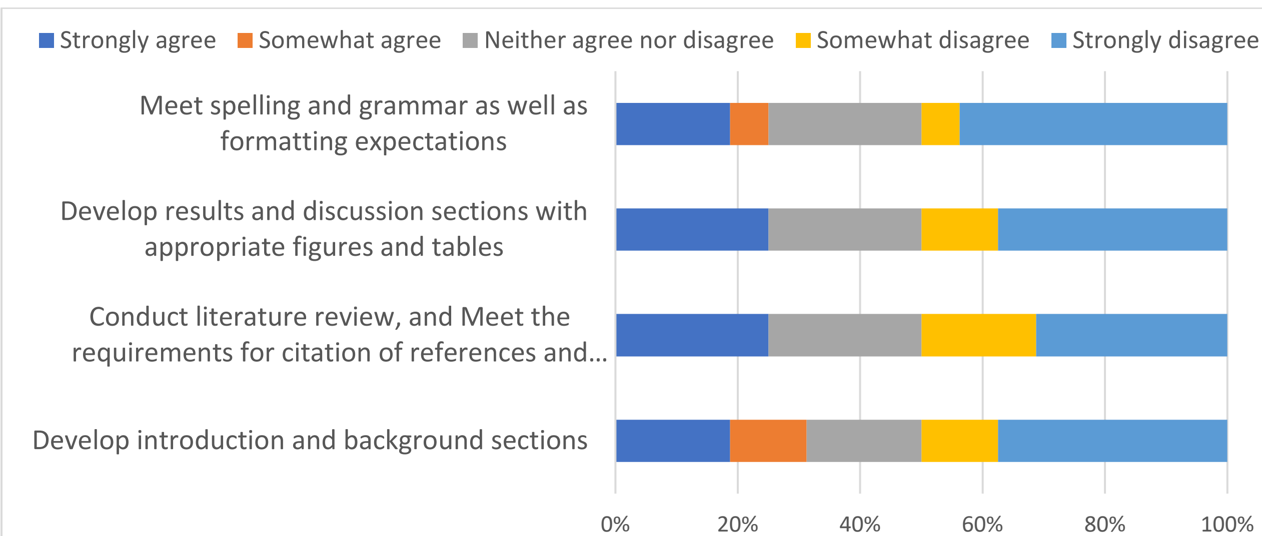

Figure 2. Survey results of communication related to EML outcome of communication from post- EML based PBL assignments.

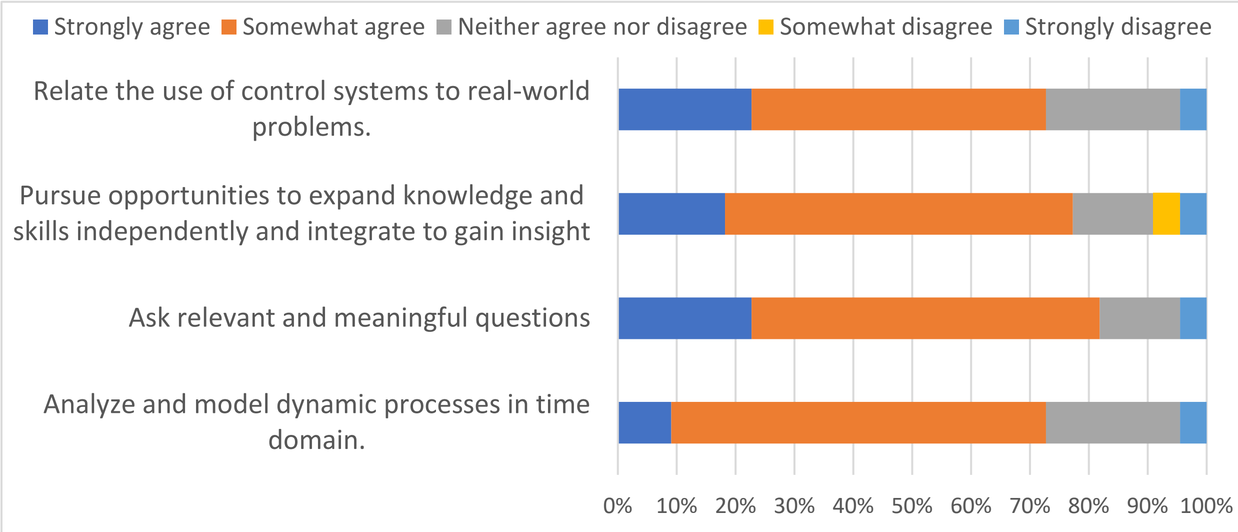

Figure 3. Survey results related to EML outcome of Curiosity from pre- EML based PBL assignments.

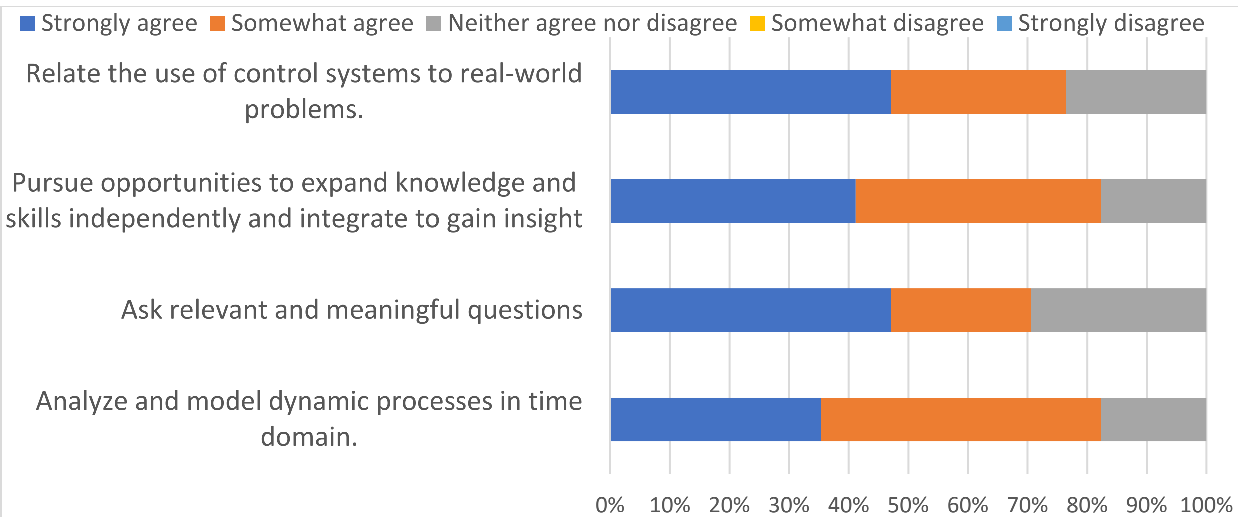

Figure 4. Survey results related to EML outcome of Curiosity from post- EML based PBL assignments.

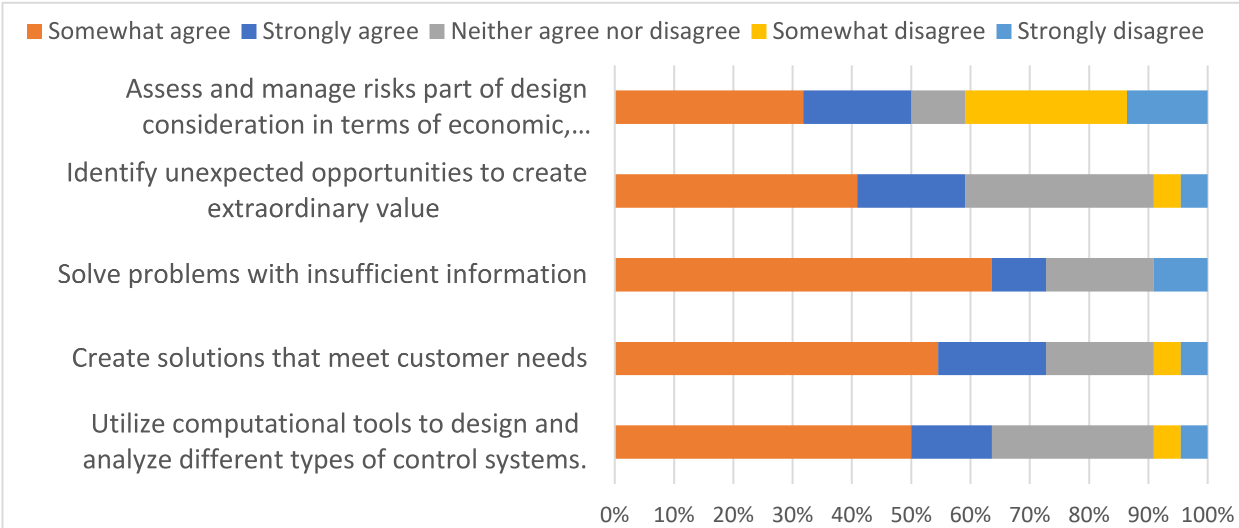

Figure 5. Survey results related to EML outcome of Creating Value from pre- EML based PBL assignments.

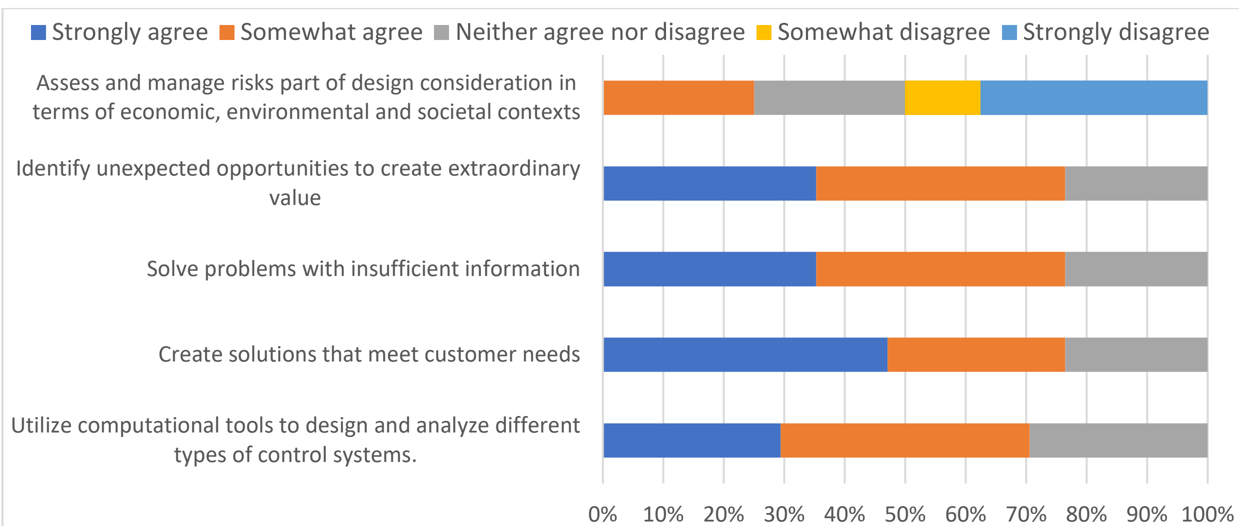

Figure 6. Survey results related to EML outcome of Creating Value from post- EML based PBL assignments.

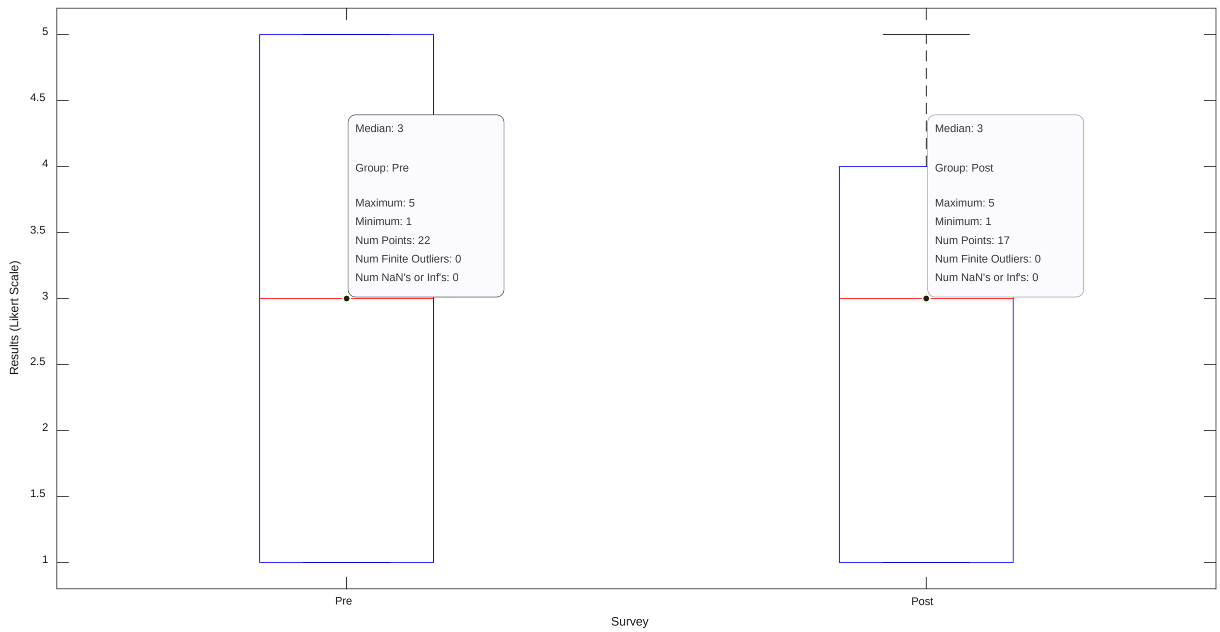

Figure 7. Boxplot of survey results for student response to be able to assess and manage risks part of design consideration in terms of economic, environmental, and societal contexts.

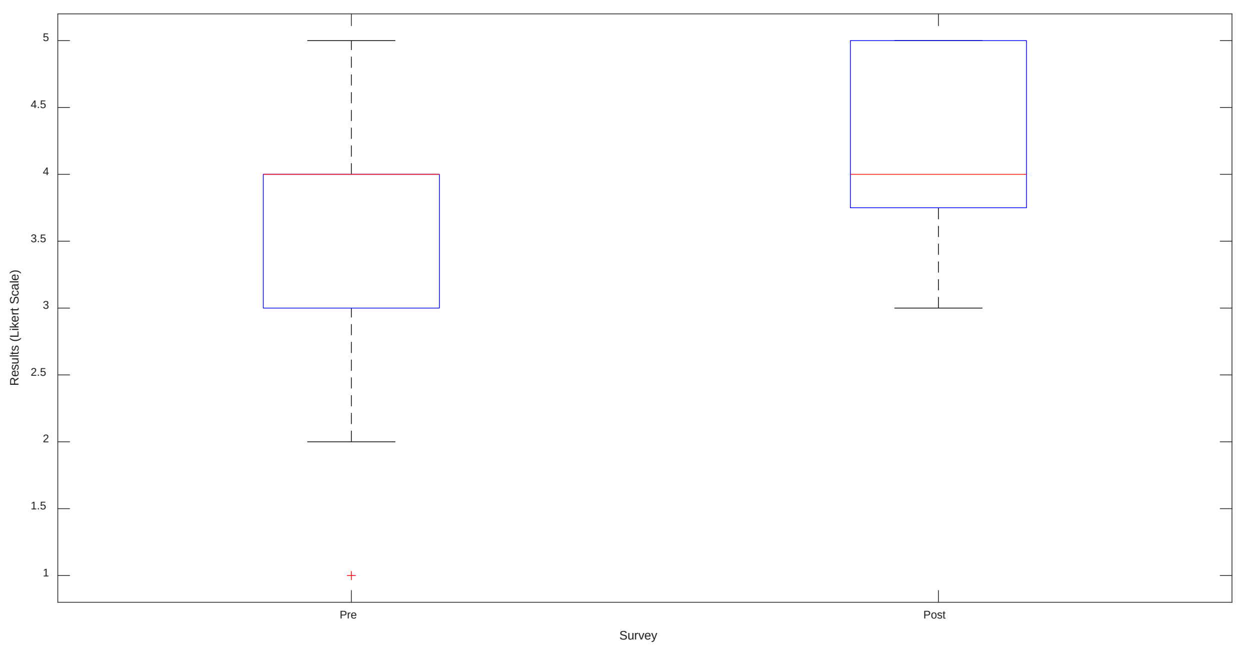

Figure 8. Boxplot of survey results for student response to be able to Create solutions that meet customer needs.

Table 1. Survey data for EML based PBL assignments.

Did the project help students in skill development?		Pre to Post Mean Gain (%)	Pre Mean	Pre Standard Deviation	Post Mean	Post Standard Deviation
Connections	Develop introduction and background sections	-6.4%	2.95	1.58	2.76	1.59
	Conduct literature review, and meet the requirements for citation of references and plagiarism	-3.1%	2.91	1.68	2.82	1.58
	Develop results and discussion sections with appropriate figures and tables	-6.4%	2.95	1.49	2.76	1.63
	Meet spelling and grammar as well as formatting expectations	-7.3%	2.86	1.63	2.65	1.61
Curiosity	Relate the use of control systems to real-world problems	+9.8%	3.86	0.92	4.24	0.81
	Pursue opportunities to expand knowledge and skills independently and integrate to gain insight	+11.0%	3.82	0.94	4.24	0.73
	Ask relevant and meaningful questions	+5.8%	3.95	0.88	4.18	0.86
	Analyze and model dynamic processes	+16.4%	3.59	1.07	4.18	0.71
Creating Value	Assess and manage risks part of design consideration in terms of economic, environmental, and societal contexts	-19.4%	3.14	1.36	2.53	1.33
	Identify unexpected opportunities to create extraordinary value	+13.2%	3.64	0.98	4.12	0.76
	Solve problems with insufficient information	+14.8%	3.64	0.98	4.18	0.86
	Create solutions that meet customer needs	+12.5%	3.77	0.95	4.24	0.81
	Utilize computational tools to design and analyze different types of control systems	+14.8%	3.64	0.93	4.18	0.78

4.1 Students need to improve ability in connection for digital communication

Table 1 presents the mean and standard deviation results of pre- and post-survey responses along with change in the mean related to connections. Students consistently disagreed (<3 out of 5) about their ability to develop technical documentation as evident by their disagreeability on developing introduction, background, results and discussions with visuals, conducting literature review, and meeting formatting requirements, which also supported by Figure 1 and Figure 2. It can be observed from the results showing decreases in agreement that the students seem to lack the confidence to be able to communicate effectively and professionally in a digital environment.

4.2 Students have high agreement in ability for curiosity

Table 1 presents the mean and standard deviation results of pre- and post-survey responses along with change in the mean related to curiosity. In the survey results in Figure 3 and Figure 4, it was shown on a consistent basis that students were agreeable on exploring the project topic. It was observed that the students increased in confidence through the PBL assignments since a high level of agreeability by students for EML outcome curiosity including relate the use of control systems to real-world problems, pursue opportunities to expand knowledge and skills independently and integrate to gain insight, and ask relevant and meaningful questions. The highest positive gain (+16.4%) of student agreement was observed for ability to analyze and model dynamic processes.

4.3 Students mostly agree on ability to creating value

Table 1 presents the mean and standard deviation results of pre- and post-survey responses along with change in the mean related to creating value. The agreeability (>3.6 for pre-survey and >4.1 for post-survey) and positive gain (>10%) of agreement for students' abilities was mostly high for creating value, which is also illustrated in Figure 5 and Figure 6. Students agreed that they can create solutions that meet customer needs with an agreeability rating of 3.77 (pre-survey) and 4.24 (post-survey) out of 5, which were the highest rating and represented one of the highest gains in creating value. However, the largest decline (-19.4%) of agreement was also observed for this EML outcome where students disagree to be able to assess and manage risks part of design consideration in terms of economic, environmental, and societal contexts. These student responses are also illustrated as a boxplot in Figure 7 where there is no significant change ($p=0.804$) from pre to post survey with median of 3 and average of 3.14 (pre-survey) and 2.53 (post-survey).
Similarly, the student responses to their ability to create solutions that meet customer needs are shown Figure 8 where there is also no significant change ($p=0.064$) with median of 4. Although students were mostly observed to have strong agreeability in creating value, they seem to have less agreeability and thus confidence with assessing and managing risks by considering societal, economic, and environmental contexts, which is an area that needs improvement to ensure students develop their entrepreneurial mindset to effectively address and assess a system design in a real-world context.

5. Discussion

5.1 Summary

From the survey results in Figure 4 and Figure 6, a strong number of students (14 to 16 out of 22 students for pre-survey and 12 to 15 out of 17 students for post-survey) agree with statements related to EML outcomes related to creating value and curiosity in the survey. They have relatively strong agreement and thus confidence in their abilities due to prior exposure on the technical topic and PBL since all students plan to graduate in the same semester or within a semester of this course offering. The results show that mechanical engineering students can perform certain tasks needed for an open-ended EML-based video project while they still require early and further exposure to develop their EML and video communication skills. The study did result in helping prepare students to think differently about PBL than just solving technical problems, and to be able to motivate development, build and digitally communicate a system of interest, which they usually have not done outside of the senior design courses.

5.2 Comparison

The results show that students can be more effective in their abilities and skills to identify a need (whether new design or continuous improvement), the individuals impacted by this need, and the method to fulfill the need (problem solving). As such it allows students to make an impact beyond just the classroom. Moreover, the projects communicated by students to the audience are limited to a set of written technical reports and live in-class presentations. Although such communication skills are important, the newer generation of students are exposed to other modes of communication in the digital environment such as social media and websites. Prior to the project, one of the students believed that "Presenting analysis in a formal documented way where an audience can understand my thoughts is probably the most valuable. And looking to others on their expertise to inform a good decision."

Although the results did not see significant improvement as illustrated in the Connections section in Table 1, certain students understood the significance of communication to be successful as an engineer in the field, which was succinctly put by a student: "Communication is key." Since they had consistent disagreeability for Connections from EML outcomes in Table 1, this confirmed observations made by the author from previous mechanical engineering courses taught regarding the limited to lack of students' ability to communicate professionally whether in the written, live oral or video form. Thus, exposure to project presentation in the digital environment was expected to add value to the students. However, this did not happen as observed from the results, which can be due to several students, especially in the rural section, being exposed to such a mode of communication for a course project for the first time. Moreover, since virtually all students were completing their senior projects and were graduating at the end of the semester, they may not have spent a sufficient amount of time to benefit from this project effectively.

Moreover, students highly agreed for EML outcomes related to curiosity and creating value. Students had mostly high positive gain in agreement of possessing ability to creating value in Table 1. Not too far behind, students also had consistent positive gains in agreement of possessing the ability to be curious and explore in Table 1. Student comments concurred with student abilities related to these two EML outcomes. One comment states that the PBL can help the student in "working as a team, learn to research, and learn how to take on a design project. These skills are important for a student because I believe it prepares the student how things operate in a work environment." A student also commented on the benefits of such an EML-based PBL experience: "the students are able to put the knowledge they have gained in their engineering courses and beyond, then apply it. This prepares the student for the field of engineering as there will be constraints in the field when it comes to budgeting and allocating resources." The students could continue to apply their technical and computational skills through PBL to prepare for the industry as illustrated by the survey responses related to Creating Value outcomes in Table 1.

A similar survey was distributed and collected for another control theory course from the prior semester to the Process Control offering. The survey was revised based on feedback received to obtain the latest survey questions, shared in the Appendix. Moreover, since this was the first such project for most students, there are some areas to improve in providing the assignments. One such student comment suggests that "…the project can be improved in terms of reference and assistance." Although references to two relevant projects were shared and assistance in the form of office hours and in-class breakout sessions were provided, further resources and information can be incorporated in future course offerings to assist students in digitally communicating their EML-based PBL assignments.

5.3 Limitations

This study is limited to a single course offered in a single semester at one university. The study is further limited by the number of students that participate in the surveys compared to the number of students in the class.

6. Conclusions

6.1 Practical Summary

The students were made aware of EML based PBL through digital communication prior to the assignments to assess their abilities based on EML outcomes: the 3 C's, and provided their responses related to their experiences that also correspond to the same EML outcomes. The results show good agreeability and confidence by students in the EML outcomes related to curiosity and creating value in the Process Control courses. Moreover, the students feel that their communication did not change or improve even after completing the video project. The students showed relatively high agreeability in curiosity and creating value while they can improve to effectively assess and manage risks for design considerations in terms of economic, environmental, and societal contexts as well as to learn to improve connection in an online environment. The students were provided exposure to such digital communication in terms of a project, and thus the students could be better equipped to enter the industry to not only actively solve problems, but perhaps strive to communicate effectively in a digital environment. The results show that mechanical engineering students can perform certain tasks needed for an open-ended video project using entrepreneurial mindset while having the capacity to further build on their skills. Students have been prepared to think differently than just technical and problem-solving aspects to be able to develop and communicate a product or in this study a part of a system – control system.

6.2 Future Research

The study is a start of long-term study to improve, implement and evaluate new teaching approaches and course assignments. There will be more data collection for future course offerings of non-design courses including Process Control, System Dynamics and Control, Energy Conversion and Experimental Measurements Laboratory. Moreover, incremental changes in the course assignments, including incorporation of micro-assignments related to EML outcomes, and revision of instructions and resources for digital communication, along with assessment tools will be made based on student feedback and faculty input after each semester. This study along with other future studies can be carried out to focus on exploration of other EML outcomes such as creating value.

7. Acknowledgements

This content was created through the author's work with the Kern Entrepreneurial Engineering Network (KEEN) and ASU Mentorship 360. For more information and additional shared content, go to https://engineeringunleashed.com/ .

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Appendix

The survey used to evaluate student learning are shown in Figures A1-A3.

The purpose of this first part of the survey is for YOU to assess your current ability to accomplish the course learning outcomes.
Do you agree with these statements?

I am able to

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Develop mathematical models and transfer functions of processes.	○	○	○	○	○
Analyze and model dynamic processes in time domain.	○	○	○	○	○
Utilize computational tools to design and analyze different types of control systems.	○	○	○	○	○
Read and interpret block diagrams, and process & instrumentation diagrams.	○	○	○	○	○
Relate the use of control systems to real-world problems.	○	○	○	○	○

Figure A1. The first part of the survey asked for students to complete before and after the assignment.

The purpose of this second part of the survey is for YOU to assess your current confidence in problem solving and critical thinking abilities.
Do you agree with these statements?

I can

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Identify unexpected opportunities to create extraordinary value	○	○	○	○	○
Pursue opportunities to expand knowledge and skills independently and integrate to gain insight	○	○	○	○	○
Solve problems with insufficient information	○	○	○	○	○
Ask relevant and meaningful questions	○	○	○	○	○
Create solutions that meet customer needs	○	○	○	○	○

Figure A2. The second part of the survey asked for students to complete before and after the assignment.

Please feel free to provide comments based on above responses (such as (1) what will be or are benefits to participating in project based learning (PBL) with entrepreneurial elements, and (2) what can be improved relevant to the project). Minimum of 100 words is encouraged.

Please feel free to provide additional comments about your skills (such as on (1) describe professional skills you will or did learn (e.g., communication, collaboration, etc…) through PBL, (2) describe context specific skills (e.g., control design topic) you will or did learn through PBL, and (3) Why are these skills important for you and other engineers in the real world?). Minimum of 100 words is encouraged.

Figure A3. The third part of the survey asked for students provide comments to complete before and after the assignment.