A novel teaching approach for undergraduates in a Micro-controller Application course

Yuan-Lin Chen† & Shun-Chung Wang‡

Mingchi University of Technology, Taishan, Taiwan†
Lunghwa University of Science and Technology, Gueishan, Taiwan‡

ABSTRACT: Micro-controller application technologies have become more important for engineering students in the age of knowledge-economics, especially in the field of electrical engineering. Presented in this article is a novel teaching approach for undergraduate students in a Micro-controller Application course. The presented approach could not only attract the interests of students in micro-controller application technologies, but also improve the design capabilities of students in micro-controller applications. The handy pre-packaged experiments of hardware and software program designs are also incorporated into the teaching process. The results of student evaluations conducted before and after applying the presented approach demonstrated the fact that it is efficient and successful.

INTRODUCTION

The purpose of a micro-controller application course for undergraduate-level students at universities in Taiwan is to allow the students to grasp the essential concepts of the operational principles of micro-controller devices and their application in both hardware and software design. In Taiwan, there are many world-class integrated circuit design houses, as well as semiconductor foundries, which mandate high manufacturing efficiency and advanced design capabilities. Given this context, it is obvious the students in Taiwan are enjoying an excellent learning environment in which to develop micro-controller application skills.

In the past, a number of experimental kits were designed for various aspects of the course [1-5]. Some papers were aimed at teaching the methodology [6-8]. Carina Savander-Ranne et al presented a redesigned implementation of *Active RF Circuits* based on interactive teaching methods, as well as the impact of these changes on student learning [6]. An innovative systematic and comprehensive approach to teaching digital system timing for graduate-level computer engineering courses at Oregon Health and Science University was proposed by John D. Lynch [7]. Additionally, a proposal that allows students to use specially-developed hardware kits to perform real-life experiments in their homes where they can analyse given problems, create appropriate solutions and validate the actual circuit in a distance learning context was presented by Juan P. Oliver et al [2].

The traditional teaching process has been centred on the principle of enlightening by engaging primarily in a paper study first and then to follow up with an experimental course for students to practise hardware and software design. The downside is that students could find it hard to get a clear understanding of the principle of micro-controller operations during the instruction process. In the meantime, during the experimental class, the main instruction about micro-controllers must be repeated, resulting in lower learning efficiency for students.

In this article, the authors present a more efficient teaching approach, which would attract both the student's interests and to make the course period shorter, i.e. students could develop high-performing technical skills in the micro-controller course with a shorter class period. The teaching approach had been applied in a micro-controller course for undergraduate students at Mingchi University in Taiwan. The evaluation results from the students measured before and after using the approach are very encouraging and demonstrated its efficiency and success.

GOALS OF MICRO-CONTROLLER APPLICATION COURSES

The goals of the teaching approach presented here for micro-controller application courses were that students should gain knowledge of the principles of micro-controller operations and could design a real-world application project using their micro-controller knowledge. The period of the micro-controller applications course at Mingchi University in one

semester is a total of 51 hours (3 hours per week times 17 weeks). The syllabus of this industry-oriented micro-controller course is described in Table 1. Teachers had already integrated lectures on theory with lab experiments into a single course for undergraduate engineering students.

By understanding the operating principles of micro-controllers, students are expected to learn the hardware architecture of a micro-controller and related software programming. A popular industry-grade 8-bits micro-controller, HT46R24, was selected and taught. The features of HT46R24 contain a rich set of functionalities such as pulse width modulator (PWM), an analog to digital (A/D) converter, interrupts, I^2C bus serial interface, halt and wake-up mode and watchdog timer (see www.holtek.com.tw for more details). These are the most important features of a micro-controller that the students have to know.

The second goal of the course is for students to acquire the ability to design a real-world application based on a micro-controller topic. Technologies such as hardware circuit design, PCB layout and software design are all prepared by the teacher for training students in class. Students are expected to design and complete a useful project such as a timer, a wireless remote controller, an LCD display controller, a music box, etc, which accounts a significant portion of the final grade.

The concept of the industry-oriented application is deeply embedded in the design of the course. The authors have consulted with industry leaders on essential skill set needed for equipping students about to enter the workforce. According to their views, the students should possess both design and debugging abilities, from initial circuit design, PCB layout, all the way to software programming. Hence the exercise with practical experiments plays an important role in the teaching process. The authors thus have figured out the goals of the micro-controller application course; based on these established goals, a novel teaching approach and a new teaching content has been developed and is described next in this article. See Table 1 for the course syllabus.

Table 1: Syllabus of an industry-oriented micro-controller course.

Sections	Description	Contents
Principle of micro-controller	Students should gain in-depth knowledge of the principle of micro-controller operations. An off-the-shelf micro-controller, HT46R24, widely applied with an industrial specification, is used to prepare lectures for undergraduate students. All contents of the course are listed on the right side. Two tests on micro-controller principles are required; they account for 30% in total grade. The experimental laboratory occupies another 40% of total grade. Students should practise each experimental unit for understanding the principle of micro-controller technology.	• Hardware structure of micro-controller • System architecture • Program memory • Data memory • Special function registers • Input/output ports • Timer/event counters • Pulse width modulator • Analog to digital converter • Interrupt • I^2C bus serial interface • Halt and wake-up mode • Watchdog timer
Product design based on a micro-controller application	Students should develop the ability to design and implement a real-life project based on a micro-controller application as the final report, which accounts for 30% of total grade. The techniques of circuit design, PCB layout and software programming are all utilised.	• Timer • Extra-sonic distance measurement • Wireless remote control • LCD display control • Music box

COURSE STRUCTURE AND TEACHING PROCESS

The course structure of micro-controller applications is shown in Figure 1. The nine categories within it consist of what are considered the most important skills for students to acquire: LED control technique, interrupt control technique, LCD display control technique, music control technique, watchdog technique, A/D control technique, PWM control technique, wake-up technique and I^2C bus communication technique. Totally, 25 laboratory experiments were designed for hands-on practice. These contain all the most significant principles which should be known to students.

Teaching contents per each lab are listed in Table 2. It was intended to combine the lecturing section with the laboratory experiment as an integral unit to improve the learning experience of students. The result is that 10 teaching items are addressed in each lab. First, the goal of an experiment is introduced, and then the operation of the experiment is clearly described. For example, sometimes photographs are provided to aid the students in visualising the operation of an experiment, as illustrated in Figure 2 (a), which shows the operation of Laboratory 7 and Laboratory 12, and (b) for Laboratory 7, which demonstrates a static 8x8 LED matrix display experiment. Note that both pictures in Figure 2 (a) and (b) are clear and of high quality to show what the experiment's results should be.

Figure 3 depicts the flow of teaching steps for this proposed approach to the course of micro-controller application. A lecture will cover the hardware structure of micro-controllers in the beginning, and continue on with a sequence of incremental experiments to build up the students' knowledge base. The lectures about the experiments will be given during all experiments. At the end, the examples of micro-controller applications are presented to the students, who designed the micro-controller applications. A final report is submitted by students as part of the grade evaluation. Figure 4 describes the teaching practice flowchart of each experiment. Note that, here, the focus in lecturing is the relationship between hardware and software. This is the most important point, to deepen and solidify the students' knowledge.

Some product-oriented project examples were used in the teaching to inspire students to apply the micro-controller technology to real-world products. Figure 5 shows an extra-sonic distance measurement system, which can measure the distance between 20 mm and 3,000 mm with a resolution of 1 mm. The students need to know how to design the circuit, and how to organise the layout of the PCB. To complete the project, the students must design the software and debug the code.

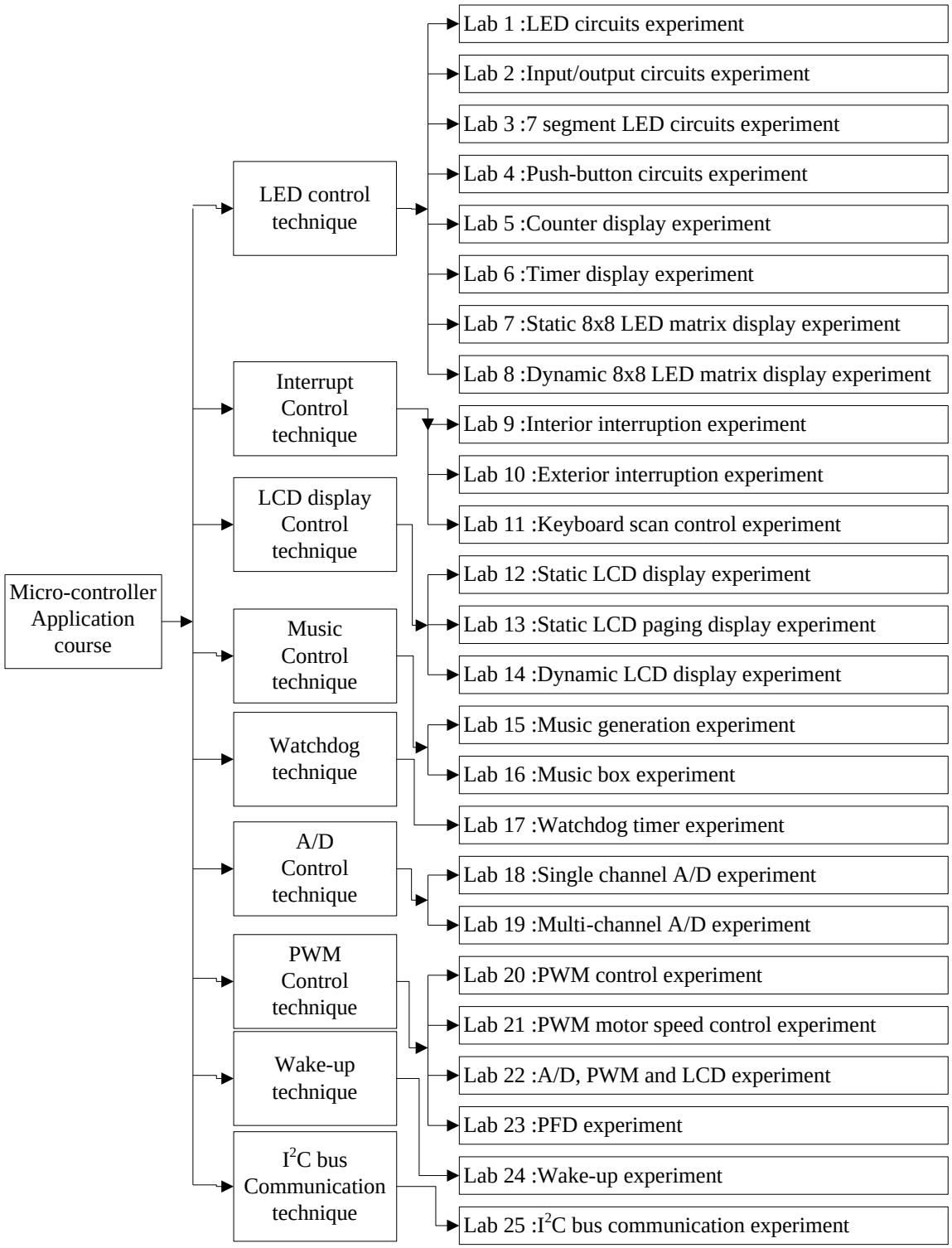

Figure 1: Course structure for micro-controller applications.

Table 2: Teaching contents of each lab in the Micro-controller Application course.

Item		Description
1	Goal of experiment	It is necessary to mention the theme for each experiment so that students can understand the purpose of the topic.
2	Action of the experiment	The descriptions of action of the experiment were presented for students to check the correctness of the experiment's results. At the same time, the actions could help students to realise how the hardware and software work together to achieve a goal.
3	Required knowledge for the experiment	The knowledge necessary for the experiment is introduced in this part. An excellent impression on students occurs when pertinent knowledge of the experiment is comprehensively taught. For example, there is a lecture on the frequency of each musical scale in the music generation experiment. The student also needs to know how to generate the sound by program control.
4	Circuit diagram of the experiment	The circuit diagram tells students how to connect the hardware. The circuits will be jointed using wires by students in the laboratory experiments.
5	Program flowchart of the experiment	Program flowchart describes the control flow of the software. The flowchart could help students to understand how the program works.
6	The experiment's program	The program is designed and coded in the C language. A sample program for the experiment is listed in this section.
7	Functional description of the program	The function is illustrated step by step for each component of the software.
8	Steps in the experiment	The experimental process is described step-by-step.
9	List of the experimental elements	All materials needed in the experiment for teacher and students are listed to ensure efficient execution of the steps.
10	Homework	Some homework to be prepared by students.

Figure 2: Examples of the results of experiments: (a) 8x8 LED matrix display; (b) LCD display experiment (l-r).

RESULTS AND DISCUSSION

The teaching approach presented in this article has been formally included into the undergraduate course at Mingchi University in Taiwan. The length of the course is one semester, consisting of 51 hours (3 hours per week times 17 weeks). This new teaching approach was applied to the new semester in 2008. The empirical data were collected for the consecutive three years: 2006, 2007 and 2008 to evaluate this teaching approach.

Figure 6 shows the total number of students in the class of the Micro-controller Applications course at the Department of Mechanical Engineering, Mingchi University, in the recent three years. It is obvious the total number of students grew greatly in the year 2008. That implies the students had shown more interest in this class than in previous years. It is, therefore, assumed that the teaching method was a success, because more students expressed a desire to learn the technology of micro-controllers.

Figure 7 depicts the average score of students in recent years. It can be seen the average score in the year 2008 is higher than the year before. The results demonstrate the efficiency of learning by the students in 2008. Also, the average score for the final projects submitted by the students in 2008 is higher than in previous years, 2006 and 2007. At the same time, it was discovered that the students spent more time on the final projects when the new teaching method was used. This implies the students took more interest in the Micro-controller Application course in 2008 than before.

The students were asked in a feedback questionnaire to evaluate the course design and the teaching process at the end of the class. Table 3 lists the results of the feedback questionnaire for the course on micro-controller applications. Each item was scored from 0 to 10. (Here, 0 implies *Do not agree* and 10 *Agree very much*.) Three questions were asked about the feelings of students toward the course at the end of semester. The first question: *Do you think the design of the course is helpful to you?* - was to determine how helpful the course was for students learning micro-controller

technology. The second question: *Do you think the learning process is efficient to you?* - was to determine how efficient the learning procedure was. The third question: *Do you think the teaching process was interesting?* - was asked to determine whether the teaching process was interesting for the students. The results of the questionnaire could be used to modify the teaching content and teaching process to better suit the students.

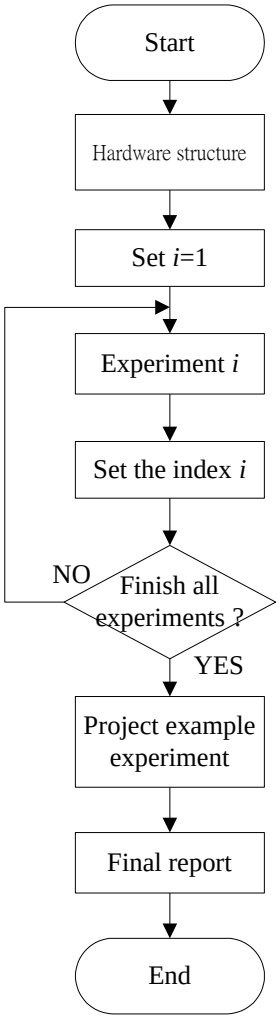

Figure 3: Teaching process of the course on micro-controller application.

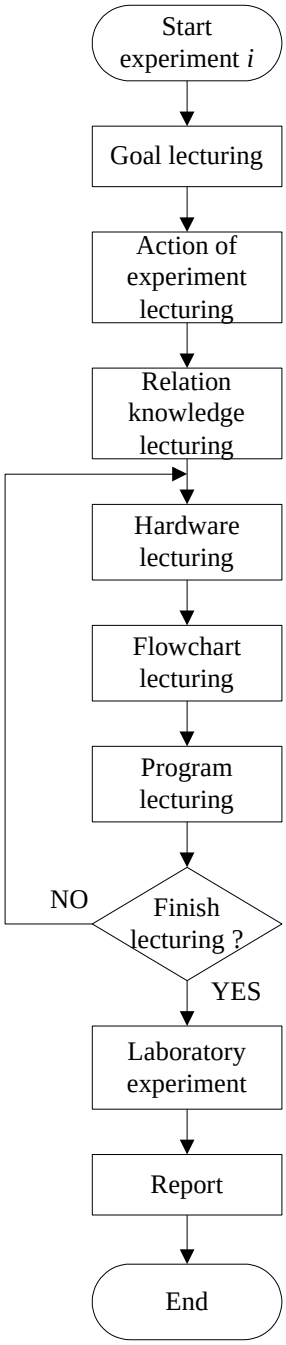

Figure 4: Teaching practice of each experiment.

Figure 5: Photograph of the extra-sonic distance measurement system project.

The evaluation results of the feedback questionnaire of the course are in Figure 8. The results show that the students gave a higher score when the new teaching method was used.

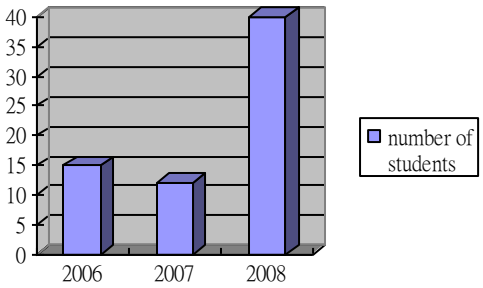

Figure 6: The total number of students in the class in recent years.

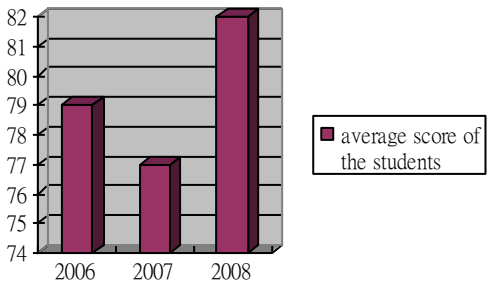

Figure 7: The average scores of students in recent years.

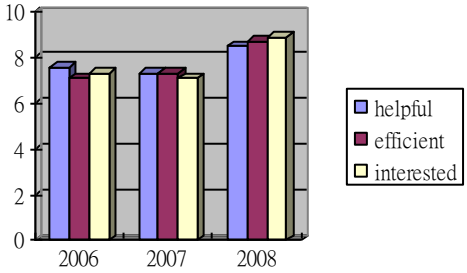

Figure 8: The evaluation results of the course by students.

Table 3: The questions on the feedback questionnaire of the course, Micro-controller Application.

Question	Scale (0=Do not agree, 10=Agree very much)
Do you think the course design was helpful to you?	
Do you think the learning process was efficient?	
Do you think the teaching process can increase your interest?	

CONCLUSION

A novel teaching approach for undergraduate study of micro-controller applications was presented in this article. The lecturing and lab experiments were integrated in the teaching to deepen students' knowledge and understanding. The course contains project examples which could be the real-world products in the marketplace. Both hardware and software training was implemented in the course. The high evaluation results from an evaluation questionnaire by the students were presented to demonstrate the performance of this teaching approach. The benefits of the teaching method include a shorter period for the Micro-controller Application course. At the same time, it achieves a higher efficiency in teaching the course. The scores of the students were increased when this teaching approach was used.

ACKNOWLEDGEMENT

This work was supported by the National Science Council of Taiwan for financial support under contract number NSC 94-2516-S-131-001. The authors would like to thank the students of the Micro-Controller Application course for their assistance and excellent co-operation in this research.

REFERENCES

1. Liao, W.B., Gu, J.C., Shen, K.Y. and Chen, Y-L., An experimental kit for undergraduate pwm power converter laboratory. *UPEC2003*, Greece, 1-3 September, 201-204 (2003).
2. Oliver, J.P. and Haim, F., Lab at home: hardware kits for a digital design lab. *IEEE Transactions on Educ*., 51, **3**, 46-51 (2008).
3. Schertz, D.R., A remotely accessed micro controller laboratory, *Proc. 27th Annual Conference of the IEEE Industrial Electronics Society*, 1781-1783 (2001).
4. Landi, C., Liccardo, A. and Polese, N., Remote laboratory activities to support experimental session for undergraduate measurements courses. *IMTC 2006 - Instrumentation and Measurement Technology Conf.*, Sorrento, Italy, 24-27 April, 851-856 (2006).
5. Leva, A., A hands-on experimental laboratory for undergraduate courses in automatic control. *IEEE Transactions on Educ.*, 46, **2**, 263-272 (2003).
6. Savander-Ranne, C., Lundén, O-P. and Kolari, S., An alternative teaching method for electrical engineering courses. *IEEE Transactions on Educ.*, 51, **4**, 423-431 (2008).
7. Lynch, J.D., Teaching digital system timing: a comprehensive approach. *IEEE Transactions on Educ.*, 51, **3**, 325-330 (2008).
8. Tutunji, T.A., Saleem, A. and Rabbo, S.A., An undergraduate Mechatronics project class at Philadelphia University, Jordan: methodology and experience. *IEEE Transactions on Educ.*, 51, **3**, 365-374 (2008).