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Microcontroller Laboratory practices through project-based learning

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Abstract: This paper discussesa course in microprocessor and microcontroller system design in electrical engineering education to facilitate the student learning outcomes through hands-on projects, simulations based onlow-cost platform. This course aimed to develop design and technical skills along with communication and team management skills. A project-based learning (PBL) approach was taken into consideration. Students were asked to work on a mini design project. The main focus of the course was on laboratory, where they combined learning of microcontroller, control systems and power electronics courses.Students developed the hardware prototypes using 8051 microcontroller and they were introduced open source hardware like arduinoand also encouraged to work on such platform which enabled them to undertake a range of design activities. The students with same wave length came together to form groups. The groups were given a time span of a semester to complete their undertaken project task. Evaluation of this course was obtained from students, staff, and an external examiner, and the results show that the PBL achieved its educational objectives.

Keywords: Design laboratory courses, hands-on-practice, outcome based teaching-learning, project-based learning (PBL), Continuous Assessment, Attainment

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1. Introduction

The transistor was invented by WilliamSchokley Jr. and his colleagues in Bell Laboratories inthe late 1940s, which is considered as start of a new era.In earlier days' vacuum tubes were used, due to reliability, consumption of more power and its bulky size, research and development efforts put in solid state devices. The basic idea was to use semiconductor devices to control the current using small impurities. In 1960s integrated circuit (IC) technologies were introduced. IC is one in which number of transistors or components can be fabricated on a single silicon chip. Later, in 1970s first microprocessor was developed for calculation purpose.

Then the growth of different types of processors and microcontrollers from various manufacturers were started and rapidly grown in decades. The growth was not only in manufacturing but also in their features regarding memory size, speed of operation, communication and many more. This growth had opened the door for the field of embedded systems for all kinds of domestic and industrial applications. Due to adopting embedded systems in the engineering applications the efficiency, reliability, flexibility, performance were increased and consequently the human efforts and process time has been reduced. So, this field required skilled man-power. The challenge of educational institutes isto cater the human resource with certain skill-sets to full-fill the needs of industry.

The microprocessor and microcontroller are the base courses for understanding embedded systems. Today, there are numerous high speed processors and controllers, but the basic architecture for all such devices are similar and which is taught in undergraduate studies.The need of the time is to effective utilization and selection of appropriate processor or controller for a particular application. In recent times, different active learning strategies have been implemented for teaching microprocessor and microcontroller course.One of the key features of these methods is the 'training and education'or 'hands-on-experience' in laboratory for the theoretical understanding of microprocessors[1]–[3]. Various active learningstrategies, such as problem- or project-based learning, havebeen applied in order to stimulate students' motivation andaccomplish more learning outcomes [4], thereby requiringadditional laboratory facilities, larger budgets, and more timeand commitment from both students and teachers.

Problem-based learning (PBL) was implemented for second year undergraduate students for microcontroller systemlaboratory course by Hedley and Barrie [3]. Though the lectures provided the fundamental knowledge and a number of case studies, thefocus of thecourse was the laboratory where the PBL model was applied.The authorsconcluded in their paper that the course was successful, but they alsopointed out several limitations, such as students' having little confidence in their ability to approach a complex open-endedproblem, uneasiness with being a member of a team, and lackof adequately trained people to support the students.M. Abdulwahed and W. Balidinvestigated to check whether the project based learning would enhance students' learning outcomes and engagementwith an embedded system course. In their strategies, they divided students into two groups namelycontrol and experimental. Thecontrol group was taught in the conventional way, which is attending thelaboratory session only, while PBL pedagogical methodology was implemented for the experimental group. For the second group, they were assigned weekly problems to solve during andafter each laboratory session. The results showedthat the experimentalgroup got upper hand on the control group. Also, it was seen that the motivation and skills sets were enhanced[5].

In recent times, many of the recent microprocessor and microcontroller courses have adopted various active learning methods under outcome based education (OBE).Most of the instructors include well-planned formal laboratory hours orpredetermined experiments, but the problem with such thing is that students followthe course plans somewhat passively. This predetermined structure of course plan can prevent students from controlling theirindividual, needs-based learning, and can lead to adverse effect onthe advantageous of active learning methods. Inaddition to get the hands-on experience in the laboratories, the courses haveused industry-developed or department-developed hardwaresystem boards or modules [1]–[6].Use of educational set-ups or kits would save student time and reduce the costof hardware preparation and also will help to understand the concepts up-to certain level. However, at the same time, suchmodules may prevent thorough understanding of, and giveless experience in, microprocessor and microcontroller based design since bothhardware and software are essential for any embedded systemdesign. Course-Mini projects provides the new dimensions of course delivery and assessment methods of student learning in core Laboratory course, attainment of course learning outcome (CLOs) and program outcomes (POs) through cooperative teaching learning activity [7], [10],[11].

2. Course Objectives and Outcomes

Microprocessors and microcontroller laboratory (EE3551) course is a one credit course in the curriculum for third year (T.Y.) B.Tech electrical engineering undergraduate program. The course demands for higher understandings and skills for any electrical engineering student to acquire. It is not easy to take more than one such course during one semester curricula for students. Students have to study architecture, instruction sets and interfacing application of both, microprocessor 8085 and microcontroller 8051. Another limitation is various courses during one semester time span, student study times or limitations in infrastructure or resources.So, the challenge is to foster a course that can provide basic knowledge, analytical skills, practical skills, design experience, and self-learning capability for different processors or controllers. Three course objectives were adopted for the microprocessors and microcontroller laboratory courseas given below:

On completion of this course students shall be able to:

1. Develop of assembly and/or C level programs and providing the basics of the processors.

2. Interfacing the external devices to the processor according to the user requirements to create novel products and solutions for the real-time problems.

3. Assist the students with an academic environment aware of excellence guidelines and foster lifelong learning needed for a successful professional carrier.

The learning outcomes such as knowledge application, problem analysis, team-work skills, communication skills, project and finance management skills, design experience, self-leaning capability along with ethical responsibility should be reflected in the course since the educational objective of Department of Electrical Engineering, at RajarambapuInstitute of Technology (RIT), Sakharale are as given below:

Electrical Engineering graduates will be:

Table 1. : Program Outcomes (POs) of Department of Electrical Engineering

Sr. No.	Program Outcomes (POs) Statements
PO1	Apply knowledge of mathematics, science, and electrical engineering.
PO2	Design and conduct experiments, as well as to analyse and interpret data.
PO3	Design a system, components or process to meet desire d needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.
PO4	Function on multidisciplinary teams.
PO5	Identify, formulate, and solve electrical engineering problems.
PO6	Demonstrate professional and ethical responsibility.
PO7	Communicate effectively at work.
PO8	Understand the impact of electrical engineering solutions in global, economic, environmental, and societal context.
PO9	Engage in life-long learning.
PO10	Use the techniques, skills, and modern engineering tools necessary for engineering practice.
PO11	Apply the knowledge to evaluate contemporary issues with project and finance management skills.
PO12	Participate and succeed in competitive exams.

PEO1: Apply knowledge and skills to pursue successful career in power sector, manufacturing and process industries.

PEO2: Utilize expertise to become an academician, practicing engineer and entrepreneur to serve the society, ethically and responsibly with concern to environment.

PEO3: Engage in lifelong learning to seek excellence in professional life.

To meet the program education objectives, program outcomes (POs) have been defined considering the graduate attributes (GAs), are given in above table.

The course learning outcomes were developed in line with the objectives defined above. These outcomes also addressthe industry needs.

The relation between program outcomes (POs) and course outcomes (COs) is depicted in the following table.

Table 2. : Course Outcomes (COs) of MPMC Lab (EE3551)

Sr. No:	**Course Outcomes (COs):** On completion of the course, the student will be able to:
CO_EE3551_1	Create a template program, compile it, and then build the executable file.
CO_EE3551_2	Examine the effects of executing many of the 8085 and 8051 instructions by tracing the execution of a program in GNUSimulator and Keil for microprocessor and microcontroller respectively.
CO_EE3551_3	Write their own program in assembly language for 8085 and 8051.
CO_EE3551_4	Write the steps they go through to perform their tasks.
CO_EE3551_5	Apply their programming knowledge (assembly and C) for real time applications.

1. Course Development Strategies

Table 3. : CO-PO Mapping

COs \ POs	a	b	c	d	e	f	g	h	i	j	k	l
CO_EE3551_1	✓	✔								✔		
CO_EE3551_2		✔		✔						✔		✔
CO_EE3551_3		✔	✔		✔					✔		✔
CO_EE3551_4	✔						✔	✔				
CO_EE3551_5		✔	✔		✔				✔	✔		

The strategies followed to design the course are listed here.

1) The course should provide undergraduate students with general understanding, practical skills, and embedded system design experience on microprocessor and microcontrollers in one 13-week semester.

2) The course should be an intense, student-centred active learning course based on PBL.

3) The course should foster lifelong self-learning skills that can be used later for more advanced and complicated embedded system design.

4) The formal class time of 3 hours per week is for explanation of theory, instructions, demonstrations, and project discussion, without any formal laboratory hours.

5) The course instructor provides clear and concise outlines of thefundamental concepts and functions and plays a role as a facilitator [8].

6) Demonstrations of basic functions and the integrated development environment (IDE) are given by a student mentor in the classroom immediately after the professor's lecture.

7) Ill-structured PBL is the core of the course, where students decide what more they need to learn to accomplish their projects;

8) The course encourages students to get together at their convenience to learn as a group (cooperative learning) through an open-ended project.

9) The project room, with basic electronic equipment and tools should be available as on required for students.

10) All students should make his/her own hardware on bread- board or PCB using a microcontroller and use this for their hands-on training and group project.

11) Student teams should freely choose an appropriate project topic that will be reviewed and confirmed by the professor to ensure that it meets course objectives and learning outcomes.

12) The course should strongly motivate students and provide a supportive environment.

Table : 4. Mapping of Course Objectives with Strategies

Course Objectives	Strategies
1) Develop of assembly and/or C level programs and providing the basics of the processors.	1, 4, 5, 6, 9, 10
2) Interfacing the external devices to the processor according to the user requirements to create novel products and solutions for the real - time problems.	2, 7, 8, 9, 11, 12
3) Assist the students with an academic environment aware of excellence guidelines and foster lifelong learning needed for a successful professional carrier.	2, 3, 7, 8, 9, 10, 11, 12

Table 2 shows the mapping between three course objectives and the strategies derived for the course. The first object is mainly related to classroom activities i.e. teaching-learning activities in the classroom for basic concepts and skills. The objectives two and three mainly focuses on the student centric learning activities through program based learning (PBL). The strategies were reviewed with respect to course objectives, course learning outcomes, resources available, infrastructure and overall curriculum structure.

The strategies derived above mainly focuses on 'hands-on-experience' for students with simple microprocessor or microcontroller based system built by a student using any resources available.

4. Microprocessor and Microcontroller Application Course:

A. Teaching-Learning Activities and Detailed Plan

The course structure consists of various learning activitieslike: discussions or lectures, think-pair share, brain storming, peer-instructions, handouts, demonstration, self-learning and student project presentations as shown in detailed plan in Figure 1. The first column shows the topic or experiment to be performed, second is the mapping with respective course outcome. Third column depicts the level of blooms' taxonomy and practical number in fourth. The schedule of example demonstration by student mentor or schedule of project work and project presentations in the fifth column, and the last sixth column describes the main activities that should be done during corresponding weeks, either by course instructor or students.

Sr. No:	Sub Outcomes/ Topic Learning Outcomes/ Question Bank/ Lab Experiments: Labels to the right indicate: CO=Course Outcome, BL=BLOOMS level. On completion of the practical on a topic, the student will be able to:	CO	BL	Practical No:	Planned/ Delivered Date	Activity/ Mode of Delivery/ Instructions
1.	**TITLE: Arithmetic and Logical operations using µP 8085.** **AIM:** Write a program using 8085 and verify for: (a) Addition of two 8-bit and 16-bit numbers (b) Subtraction of two 8-bit and 16-bit numbers **TLO:** Employ the arithmetic instructions in various operations using 8085 µP	1	3	1	2nd Week of July	Discussion of various instructions; Moodle – instructions, Think-Pair-Share; 8085 microprocessor kit, Introduction to Software
2.	**TITLE: Data Transfer operation using µP 8085.** **AIM:** Write a program using 8085 and verify for: (a) Transfer data of 10 blocks from one memory location to another. And perform the addition of those ten numbers and store at one location (addition is up to 9-bit) (b) Perform multiplication, division of two 8-bit numbers **TLO:** Solve some mathematical operations using 8085 µP	3	5	2	3rd and 4th Week of July	Discussion of various instructions and algorithm; Brain storming, Think-Pair-Share; 8085 microprocessor kit , Demonstration on Software
3.	**TITLE: Code conversions using µP 8085.** **AIM:** Write a program using 8085 and verify for: (a) Convert two BCD numbers in memory to the equivalent HEX number using 8085 instruction set (b) Convert HEX number to its equivalent BCD number using 8085 **TLO:** Write and verify the program using µP Kit and Software software for code conversion	2	4	3	1st Week of August	Discussion of various instructions and logic; Brain storming, Think-Pair-Share; 8085 microprocessor kit , Verification on Software
4.	**TITLE: Programs on finding largest/smallest number using µP 8085.** **AIM:** Write a program using 8085 and verify for: (a) To find the largest number in an array of data using 8085 (b) To find the smallest number in an array of data using 8085 **TLO:** Write an ALP to find smallest and largest number in a given array	3	3	4	2nd Week of August	Discussion of logic flowchart algorithm,; Brain storming, Peer-instruction; 8085 microprocessor kit , Verification on Software
5.	**TITLE: Parallel port interfacing using 8255 with µP 8085.** **AIM:** Study of PPI interface 8255 with 8085 **TLO:** Explain the interfacing of PPI 8255 with 8085	4	2	5	3rd Week of August	Discussion; Handouts, Lecture; 8085 and 8255 Interfacing
6.	**TITLE: Parallel port interfacing using 8255 with µP 8085.** **AIM:** Interfacing output device (LEDs) with 8085 using PPI 8255 **TLO:** Demonstrate the interfacing of output (LEDs) with 8085 using 8255	5	5	5	4th Week of August	Discussion; Handouts, Demonstration; 8085 and LEDs interfacing using 8255
Sr. No:	Sub Outcomes/ Topic Learning Outcomes/ Question Bank/ Lab Experiments: Labels to the right indicate: CO=Course Outcome, BL=BLOOMS level. On completion of the practical on a topic, the student will be able to:	CO	BL	Practical No:	Planned/ Delivered Date	Activity/ Mode of Delivery/ Instructions
7.	**TITLE: Arithmetic and Logical operations using µC 8051.** **AIM:** Write a program using 8051 and verify for: To perform two 8-bit numbers addition, subtraction, multiplication and division using 8051 instruction set **TLO:** Perform different arithmetic operations using 8051 µC instruction set	2	3	6	1st Week of September	Discussion of various instructions; Moodle – instructions, Think-Pair-Share; 8051 microcontroller kit , Introduction to Keil
8.	**TITLE: Programs on ascending/descending order using µC 8051.** **AIM:** Write a program using 8051 and verify for: To arrange the given set of numbers in ascending and descending order using 8051 instruction set **TLO:** Write the steps or algorithm to perform the given task	4	2	7	2nd Week of September	Discussion of various instructions; Brainstorming; Keil
9.	**TITLE: Program on generation of square, saw-tooth and triangular wave using µC 8051.** **AIM:** Write a program using 8051 and verify for: To interface DAC with 8051 to demonstrate the generation of square, saw tooth and triangular wave **TLO:** 1. Write an ALP and CLP using 8051 µC Kit and Keil Software 2. Demonstrate the results / waveforms in Proteus Software	2	3	8	4th Week of September	Discussion of logic flowchart algorithm; Brain storming, Peer-instruction; 8051 microcontroller kit, Programming on Keil and Verification on Proteus software
10.	**TITLE: Programs on LED / 7-Segment display using µC 8051.** **AIM:** Write a program using 8051 and verify for: Programs on LED / 7-Segment display using µC 8051 **TLO:** Interface 7-Segment LED using 8051 µC in Keil and verify in Proteus	5	3	9	1st Week of October	Discussion of logic flowchart algorithm; Demonstration, Peer-instruction; 8051 microcontroller kit, Programming on Keil and Verification on Proteus software
11.	**TITLE: LCD interfacing using µC 8051.** **AIM:** Write a program using 8051 and verify for: Program to interface LCD using µC 8051 **TLO:** Interface LCD using 8051 µC in Keil and verify in Proteus	5	3	10	2nd Week of October	Discussion of logic flowchart algorithm; Moodle, Peer-instruction; 8051 microcontroller kit, Programming on Keil and Verification on Proteus software
12.	**TITLE: DC motor interfacing using µC 8051.** **AIM:** Write a program using 8051 and verify for: Program interface DC Motor using µC 8051 **TLO:** Interface DC Motor using 8051 µC in Keil and verify in Proteus	5	4	11	3rd Week of October	Discussion of logic flowchart algorithm; Self-learning; 8051 microcontroller kit, Programming on Keil and Verification on Proteus software
13.	**Project-based learning (PBL)**	1,2, 3,4, 5	5	--	2nd Week of July to 2nd Week of October	Discussions/ Lecture, Demonstration,; Self-learning/ Peer-coaching,; Student presentation

Figure1: Teaching-Learning Activities over a Semester

A. Hardware System

The technological development in microprocessors and microcontrollers, for example, the programmers working on the in-system programmer (ISP), lead to learn and built embedded systems easily and quickly. It is a good simple microcontroller system that can be quickly and inexpensively built for most microprocessor courses. An inexperienced student can collect several electronic parts on a printed circuit board (PCB)with an ease.

Figure 2 and 3 shows the simulation diagram for the system, and Figure4shows the hardware system on abreadboard and a PCB, respectively. The circuit was chosentaking into account simplicity, cost, the functions to be discussed in lectures, and the possibility for further extension. Students used to write the code in assembly language or embedded C language for programming and then generate the '.hex' code from the 'keil' software. This machine code was then used in simulation software – 'proteus' for verifying the logic.

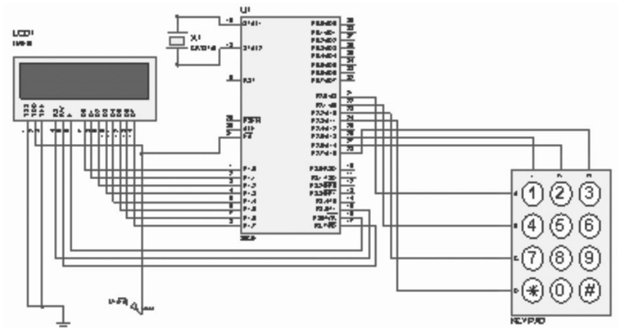

Figure 2: Interfacing Keypad and LCD with 8051

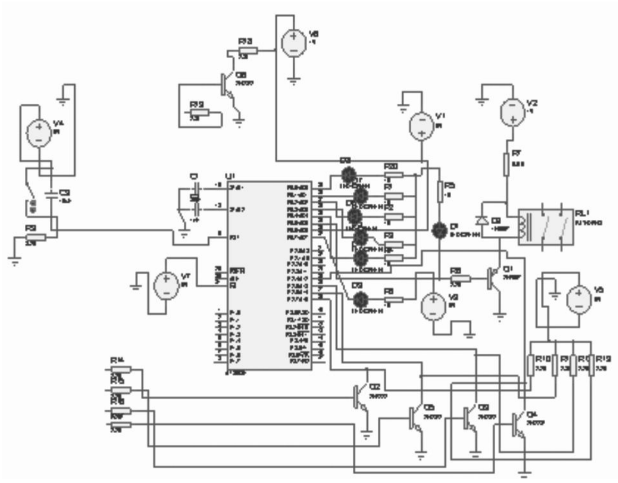

Figure : Level controller using 8051

The 8051 family microcontroller was chosen for its simplicity, easiness to learn, use and popularity in the industry. Different development boards were used to realize the simulated project works by the students. Simple development boards used for particular applications are as shown in Figure 4.

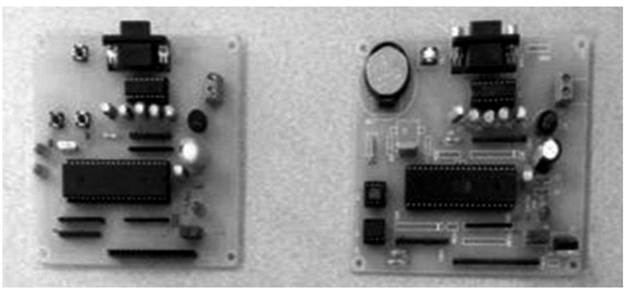

Figure : 8051 Application development board

The general development boards are used for demonstration of experiments and hands-on-experience for the students. There were two development boards, one of 8051 microcontroller and other PIC development board. These development boards have on-board keypad, LEDs, pins for interfacing LCD, seven-segment display etc. These development boards are as shown in Figure 5.

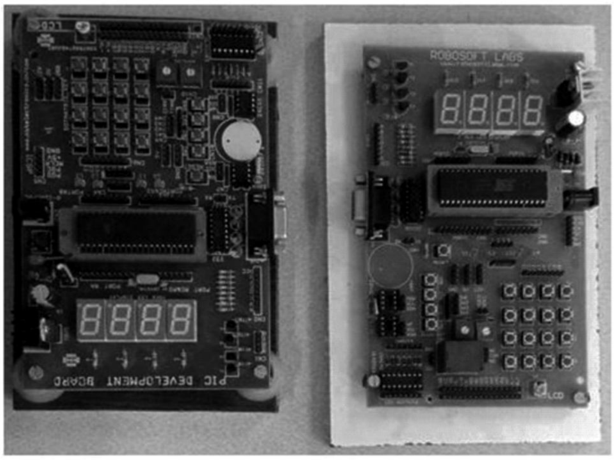

Figure 5 : 8051 and PIC Microcontroller development boards

To program the microcontroller students use the universal programmer present in the department, through which they used to load the '.hex' file into the ICs. The universal programmer used for dumping the code into the ICs is shown in Figure 6.

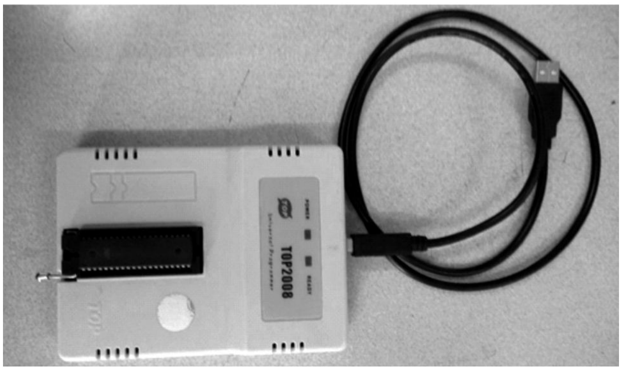

Figure 6 : Universal programmer

The electronic components for the hardware system andtoolboxes containing drivers, a cable cutter, digital multimeter,soldering kits, and breadboard are pre-prepared, ready to bechecked out by students at the beginning of the semester.

A. Lecture, Demonstrations and Projects

Course instructor used to discuss about the course content and guide in regards with projects. After the discussions, a student mentor demonstrates a fundamental example closely related to the lecture content. Withhis/her own controller breadboard system connected toa computer, the mentor demonstrates and explains how toprogram, how to download the program, and how to executeit in the classroom.Another role of the mentor student is to give advice to studentsor to answer questions in the project room, when students are building their ownhardware system.

The project based learning (PBL) is the core of the microprocessors and microcontroller laboratory course.PBL also had main meansof achieving the learning outcomes; the project plays themost important role in the course outcomes as well as achieving the graduate attributes. Generally, 3-4 program outcomes are achieved through theory courses, and to achieve remaining program outcomes project plays a vital role. As discussed earlier, many microprocessor or microcontroller related courses are based on hands-on-experience, most of them havewell-planned or structured problems or projects, which limits students'autonomy and reduces its advantages for students' autonomouslearning. Here, however, a fully open-ended approach anddiscovery-based learning [9] are adopted, asking students todetermine their project topic, the direction of projects, and whatthey have to learn to accomplish the project in a cooperativelearning environment.

Details of Project-Based Learning:

Phase I: Formation of the group

1. Like minded students will gather and form group
2. Strength of group will be 3-4
3. Pre requisites regarding understanding process, architecture and instructions of 8085 and 8051 to be provided in prior to identifying problem and to understand the process for course mini-project through Moodle.

Phase II: Problem Identification and Literature Survey

1. Identification of any system, process and submission of one-page synopsis.
2. Identifying problem related to course from the process or system.
3. Literature survey and finding references

Phase III: Problem Analysis and Solution

1. Understanding the exact process with all corners of technical aspects (keen observations of real time process and situations).
2. Analyse different parameters, variables.
3. Write the algorithm/ draw flow-chart for the system/process.
4. Write the program and simulate it to verify the outcomes.

Phase IV: Software/ Hardware Implementation

1. Listing out components required with proper ratings
2. Cost estimation from various suppliers (observe market scenario, prefer low cost)
3. Circuit design and implementation in simulation environment.
4. Real time implementation
5. Cost effectiveness: optimization of cost and optimization of components

Phase V: Report and Presentations

1. Writing the report of the course mini-project.
2. Final presentation in-front of other batches and faculty.

The rubrics were developed for assessment and evaluation process, as shown in figure.

D. Evaluation

The students are evaluated on their performance on learning activities in the laboratory hours, their regularity, and mainly on their project results. Three internal faculties, course instructor and students evaluate the project presentation and demonstration. There is end-semester examination (ESE) where external examiner evaluates the students' performance. The assessment and evaluation is as per the table 5.+

Table 5 : Assessment and Evaluation Scheme

Assessment & Evaluation Scheme	Weightage
In-Semester Evaluation (ISE) 50% a. Continuous Assessment Sheet (CAS)	15%
b. Programming Test I (PT I)	05%
c. Programming Test II (PT II)	05%
d. Project-Based Learning (PBL)	25%
End Semester Exam (ESE) 50% e. ESE	50%
TOTAL	**100%**

Sr. No.	Rubric	1-Bad	2-Poor	3-Average	4-Good	5-Excellent
1.	Problem identification	No prototypes, process	Implementing prototype of existing process without considering real time facts	Implementing prototype of existing process with considering real time situations	Developing µP/µC based solution for manual process but not considering real time situations	Developing µP/µC based solution for manual process considering real time factors
2.	Literature survey / Gather information from multiple sources	Limited information with random data	Uses limited information, based on common knowledge and opinion.	Uses limited information, based on facts or expert opinion.	Uses wide range of information, based on some evidence.	Uses wide range of carefully evaluated, evidence-based information.
3.	Analyze and evaluate information And Formulate solution/ Defend position/ Problem Description	No solution	Needs to identify solution/ position or explain reasoning, no counter arguments, when appropriate.	Needs to focus solution/ position, some distinction between points, argument poorly supports solution/position.	Identifies appropriate solution/position, distinguishes between points, and argues using coherent perspectives.	Identifies appropriate solution/position with sharp distinction between points, coherent perspectives including strengths and limitations.
4.	Demonstration with the use of appropriate tools and techniques – virtual and physical	Not used any tools	Relevant tools were not used	Tools were used but could not make the best use of them.	Tools were used and could meet the requirements.	Tools were used to most and clear design was done that demonstrates the system in detail.
5.	Presentations (eye contact, confidence)	Casual presentation	Student could not introduce well in professional manner and delivers all of report by reading presentation with no eye contact.	Student could introduce in casual manner and occasionally uses eye contact, but still reads most of report.	Student introduces well in professional manner and maintains eye contact most of the time but frequently returns to notes.	Student maintains eye contact with audience, rarely returning to notes.
6.	Knowledge of topic demonstrated during presentation, and responses given to other members	Very limited knowledge	Student does not have grasp of information shows limited knowledge and no deeper understanding	Student is uncomfortable with information shows some knowledge, but limited understanding	Able to demonstrate noteworthy and emerging understanding	Student demonstrates full knowledge (more than required) and expertise; shows clear understanding
7.	Report	Very poorly organized	Poorly organized; no logical approach; Unable to find specific ratings and details of the components used and method of approach.	Some organization; Points jump around; beginning and ending are unclear. Details are somewhat sketchy. Do not support topic.	Organized; points are somewhat jumpy; sense of beginning and ending. Some details are non-supporting to the subject.	Good organization; points are logically ordered; well-mannered beginning and end. Supporting details specific to subject.

Figure 8 : Rubrics for Project Based Learning (PBL)

The mapping of various internal evaluation schemes are mapped with the course outcomes to find the attainment of each course outcome.

Table 6. : Correlation between Evaluation Schemes and Course Outcomes (COs)

Sr. No.	Evaluation Scheme	CO1	CO2	CO3	CO4	CO5
1.	CAS	✓		✓	✓	
2.	PT I		✓	✓		✓
3.	PT II		✓	✓		✓
4.	PBL	✓	✓	✓	✓	✓

5. Results and Discussions

The attainment of course outcomes is done through two modes; one is direct attainment, which is achieved through the average of individual marks obtained by the students in each evaluation schemes mentioned above. The other one is indirect attainment which is calculated from course end survey.

For the Microprocessors and Microcontroller (MPMC) Lab (EE3551) course, the student feedback was taken from end-of-semester course evaluation surveys i.e. course end surveys. Out of 73 registered students, 71 before the course redesign, and all 71 registered students after there design, participated in the surveys. Figures8 and 9 compare the feedback before and after the course redesign given by the student opted this course.

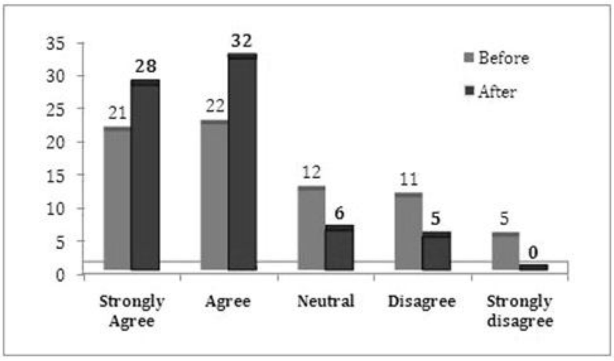

Figure 9: Survey result comparison before and after the course redesign for "Laboratory activities helped me to learn about microprocessors and microcontroller." Sample sizes are 71 (before) and 67 (after).

The course end survey (CES) taken for the course outcomes (COs) of EE3551 from the students feedback is shown below for two course outcomes results in Figure 10-11.

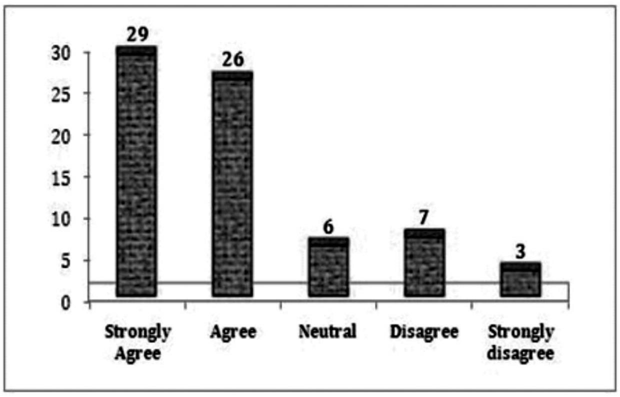

Figure10 : CES results for "Create a template program, compile it, and then build the executable file. "Sample size =71

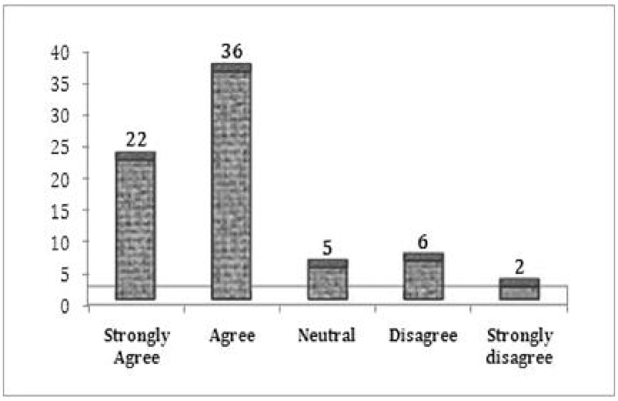

Figure 11 : CES results for "Apply their programming knowledge (assembly and C) for real time applications. "Sample size =71

Figure 10 and 11 shows more encouraging results taken on course outcomes. More than 77%of the students who took the course claimed that they could create a template program, compile and then build it for any applications. Similarly survey is conducted for all five course outcomes.The direct attainment is

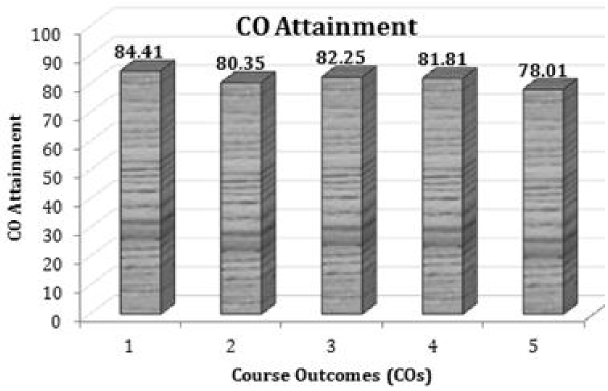

Figure 12: Course Outcomes (COs) Attainment

calculated from continuous assessment sheets (CAS) of each student, programming tests (PT-I and PT-II) and project-based learning (PBL). The average of thesein-semester evaluation schemes are taken into consideration to calculate the attainment of each course outcome and is as depicted in the figure 12.

The total attainment of course outcomes is obtained from 80% of direct and 20% of indirect attainment.

Microprocessors and micro controller course requires practical abilities, such as fundamental knowledge acquisition and applications, problem-solving skills, higher-order thinking, project planning and management skills, and self-directed learning, it seems that the students achieved the learning outcomes to a certain extent.

6. Conclusion

In this paper, a hands-on-experience in microprocessors and micro controller laboratory course using project-based learning (PBL) without a conventional laboratory was introduced. The course was composed of mainly four learning activities; lectures-discussions, program demonstration by a course instructor and student mentor, project presentation, and project execution in front of course instructor and other faculties. In the course, students had to build their own hardware system on a breadboard or printed circuit boards and learn how to program, download, and execute based on a student mentor's demonstrations. Students were also asked to choose their own design topic for their team project, using minimum guide lines provided by course instructor, and were encouraged to learn whatever necessary to accomplish the project autonomously with self-learning and peer-coaching.

The EE3551 course and its learning activities received a very good response from students; most of the students were attracted towards PBL activity. The course motivated students to participate more actively and to spend more time on their learning activities. The satisfactory level of the students in this course was above75% and voted for strongly agreed or agreed during the feedback at the end of the semester. The findings from overall teaching-learning activities of this course from course takers and fellow faculty, some improvements are required in terms of allotted time, advanced processors or controller. Including these constraints will help to improve the PBL activity furthermore effectively.

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