Implementation of Problem Based Learning into Materials Testing lab

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Abstract

Entrepreneurial Mindset Learning (EML) and Problem-based learning (PBL) are recent trends in higher education that develop the necessary skills and enhance learning in engineering education. A problem-based learning project was implemented into Materials Testing Lab to promote student interaction in class and increase problem solving, time management, and teamwork skills. A three week project was developed in order to expose students to open-ended real world problems through experimental activities in the lab. Students carried out experiments, calculated material properties, and applied them to a real-world mechanics problem. The project details are further described and show success in implementing problem-based learning into a lab format. Students have stated improved learning through the use of problem-based learning.

Introduction

Engineering consists of taking abstract problems and developing scientific and creative solutions to solve them. Therefore, improving critical thinking and problem solving skills are essential for preparing engineering students for dealing with real world problems. In engineering coursework, traditionally taught courses sometimes lack teaching students how to solve abstract problems that aren't the straightforward textbook problems. Problem-based learning techniques have been used to help students learn course objectives through problem solving, abstract assignments, and inverted learning [1]–[4]. Problem-Based Learning (PBL) is a teaching/learning approach which often includes open-ended, vague and sometimes ill-defined real-world problems as the starting point; the challenges involved in dealing with such problems promote critical thinking and problem solving skills. Similarly, the Entrepreneurial Mindset Learning (EML) aims at instilling the entrepreneurial mindset in engineering education by introducing open-ended real-world problems with focus on curiosity, connections, and creating value. These teaching techniques have shown to improve problem solving skills in students and offer an alternative way to set up the classroom compared to traditional teaching. On the other hand, there are challenges in implementing PBL/EML techniques in the engineering education. Many novis problem-based learners who are not familiar with the EML/PBL course settings often struggle with identifying the required information in addition to choosing the right approach to solve the problem. Nasr and Ramadan [6] reported that "The majority of students are formulae-driven. Effective methods need to be employed to discourage students from reaching out for quick equations to plug and chug in". Similarly, Mitchell and Smith [7] mentioned that engineering students often had difficulty relating prior knowledge from earlier coursework to the problems provided in a third year PBL course in communications systems.

Regarding the importance of problem solving skills as well as the benefits and challenges of problem based learning, a EML/PBL module was initiated, designed and implemented in a three week period in a Materials Testing lab. Labs often provide basic understandings of procedures and experiments used in science and engineering, but can sometimes lack interactive and critical thinking skill development. This paper describes the traditional lab format used in Materials Testing lab and issues with it, the new problem-based learning format implemented into two of the ten lab sections, and the results of these lab sections compared to the traditional lab format.

Traditional Lab Format

The traditional teaching format for Materials Testing lab includes a short lecture (~15 minutes) on the subject matter and a brief review of the fundamental concepts followed by the hands on experiments in the lab (50-90 minutes). The traditional version of the lab has been taught many times by the instructors. The students were provided with the lab procedures and data sheet forms before conducting the experiments. The experiments were carried out in three different formats, depending on the difficulty level, safety concerns and the availability of work stations:

1. *Small groups:* Individual groups (3 students) each do the experiment
2. *Large Groups:* Class split into two groups and each large group does the experiment
3. *Demonstration:* Demonstrating one experiment for the entire class

The implemented problem-based learning for the lab will take the place of splitting the class into two groups. The small groups lab experiments are generally interactive allowing all the students to participate in the hands-on activities. The large groups experiments that requires splitting the class into two large groups is less interactive; only a few volunteer students get involved in the experiment and the rest often pay less attention. Similarly, the single experiment for the entire class usually involves the instructor operating the equipment due to the need for technical ability and training on the machinery. The large groups and demonstration portion of the lab experiments were redesigned using the EML/PBL to enhance students learning. Increasing student engagement was not the only motivation for redesigning the lab curriculum. Many times, even in the small groups activities, the students do not know the reason of conducting the experiments or its application in real world problems that engineers would face. It has been observed that some students just follow the lab procedures provided by the instructor and do not have to take the initiative on higher order thinking that requires more cognitive processing. The EML/PBL modules were implemented in redesigning the Materials Testing lab in order to involve students in the activities that promote evaluating, applying, analysing , and synthesizing the subject matter rather than memorizing the knowledge and procedures. Such activities are aligned with the concept of education reform based on Bloom's taxonomy [8].

Interactive Problem-Based Learning Format

When designing the new interactive problem-based learning lab format, several goals, objectives, and learning outcomes were formulated to help students improve their learning quality:

1. Exercise problem-based learning to help create material tests which provides them information for their analysis of a problem
2. Relate the lab tests to real world problems
3. Practice teamwork and time management skills
4. Improve technical report writing skills
5. Students still learn concepts previously taught in the traditional lab format including non-destructive testing methods to evaluate material properties

To achieve the goals, three lab activities were combined into a project to facilitate the problem-based learning. The labs chosen for this project included topics covering finding elastic constants using nondestructive testing methods such as strain gages on a metal beam, composite beam, and dial gages to measure deflection for a simply supported and cantilever beam. Rather than students doing one experiment a week and turning a lab report the following week, students were able to use the three weeks to conduct all of required experiments and work on the project that was assigned in the new format. The first week of the project, the instructor would give a lecture over the fundamental concepts as well as the logistics of the lab. Afterwards, the students were free to work on the experiments and lab projects under supervision of the instructor and the lab assistant. The second and third week of the project the students could come straight to the lab to finish any experiments and work on their project. Their report was then due the week after the third lab time.

The project involved examining and testing four different beams. The beams and tests were the same as the tests that students would normally do in the traditional experiment; the main difference is that students need to identify the appropriate test required for designing their project and use the collected in the design process. Students would then have to use the data to solve an open-ended real-world problem assigned to each group. Each group was considered to be a “consulting group” and were supposed to use the “equivalent beams” to test for unknown properties of beams. This would then be used to see if an old structure could withstand new loading. The following is the problem statement given to the students:

Joe Miner has recently purchased an older building for his manufacturing business. He plans on bringing a lot of new equipment into the second floor of his building which will cause higher loads on the beams. Since the building is so old, the plans are hard to read and do not state what type of material is used or the material properties of the beams. Joe wants to be sure that his beams will be strong enough and meet serviceability requirements but does not know how to analyze them. Joe calls your group (consulting firm) for advice. Here is the information he provided:

- *There are four types of beams in his floor, three simply supported and one cantilever on an overhang*
- *The big aluminum and composite beam have strain requirements in the code of (_A_) μin/in*
- *The wood and small aluminum beam are controlled by deflection requirements of (_B_) inches*
- *The uniformly distributed loading on the aluminum and composite beam is (_C_) kips/ft and they have a length of (_D_) ft and (_E_) ft respectively. Their cross section dimensions are (_F_) inches wide by (_G_) inches tall.*

- *For the composite beam, assume the steel and aluminum section are each half of the cross section with the steel being on the top.*
- *The small aluminum beam has a uniformly distributed load of (_H_) lbs/ft. The length of the beam is (_I_) ft and dimensions of this beam are (_J_) inches (width x height).*
- *The wood cantilever has a point load at the end as it is used to hang equipment. The equipment has a weight of (_K_) lbs. The length of the cantilever is (_L_) ft with (_M_) inch cross-sectional dimensions (width x height).*

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
A	300	280	350	400	300	250	425
B	L/360	L/240	L/400	L/360	L/240	L/400	L/360
C	4	3	3.5	2	5	2.5	3.25
D	20	25	21	30	18	26	28
E	21	23	19	26	27	28	25
F	10	12	12	8	9	12	10
G	20	22	24	16	18	24	20
H	450	300	600	500	850	700	625
I	15	18	26	16	21	14	19
J	6x12	4x8	5x10	7x14	6x12	3x6	5x10
K	100	150	90	50	75	200	120
L	8	6	10	5	4	7	9
M	4x4	2x6	2x8	2x6	4x4	2x6	2x10

To help facilitate this project, a “framework” was used to help facilitate the problem based learning as suggested by Jonassen and Khanna [3] since most students would not be familiar with a problem-based learning project or approach to teaching . Part of the framework included giving students basic instructions to know how to run the experiments on the beams. Students were also given worksheets to complete for each beam they tested. These worksheets were accompanied with an equation sheet so they would not have to derive every equation, however the equations were not labeled so students needed to figure out and understand how and when to use each equation. The worksheets guide the students to help solve for the material properties of the beams, but for solving the overall problem, the students needed to figure out what they needed to use from the experiment and come up with their own analysis of the beams to solve the overall problem. Students needed to discuss the approaches, perform the analysis and state whether the beams would be able to meet serviceability limits to hold the load. If the beams did not meet the serviceability limits students would also have to come up with a suggestion of what could be done to make the beams meet the serviceability limits just as a consultant would suggest. Each group was given a different set of parameters so that the results would be different between all groups ensuring they would complete their own analysis.

During the lab experiments, students could choose to test as many or as little beams as they chose to each week as long as they complete all of the tests by the end of the third week. To help keep students on track, it was required for them to turn in at least one of the beam worksheets each week to help keep them on track and keep any group from procrastinating everything to the final week of the project. After the initial explanation of concepts and the project directions, the instructors would walk around and answer student questions throughout the lab time.

Results

The overall efficiency of the problem based learning in the lab was evaluated by three methods: a) student surveys, b) grade comparison, and c) instructor observation. These metrics were used to provide insight for future implementations of the EML/PBL module in the lab as well as enhancing the learning environment for students.

a) Students survey: The anonymous survey was taken to better understand students opinion on what they do and don't like about the project as well as their impression on it how the new module affected their learning. The following questions were included in the survey questionnaire:

- What did you like about the project?
- What did you dislike about the project?
- Did you like working in individual groups?
- What would you have liked to know now that you finished the project?
- Were any parts too hard or easy?
- Was anything explained unclear?

- Do you feel the project helped you understand the experiments and material better or worse than the previous lab format?
- How well did your group work with the flexibility of the project?
- Are there any improvements you would suggest for this project?

In total 27 of the 42 students participated in the survey. Based on the survey, many of the students like that the lab project incorporated a real-world aspect to it as well as the increased flexibility compared to the more rigid traditional lab format. The dislikes had more sporadic answers with the one common answer being that students did not appreciate that the report was longer than the traditional lab reports. Some suggestions to the lab and comments about what students wish they had known revolved around them not realizing they could start on the report before every beam was completed and not realizing the report would take longer than an individual week's report from the traditional format. When comparing the hands-on aspect of the lab when working with their individual groups, 96% of the students preferred this method compared to the large group lab activity in the traditional lab format. Many students enjoyed the flexibility of the project, but some groups struggled with the flexibility due to procrastination. Groups struggling with the flexibility noted that they procrastinated which made the project a lot of work for a short period of time. Students in this lab come from many majors and range between sophomores to seniors so the range of experience in handling a project varied between groups. Figure 1 shows the results of how students felt like their groups did with the increased flexibility of the lab project.

When asked about the difficulty of the project, a majority of the students felt that the project was the right difficulty. Some of the parts that students felt were too difficult varied from a few students thinking the calculations were too difficult with the rest of the comments being all about different parts of the lab. Figure 2 shows the results of how the students felt about the difficulty of the project.

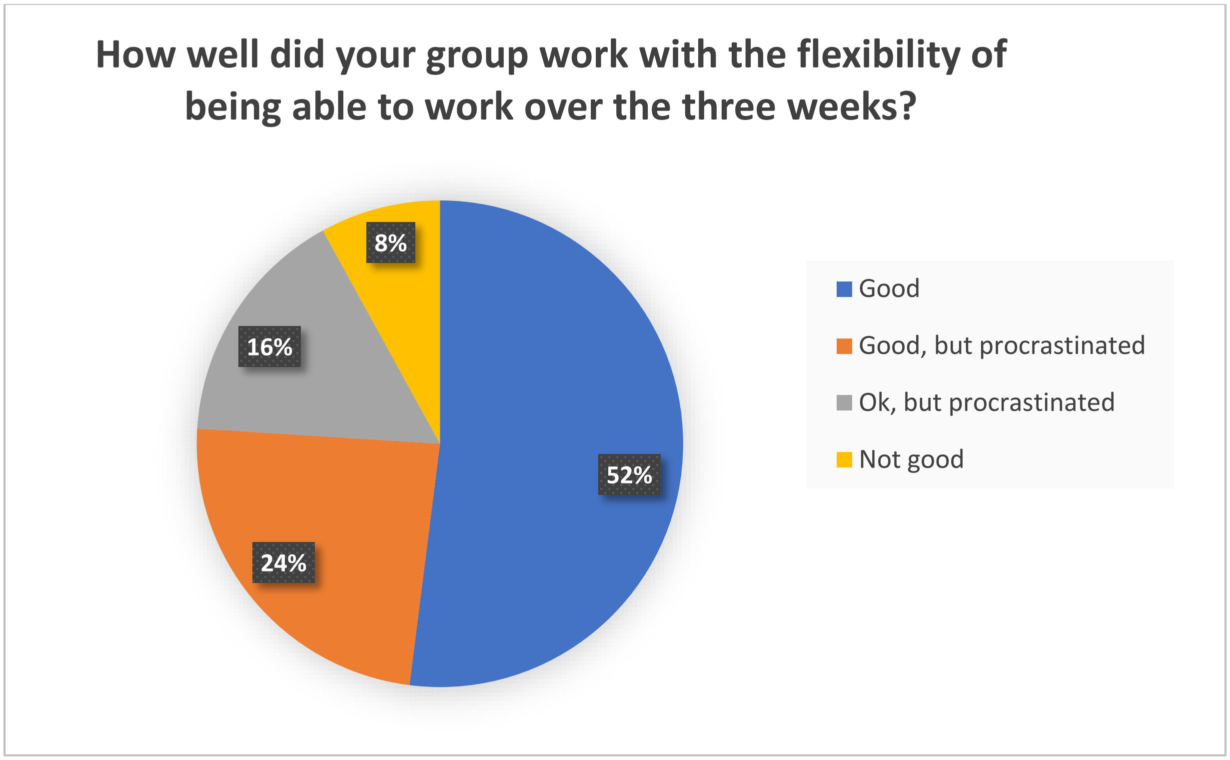

Figure 1: Student Survey Results on Flexibility of the Lab Project

Most importantly, the students evaluated how they felt the project and new lab format affected their learning. The majority of the students felt like the project improved their learning. The students felt like they got a lot more out of the experiments as well as learning how to apply them to a real-world problem. Figure 3 shows the results of the survey on student thoughts on the new lab format.

b) Grades comparisons: After analyzing the results of the survey, the grades between the two sections with the lab project and eight sections with the traditional format were compared for the three week period. The sections with the new lab format had an average of 87.4% while the sections with the traditional format had an 88.8% average. The range of the average scores in the sections with the traditional format was 86.1% to 91.7%. All the sections with the new lab format fell in between this range. These results are promising as it shows not to have greatly changed the overall grading distribution of the lab while improving the lab results. The scores do not reflect the level of knowledge and understanding of concepts between the two types of lab formats as the scores were calculated over different types of assignments and tasks.

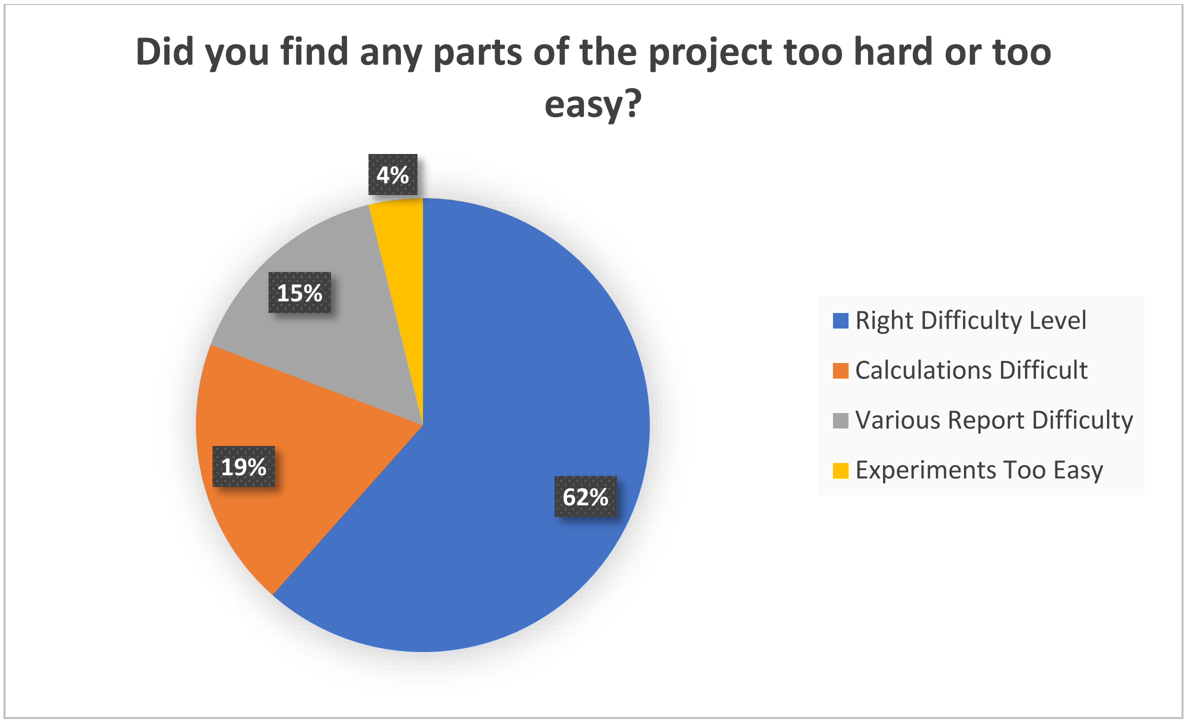

Figure 2: Student Survey Results on Project Difficulty

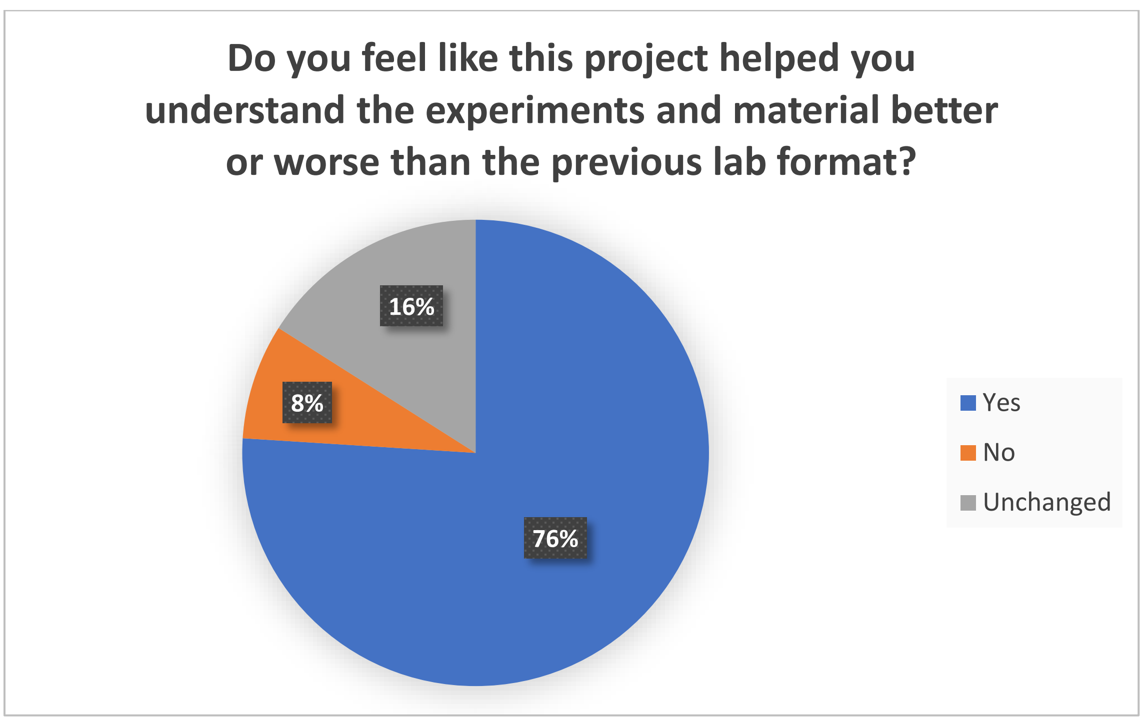

Figure 3: Student Survey Results of Learning Evaluation of New Lab Format

c) Instructors observation: The final evaluation of the lab project came from the observations of the instructors. The instructors noticed that in the new lab format students seemed to enjoy the more interactive lab format and hands on aspect. This lead to a greater learning and understanding of the experiments rather than the students just taking the data they wrote down to follow directions to write a lab report. The students noticeably showed more problem solving and teamwork skills within the lab which led to better class discussion and more interactive environment. Several groups also noted how they enjoyed the flexibility of the lab as some students had busy test weeks and could choose to work longer one of the other weeks. From an instructor viewpoint it seemed that the students enjoyed the lab more and the instructors enjoyed teaching the lab more by working to answer all the individual groups' questions.

Next Steps:

Problem-based learning through implementation of a project was shown to improve the learning and success of Materials Testing lab. The use of a basic framework to facilitate the problem-based learning showed to be successful in guiding students while still stretching their abilities. The new lab format added a more interactive aspect to the lab compared to the traditional format which students enjoyed. Students also enjoyed the ties to a real-world problem which helped increase interest and importance into the lab. The new lab format still aligned with the former grading system and topics. The new lab project met the goals set out at the beginning of the project by creating a problem based learning project, improving time management, writing, and teamwork skills, and having a more real world aspect compared to traditional labs. This course in the future will be looking to implement other problem-based learning techniques to other experiments throughout the semester based on the success of this project.

Following the successful implementation of the EML/PBL module in the first semester in the pilot sections, all the lab sections were redesigned in the next semester using the EML/PBL module. Minor changes were made based upon student comments and discussion among the instructors. One of these changes included offering a review of the rough draft of the report during the third week of the lab if students had already finished all the experiments. The second semester of the lab project proved to be successful just as the first. Upcoming work on the new lab format includes plans to add material on the project to the course website as well as implementing more problem-based learning techniques into other labs throughout the semester.

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