A HANDS-ON APPROACH TO TEACHING MICROCONTROLLER

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ABSTRACT

Practice and application-oriented approach in education is important, and some research on active learning and cooperative problem-solving have shown that a student will learn faster and develop communication skill, leadership and team work through these methods. This paper presents a study of student preference and performance while learning the microcontroller subject with a 2-day curriculum that emphasized on hands-on approach. The curriculum uses the PIC16F877A microcontroller and participants learned to develop basic circuits and several other applications. Programming was completed on the MPLAB platform. Results show that participants had better understanding in this subject after attending the hands-on course.

Keywords: hands-on approach, microcontroller

1. INTRODUCTION

Microcontroller subject is one of the compulsory subjects for Electronic Engineering undergraduate program [1]. Traditionally, this course was taught focusing primary on computer software and hardware architecture [2]. However, the advancement in semiconductor electronics nowadays changed the way industry solves manufacturing and process control problems. Many control problems can now be solved more effectively and reliably using microcontroller rather than using mechanical or electrical switching systems. The increased used of microcontroller in industries led to new trends in microcontroller education [2].

There are two teaching methods in teaching this subject which are traditional approach and alternative approach [3]. The traditional teaching method emphasizes direct instruction and lecture, seatwork and the student learn through listening and observation. In the Faculty of Electrical Engineering in Universiti Teknologi Malaysia, microcontroller subject is taught as a lecture in a classroom or lecture hall, for a period of three to four months. During the semester, students were taught theories about the internal architecture of microcontroller and how to use the microcontroller through programming with a simulator. At the end of the course, students may be given assignments to design or develop an embedded system using the knowledge they have acquired throughout the semester. However, due to time constraint and the lack of hands-on practice in class, students had difficulty in completing their tasks.

The alternative teaching methods emphasize on group activities, students-led discovery and hands-on activities. Learning microcontroller courses with real-world applications provides the opportunity of tackling problems which would not be normally encountered in traditional learning [2]. The hands-on approach of teaching in engineering curriculum must be exposed to undergraduate students since first year for them to retain in the coming year [4]. Several academicians also have proposed new method to teach microcontroller subject [5,2].

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Fig. 1: The 2-Day PIC Microcontroller: Hands-on course

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In Universiti Teknologi Malaysia, a 2-day “PIC Microcontroller: Hands-On” course was designed to complement the classic form of lecturing. Fig. 1 shows the facilitator discussing with two participants. Students have the option to attend this course if they needed to. During this course, the students have to construct and program a microcontroller based on tasks given. The level of difficulty ranges from elementary to intermediate tasks such as LED blinking to motor control.

The course had been conducted many times and had been improved over the time, but only recently a formal survey in the form of questionnaire was conducted to gauge the response of participants and investigate the effectiveness of the course. This paper describes and discusses the results of this survey.

2. METHOD

A total of 18 participants were involved in this case study. The participants attended a 2-day short course on microcontroller,

where 15 hands-on kit were handed to the students. Twelve participants were given individual kit to work on, while the remaining six shared the kit in pairs. All participants, either individuals or in pairs, were given the same tasks and each task had to be completed within 10-30 minutes.

All participants were between 18-32 years' old, with 12 male and 6 female participants. Their background included Medical Electronics, Mechatronics, Mechanical, Electrical and Computer Science. At the point of data collection, most of the participants had recently completed their undergraduate programs and currently working as research assistants in the university.

The course lasted 9 hours, starting from 8 am till 5 pm each day, with half hour break for tea in the morning and evening, and an hour break for lunch. During this microcontroller short course, the participant learned by actively completing allocated tasks rather than by passively absorbing information. Explanation of technical concepts preceded each task. Tasks were designed such that the students progressively applied what they had just learnt, and increased in difficulty from easy, medium to hard.

Delivering the microcontroller subject through a 2-day short course, with practical sessions, have its challenges:

1. The participants come from various backgrounds.
2. Most of the participant does not have much experience working with a microcontroller and had varying levels of competency in programming.
3. Time is too limited to cover an entire one semester subject syllabus.

Taking into consideration the factors above, we selected several major concepts to be discussed, that will help the participants to grasp smaller technical details while working on a solution to their tasks. The focus was on learning through practice.

Course outline

Day 1
Introduction to microcontroller
Assemble microcontroller basic circuit and use starter kit SK40C
Programming in assembly and C-language
Basic I/O: output (LEDs, 7segments, LCD)
Day 2
Basic I/O: input (switch)
Advance I/O: controlling motor (servo motor, DC motor and Stepper motor)
Demonstration

On day 1, we started the course by providing the student with MPLAB software from Microchip Technology Inc [6]. This was the platform on which source code for the tasks would be written. During the installation process, we showed some video clips of robotic competitions where participating robots were controlled using the microcontroller. The objective of showing the videos was to expose the participants to the variety of designs and applications that can be achieved with a microcontroller, e.g. how the robot can move with intelligence. Following the clips, participants were given short lectures on the basics of microcontroller and the supporting elements required to construct a basic working circuit. The supporting elements such as voltage regulator, oscillator and capacitors were provided for the participants to start building their own circuitry.

Simple programming using the assembly language was also taught. Participants were then given simple task such as making an LED (light emitting diode) blink at specified intervals, and progresses to multiple LEDs blinking with several blinking patterns. In the afternoon, participants were taught basic C language to replace the assembly language that was used in the morning session. SK40C PIC starter kit from Cytron Technologies [7] was introduced to the participants. This SK40C starter kit has built-in microcontroller, voltage regulator, oscillator and input-output connectors. This starter kit reduces the hardware configuration time for participants when trying to complete a task.

We started the 2nd day with short video clips of robots and automatic systems, ranging from straight-forward designs to sophisticated devices. From the earlier task of LED blinking, the participants progressed to more challenging tasks such as detecting inputs, directions of a servo motor, DC motor and stepper motor.

At the end of the course, all participants completed a set of questionnaire to state their level of expertise in microcontroller upon entry to the course, preferences and feedbacks. Participants were not required to state their names and details on the form. Responses from the participants were then analysed and presented in the results section.

3. RESULT

Participants were categorized into four skill levels:

(1) **no experience**,
(2) **novice**, who has learnt simple theory in class and has previously completed LED blinking projects using microcontroller,
(3) **intermediate**, who has experience in developing simple embedded system, and
(4) **advanced**, who has experience in developing complicated embedded system.

From the 18 participants, 9 had no experience, 7 were novice and the remaining was intermediate. There was no advanced participant in the course.

i. Teaching platform

Participants were asked to state if they prefer to be taught using (a) Only basic circuit, which they assembled on their own; (b) the SK40C starter kit or (c) combination of both platforms. As shown in Fig. 2a, 78% of participants preferred to be taught on both platforms, where they get to learn how to construct a basic microcontroller circuit from scratch, and then switched to simpler method of using pre-fabricated starter kit. 22% chose to be taught using only the SK40C starter kit, without having to construct their own circuit. No participants wanted to be taught

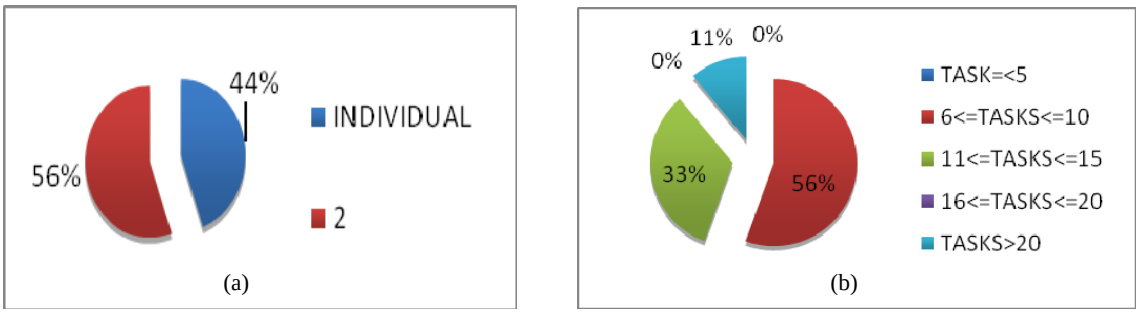


Fig. 2: (a) Percentage of participants with their preferred type of teaching platform (b) Percentage of participants with their preferred programming language

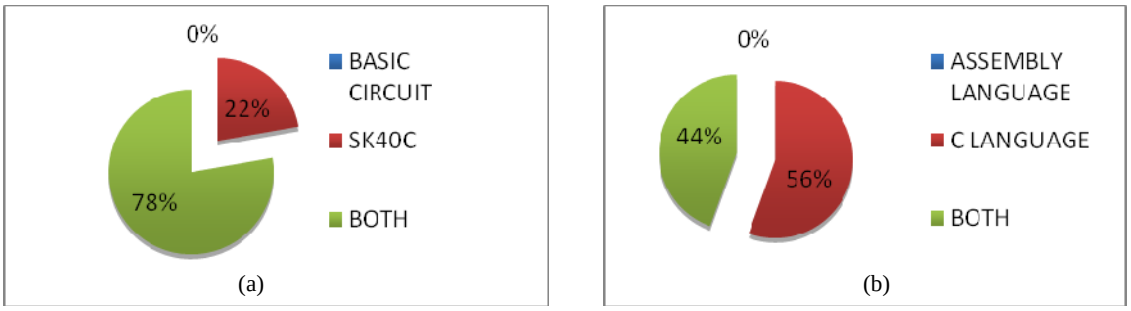


Fig. 3: (a) Percentage of participants with their preferred number of members in a group, (b) Percentage of participants with their preferred total number of tasks

using only the basic circuit. All the participants with no prior experience chose to be taught on both platforms. Four participants chose to learn only using the starter kit, two of whom were novice and the other two were intermediate.

ii. Programming language

56% of the participants chose to learn programming in only C-language while the remaining 44% preferred to learn both assembly and C-language to program the microcontroller (Fig. 2b). From the analysis of the survey, we found that 50% of the participants who chose to learn only C-language were novice, 20% of them were intermediate and 30% were inexperienced participants.

ii. Number of members in a group

As shown on the Fig. 3a, 56% of all participants preferred to work in pairs to complete their tasks. From the individual category, 60% preferred to have been assigned a partner, while 40% from the paired category hoped they had worked individually. All inexperienced participants preferred to work in pairs regardless of whether they had been assigned to the individual or paired categories during the course.

iii. Number of tasks

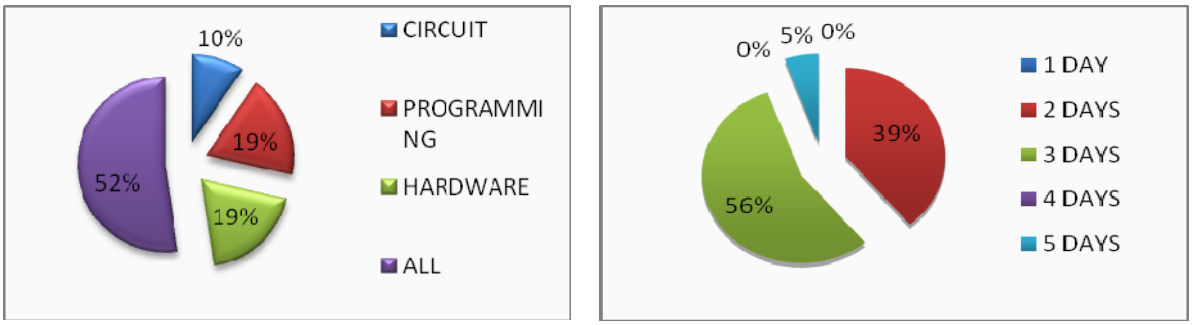
The number of tasks assigned during the course was 15. Participants attempted all tasks, although most of them managed to successfully complete only the first 10 tasks. Fig. 3b shows the preferred number of tasks according to the participants. Ten participants (56%) wanted the number of tasks to range between 6 to 10. Out of these ten participants, 40% were novice while 60% had no experience with microcontroller. Only 2 participants wanted more than 20 tasks. The two who wanted additional and more challenging tasks were experienced in embedded systems, and were ranked in the intermediate level.

iv. Skills

Participants were asked to choose the skills they considered most valuable to them, which they want to focus on. Four options were given: circuit construction, programming, hardware (motor, 7-segment display) or all options. They were allowed to choose more than one. The most selected option was 'all' skills. The skills jointly ranked second were programming and hardware skills. Participants with no experience mostly chose to focus on 'all' skills. Fig. 4a shows percentage of participants with their preferred skill to focus on.

v. Video clips and other presentations

During the short course, a combined total of about one hour was allocated for showing video clips and additional presentations. The video and short presentations were about international robotic events, student projects and some simulated product designs. These video and presentations were meant to provide participants with an overview of microcontroller applications and its performance. All participants liked the video clips and other short presentations in the course. Participants agreed that the duration for these additional elements were just right with 6% wanted longer duration for these elements.



(a) (b)

Fig. 4: (a) Percentage of participants with their preferred skill to focus on, (b) Percentage of participants with their preferred duration of the course.

vi. Duration of course

As shown in Fig. 4b, 56% preferred that the course to be held for 3 days while 39% agree with the current duration of 2 days. 5% wanted the course to be 5 days' long.

4. DISCUSSION

The feedbacks obtained from participants of the short course have been favorable and encouraging. Many claimed that they have better understanding of the microcontroller after the two days hands-on course.

From the survey, it was found that pairing the students had a positive impact in the learning. Most participants preferred to work in pairs and from observation during the course, participants who were allocated individual kits also chose to discuss with friends and work together to complete their tasks. This scenario applied mostly to participants who had no experience and novice. For expert participants, they enjoyed working individually as they were able to work faster, and could attempt more complicated tasks based on their interest, with help from the instructor. To make the course effective for all participants, the instructor has to be aware of participants' skills and prepare additional tasks with a higher difficulty level for skilled participants who completed their tasks early.

From earlier experience in separate courses, three or more participants per group were found to be unsuitable as discussion would be longer, and often, one or two participants would be left out during the hands-on. Two participants in a group was ideal for this type of short course as both could work together to complement each other in understanding and applying theoretical knowledge to applications. They also managed to complete the tasks faster.

Constructing a basic circuit from scratch helped the participants to understand the fundamental requirements of a microcontroller circuitry. While using the starter kit eased their work, it was still important for students to know how the starter kit was constructed, which was achieved by having students construct their own basic circuit using proto-board and wires. With this lesson, the participant then moved on to use starter kit that allowed them to focus on programming their applications rather than being hindered by errors in wiring or hardware faults.

While the knowledge imparted by hands on approach should be comparable to that of the conventional lecture-based curriculum, the hands-on approach differed from the latter in two important ways:

1. Students must actively participate in their own education, with the emphasis being on learning.
2. Participant's immediate hands-on practice that follows a theoretical lecture will provide realistic representation to that new knowledge and encourage them to become self-directed learners.

One improvement as suggested by the participants was the extension of the course duration from two to three days. This was to give time for participants to digest their knowledge and to ensure participants would be able to complete all the tasks assigned. A thorough review of the course with the extended duration needs to be done to ensure optimal delivery of this microcontroller subject.

5. CONCLUSION

From the survey, the hands-on microcontroller short course was found to help in better understanding of the microcontroller. The practical sessions were fun for the students as they could explore their ideas through programming, and each participant came up with variety of solutions for the same task. Students learnt from each other and improved their performance. A 2-day hands-on would not be able to replace theoretical lectures, but will serve as a helpful addition to enhance student's learning.

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REFERENCES

[1] C. E. Nunnally , "Teaching microcontrollers ", *Proc. of Frontiers in Education Conference, 1996. FIE '96. 26th Annual Conference*, vol.1, 6-9 Nov 1996, pp.434-436.

[2] T. K. Hamrita and R. W. Mcclendon “A New Approach for Teaching Microcontroller Courses*”, *International Journal of Engineering Education*. vol. 13, no. 4, July 1997, pp. 269-274.

[3] “Traditional Education” *http://en.wikipedia.org/wiki/Traditional_education*, September 22, 2011.

[4] W.K. Daniel, E. C. Lawrence and F. S. Jacquelyn.; “Improving Engineering Student Retention through Hands-On, Team Based, First-Year Design Projects”, *Inaugural International Conference on Research in Engineering Education, ICREE, Honolulu, HI*., June 22-24, 2007

[5] S.M Miri and R.J. Fu, "A hands-on practical approach to teaching engineering design", *IEEE Transactions on Education*, vol.36, no.1, Feb 1993, pp.131-136.

[6] *www.micrcochip.com*, September 22, 2011.

[7] *www.cytron.com.my*, September 22, 2011.