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An approach for attainment of relevant Program Outcomes through Microcontroller laboratory course

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Abstract: Embedded product design has emerged as an important area of study in the curriculum for undergraduate program in Computer Science. This necessitates the inclusion of hardware courses like Digital Electronics, Computer Organization and Microcontrollers as pre-requisite courses, in the lower semesters. This helps students to develop keen interest, skill and proficiency in the area of Embedded system design. This also helps them to compete with peers from other engineering branches in the domain of Embedded Systems.

Here we present a set of activities, their related outcome based assessment techniques and outcome based strategies applied to the laboratory course on 8051 Microcontroller laboratory in Computer Science & Engineering at the IV Semester level. This laboratory was an extension of the hands on experience the students had in the course on Digital Electronics in the III Semester. The laboratory course on 8051 Microcontrollers was based on the usage of 8051 compatible Atmel 89C51ED2. The course was designed to consist of initially, conducting simple programming exercises using 8051 assembly language and then simple interfacing exercises using Embedded C programming. Later when they developed some proficiency and familiarity in 8051 environment student' teams were made to work on course projects which required them to design and build projects using 8051 or any other microcontroller of their choice. This promoted their self-learning, improved their knowledge of programming the microcontroller to interface with the outside world to develop useful applications and provide solutions to some common problems in society. This activity resulted in enhanced motivational levels amongst students, increased their involvement in the team and improved their knowledge due to self learning.

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1. Baground

Microcontrollers have been used in various applications in industries and domestic products. Examples of such products are digital camera, automatic or semi-automatic washing machines, microwave ovens, electronic voting machines, water level indicators, gas leakage detectors and many others. Inclusion of the study of Microcontrollers in the Computer Science curriculum for undergraduate students helps them build such products. The curriculum has to be designed to help students to understand assembly language programming, debugging, interfacing techniques and building applications.[1]. The educational process today has seen tremendous shift towards on-line teaching and learning environments [2]. This environment is most suited to theory courses which do not require any practical hands-on approach for it's through understanding. But it's effectiveness in handling laboratory oriented courses leaves much to be desired. Hardware experiments in particular can never be understood by watching lectures and on-line video presentations [3]. A number of online simulation tools have contributed to the engineering learning experience but they can never replace actual hands-on experiences and thus learning from one's own mistakes [4]. Hardware troubleshooting is another very important skill that the students should acquire at a very early stage which cannot be imparted through traditional on-line teaching methods [4]. In order to engage students cognitively it is very important for them to actively participate in the classroom learning activities. Today's students are capable of critical thinking and are good at self learning provided they feel what they are learning can be applied to solve problems. They prefer to work in teams in a student centered learning environment [5]. They are self-sufficient, resourceful and entrepreneurial problem solvers. Hence the onus is on the teachers to develop teaching strategies to maximize engagement and retention in the class. In this paper the authors have made an attempt to enhance the learning of students and thereby attain some of the program outcomes as stipulated by the National Board of Accreditation [6] through the laboratory course on 8051 Microcontrollers.

2. Introduction

8051 Microcontroller and it's applications is a very important course taught in the second year curriculum for undergraduate students of the Computer Science Program [7]. The objective of the course is to teach the students how to design microcontroller-based systems. The particular microcontroller used in this course at the present time is the Atmel 89C51ED2 [8]. This is a general purpose microcontroller that is simple enough for the students to learn its operation quickly and with on-chip peripherals that are sophisticated enough for covering a wide range of applications. The integrated development environment (IDE) used is KEIL µVision3 [9]. It supports assembly and Embedded C programming. Elements of the design flow such as editing of programs, compiling and flashing, debugging and reflashing of the microcontrollers are done in one development platform- Atmel Flip 2.4.2 [10]. The project board supports KEIL µVision3 and has basic electronic components such as switches, LED's, dc voltage supplies, LCD, hex keypad, analog-to-digital & digital-to-analog converter, temperature sensor, external interrupts and a breadboard for prototyping and is packaged as a Student Learning Kit (SLK) offered by Advanced Electronic Systems. This microcontroller course with the ALS-EMB-EVAL-03 kit is a viable approach for equipping students with the skills and tools that they need for prototyping embedded systems and for preparing them for their future design projects. The Atmel 89C51ED2 [8] have the following features:

- On-chip 64KB flash Program/Data memory
- On-chip 1792 bytes Expanded RAM (XRAM)
- On-chip 2048 bytes EEROM
- On-chip SPI interface
- On-chip 16-bit Programmable Counter Array
- Operating Frequency 11.0592MHz

The pedagogical approach to achieve the objective of this course consists of several stages. The first stage is to educate the students on CPU programming model, common addressing modes and assembly language programming [11]. This is done by lectures and by demonstration of the assembly program execution in the KEIL µVision3 debugger [9]. The debugger allows the users to see the source assembly program, the assembled program, the CPU registers, the contents of RAM and Flash, the data of the program and other information in a number of windows on one screen. The effects of assembly instructions on the CPU registers and memories are clearly demonstrated to the students in the debugger by executing sample programs line by line. The students gain further understanding of programming model, addressing modes and assembly language programming by performing a set of exercises with guidance [11]. The microcontroller course covers the fundamentals of microcontrollers with emphasis on hardware interfacing, software design and applications. Topics include microcontroller hardware architecture, assembly instruction set, addressing modes, memory map, general purpose inputs/outputs (GPIO) [11]. The next step is to educate the students on the microcontroller peripherals. This is done by lectures and labs. The particular peripherals covered include general purpose input/output DIP switches, timers, analog-to-digital and digital-to-analog converters, LCDs, hex keypad, serial communication interface and interrupts. In the lectures, the coverage of each of these resources begins with their functional description followed by detail explanation of the control, status and data registers (i.e., how to configure and use them).Programs were developed for showing the students the applications of the peripherals [12]. Execution of these programs in the debugger is shown to the students in the labs. The students can see clearly the benefits of these microcontroller peripherals. The application programs were written in both assembly and Embedded C, which are often shown side by side to the students so that they appreciate the differences and similarities in developing application programs in both languages. These programs are distributed to the students and they use them in their class projects later. Further, the students are required to configure and use the peripherals in the labs by writing their own programs in assembly and Embedded C. Students learned practical skills by doing the labs. They applied the lab skills to the construction of their projects. There were twelve labs for the students to do. The students had one week to complete every lab. The contents of the labs are briefly described below.

In the first lab the students were given a guided tour of the KEIL µVision3 integrated development environment. The students learned how to create and build their assembly and Embedded C programs, to flash the program into the AT89C51ED2 microcontrollers and to execute the program. In order for the students to understand the internal operations of a microcontroller and to be able to develop their own programs in assembly, the next three labs covered intensive assembly language programming and debugging assembly language programs in KEIL µVision3.The students also wrote many assembler subroutines that they would use later on in their labs and projects. The focus was then shifted from the CPU to the peripherals. The fifth lab covered the GPIO, which was our first topic for the peripherals. The students were taught how to configure various ports on the microcontrollers to function as input and output pins. Demonstrations of GPIO for sending signals out and reading signals in through execution of programs in assembly and Embedded C on KEIL µVision3 were given to the students. The sixth lab covered was LCDs. Students were explained the internal structure of LCD and it's interfacing with the 8051 for display of various messages. The seventh lab covered was interfacing of hex keypad to the 8051 which resulted in students building single digit calculator. The eighth lab covered the serial communication interface (SCI). The students were taught how to configure the control registers for setting various baud rates, modes of operation and data formats. They also learned how to use the status registers for checking the state of communication between the microcontrollers and the external device. Demonstrations were given to the students in class using the Serial Communication Interface (SCI) to communicate with a PC through a com port on the PC and showing how to display characters on a hyper terminal. The ninth lab was to learn how to configure and use the on-chip analog-to-digital converters. This topic was included in the syllabus so that the students would be able to use it for reading sensors such as temperature sensors, potentiometers, accelerometers and other sensors with analog outputs. This has enlarged the set of components that the student could use for their projects. In the lectures, the students learned how to configure the ADC control registers for various modes of operation such as single or continuous conversion, single channel or multi-channels operations, sampling rate, resolution, conversion time and other features. In the tenth lab the students learned how to use GPIO for reading incoming digital signals to the microcontrollers and for sending signals out of the microcontrollers using the on-chip digital-to-analog converter. Lab exercises included generating a sequence of pulses of varying duty cycles. The skills learned were applied to turning on and off dc motors and other actuators. The students also learned how to configure the on-chip PWM for generating pulse width modulated signals in the eleventh lab. They used the PWM for motor control. They built a microcontroller-based system that read an analog sensor input and proportionally controlled the duty cycle of a PWM signal. The PWM signal drove a motor driver chip that controlled the speed of a dc motor. In the twelfth lab the students were taught how to write assembly and Embedded C programs so that the internal and external peripherals can generate interrupts to the microcontroller.

3. Implementation

In depth coverage of theoretical basic concepts together with hands-on interfacing experience of various peripherals culminated in students being thoroughly prepared to build useful working models in the sixth week of the running semester [13]. Accordingly teams comprising of 3-4 students were formed. Each team worked on different pre-defined problem statements. Sample problem statements included Electronic voting machine, Solar-Powered Home Lighting System, Heart Rate monitor system, LPG gas leakage detection and protection, Smart energy meter, Line Follower Robot, Automatic Toll gate system, Password Based Digital Locking System Using Microcontroller, Train Collision Prevention and Signaling using IR. The students received help in selecting electronic parts, sensors, actuators and other components from the instructors. Periodic project updates and final project reports were required in addition to PowerPoint presentation of the projects. A good number of projects were successfully built for this course. Fig. 1 shows the implemented model for automatic toll gate system and Fig. 2 shows the model that was implemented for automatic room light controller. The project reports document that the students used the skills that they had learned in the lectures and the labs.

The NBA document [6] for undergraduate engineering program was referred and the following Graduate Attributes (also known as Program Outcomes) (PO) were selected for attainment through this course.

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization for the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of

mathematics, natural sciences and engineering sciences

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data,

and synthesis of the information to provide valid conclusions.

PO 5: Modern Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and complex engineering activities, with an understanding of the limitations.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

The attainment of the above POs was meticulously planned through series of activities spread over the entire duration of the running semester. These activities were assessed through Continuous Internal Assessment (CIE) which was accorded 80% marks weightage and Semester End Examination (SEE) which was accorded 20% marks weightage as shown in Table 1.

Table 1. Students Assessment through CIE + SEE

	Assessment	Weightage in Marks	Schedule
Continuous Internal Evaluation (CIE) (80%)	Written Tests (5x5 M) on theory and lab concepts.	25	week 2 to week 6
	Assessment1 -ALP	15	week 7
	Intermediate Assessment of Course Project (11th week) • Problem Definition • Design	15	week 9
	Assessment 2-Embedded C	20	week 10
	Simulation of circuit (course project) on Proteus	05	week 11
	Total	80	
Semester End Examination (SEE) (20%)	Course project		week 16
	Model Implementation	10	
	Presentation	05	
	Future scope	05	
	Total	20	

Reviews were conducted at different stages throughout the entire semester duration of 16 weeks. The phasewise activities and their corresponding assessment parameters along with marks weightage, addressed POs and Blooms Level (BL) is as shown if Table 2.

Table 2. Phasewise assessment

Sl.No.	Parameters	Marks	POs	BL
Phase 1: Written Tests on theory and lab concepts (Basic Knowledge & Design)				
Sl.No.	Parameters	Marks	POs	BL
1.	Proficient in demonstrating basics of 8051	10	1	L2
2.	Logically and syntactically correct program	15	1	L3
Phase 2: Assembly Language Programs (Programming proficiency)				
	Parameters	Marks	POs	BL
1.	Logically and syntactically correct program with proper documentation and indentation with no syntax errors	10	1	L3
2.	Completely executed program valid for all inputs and given modifications.	5	1	L3
Phase 3: Interfacing 8051 to peripherals using Embedded C Programs (Programming proficiency)				
Sl.No.	Parameters	Marks	POs	BL
1.	Identification of appropriate parameters of peripheral s and it's proper interfacing to 8051	5	2	L3
2.	Logically and syntactically correct program with proper documentation and indentation with no syntax errors	10	1	L3
3.	Completely executed program valid for all inputs and given modifications.	5	1	L3
Phase 4: Intermediate Course Project Assessment (Design)				
Sl.No.	Parameters	Marks	POs	BL
1.	Information is gathered from multiple, research - based sources	5	4	L3
2.	Understands the given problem statement by taking into account the limitations of the components and arrives at an appropriate solution.	10	2	L3
3.	Simulation of the designed circuit	5	5	L3
Phase 5: Final Course Project Demo (Model/Prototype implementation)				
	Parameters	Marks	POs	BL
	Model is completely working as per the proposed design during intermediate assessment.	10	4	L3
	Demonstrates effective individual and team operations, communication, problem solving and leadership skills.	5	9	L3

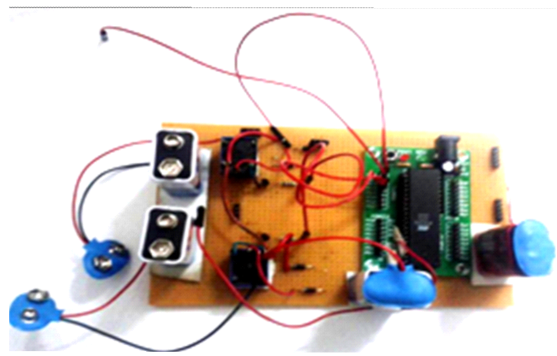

Fig. 1 Automatic Toll gate system

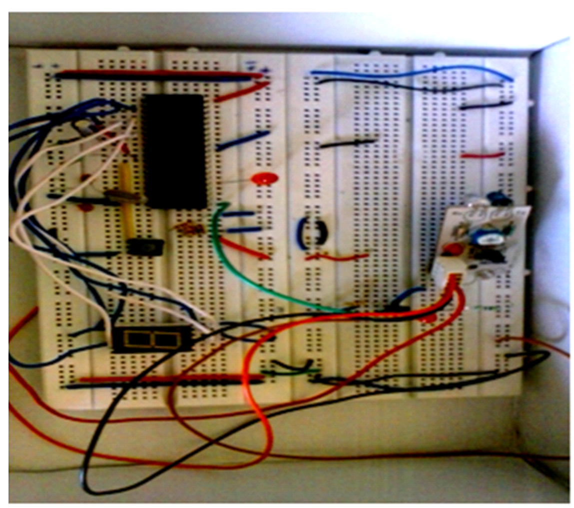

Fig. 2 Automatic room light controller

4. Results and Analysis

The attainment of results for all the planned activities for Continuous Internal Assessment (CIE) and Semester End Examination (SEE) is explained below. PO attainment for various reviews are mentioned below [14]

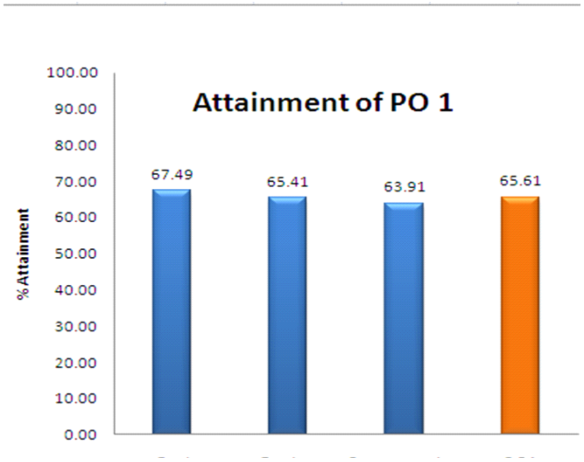

Fig. 3 Attainment of PO 1

As seen from Fig.3 the attainment of PO 1 is 65.61%. Five written tests each carrying five marks and two mid way hands on lab activities were conducted as part of this assessment. This shows that the students' basic knowledge, design and programming skills were found to be satisfactory. This score can be improved upon by strengthening the learning of pre requisite courses like Digital Electronics and Computer Organization.

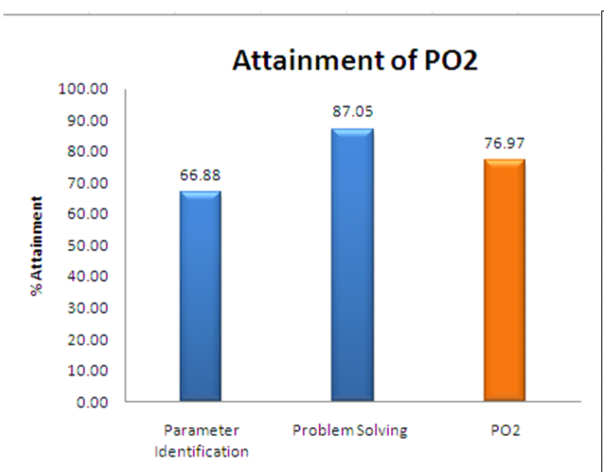

Fig. 4. Attainment of PO 2

As seen from Fig.4 the attainment of PO 2 is 76.97%. PO 2 was assessed during hands on lab activity and intermediate course project assessment. This shows that the students' are able to understand the given problem statement by taking into account the limitations of the components and can arrive at an appropriate solution.

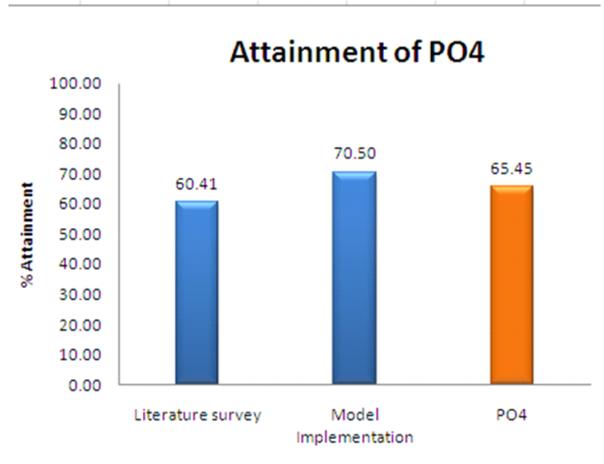

Fig. 5. Attainment of PO 4

The attainment of PO 4 is averaged at 65.45% as is seen from Fig.5. This can be attributed to the fact that the ability of IV semester students to survey available literature is limited and can be expected to improve as they move to higher semesters. However their ability to build models is found to be good.

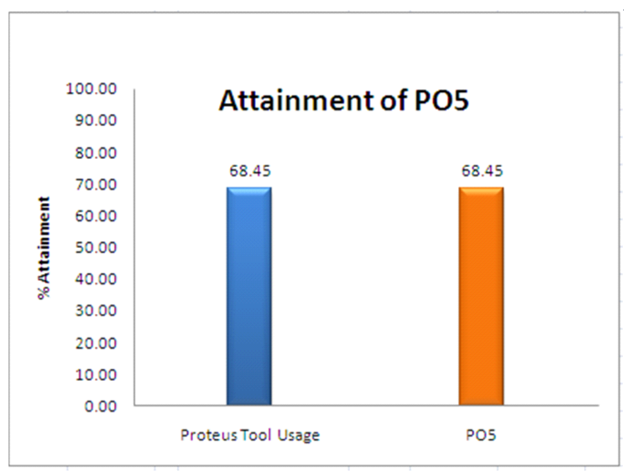

Fig. 6. Attainment of PO 5

In order to familiarize students in the usage of modern engineering tools, the Proteus Design Suite which is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules, was introduced. They used it for simulation of the prototype they had designed for their module. Fig. 6 shows that students could attain 68.45% for PO 5 which is fairly satisfactory.

As per the plan, the final course project was assessed in the semester end practical examination.

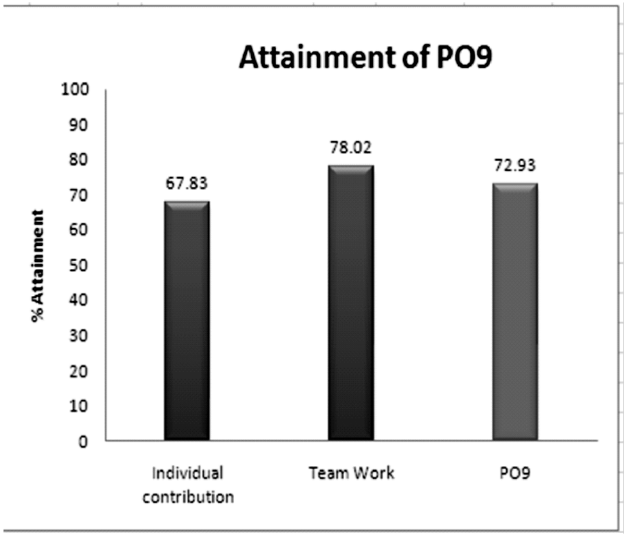

Fig. 7. Attainment of PO 9

\Individual contribution in the model implementation was carried out through blind peer review process. Each individual in the team was given an assessment peer review form where they were asked to assess the other team members with respect to certain parameters. Assessment rubrics for assessing team work were as shown in Table 2 and is 72.93% as shown in Fig.7.

5. Conclusion

This paper presents the results of implementing tutored continuous and final coursework in the teaching of microcontroller laboratory course in particular applied to interfacing 8051 to various peripherals using assembly and embedded C programming skills for students in a Computer Science and Engineering degree program. The fundamental assumption that professional students are able to apply both the knowledge they had acquired during lectures and laboratory activities and the applied knowledge they had discovered themselves was found to be true because this approach was found to have a positive impact on students in terms of concept understanding, motivation, presentation skills, confidence boosting, creativity, team work and innovative thinking. Different reviews conducted at various levels have helped students in continuous improvement of their knowledge, analysis design and conduction ability.

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