A Project-Based Learning Alternative for First Year Engineering Students

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Work in Progress: A Project-Based Learning Alternative for First Year Engineering Students

Abstract

Some say engineers are like dogs: if you throw them a bone they will go and fetch it. This crude analogy reflects some of the strong qualities of engineers, like problem-solving (fetching the bone), but it also reflects the fact that someone else has to not only throw them the bone, but must also choose which bone to throw. Educational techniques and courses for improving initiative, curiosity, creativity, and grit in engineers are becoming increasingly important to prepare them for the dynamic working environment they will find after graduation. In this work in progress, we expose the results of a freshman course that has been organized as a project-based learning (PBL) class. It is different from the traditional PBL approach by the fact that the students are required to propose their own projects. Each team, typically four students, receives a Raspberry-Pi and/or a NodeMCU for prototyping their ideas. The goal is to propose a project with an innovative solution. First year students usually, but not always, lack the skills needed to create their own solutions from scratch. However, they can, and are encouraged to, use the vast amount of resources available on the internet and adapt them to fit their needs. The results of this experience are evaluated by surveys and contrasted with control groups taking the same course in a traditional setting. This new PBL approach encourages students to think critically and creatively while gaining experience defining and solving a real engineering project.

Introduction

Engineers today are expected to maintain a combination of technical problem-solving capabilities, content literacy, and societal skills of communication, creativity, and collaboration[1]. Effective teaching practices and educational constructs have become an increasing focus in undergraduate engineering programs as universities continue to improve the quality of education for the next generation of engineers to meet these societal needs. Although extensive research has been done to connect how people learn with effective active learning methods in undergraduate courses, research continues to show that universities typically tend to lean on traditional lecture-style approaches[2 3 4]. This work-in-progress paper seeks to show how a Project-Based Learning (PBL) project implemented in a first-year electrical engineering course actively engages students in real-world engineering experiences and, as a result, increases creativity and motivation in students. This work is based on a course implemented at Universidad Técnica Federico Santa María in Chile and used as preliminary data to design a new study to be conducted at Texas A&M University.

1 Project-Based Learning

Project-Based Learning (PBL) is described as "an ill-defined task with a well-defined outcome situated within a contextually rich task requiring students to solve several problems, which when considered in their entirety, showcase student mastery of several concepts of various subjects"[5]. As engineering content is traditionally known for its complex, often abstract, scientific and mathematical concepts, it is important for learners to have concrete experiences with these concepts in order to make connections with their own prior knowledge, an idea aligning with Constructivist Learning Theory[6]. Students cannot be passive when learning science and mathematics as information is not merely transmitted by the instructor, but is constructed by the student as new information is evaluated and constructed based on existing ideas and beliefs[7]. So often engineering has been taught in a manner where repetition and remote memorization are vital for student success, yet a deep understanding and real-world connections to the concepts are lacking. Project-based learning provides students with concrete, hands-on experiences to develop content knowledge in a way that seek solutions for an end product benefiting a real user[8]. Providing students with opportunities to make connections between engineering content and real-world problems allows for a deeper understanding and purpose behind the learning.

In addition to providing students with the "why" behind the engineering content, project-based learning has been shown to have many other benefits for students, such as increased leadership skills, collaboration, and communication. Researchers have also found that project-based learning implemented in undergraduate courses provided students with opportunities to take ownership of their learning and share in leadership roles that improved the overall goals of the group[1 5 9 10]. By adjusting the roles traditionally set in undergraduate engineering and having students take ownership of their learning, supported by guidance and proper questioning from the instructor, goals such as communication and collaboration are promoted through an active learning environment and real-world projects.

2 Motivation in Engineering

Developing an understanding of intrinsic and extrinsic motivators for students in an engineering setting is vital when assessing the pedagogical methods of an instructor or a course. Motivation plays an important role in reducing student attrition as students who are motivated in their coursework have a higher chance of persisting in engineering[11]. A study done on undergraduate engineering students showed that, even though most students identified as being extrinsically motivated by grades, the teacher played an important role in influencing intrinsic motivation by inspiring students to learn content for the benefit of themselves[12]. Through the development of activities and delivery of content, teachers must consider the students' personal connections with the content in order to influence motivation. Student engagement is often directly linked to a connection with real-world applications and purpose, allowing students to investigate questions that are relevant to them[9 13]. If students have a say in the nature of the project or task, the student tends to be more motivated to complete the assignment[14]. When students see a direct connection between themselves and the problem, they have more interest in coming up with a solution and are more likely to persist through challenges. Researchers have shown that students' self-efficacy in science and engineering increase with tasks where students can see the value of the problem, driving students' motivation to persist[15]. It is important for teachers to provide opportunities for students to make these real-world connections and motivate students to see how a thorough understanding of the concepts will directly impact real-world problems.

3 Creativity in Engineering

Engineers are responsible for solving the problems of tomorrow and developing new and innovative ideas surrounding the critical issues in society, such as infrastructure, economic development, medicine, and the environment. Psychologists have done extensive amounts of research on creativity, including the importance of creativity and effective strategies for implementing creativity in education[16 17 18]. Creativity in engineering is often linked with innovation and, as a result, the authors of this paper have chosen to adopt Torrance's definition of creativity with the idea that creativity is the process and innovation results in the end product.

Within the context of engineering education, creativity has been identified as a vital component to producing innovative engineers, yet there has been limited research on effective implementation of teaching creativity in engineering[19]. Researchers have shown that creativity levels can be increased through practice[20]. For general education, researchers have found that several effective ways to influence creativity include increasing rewards of creative output, providing clear guidance during the creative process while also ensuring students that ambiguity is good, as well as encouraging students to search for multiple answers and learn from failures which provide opportunities to grow and adapt[21]. In addition, it is important for students to brainstorm ideas and collaborate during this iterative process. Researchers suggest that collaboration and brainstorming positively influences creativity and is a necessary catalyst for creative thinking[19 21]. With these ideas in mind, implementing opportunities to target creativity in engineering will benefit students and their abilities to produce innovative solutions.

But what is being done in undergraduate engineering programs to effectively implement creative practices[22]? Several programs have utilized Project-based and Problem-based Learning pedagogy to influence student creativity. One university in particular implemented PBL in a Mechanics of Structures course and found an increase in creative processes compared to conventional learning environments[23]. Many of these case studies found similar results where the open-ended nature of the projects and opportunities to collaborate increased group creativity[10 16 21]. What is important to note is that most of these case studies involve students in upper-level courses, including senior design or capstone projects. So how do students continually practice creativity if the number of opportunities to improve only occur during the later years of an engineering program? The authors of this paper explore a PBL pedagogical opportunity for first-year engineering students in an electrical and computer engineering course that they believe provides students with sufficient opportunities to expand their creative processes.The intention of this work-in-progress paper is to outline the process of replication of this PBL approach from Universidad Técnica Federico Santa María to be implemented in a research study at Texas A&M University.

4 Description of class structure and teaching methods

Prior to implementing a new project, it is first crucial to outline the teaching methodologies and principals that guide this kind of inquiry project. By first establishing the goals the instructor has for the students, there is more alignment with the selection of teaching strategies and methodologies. Some of the goals the instructor has for the students include:

- provide students with an overview of the Telematics major
- develop project-management and problem-solving skills
- implement information technology systems using a Raspberry Pi/NodeMCU
- increase understanding of analog and digital electronics through developing simple circuits
- increasing student motivation
- fostering student creativity
- building student independence

The methods that the instructor chooses to utilize should align with the goals, therefore supporting how research shows students learn. With this project, the instructor hypothesized that by creating a student-centered learning environment where students must propose their own projects, and the instructor takes a supporting role as opposed to the sole provider of knowledge, students would build independence, gain motivation, and boost creativity while gaining an understanding of fundamental tasks performed in the Telematics major.

The class consisted of 50 first-semester Telematics Engineering students at Universidad Técnica Federico Santa María. Telematics Engineering is similar to Electrical & Computer Engineering at most universities within the United States. Students are introduced to the project at the beginning of the semester and have the entirety of the semester to work on the project.

Throughout the course of the project, students will learn how to perform fundamental tasks in the Telematics major, similarly to how they would in a traditional course, but with the PBL approach. As these are first-semester engineering students, students are not expected to have any background in computer programming and electrical engineering.

To develop the project, a Raspberry Pi or NodeMCU microcomputer[24] is given to each team. This is an ideal platform to start developing the skills the students will need to acquire through their major. Since the students are not expected to have previous knowledge of computer programming, networking, the Linux operating system, nor circuitry, they are encouraged to look and use tutorials and materials available on the Internet as well as collaborate with their peers.

The evaluation is to the group as a whole, each team member will have the same grade. The evaluation has four instances throughout the semester:

- Proposing the project: The team has to come up with three ideas for a project after two weeks from the start of the semester. They have to choose one out of those three to start the development and planning process. The ideas are presented to the class, where peers and the instructor can make comments and ask questions, further solidifying their projects details.

Students propose three ideas and receive feedback. The instructor pushes and encourages students to come up with their own ideas. Examples from previous projects were provided to students who may find difficulty with this task. Students were encouraged to develop an initial idea and continually iterate to refine this idea throughout the first part of the semester.

- Progress report: A presentation in the middle of the semester where the teams show their progress, main difficulties, and modifications to the original plan. This encourages students to further understand the iterative nature of the creative process[21].
- Project report: The teams have to produce a final report about their projects, describing their prototype and instructions about how to reproduce it. This material is saved for future years as a repository for the course. Future students can utilize these instruction manuals for troubleshooting their own projects.
- Course projects fair: The course will end with a Projects Fair where the students show their projects implemented and working. Students display a poster alongside their working prototype and explain the project to visitors (faculty and students at the university).

During the semester, the instructor checks with groups on their project progress and team management structures. The instructor plays an important role in the facilitation and assistance of the students, providing support for project management and teamwork, as well as supporting students who seem to be struggling with the project. The role of the instructor becomes more of a mentoring/coaching role instead of a traditional lecturer. There is also a Teaching Assistant available to support students with technical concerns, like debugging and circuitry.

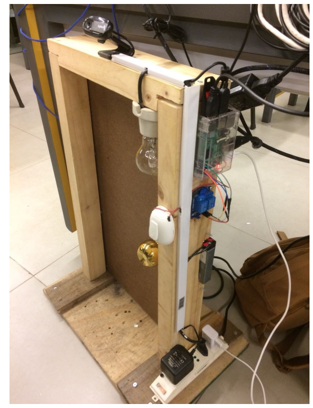
Figure 1 shows two project examples. Figures 1a and 1b are of a smart bicycle that has a speedometer, a heartbeat meter, LED array for display at the spokes, and a small LCD in the handlebar. The students manually crafted the sensors for both speed and heartbeat. The spokes LED array can display signs when the bicycle moves beyond a certain speed. Figure 1c is a smart door prototype. The door has a video camera (webcam) with a microphone and a speaker connected to the Raspberry Pi. Face recognition is performed directly on the Raspberry Pi using the Open CV API[25] to automatically open the door for registered users. The students also integrated messaging using the Telegram messaging app API; whenever someone rings the bell, a link is sent to the Telegram users. The link directs to a web page to perform a videoconference with the person at the door. The communication is realized using the WebRTC (Real-Time Communications) technology[26], therefore, there is no need for additional software beyond a recent version of a web browser.

5 Preliminary Results and Discussion

The students at the end of the semester voluntarily complete an anonymous survey about the class. The survey is a common end of course evaluation for the university and answered by the students in all the courses they take. The survey was not set up specifically for this study, but provides insight into how the authors can frame a future study. It is, therefore, a general tool to measure the students' perceptions about a course and the instructor of that course. The survey is a compound of 19 statements plus two open questions. These 19 statements are evaluated by the students using the following scale: 1 Never, 2 Sometimes, 3 Frequently, 4 Always. Table 1 shows

(a) LCD on a smart bicycle

(b) LED array on a smart bicycle



(c) Smart door prototype

Figure 1: Examples of projects realized by students.

the survey items that can be related to this work. The survey focuses on the instructor performance perceived by the student, and not much on the student's learning experience. In all of the answers (37 out of 50 students answered the survey), the average score was 3.8 and 3.9 out of a maximum score of 4. Those results, however indirectly, lead the authors to believe that the motivation, engagement, and collaboration were significant during the semester.

Table 1: Survey Results

Statement	**Average Evaluation**
The instructor created a favorable atmosphere for learning	3.8
he/she answered appropriately the students' questions	3.8
she/he motivated the students to acquire the course contents	3.9
he/she stimulates the student engagement in class	3.8
he/she promoted the student dialogues and discussion	3.9
he/she established a trusted relationship with the students	3.9
he/she was committed to the students' learning process	3.9

There are two open-ended questions in the survey where the students can freely elaborate on the course. Those are: ”What is your general opinion about the course?” and ”How can it be improved?”. Some of the answers are:

“The most complete course I have during the first semester. As first year student, the number of things learned during this class is so significant that one realizes if I want to continue in this major. It is demanding, because we have to do everything, but it is worth it. The instructor helps the students to develop their projects and make the best possible out of them.”

“Fresh and dynamic, promotes engineering as something that has to be founded over bases of creativity. ”

These comments reflect the motivation, engagement, and the importance of creativity the students perceived during the course. However, there are also some comments that are negative, the most common complaint is:

“The instructor seems not interested in teaching us, we have to learn everything by ourselves”.

This comment reflects how students typically enter an undergraduate program with an expectation of how they think they should be taught based on their prior experiences, but when met with a new way of thinking the student may be resistant. To assist students in successfully transition into this new style of learning, the instructors plans on providing insight at the beginning of the semester for the intentions of the pedagogical change. When students are made aware of the teacher’s pedagogical decisions, they may be less resistant to this new environment.

6 Future work/plan

The results of this study have helped set up future research on creativity and motivation in first-year engineering students at Texas A&M University. The instructor at Universidad Técnica Federico Santa María spent one year as a visiting professor at Texas A&M University in collaboration with first year engineering faculty. A new elective course is proposed to supplement the current curriculum and implement this research study. Currently, the first engineering course that students take at Texas A&M University, ENGR 102: ENGR Lab I Computation, is a 2-credit hour course to learn programming with Python 3. The new proposed course will be a 1-credit hour laboratory-based course taken concurrently that will mimic the course taught at Universidad Técnica Federico Santa María. First-year engineering students at Texas A&M University are general engineering majors; they have not selected their major yet and will be a mix of different disciplines and backgrounds.

The proposed course will follow the same methodology as the original course – students will work in teams and take initiative to propose their own projects. The course will complement the first-year engineering program by encouraging students to use the Python skills they acquire in the current curriculum to develop a product with the Raspberry Pi (or equivalent technology) given to them. The first time the proposed course will be taught, it will be limited to 48 students for a total of 12 teams.

The proposed course will initially be co-taught by two instructors: one first year engineering faculty and one graduate student in engineering education. The first year engineering faculty will ensure that students are utilizing their knowledge gained from the rest of their classes as well as help direct students in their projects. Like the original course taught at Universidad Técnica Federico Santa María, the proposed course will use the PBL approach with the instructor serving in a supporting role. The goal is for the course to be student driven and encourage self-learning, with additional support as needed from the instructor. The graduate student will manage the research to study creativity and motivation of the students taking the course. This includes monitoring students’ performance and engagement, setting up and administering testing instruments, and analyzing the data to be collected.

The authors plan to use the MUSIC model instrument[27] to evaluate motivation, and the Abbreviated Torrance Test for Adults[28] to evaluate creativity. The MUSIC model focuses on student perceptions of motivating influences in the classroom (empowerment, usefulness, success, interest, and caring). The Torrance Test is a well-established instrument that focuses on divergent thinking and creativity. First-year engineering students that are not enrolled in the proposed course will serve as the control group, while students enrolled in the proposed course will be the treatment group. The first year engineering faculty that will teach the proposed course will also teach sections of the traditional course in order to minimize the effect of the instructor. Surveys will be sent to students at the beginning of the semester to determine a baseline, and again at the end of the semester to measure differences between the two groups. Peer evaluations will also be implemented to assess participation and individual contributions to the group project. Common exams are used in all sections of ENGR 102 and will be used as an individual assessment of content mastery. The overall goal of this work-in-progress study is to analyze the impact of a project-based learning curriculum on student creativity and motivation in a first-year engineering course.

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