Paper ID #23833

Incorporating the Entrepreneurial Mindset into a System Dynamics Course

Dr. Louis A. DiBerardino III, Ohio Northern University

Dr. DiBerardino is an Assistant Professor of Mechanical Engineering at Ohio Northern University. His teaching and research interests are in first-year engineering, dynamic systems, and musculoskeletal biomechanics, and integrating curriculum with the entrepreneurial mindset.

Dr. Lawrence Funke, Ohio Northern University

Dr. Funke received his PhD in Mechanical Engineering from the University of Notre Dame in 2017. He is currently an assistant professor at Ohio Northern University.

Dr. David R. Mikesell, Ohio Northern University

David R. Mikesell is chair and associate professor of mechanical engineering at Ohio Northern University. His research interests are in land vehicle dynamics, autonomous vehicles, and robotics. He joined the faculty in 2007 after work in automotive engineering at Ohio State (PhD), six years designing automated assembly machines and metal-cutting tools for Grob Systems, and four years' service as an officer in the U.S. Navy. He holds bachelor degrees in German (Duke) and Mechanical Engineering (ONU).

Incorporating the Entrepreneurial Mindset into a System Dynamics Course

1. Introduction

Project-based learning (PBL) has been gaining popularity for some time in engineering education. There are several studies [1-3], including meta studies [4-6], that show the effectiveness of PBL, especially in terms of increased understanding, motivating students, retaining students, and helping to bridge the gaps between the classroom and workplace. Being able to work on real-world problems in a group setting is an important, necessary step to becoming a successful engineer; though, there is more to being a good engineer than simply being able to solve problems. More universities are starting to introduce entrepreneurial-minded learning (EML) as well (e.g., [7]). EML focuses on teaching the students to go beyond problem solving to be able to identify a need, who is affected by this need, and how to satisfy the need (solve the problem) in a fashion that creates value. Studies show that EML is successful in doing this and helps to create engineers better posed to make an impact in the workplace [8-11]. Duval-Couetil discusses the proliferation of entrepreneurial-focused education and that there is strong anecdotal evidence of its benefits [12]; though she also emphasizes the lack of studies with validated assessment tools. While the number of participants involved was not large enough to fully validate the assessment surveys used for this work, the surveys were based on validated assessment methods, as discussed in Section 4.

EML techniques are generally more easily incorporated into design-focused courses [13] or even as online modules separate from a specific technical course [14]. Some work has been done to incorporate EML into non-design-focused courses. Hassan et al. [15] incorporated an EML project into a sophomore circuits class as an extra credit assignment. While this work was successful, it was optional, smaller in scope, and covered fewer EML learning outcomes than the framework herein. Additionally, Duval-Couetil et al. [16] performed a study across multiple universities that showed that increased exposure to EML led to increased understanding and appreciation of entrepreneurial-minded thinking. Most schools interested in instilling the entrepreneurial mindset are able to effectively incorporate it into design courses, particularly at the freshman and senior level, but often struggle to incorporate it into the more technical courses sophomore and junior years. This work presents a framework to help fill this gap in the integration of EML into the entire degree program.

This framework seeks to facilitate the transformation of technical projects into EML opportunities that allow the full content of the course to be covered while increasing students' exposure to, and understanding of, entrepreneurial thinking. It has been implemented in a system dynamics course for junior mechanical engineering students at Ohio Northern University during the fall semesters of 2016 and 2017. Pre- and post-project surveys are used to assess the project's effectiveness both in terms of the students' understanding of the technical material and their understanding and views on the importance of entrepreneurial minded thinking in technical areas. Specifically investigated are how the project changes students' opinions of the applicability of the entrepreneurial mindset in a non-design course, and improvements in students' attitudes and self-awareness of the entrepreneurial mindset.

The remainder of the paper is structured as follows. Section 2 details the general framework for implementing entrepreneurially-minded project-based learning (EML/PBL) developed by the authors. The specific implementation in a system dynamics course is presented in Section 3. Section 4 then presents how data was obtained to determine the project's effectiveness, the data itself, and discussion of these results and the instructors' observations. The paper concludes with some thoughts on how to continue to improve the framework and the implementation in Section 5.

2. Framework

The general EML/PBL framework presented in this section is designed for technical courses where obvious opportunities like product design do not exist. This framework can easily be applied to existing course projects across a broad spectrum of technical courses, as discussed in Section 3. The following EML outcomes may be targeted when implementing the framework into a course project: formulate salient questions, identify unexpected opportunities to create extraordinary value, identify the needs and motivations of various stakeholders, create solutions that meet customer needs, integrate non-monetary and monetary factors into a proposed solution, present technical information effectively, and produce effective written reports. These outcomes represent a subset of the entrepreneurial mindset goals articulated by the Kern Entrepreneurial Engineering Network (KEEN) [17].

The most important component of the framework is to include a specific customer and stakeholders. Projects in any technical course can be adapted to include these components. For example, in a system dynamics course, students could design and optimize an electromechanical system like an elevator to meet building owner and tenant needs. Similar projects can be developed for thermo-fluids (a water supply or HVAC system for a developer), machine design (a new linkage of a stamping machine for an auto parts manufacturer), circuits (an improved analog filter for an electronics producer), etc. A real-life customer can be used, but an instructor playing the role of the customer also works well. The instructor-customer should draw clear boundaries between the two roles, and be sure students clearly identify to whom they are talking. The addition of a customer allows several opportunities to incorporate EML. The project deliverables can be addressed to the customer, allowing for a bid proposal rather than a traditional class report. This requires students to focus on real-world communications and cost minimization. Students can also be required to research the customer's existing solution (if one exists) to find opportunities for improvement. Perhaps most importantly, the project can be given in a manner that the instructor does not know many of the details of the bid proposal, and students are required to formulate questions to ask the customer. The customer may also be vague and difficult to work with if desired, even providing incorrect information initially. This allows an easy opportunity to assess students' abilities to find the correct information to complete the project.

Stakeholders should provide an additional layer of constraint on top of the customer's cost requirement. Examples include user safety, convenience, size, etc. Conversely, another layer of involvement could be used to assist the students, such as a "boss," who might give some additional information or entice the students to ask certain questions or consider certain aspects of the project they may have neglected. The authors used this as a method to deliver just-in-time information, rather than providing it at the onset of the project.

The next component is the manner in which students are provided information. In the traditional technical project, students are usually given all of the information they need to solve the problem, and must simply apply (or extend) what they've learned in class to find the best solution. Providing insufficient or vague information forces students to seek information and ask pertinent questions. Students may even find that their perceived scope of the project changes with the information they find. A simple example is to propose that students "minimize cost and maximize safety." Students would then need to find out what that means through one or more modes of research. One such example, not used in this project, is that students must find existing manufacturer specifications or other published research. An example might be finding the dimensions of a forklift from the manufacturer's website for a project where students are analyzing the effect of different lifting motors. Another example, used below, is asking the customer questions. This enhances students' informal professional communication skills, and if the customer is particularly difficult, can also enhance students' abilities to ask pertinent questions.

Since the above components of the framework involve asking questions, the manner in which these questions are received and answered is very important. Through several iterations, the authors have found the best results by implementing several intermediate "questions" assignments. Here, students can submit questions electronically, separated as customer and instructor questions. The instructor-customer (or each independently if not the same person) then answers the questions as only the instructor or customer depending on the type of question. In order to enhance students' abilities to ask proper questions, the authors found it useful to not answer questions addressed to the wrong person. For example, if a student asks the instructor "what does 'safety' mean?", the instructor responds with "ask the customer." Electronic submission of the questions at defined due dates allows for direct assessment of students' efforts, and drastically reduces the amount of time needed to answer questions in person.

To identify unexpected opportunities, the project should include some manner of vague or hidden information that is not needed to successfully complete the project, but when acted upon will produce great value. In the example below, the building owner has "spare parts" laying around that students might realize could be used to produce mechanical advantage for the elevator actuator, lowering the build cost compared to a direct-drive system. Of course, students should only learn these things through their own research and ingenuity, and by asking the right questions. Since students' discoveries of these unexpected opportunities are not tied to their assessment on the project, the inclusion in the framework serves more as a litmus test to the instructor. A project debrief would be necessary to make all students aware that opportunities to further improve their bids were available.

Reporting the solutions is the final component, and should involve students submitting a bid proposal to the customer, rather than a report to the instructor, to maximize effectiveness. It should be made clear to the students that winning the bid not only depends on their group having the best solution, but also a professional and well-written bid proposal. Requiring that students prove their choices are the best also allows assessment of the technical aspects of their work. Following the framework, students should strive to minimize cost (or whatever else the customer requires) as well as non-monetary factors like safety. Awarding the winning bid bonus points can also limit the amount of inter-group sharing of information, helping ensure that each group is required to seek the necessary information to complete the project. When implemented, this framework provides a means to incorporate EML into a project that traditionally might only include technical calculations and analysis, and perhaps a cost minimization. Here, the focus is placed on the customer, and seeking information that is not initially provided. Students will gain experience working with a real-world customer (or at least the best one the instructor can impersonate) and will be forced to complete the project under real-world circumstances where they are not necessarily given sufficient information, or even given incorrect information initially.

3. Implementation

The framework detailed above was used to develop a course project in a system dynamics course for the entire cohort of junior mechanical engineering students at Ohio Northern University, a small, private, undergraduate institution. Traditionally, students would complete a project encompassing the simulation and analysis of an electromechanical system such as a conveyor system or hybrid-electric vehicle. This would allow students the ability to apply what they have learned throughout the course, and perhaps even perform a cost optimization. However, students were generally given all of the required information, and simply needed to learn *how* to solve the problem.

The following scenario was provided to the students: "The PNC Bank building in Toledo, built in 1932, is looking to replace their elevator motors in order to meet today's electrical standards. Your company, Rise High, Inc., may go bankrupt in the current economic climate unless you can win the bid. You must propose a design to the building owner that will replace the motors at the lowest cost while providing the most convenience for the building tenants. The owner has mentioned that other than the motors, the remaining equipment is available for reuse or repurposing. Due to the implications of the future of your company, it is imperative that you not share any intellectual property to better your chances of winning the bid (up to +10% extra credit). Understanding the customer's needs is also of utmost importance."

The instructor served as the customer and followed the framework guidelines when communicating with students. Students worked in self-selected pairs. Two intermediate assignments were due before the final bid proposal: modeling and simulation of a brushed-DC motor in Simulink, and a flowchart describing the general operation of an elevator. These were individual assignments to ensure all students were familiar with modeling electromechanical systems in Simulink and elevator operation. Further, these assignments ensured students would not begin the project shortly before the final due date, and gave them an opportunity to formulate questions early in the project. Students were also required to electronically submit questions to the instructor and customer with these assignments. In addition to the benefits of question submissions discussed in the framework above, requiring questions here allowed individual assessment of students' curiosity. The simulation and first set of questions were due nine days after the project was assigned, and the flowchart and second set of questions were due after another nine days. After completing the two intermediate assignments, students were given six days (plus a week-long break) to work on the project in their team before a final set of team questions was due. Students then had eight additional days to complete the project. Approximately nine days before the final due date, students received a memo from their "boss" at their engineering firm. This memo served to remind students not to share their ideas (to win the bid), to alert students that they should confirm all design decisions with the customer (mistakes were intentionally included with the bid request), and provide a list of motor replacement options that they must choose from. Students could potentially be left to find components on their own, but the instructors felt that this would be especially difficult for motors large enough to move an elevator, and was outside the scope of the course.

The particular information that students should have discovered when questioning the customer were building height; maximum acceleration; available equipment; inertial properties of the elevator, main sheave, and counterweight; maximum load; maximum rise time; and that the customer desired the lowest capital plus 10-year operation cost. Some of the information was given the first time students asked for it. Other information was withheld until later question submissions. For example, the initial project description mentioned cost, tenant convenience, and customer needs. When students initially asked what the customer's needs were, he replied with "tenant convenience and safety." When asked again, the customer mentioned that he'd like the elevator to rise from the lobby to the top floor in under 40 seconds. When asked specifically about safety, or a maximum acceleration, the customer initially stated that yes, there was a maximum safe acceleration, but he needed to check with the building inspector. The actual value was not disclosed until the final question submissions. Similarly, the customer was vague about what equipment was available outside of the car, cable, main sheave, cables, and counterweight. He stated that he needed to check with the building engineer to see what else was available. Only when asked specifically about additional pulleys or gears did the customer say that a 2:1 speed ratio was available. The initially vague responses served to force the students to ask clear pointed questions, rather than allowing them to fish for information by asking the broadest questions possible.

Students used Simulink to model the elevator system as a brushed-DC motor with the effective inertia of the entire system added in, and specific step/ramp/etc. controls for the motor's voltage and brake to produce their desired car motion. Within their bid to the customer, students were asked to provide their MATLAB code and Simulink diagram, position and acceleration plots of the car's motion to prove it satisfied the customer's requirements, and a 10-year electricity cost based on average daily usage data made up by the instructor. Sixteen percent of the bid grade was based on whether the team discovered all necessary information, 42% on whether they actually met the customers needs and had correct simulation results, and 42% on the general report formatting, presentation of results, and quality of discussion. Overall, about 50% of the bid grade was EML related. One bid winner was chosen from each course section by the instructor based on highest scoring rubric and lowest project cost.

4. Results and Discussion

Fifty students in two sections were surveyed before and after the completion of the project. The pre-and post-surveys were identical. Only the data from the 29 students who completed both pre- and post surveys are used in the analysis that follows. The surveys were not connected to the students' grades or any other incentive in any way. Additionally, the surveys were administered and anonymized by a faculty member with no connection to the course to prevent any bias in the process. The surveys were based on the valid and reliable tool developed by Carbery et al. [18] and used by other researchers, see [19] as an example. The specific questions of this validated tool had to be changed to obtain the desired information. Therefore, the surveys were used as a tool for the authors to obtain internal feedback and no broader claims of reliability are made in regards to the findings presented below since larger studies would have to be performed to fully validate the tool.

In each survey, students were asked to rate their perception of the importance of the following seven statements in the field of system dynamics:

1. Formulating relevant and meaningful questions
2. Identifying unexpected opportunities to create extraordinary value
3. Identifying the needs and motivations of various stakeholders
4. Creating solutions that meet customer needs
5. Integrating non-monetary and monetary factors into a proposed solution
6. Presenting technical information effectively
7. Producing effective written reports

Students rated these statements on a five-point Likert scale. To facilitate numerical analysis, the following values were assigned to the responses: (1) Strongly disagree, (2) Disagree, (3) Neither agree nor disagree, (4) Agree, and (5) Strongly agree. Figure 1 displays the average perceived importance of each of these seven statements before and after completing the project.

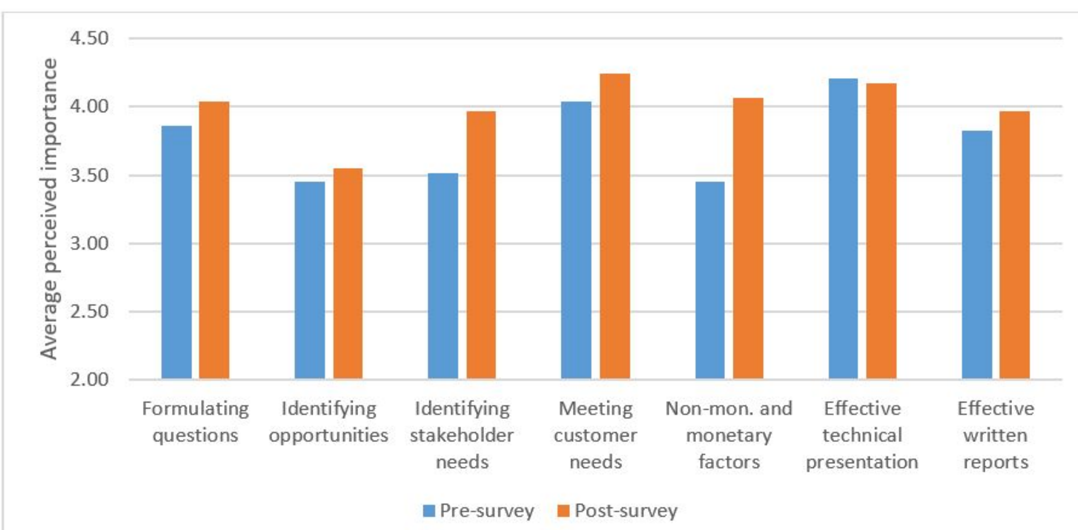

Figure 1. Average perceived importance of seven topics

Marked increases were noted for two of the seven statements. The largest increase (+0.62) was observed for "Integrating non-monetary and monetary factors into a proposed solution." Students were uncertain about the importance of these factors before the project, but the average response was above "agree" afterward. Another large increase (+0.45) was observed with respect to "Identifying the needs and motivations of various stakeholders." Smaller increases were noted for the other statements. "Presenting technical information effectively" remained essentially unchanged, though students agreed on its importance from the start.

In addition to the perceived importance of topics, students were also asked to rate the confidence in their abilities in eleven areas related to course skills or to the entrepreneurial mindset. The survey asked students to "rate how successful you would be in performing the following tasks" on a scale of 0-100, where 0 = "cannot expect success at all" and 100 = "highly certain of success." The eleven tasks are as follows:

1. Model electromechanical systems
2. Simulate electromechanical systems using Simulink
3. Solve problems with insufficient information
4. Ask relevant and meaningful questions
5. Identify/evaluate information sources
6. Identify unexpected opportunities to create extraordinary value
7. Create solutions that meet customer needs
8. Determine a solution based on monetary and non-monetary constraints
9. Provide a clear, well-written solution to a given problem
10. Present technical information effectively
11. Produce effective written reports

The average results from this survey are displayed in Figure 2.

The largest improvements in self-confidence were seen in the first three tasks. There was not a great disparity in the average post-survey results for any of the tasks, but the pre-survey revealed low confidence in modeling electromechanical systems, simulating these systems in software, and solving problems with insufficient given information. The expectation of success in these tasks increased by 32%, 60%, and 40%, respectively, when comparing post- to pre-survey results.

For the purpose of this study, the entrepreneurial mindset-related tasks were of most interest; thus the sharp increase in confidence in solving problems with insufficient initial information is significant. Another entrepreneurial-related task, solving a problem using both monetary and non-monetary constraints, showed a substantial (14%) improvement. The tasks to identify and evaluate information sources, as well as identify unexpected opportunities to create extraordinary value, both improved by more than 8%.

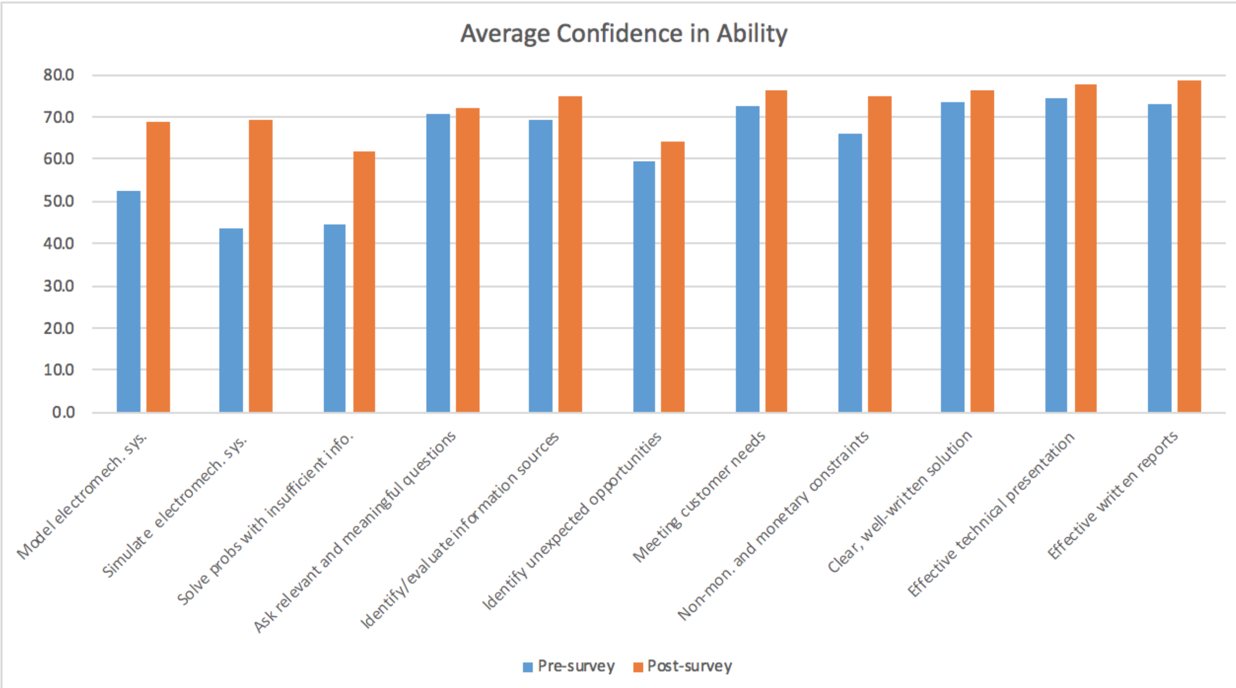

Figure 2. Average confidence in ability

Figures 1 & 2 show only the average of the student responses. A number of students reported lower importance of or confidence in some areas after completing the project. The survey results were compared with student project grades, as shown in Figure 3; however, no correlation was discernible. Survey results were also compared with student course averages (not shown), with similar results.

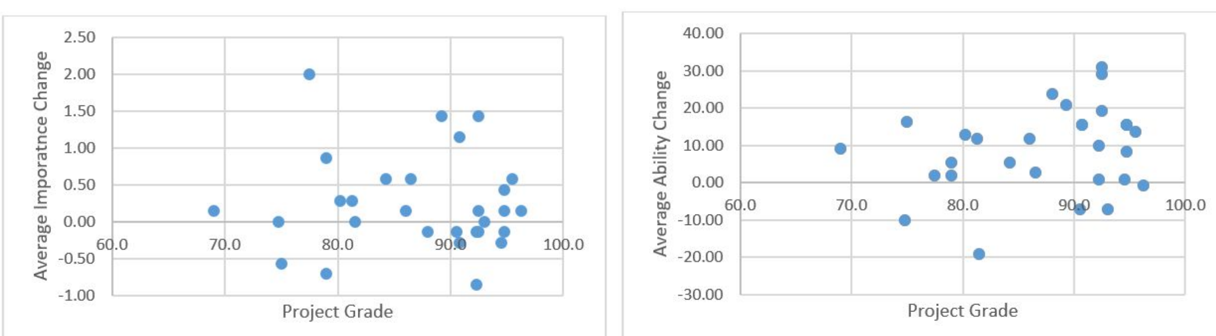

Figure 3. Average self-reported changes in topic importance and task ability vs. project grade

Overall, the survey results are encouraging in several ways. First, they enhance the literature on EML implementation by introducing an assessment tool based on validated metrics; though additional work is required to fully validate it. Second, the self-confidence surveys provide evidence that the framework presented here helped students achieve several EML outcomes in addition to the technical learning objectives traditional to system dynamics projects. Finally, the importance surveys suggest that students gained a better appreciation for the importance of having an entrepreneurial mindset in a traditionally-technical course. This increase in perceived importance and ability in EML outcomes is the most encouraging. It indicates that the framework presented is an effective way of continuing EML through the more technical curriculum typically seen during the sophomore and junior years. It is also significant that these positive EML outcomes did not come at the expense of technical outcomes. The students' increased confidence in modeling and simulating electromechanical systems, and the fact that 23 of the 29 respondents received a B or A on the project bear this out.

It should be mentioned that while this framework is effective it is not necessarily easily implemented. The project was initially met with heavy resistance by the students because it was unlike the projects they were used to, and they were not "spoon fed" all the necessary information to solve the problem. Eventually, the students do begin to realize the importance of customer interaction, and fully examining the problem to make sure they are asking the right questions, leading to an increased understanding and awareness of the entrepreneurial mindset. The framework is more easily implemented with time, both for instructors and students. Every time the project is used, it is easier for the instructors since they know where sticking points are and have learned the best way to handle the more difficult aspects, such as answering the large amount of required questions efficiently. The students' resistance is also lessened after several implementations. This is likely due to the combination of seeing more similar projects in other courses as EML is more fully integrated at Ohio Northern University and since they hear about the project from students who completed it the previous year. Based both on these results and their personal experiences, the authors believe that the benefits gained far outweigh the initial growing pains associated with implementing this framework.

5. Conclusions and Future work

Project-based learning (PBL) and entrepreneurial-minded learning (EML) have both been shown to have positive impacts on a student's education. Currently, however, EML is most frequently implemented in design-centric courses, particularly in the freshman or senior year, leaving a gap during the more technical-centric courses in between. The work herein sought to help rectify this discrepancy by presenting a general framework to implement EML in a technical course. The framework was implemented via a project in a required junior-level system dynamics course and surveys were administered to determine the project's effectiveness in instilling the importance of EML outcomes in technical courses.

The results were very promising in that a significant increase in both perceived importance of and confidence in ability to do several EML outcomes was observed. Additionally, the results indicate that the benefits of PBL and the students' technical competency was not sacrificed. This indicates that implementing projects using the framework discussed herein has a large potential to further expose students to EML effectively. There can be some difficulties in implementing this framework, namely student resistance to such a different type of project, and increased workload on the instructor, particularly the first time it is implemented. These difficulties do diminish as the framework is used more both at an institution and in a particular course.

There are some suggestions that the authors plan to implement in the future and areas requiring additional research. The specific implementation at Ohio Northern University is in a class with two sections taught by different instructors. The authors plan to take advantage of this in the future by designating one instructor as the instructor and one as the customer. This creates a more realistic scenario when an external customer is unavailable and helps to ease the burden of determining which role the instructor is playing at a particular time. It is also suggested that the project be completed at least one week prior to the end of the semester. This would allow for a project debrief in which the opportunities to further improve the students' bids could be discussed. More generally, having time to discuss the project after completion would likely help improve the students' awareness of the EML outcomes. Finally, performing similar studies with significantly more participants would allow the validation of the assessment tools used. This would better help fill the gap in the literature of quantitative data supporting the use of EML, as discussed in Section 1.

Acknowledgements

The authors would like to gratefully acknowledge the Kern Entrepreneurial Engineering Network (KEEN) for funding which partially supported this work.

References

[1] Svihla, V., and Reeve, R., 2016. "Facilitating Problem Framing in Project-Based Learning". *Interdisciplinary Journal of Problem-Based Learning,* 10(2).
[2] Mikesell, D. R., and Yoder, J.-D. S., 2011. "Teaching dynamics with a design project." *ASEE Annual Conference and Exposition*.
[3] Bigelow, K., 2016. "Creating Assignments that Excite and Empower Students: The Sports Biomechanics Video Presentation". *40th Annual Meeting of the American Society of Biomechanics*, pp. 1–2.
[4] Prince, M., 2004. "Does Active Learning Work? A Review of the Research". *Journal of Engineering Education,* 93(3), pp. 223–231.
[5] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., and Wenderoth, M. P., 2014. "Active learning increases student performance in science, engineering, and mathematics". *Proceedings of the National Academy of Sciences,* 111(23), pp. 8410–8415.
[6] Smith, K. A., Sheppard, S. D., Johnson, D. W., and Johnson, R. T., 2005. "Pedagogies of Engagement: Classroom-Based Practices". *Journal of Engineering Education,* 94(1), pp. 87–101.
[7] "KEEN - Partners," https://engineeringunleashed.com/Partners.aspx.
[8] Ta ¨ks, M., Tynja ¨la ¨, P., Toding, M., Kukemelk, H., and Venesaar, U., 2014. "Engineering students' experiences in studying entrepreneurship". *Journal of Engineering Education,* 103(4), pp. 573–598.
[9] Duval-Couetil, N., Reed-Rhoads, T., and Haghighi, S., 2012. "Engineering students and entrepreneurship education: Involvement, attitudes and outcomes". *International Journal of Engineering Education,* 28(2), pp. 425–435.

[10] Eisenstein, E. M., 2010. “Engineering and entrepreneurship: Creating lasting value from engineering”. *2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*.
[11] Kriewall, T. J., and Mekemson, K., 2010. “Instilling the Entrepreneurial Mindset Into Engineering”. *The Journal Of engineering entrepreneurship,* 1(1), pp. 5–19.
[12] Duval-Couetil, N., 2013. “Assessing the Impact of Entrepreneurship Education Programs: Challenges and Approaches”. *Journal of Small Business Management,* 51(3), pp. 394–409.
[13] Dahm, K., Riddell, W., Merrill, T., Harvey, R., and Weiss, L., 2013. “Implementing Entrepreneurial Assignments in a Multidisciplinary, Sophomore-Level Design Course”. *Advances in Engineering Education*, pp. 1–37.
[14] Thoroughman, K. A., Hruschka, A., and Widder, P., 2014. “Engineering Virtual Studio: KEEN Modules to Foster Entrepreneurial Mindset in an Integrative, First/Second Year Online Course”. *American Society for Engineering Education conference proceedings*.
[15] Hassan, F., LeBlanc, H., and Al-Olimat, K., 2013. “Inculcating an entrepreneurial mindset in engineering education: Project approach”. *Proceedings - Frontiers in Education Conference, IEEE*, pp. 121–126.
[16] Duval-Couetil, N., Shartrand, A., and Reed, T., 2016. “The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes”. *Advances in Engineering Education,* 5(1), pp. 1–28.
[17] “KEEN Framework,” https://keenwarehouse.blob.core.windows.net/keen-downloads/KEEN_Framework_spread.pdf.
[18] Carberry, A. R., Lee, H. S., and Ohland, M. W., 2010. “Measuring Engineering Design Self-Efficacy”. *Journal of Engineering Education,* 99(1), pp. 71–79.
[19] Hylton, J. B., France, T., and DiBerardino III, L. A., 2017. “Impact of Various Pedagogies on Design Confidence, Motivation, and Anxiety of First-Year Engineering Students”. *ASEE Annual Conference and Exposition*.