Project-Based Approach to Intensify STEM Education Experience – A Case Study

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Abstract

The evolution of engineering made an impact role in technology. Innovations with recent technologies brought a new lifestyle and wide variety of benefits. The engineering is an important drive to bring the technological innovations, which raised the growth and prosperity of United States (US). To obtain the scientific approach and to develop the prototypes/models hands-on experience is one of the best ways that should be accommodated in traditional lecture or labs related to the course. Theoretical knowledge alone is inadequate to reach high standard or not well acquainted with the modern designs. To meet or serve the workforce for industry standards, the old pedagogies have to be updated along with the updates in science, technology, engineering, and mathematics (STEM). In this work, we present the statistics of a typical course lab, Microprocessor based system design lab. This lab is the combination of Assembly language as first part and C language with DEMOEM hardware as second part. The course is intended for undergraduate and graduate level students. The statistics depends on different attributes such as the student feedbacks from classroom course, lab, materials, etc. The other attributes included are grades, team/group achievements, research motive, etc. In this course, most of the students enrolled are first generation, the diverse background of students and the learning curves of the students are always challenging. Considering that, new techniques are adapted/upgraded every year to better improve the standards and outcomes of the course and also developing exercises in lab.

Keywords: Project-based approach; student feedback; team-project; microprocessor-based systems; STEM education;

Introduction

The outcome of any engineering course and/or the graduated student should reach the standards of industry and must capable to address future challenges. However, the method of enhancing the STEM education success is not simple as the constructed assumptions. The growth of engineering education grants the solutions for distinct problems through scientific approach. Hands-on experience eases the scientific approach and acts as a major trademark for STEM education growth (Pusca, D et al., 2017). In fact, there are several objectives in STEM education, such as to develop the solutions to diverse fields within economic range, time frame, instant/critical solving skills, vision, intensifying lifespan of technology, etc. Some of the above attributes can be addressed at university level and few can be addressed at Research laboratory/Organizations. In a university the students range are from undergraduate level to graduate level (Masters and PhD). Mostly, the strength of undergraduate students in number is eventually high compared to graduate level. The enrollment also has an impact based on the department and the highest enrollment is in Computer Science, which is 17.6% by 2015 and it has a potential annual growth since 2007. Likewise, Computer Engineering is 16.2%, and Electrical/Computer Engineering is 21.3%. The enrollment in Masters degree also increased, which is 32.2 % in Computer Science, 20.4% in Computer Engineering, 18.8% in Electrical engineering (Yoder B.L., 2012). For graduate level students, especially Master's degree, they can opt for complete course work, or project, or thesis. The choice of project/thesis requires research attribute. As they start their first step in research at Master's level, they may loose more time and eventually, the result/output may not be extraordinary. If they know the basics of research at undergraduate level (Padmaja, A et al., 2015; Petrella, J.K. and Jung, A.P., 2008), they can pick up the concepts faster and thus they can save the initialization time of research at Master's level. This method ultimately boosts the purpose of STEM education.

The success of core/basic courses can be improvised when the labs are assigned to that course (Feisel, L.D. and Rosa, A.J., 2005). The design of labs in terms of complexity really makes a massive mark, it also explains how well the course reached the students. Mostly, 10 to 12 labs are assigned to a course, and the complexity starting from introductory (easy) to advanced level. Some of the tools used at university level are also practiced in industries and so it can be an advantage, when the students excel in those tools (Abramo, G et al., 2012). When the results are satisfactory, then the designers in industry try to implement as hardware by following the roadmap. The students work in individual or group according to the course requirements. Students gain theoretical knowledge from class and when they practice the theoretical concept in lab, then they will know the challenges that are not expected in theory. This practice will develop better skills such as practical thinking, spontaneous thinking, applying new methods to solve the bugs, analyzation of problems. The students upon completing the labs, the proficiency develops and then they are capable of handling complex tasks.

The courses such as Microprocessor based system design needs a hands-on experience lab to exercise better from the theoretical knowledge. Microprocessors are widely used in different commercial applications. So, the industries look for the students, who have practical knowledge along with theory (Davies, A.C., 2013; Goettler, R. and Gordon, B., 2009). It is a challenge to instructor, to bring a student who can meet the standards of an industry. Hands-on experience brings the comprehension to students and so then can be aware of multiple connectivity of resources. One of the big challenges is adapting hands-on experience to each student. However, it is not simple to claim that every student is aware or capable. As we know the popular quote, the practice makes perfect. The outcome of any course and/or lab is majorly relied on the students' hard work. It is the responsibility of an instructor to make sure that every student follows the course as well as lab materials and make sure that students are practicing/reviewing the provided material. The other challenge is how a project is integrated to hands-on experience lab.

In this work, we are sharing the techniques or pedagogies we integrated in traditional teaching pedagogies (Kersten, S., 2018; Felder, R.M. and Silverman, L.K., 1988). This paper explains the statistics of Microprocessor based system design lab, which is considered between 2014-2018 that are offered in fall semesters. The statistics were analyzed and then the labs are modified based on students' feedback (SPTE) and from the grading statistics. The lab has 10 experiments in total, which is divided into two parts. The first part comprises 5 labs, and these are executed on IDE68K tool by writing the code in Assembly Language. The IDE68K suite is compatible to assembly or C programs and can be executed on built-in simulators (Topaloglu, T. and Gürdal, O., 2010). The second part needs C language and a DEMOEM hardware. This hardware with hands-on experience brings more advantage and eases the theory understanding. To bring the better outcome from students, where they are capable to compete with the requirements of industries, continuous development of teaching pedagogies is applied. The result/outcomes are satisfactory. However, there will be still an improvement when traditional teaching pedagogies are updated and/or developing hybrid teaching pedagogies (Bringle, R.G., 2017).

The following sections explains the proposed approach, feedback evaluation, and conclusion. The labs that are in first part are performed individually, and the second part is performed as a team/group. Finally, the same team will be exploiting a topic for the project within the scope/connection to the course. The evaluation of each student is based on their individual work and based on his/her contribution in team for the labs as well as project.

Lab: Part-01

IDE68K: Integrated Development Environment for 680x0 Microprocessors

The IDE68K suite integrates the entire process of editing, compiling and/or assembling Assembly or C programs written for the 68000 family microcomputers and running either on built-in simulators or on an external microcomputer system connected to a personal computer through a serial port.

Using IDE68K Suite, we perform (develop and simulate) the following Labs:

Lab 01: Get acquainted with 68000 family microprocessors and IDE68K suite
Lab 02: Implement 68000 Assembly language sub-routine
Lab 03: Capture and handle 680x0 exceptions and interrupts
Lab 04: Program I/O devices for 680x0 microprocessors
Lab 05: Program 680x0 internal timer to generate interrupts
Lab 06: Compare the executable files from Assembly and C Programs

Note 1: Make sure directories are set properly (see Figure A below).

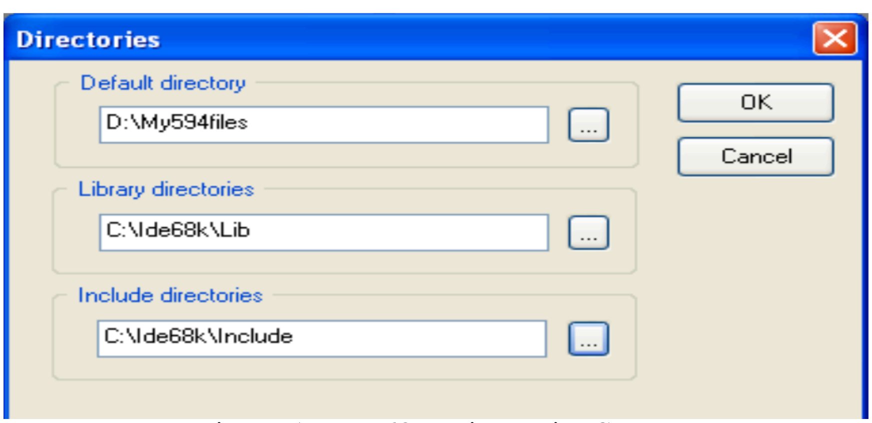

Figure A: IDE68K Directories Setup.

Default directory: where .ASM file is stored; .LST and .HEX files should be created here.
Library directories: (depends on the installation, for C) where the .lib files are stored.
Include directories: (depends on the installation, for C) where the .h files are stored.

Lab: Part-02

CodeWarrior Development Studio

CodeWarrior (NXP CodeWarrior 2019) is an integrated development environment for the creation of software that runs on a number of embedded systems (Wolf, W. and Madsen, J., 2000). CodeWarrior Development Studio is a complete IDE that provides a highly visual and automated framework to accelerate the development of the most complex embedded applications. Currently, CodeWarrior supports C, C++, and Assembly programming languages.

Using CodeWarrior Tools, we perform (develop and implement) the following Labs:

Lab 07: Get acquainted with CodeWarrior software and DEMOEM board (blinking LED)
Lab 08: Manipulate digital output and input (Pushbutton + blinking LED)
Lab 09: Manipulate analog input and output (ADC + DAC/PWM)
Lab 10: Moderate programing (Sensors in Midterm board)

For each part of the lab, initially a sample template with related sample code is provided to students. Then the students work on their tasks individually or as a group according to the instructions given by the instructor. After completing the second part of lab, students as a group are engaged in project. The project uses the hardware that is provided to students as part of the lab from department/university. Students are encouraged to buy additional components, as required to complete the project.

Proposed Approach

In engineering, mostly when related to computer science/engineering departments, the courses curriculum designed or offered should be more related to industry requirements (Asaduzzaman, A et al., 2013, May, E. and Strong, D.S., 2006). If not, the students stay behind the modern technology and they may not be successful in current trend. So, the STEM education is encouraged, where the standards of teaching at university level should fulfil the requirements of industries. They are several challenges in meeting the standards of industry as they always update according to the market. The hardware as well as the course designs must be updated that can meet the requirements of industry.

The other challenges include students' concentration, students preparation in prior for the lab. Initially, in Fall 2014, few questions about the lab are asked to students at random. This practice helped/alerted the students to prepare ahead before attending the lab. To attain better outcomes, several approaches are blended periodically. This course is an intermediate level, where it has a lab-based format and foster collaborative training. The lab manual is posted in Blackboard and it is open to all the students enrolled in that course. So, with the material provided online, they come to lab that highlights ideas, allows to think in diverse, experimenting in a satisfactory approach to complete the lab. To enrich the student's interest, several discussions are conducted in teaching class and lab. The students are always encouraged to participate with more effort and enthusiasm. These approaches not only help individual, it also reflects the improvement as a team.

In Fall 2015, at the start of every lab, students as a team were asked few questions randomly to make sure the students follow the course as well as labs. The other tasks by the students are as usual. For the first lab, lab instructor demonstrates about the IDE68K tool, basically how to run and debug the programs. The programs in this tool can be simulated either in command line mode or in virtual simulator. After completing the task of each lab, to encourage the students and bring more interest in them few extra points are added for few labs.

In Fall 2016-2018, prior to the start of every lab, quiz is conducted, and it is individual to every student. Even though the students do the programming for each lab in a group, they must do the quiz as individual. This practice made everyone intensive and made everyone prepared to do the lab. We divided the grading points for the quiz as well as lab. In first part of lab, every student performs individually, and in the second part, for the hardware, students are formed into groups. After completing the labs from second part, one make-up lab is allocated and so the students can perform any missing labs from 1 to 10. As we know, every class is a mixture of students with different intelligence levels. It is very hard to design a course considering the mixed type of students. To initiate the deeper knowledge and develop critical thinking, extra bonus point tasks are provided in each lab. But they will be considered as extra bonus points, this practice will bring the interest in students and so they can be pro-active in accomplishing the tasks. This practice really brought the good feedback and great outcome. It means, the students' abilities are enhanced, when compared to the previous batch of students that is between 2014-2015.

Finally, theory to practical (TTP) technique is implied when they enter labs class (Macías-Guarasa, J et al., 2006). Then the knowledge gained from theory and practical leads to next level, that is implementing the project and this procedure is called as From Theory and Practice to Project (FTPP). This phase helps the students not only in proficiency but also helps them in engaging as a team. The project chosen by the group should be documented and presented using PPT at the end of semester, that is obviously in final week. The project work is also graded and given weight points for each phase of project. In the middle of the semester, the students as a group must come with their own ideas to the instructor and submit a documented proposal that is less than 3 pages. By reviewing the proposals, the instructor accepts or rejects the project idea .The instructor gives suggested changes, if their idea is permissible. The procedures in this lab brought the brighter outcomes compared to previous teaching pedagogies.

A Case Study – Microprocessor Based System Design Lab (CS 594L)

We use CS 594L (Microprocessor Based System Design Lab) where we apply the theoretical knowledge learned in class and perform the labs. CS 594 is a mandatory core course for BS in computer engineering (CE) program and a technical elective course for computer science (CE) and electrical engineering (EE) programs. Hence, we do have a mix of different backgrounds. In this case, it is difficult to design the course that can be easy and/or knowledge transferrable to everyone.

CS594L Lab Outline

CS 594L has quiz, lab assignment, and project activities to evaluate students' performance. The outline of CS 594L course for fall semesters between 2014-2018 is presented in Table 1.

Table 1. CS 594L Lab Plan for a Fall Semester

Week	Labs/Activities
1	Lab 01: Get acquainted with 68000 family microprocessors and IDE68K suite
2	Lab 02: Implement 68000 Assembly language sub-routine
3	Lab 03: Capture and handle 680x0 exceptions and interrupts
4	Lab 04: Program I/O devices for 680x0 microprocessors
5	Lab 05: Program 680x0 internal timer to generate interrupts
6	Lab 06: Compare the executable files from Assembly and C Programs
7	Lab 07: Get acquainted with CodeWarrior software and DEMOEM board (blinking LED)
8	Lab 08: Manipulate digital output and input (Pushbutton + blinking LED)
9 Fall Break	DEMOEM Development Board; CodeWarrior Software; "Blinking LED" – the first Microprocessor Based Embedded System;
10	Lab 09: Manipulate analog input and output (ADC + DAC/PWM)
11	Lab 10: Moderate programing (Sensors in Midterm board)
12	Lab 11: (Optional) Happy Birthday Song
13	Lab 12: (Optional) Elevators
14 Thanksgiving Break	Guest Speaker and/or Industry Visit;
15	Make-up Lab
16	Project Development
Final Week	Project Presentation / Report Submission by Students (one per group);

Assessment and Results

The results presented in this section are based on the feedbacks from the engineering students enrolled in CS 594 course in fall semesters from 2014-2018. BS in CE students take CS 594 as a mandatory core course. A total of 200 students enrolled in CS 594 course for fall semesters. Students' feedbacks are collected during the SPTE and ABET evaluations before the end of the semester. The evaluations are done according to the year as well as an average of 5 years. However, the results on average of 5 years is presented in this paper.

Students' Feedback during ABET Evaluation

The following two outcomes are assessed in fall semesters 2014-2018.

Outcome A: Why this course is important and what is the goal/objective of the course?

Outcome A: Does the quiz in prior to the lab experiment helps in completing the lab exercise easily?

Outcome B: Students become capable of learning assembly language programming, using NXP DEMOEM board hardware and software to develop and test microprocessor based embedded systems.
Outcome B: Does the lab project enhances the knowledge on NXP hardware/software?

The questions, rubric for each question, and students' feedbacks are summarized in Table 2.

Table 2. Students' Feedbacks during ABET Evaluation

Question	**Rubric**	**Result**
(Outcome A) Why this course is important and what is the goal/objective of the course?	Question based on classroom lectures/discussions	90% of the students answered this question satisfactorily.
(Outcome A) Does the quiz in prior to the lab experiment helps in completing the lab exercise easily? Agree or disagree; explain why?	This question was scored either agree or disagree.	90% of the students agreed.
(Outcome B) Students become capable of learning assembly language programming, NXP DEMOEM board hardware and software to develop and test microprocessor based embedded systems. Agree or disagree; explain why?	This question was scored either agree or disagree.	90% of the students agreed. The remaining students disagreed.
(Outcome B) Does the lab project enhances the knowledge on NXP hardware/software? Agree or disagree; explain why?	This question was scored either agree or disagree.	85% of the students agreed. The remaining disagreed. Students suggested they need more time.

Using the SPTE evaluations, and considering the suggestions from students, the level of complexity in quizzes, and labs are modified. Also, few topics theory are reorganized according to the students suggestion. The timeframe for the project is enhanced by properly assigning the tasks of the project in earlier classes and assigning the tool kits in advance. This practice improved the outcome in labs as well as team-project.

Conclusion

The skills and experiences required in industries are changing with the development of new and emerging technologies. The conventional curricula for engineering (and STEM) education are no more capable of preparing students to handle the upcoming industry challenges. Studies suggest that course-based research experience and a combination of project-based learning with cooperative learning are promising for modern engineering education. In this work, we present a case study how the labs are designed and the kind of tasks that are included in each lab. By designing and developing microprocessor based embedded systems students get hands-on experience. Students form groups for team-projects; each group of students is encouraged to find a topic for their project. This approach is expected to motivate students to continue researching in the related areas even after the semester ends. With the tests such as quiz, optional labs and evaluations (such as SPTE and ABET evaluations), students' feedback are collected for assessment of the proposed approach. Based on the laboratory observations, the proposed approach helps students involve more with the course materials and improve their academic performance and helps in understanding the needs and standards of the industry. According to the SPTE and ABET evaluation outcomes, the proposed approach has potential to enhance the learning experience in STEM education. Learning in groups has additional advantages; it helps reduce the demand for resources such as development boards and software licenses.

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