Constructing Microcontroller-Based 3 by 3 Football Team Sets As an Educational Tool

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Abstract: The objective of this paper is to construct microcontroller-based 3 by 3 football team sets for students to learn the knowledge of information and wireless communication technology in microcomputer related class. The constructed microcontroller-based 3 by 3 football team sets includes four parts: a mechanical set, a main control board, a motor driver board, and wireless control module. The mechanical set with two wheels is used as the feet of a robot. The main control board with 89S51 μ-controller chip is used to control the movement of the robot, such as going forward/back and turning left/right. The motor driver board is used to drive two wheels on the mechanical set. The wireless control module is used to remote control of a robot. Some investigations and evaluations have been done when the students finished the course which adopted the proposed microcontroller-based football team sets as the educational tool. Conclusively, the results indicate that applying the constructed teaching sets in an educational institute has had very favorable feedbacks from the students. The proposed tool sets can attract more students interesting in designing microcontroller-based systems and influence them in preparation for their laboratory project.
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1. Introduction

Adult learning is specifically designed for above the legal age group, which is different from other learning education such as e-learning and distance learning. For effective teaching adult students in an institution, a teacher generally needs to know how they can learn well. As Abedi and Badragheh [1] stated that adult education needs to account for motivation of the learner, reinforcement of the skill, retention of key learning, and transference of what is learn of new situations. In advance, Badragheh and Abedi [2] have also suggested that the ways to strengthen adult education are such as offering a variety of formats, schedules, and approaches, meeting people where they are, promoting participation effectively, and fostering strong leadership. Based on these teaching principles, this study tries to use microcontroller-based 3 by 3 football team sets as an educational tool to let the learners retain the knowledge of information and wireless communication technology in microcomputer related class.

Microcontrollers, programmable devices such as Intel 8951, Motorola 6811, Microchip PIC 16C57, Texas Instruments TMS1000, and Zilog Z80180, have ROM, RAM, ALU, and I/O functions inside the single ship with the advantages of small volume, easy use, and good extendibility. Using these programmable devices for hardware control would be able to simplify system design and implementation. Therefore, they are globally applied in the electromechanical related products, including automatic washers, microwave ovens, swing control, cameras, digital watches, cellular phone and so on [3]. Currently, μ-controller education is one of the most mainstream subjects in the fields of Computer, Electronic, Electrical, and Mechanical Engineering. Specifically in Taiwan, many universities view the programmable devices as necessary education for present and future engineers. For example, at Kao Yuan University (KYU), it is a requirement in Electronic/Electrical Engineering curriculums and an elective in Information Technology and Auto-Mechanical Engineering curriculums. The ultimate teaching goal is to train the students using a single chip to design a practical product. However, with the rapid growth of computer, electronic, and information technology in industries, most current related references and tools used for the μ-controller education are not good enough to achieve the teaching goal. Hence, this paper aims to construct a set of teaching tool for students to learn the knowledge of μ-controller system designing and debugging techniques.

In the past decade, many universities, such as Uni. of South Carolina, USA [4], Uni. of Penn State, USA [5], Uni. of Zaragoza, Spanish [6], Lunghwa Uni., Taiwan [7], etc., have shared their teaching experience on μ-controller related courses. At Uni. of South Carolina and Penn State, the μ-controller courses used the available μ-controller evaluation board (EVB), Motorola MC68HC11 EVB, with LCD, keypad, a motor and digital thermometer interfaces for Mechanical Engineering and Electrical Engineering students, respectively. At Lunghwa Uni., it used the published book and the developed Intel 89S51 teaching module board with the integrated development environment software for both Computer Science and Electronic Engineering students. However, using such commercial developed integrated modules as the teaching tool has one disadvantage - The tool is like a black box and it is too expensive for a student to buy it; therefore, students need to rely on laboratory facilities for their works and cannot do the experiments at home. As for Uni. of Zaragoza, it only introduced the software tool of MC68HC11 in the μ-controller course. In the reviewing some other references, Gault and Snyder [8] put much effort on solving programming problems. Athani [9], Bray etc. [10], and Freedman etc. [11] indicated that two-semester μ-controller courses are needed for students to learn well a system design of hardware and software. One semester is for introductory course with conceptual design goals; the other one semester is for project-oriented course with more hands-on experiences. Furman and Hayward [12], Jeon [13], and Lee [14] also strongly suggested that the μ-controller course should emphasize more hands-on and use relatively inexpensive kits of components as teaching tools.

Because of many kinds of μ-controllers available in the market, how to choose the "right" μ-controller for students learning well is an important issue for teachers [3, 15]. AI-Dhaher [3] pointed out that setting the "right" μ-controller teaching tool is a critical decision because it may have impacts on students' reactions to the course. Gupta and Moi-Tin [15] also indicated that the "right" μ-controller means the teacher needs to consider some factors, including popularity, availability, architecture, features, prices, tools, education support, easy use, and so on. Specifically, Schultz [16] suggested that teachers might consider 8051 or 68HC11 μ-controller as a teaching target because they are well supported and have matured to being readily available and reasonable alternative to the expensive high performance processors.

In the reviewing current 8051 μ-controller related books [17-21], three deficiencies exist: (1) some books cover only fundamental principle and software simulation, which lacks the coordination of the theory and practice, thereby decreasing students' interest in learning μ-controller advanced applications; (2) it is impossible for students doing the experiments at home because of without covering the flash downloading hardware/software tools; and (3) most books are lack of project-based examples, thereby decreasing the brainstorm stimulation on developing a practical product.

In order to overcome the weaknesses described above and achieve the goal of using μ-controller to develop a practical product, the hardware and software must be integrated efficiently because μ-controller applications are heterogeneity and involve many different programming needs and hardware interfaces. In this paper, the authors propose an Intel 89S51 based teaching tool with the capabilities of understanding its basic principle and software simulation; allowing students to do the experiments at home; and using a remote controlled vehicle system to clarify μ-controllers' extendibility. At EE department of KYU, the μ-controller courses have been offered as one of requirements for junior students and one of electives for senior students. In the proposed teaching tool, it is recommended that all students can build a simple 8951 I/O board in order to carry out the hardware/software of assignments at home rather than rely on three working laboratory hours per week. In the following, Section 2 describes the proposed Intel 8951 μ-controller teaching tool. The observations and students' reactions are shown in Section 3. Finally, the conclusions and future works are summarized in Section 4.

2. Microcontroller-Based Football Team Sets

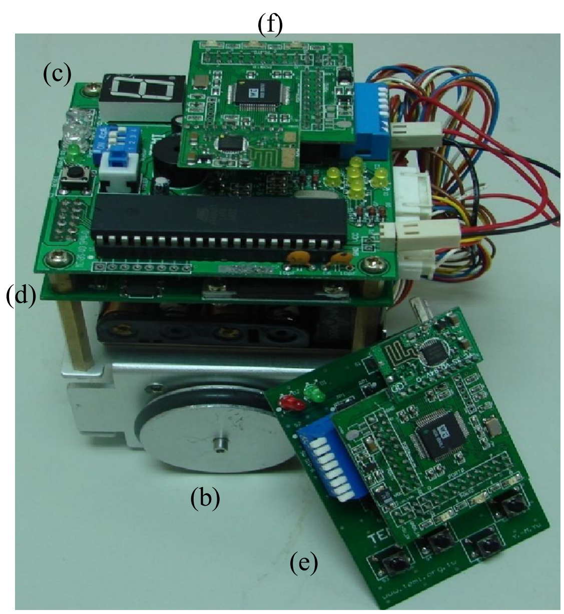
Table 1 gives the syllabus of the microcomputer course. The lectures cover three parts: (1) Introduction to microcontroller-based robot set; (2) Assemble and de-assemble a microcontroller robot set; and (3) Demonstration of the 3 by 3 football team sets, which are described in the following.

Table 1. Syllabus of microcontroller course

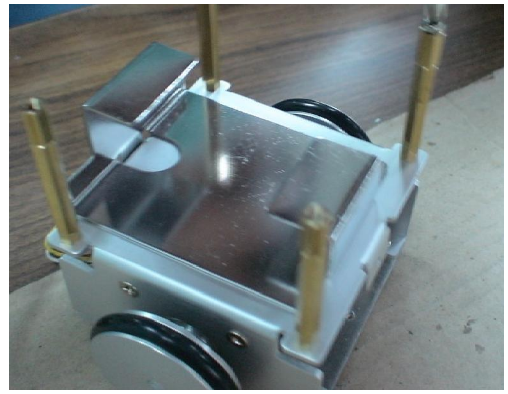
	Week	Course ontents
I	1	Intro.to AT89S51 Microcontroller
	2	Intro. to Main Controller Moard
	3	Intro. to Microcontroller Interface
	4	Intro. to Motor Driver Board
	5	Intro. to Mechanical Vehicle Set
II	6	Assignments
	7	Assemble Mechanical Vehicle Set
	8	De-assemble Mechanical Vehicle Set
	9	Assemble a robot system
	10	De-assemble a robot system
III	11	Midterm
	12	Intro. to 3 by 3 Football Game
	13	Intro. to 3 by 3 Football Team Sets
	14	Competition
	15	Competition
	16	Final Examination

2.1. Microcontroller-Based Robot Set

The microcontroller-based robot set, as given in Figure 1(a), includes five parts: mechanical device (b), main control board (c), motor driver board (d), remote control board (e), and 2.4 G Hz RF wireless control module (f). All their detail materials and circuitry schematics can be found at Website of Taiwan Embedded Microcontroller Development Institution (TEMI) [22]. As shown in Figure 1, the mechanical device uses two motors to trigger two wheels for controlling the robot's movement. The main control board including 40-pin AT89S51 IC, power switch, 6x2 male pins, push button switch, 4-pin DIP switch, LED, HT7039 IC, 7-segment display, capacitors, SMD resistors, buzzer, 2x10 male pins, 13 x2 male pins, 7447 IC, 8-pin DIP switch, five LEDs for the indication of remote sensing, 1N4148, power connector, and oscillator. The 10x2 and 13x2 male pins are connected to the 2.4 G Hz RF wireless control modules. The main parts of the motor driver board includes two Darlington ICs, two motor connectors, power switch, power connector, LED, and 6x2 female pin connector which is connected to 6 x2 male pins of the main control board. As for the remote control board, it includes power switch, power connector, 10x2 male pin connector, 13x2 male pin connector, power light, 8-pin DIP switch, and five push button switches for controlling the movement of the vehicle device. The 10x2 male pin and 13x2 male pin connectors are connected to the 2.4 G Hz RF wireless control modules.



(a)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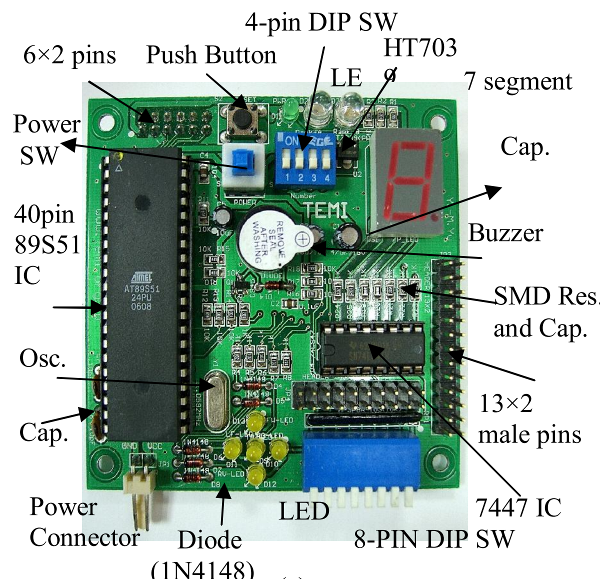

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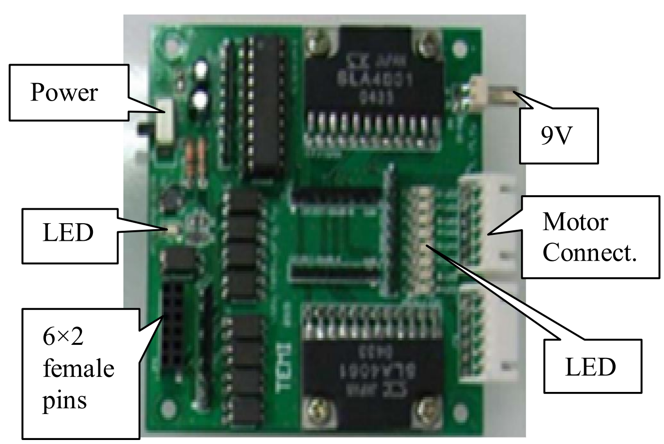

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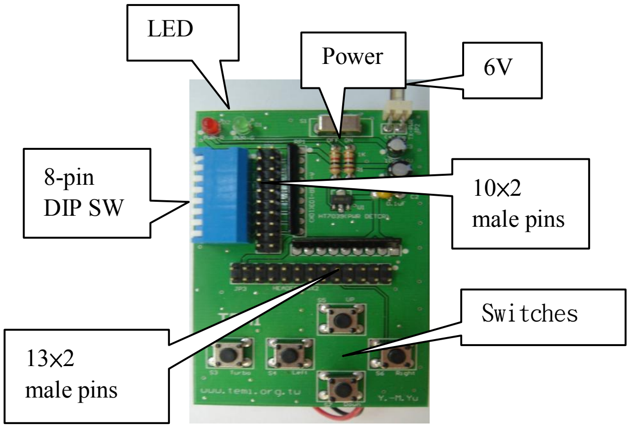

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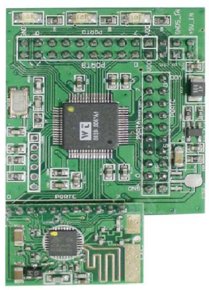


(f)

Figure 1. (a) Microcontroller robot set; (b) mechanical vehicle device; (c) main control board; (d) motor driver board; (e) remote control board; (f) 2.4 G Hz RF wireless control module.

The following gives the software control procedures in which the programming codes are downloaded into AT89S51 chip for controlling the hardware. The main functions of the software includes controlling the vehicle to go forward and back, turn left and right, and speed up the movement.

Step 1: Main board power detection, if power is "low", buzzer on, otherwise off.

Step 2: Stepping motor power detection, if power is "low", buzzer on, otherwise off.

Step 3: Enable external interrupts -- EX0,EX1; INT0

Step 4: Judge the channel set, if it is right, go to step 1, otherwise, go to next step.

Step 5: Judge the push-button pressed

Step 6: Driving motor movement: including forward, back, left turn, right turn… and so on.

Step 7: Go to step 1.

2.2. Assemble a Microcontroller-Based Robot Set

Figure 2(a) shows the box of the mechanical set; Figure 2(b) gives the assembled mechanical device and tools. Figure 3 illustrates the procedures of assembling a complete microcontroller-based robot set, as give in Figure 1(a).

Step 1: Fix the step motor in the motor stand base.

First, take out two step motors, the motor stand base eight round-head screws from the mechanical box. Then use eight round-head screws to lock two step motor on the motor stand base, as shown in Figure 3(a) and (b).

Step 2: Fix the tire and the wheel on motor's rotating axes.

First, take out two wheels and tires from the mechanical box. Then, use the screw driver to lock the wheels on motors' axes. Finally, put the tires on the wheel rims, as shown in Figure 3(c), (d), and (e).

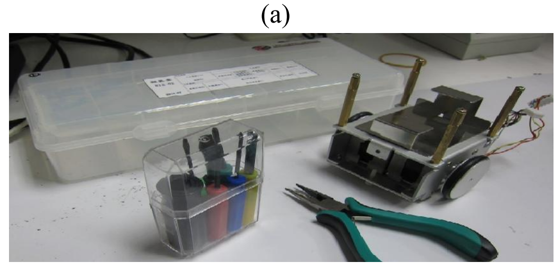
Step 3: Finish the mechanical set.

First, take out the battery sustain base and a set of screws and copper columns from the mechanical box. Then, lock the battery sustain base and four copper columns on the motor stand base, as given in Figure 3 (f) and (g).

Step 4: Complete a microcontroller-based robot set.

Figure 3 (j) illustrates the backside of the assembled robot set. After finishing the assemble of a mechanical device, a user need to attached the motor driver board, main control board, and wireless control module on the top of the mechanical device, as shown in Figure (h) and (i). In order to have the assembled robot set work correctly, a user need to prepare one 9V and four 1.5V batteries and stuck them on the battery stand base. Besides, a user has to connect the power transmission lines on motor driver board and main control board, respectively, and connect the transmission lines among the motors, motor driver board, and main control board. As shown in Figure 3 (j), two binding strips are used to fasten the transmission lines on the copper column together.

(a)



(b)

Figure 2. (a) The box of mechanical set; (b) assembled mechanical device and tools.

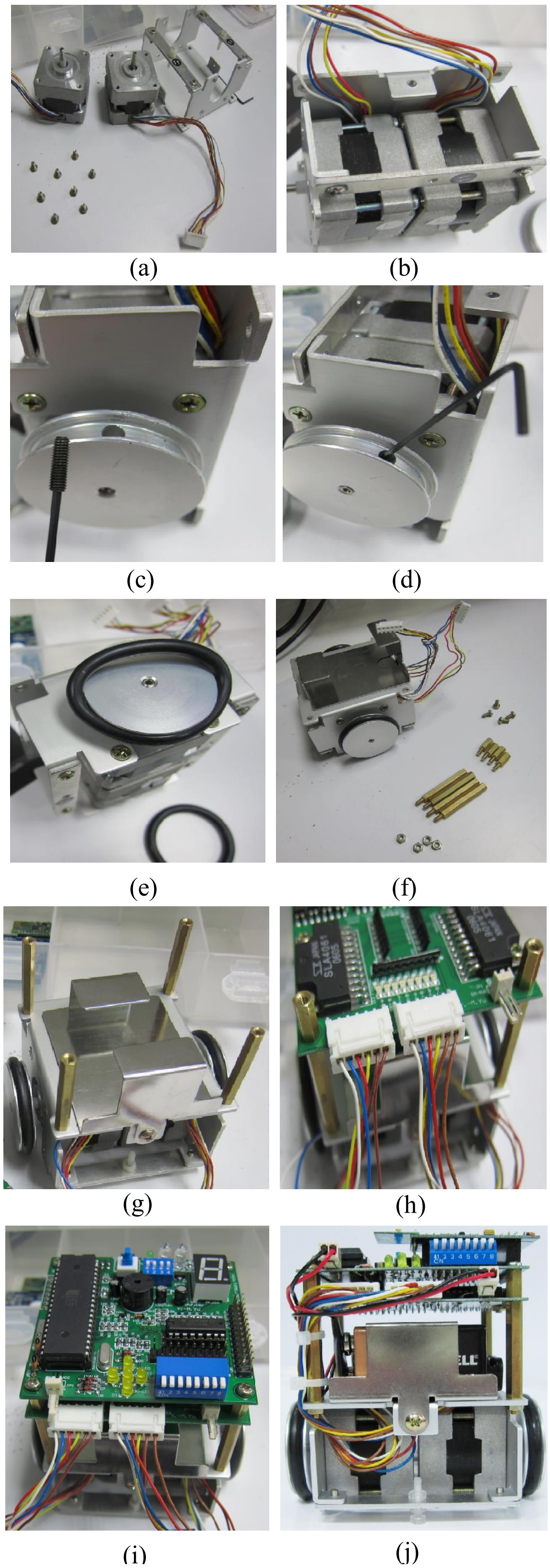


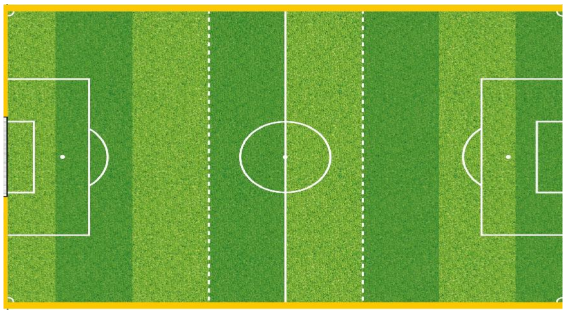
Figure 3. Procedures of assembling a microcontroller-base robot set.

3. Experimental Results

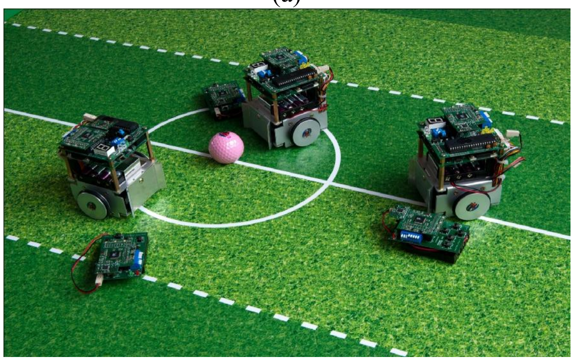
At EE department of KYU, there are about 30 sets of microcontroller-based robot facilities provided in the μ-controller laboratory for 50 students to debug and run their robot sets. Therefore, a team with two students is issued a developed robot kit with debugging facility. Up to now, the constructed teaching tool has been applied in the course for four years, which trains the students with the debugging techniques and the hardware/software integration technology. Currently, the microcontroller-based robot set is used to examine students' capability on designing μ-controller-based project. The students are required to build the hardware, including soldering each part of circuits and assembling all parts of the system, program control codes, and measure the control signals. If a student passes all the tests, he or she can obtain the microcontroller certificate issued by TEMI which is recognized by Taiwan government and local industries.

Figure 4(a) illustrates the land of the football game, where the length of the field is 2 meters; the width of the field is 1.15 meters. Figure 4(b) shows a typical 3 by 3 microcontroller-based football team set, where the golf ball is used as the football. Figure 5(a) demonstrates the competition scenario of two 3 by 3 football teams at their initial locations, respectively; Figure 5(b) shows the competition scenario of two football teams with the body appearance changed and the team-number set via the 7-segment different number displays and LED different color displays. In the football game, the time limit for each half-round is 3 minutes. A team wins the game when it kicks more balls into the football gate.

Some investigations have been done when the students finished the course. About 90% of 50 students construct their own I/O control board personally; about 80% of the students successfully complete all assignments, midterm exam, and final exam; about 60% of the students choose the μ-controller as their project design topic for their senior laboratory project course. In addition, about 70% of 30 students got the microcontroller certificate issued by Taiwan Embedded Microcontroller Development Institution (TEMI) which is recognized by Taiwan government and local industries. In addition, about 90% of 50 students would like to participate 3 by 3 football game competition. From the students' evaluation of the μ-controller course, about 70% of 50 students appreciated the knowledge of hardware/ software integration and debugging techniques. Conclusively, these results indicate that applying the constructed 3 by 3 microcontroller-base football team sets as the teaching tool in the μ-controller course has had very favorable feedbacks from the students.



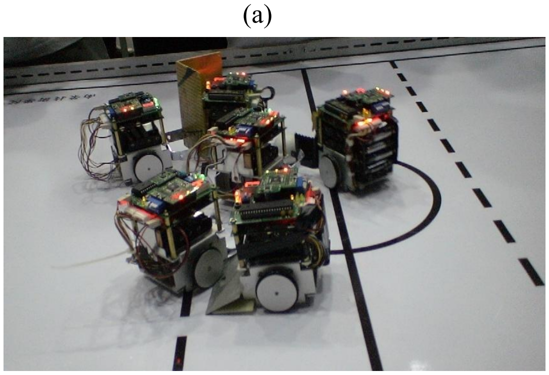
(a)



(b)

Figure 4. (a) The land of the football game; (b)3 by 3 microcontroller-based football team set.

(a)



(b)

Figure 5. (a) Competition of two football team sets; (b) changing outlook of the football team sets.

4. Conclusions

In this paper, a set of the microcontroller –based 3 by 3 football team sets has been constructed to train students to learn the information technology and communication technology skills effectively. The proposed teaching tool is different from the traditional courses in three aspects: (1) students not only learn the essential contents of μ-controller skills but also know the method to design a project by integrating hardware and software of the microcontroller; (2) students have brainstorm training opportunity on microcontroller system design; (3) students are allowed to construct their own robots personally, thereby increasing active participating opportunity. According to the students' feedbacks described in Section 3, using the constructed teaching tool attracts more students interesting in designing the microcontroller-based applications and influences them in preparation for the laboratory project which involves planning, designing and implementing solutions to the project.

This work can be extended to focus on using the microcontroller in various applications and building the interface circuits in modules to increase students' competitions in the real world.

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