

Developing a Practical Teaching Simulation Software for Ability Certification of Microcontroller Applications



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ABSTRACT: *This* paper proposes an effective educational training tool used to help students passing the professional competence certification examinations held by TEMI (Taiwan Embedded Microcontroller Development Institute) association. In order to help students passing the certificate qualification examinations, the developed educational training tool allows users to simulate both discipline and technical subjects of three types of microcontroller application professional competence certification examinations, including microcontroller, digital logical circuitry design, and welding circuitry certificates. The proposed simulation platform can allow students to learn wireless remote-control robots, tracking self-propelled vehicles, digital circuit design, and electronic component de-soldering/soldering related technology, respectively. In this paper, the developed practical educational training tool utilizes Visual Basic and C# programming languages as the development tools for developing three types of main control circuit board ability certifications and the discipline ability certification training simulation platform. In addition, the designed teaching tool aims at guiding students on their hands-on experience to inspire students' interest in microcontroller related application technology and enhance students' learning effects.

The proposed simulation tool has been used as the learning exploration with the students at Kao Yuan University in Kaohsiung City, Taiwan. According to the experimental results, this paper can provide three contributions. First, it can increase the passing rates of obtaining three types of microcontroller application professional competence certification examinations. Second, it can assist teachers in understanding students' learning performance, thereby proposing related effective and efficient teaching strategies. Third, it can increase students' professional skills and employment competitiveness, thereby cultivating more professional and technical talents to meet the needs of the microcontroller application industry.

KEYWORDS- Microcontroller applications, educational training tool, and certification examinations.

I. INTRODUCTION

The embedded system course is one of the important microcontroller application related courses for cultivating engineering technology talents at Information Technology Application Department, Kao Yuan University, Taiwan. In order to meet the educational goal of cultivating professional knowledge in the innovation and cross-field applications of information technology, designing effective teaching practice methods for guiding students to have own hands-on experiences is important issue for teachers. Therefore, this paper aims at innovating an effective educational training tool used in the practical embedded system course and hoping to increase students' learning quality, professional skills, and employment competitiveness. The developed educational training tool allows users to simulate both the discipline and technical subjects of three microcontroller application professional competence certification examinations, including microcontroller, digital logical circuitry design and electronic component de-soldering/soldering ability certificates, which are held by Taiwan Embedded Microcontroller Institute association [1].

An embedded system mainly applies the microcontroller to monitor or control different types of input and output hardware devices to perform specific application functions such as mobile phones, televisions, microwave ovens, washing machines, medical treatment, and industrial automation fields. Related daily life applications are such as the development of air purifiers [2], using 64-bit ARM microprocessors for real-time pedestrian detection [3], applying Arduino microcontroller in developing a baseball game machine with scoring and counting functions [4], and the library borrowing and returning book

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management system with the radio frequency identification and general packet radio service technology [5]. There are some literatures related to medical applications. Hsu [6] integrated smart sensor components with wireless communication technologies to collect physiological and image states for the elder living alone. The collected information can be transmitted to their relatives or medical staffs for monitoring elder physiological status. Therefore, basic safety warnings and life quality can be guaranteed. Tseng [7] applied PIC24FJ256GB106 microcontroller developed by Microchip to design the EEG measurement system. Huang [8] proposed the heart Embedded system for electrical signal ECG simulation as well as electrocardiogram and brain electrical signal EEG measurements. In the related industrial automation applications, there are a car license plate recognition system [9], an embedded system using digital signal processor to develop a single-layer two-axis precision positioning platform [10], using ARM7 microprocessor to design a remote monitoring system [11], a solar panel monitoring system using ZigBee wireless communication network to combine voltage and temperature sensors as wireless monitoring units [12], and using DSPIC30F4011 single chip to control the servo motor in PLC kit module [13]. However, Gupta & Moi-Tin [14] mentions that although there are many microcontroller kit modules on the market, how to choose a suitable microcontroller is very important. The study recommended to consider its popularity, usability, internal functions, architecture, execution efficiency, and whether there are sufficient auxiliary tools to assist users in developing application products. In addition, Schultz [15] suggested to use the MCS-51 microcontroller chip produced by Intel and the 68HC11 chip produced by Motorola to develop related application products. Therefore, this paper adopts MCS-51 microcontroller as the core chip of the practical embedded system course and uses the main control board and peripheral application board developed by TEMI (Taiwan Embedded Microcontroller Development Institute) association.

In the reviewing some literatures related to the educational simulation software, Huang [16] applied the computer simulation teaching tool to achieve the purpose of skill learning, analyzes learners with different personal characteristics and abilities, and analyzes the performance of computer simulation learning and skill implementation. Nian [17] studied the techniques of an interactive web site for the virtual electronics laboratory. Huang [18] discussed the practical skills integrated into a virtual laboratory for microcomputer I/O control experiments. Chuang [19] discussed the practical learning effects on the virtual laboratory for the digital design curriculum. The literature [20] developed a virtual simulation system named Joeq for researchers, which provides several functions, including automatic distributed control, time-course algorithm, junk data screening and compiling simulations. The literature [21] designed a microcontroller named Komodo, which acted as an interrupt service to simulate the microcomputer multi-thread processes and can be used in student skill training and teaching applications. Chang [22] explores the impacts of computer simulation technology integrated into Visual Basic programming courses on the learning effectiveness of college students as well as the learning attitude of college students in accepting experimental courses. The research results can provide schools and teachers as the reference opinions for integrating simulation technology into programming course teaching. Huang [23] developed a virtual laboratory, named simPHYSIO, which can be applied in the psychology-related courses with interactive teaching via the Internet online platforms. Esquembre [24] used Java programming language to develop a simple teaching and learning simulation software with a graphical interface. Murray, etc. [25] proposed a teaching simulation software for nursing consulting decision making. Wang [26] explores the effectiveness of applying computer simulation software on the single chip practical course for students in the high school information technology program. The study adopts a pre-test and post-test experimental research design, including basic ability pre-test, subject knowledge post-test, single-chip experimental technical post-test, and post-study satisfaction evaluation. Nein [27] explores the impact of using computer simulation software on the learning effectiveness of digital logic courses for vocational students. This research adopts a pre-test, post-test, and multi-factor aptitude test experimental research design.

As described above, many teaching simulation software with specific needs have been proposed and there is no universal simulation software that can be widely used for different courses. Therefore, this paper extends the authors' previous research [28] to develop a set of microcontroller educational training simulation software for guiding students on their hands-on experience, inspiring students' interest in microcontroller related application technology, and increasing students' learning effects. In the following, Section II describes the proposed material and method. The experimental results are shown in Section III. Finally, the conclusions are summarized in Section IV.

II. MATERIAL AND METHODS

Figure 1 is the structure of the designed practical teaching simulation platform. As shown in Figure 1, the educational simulation software displays "Microcontroller Application Ability Certification Practice Teaching Simulation Software" on the screen initially. The functions of the designed platform include three types of microcontroller application ability certifications, namely

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microcontroller, digital logic design, and electronic component de-soldering/soldering as well as the related ability certification information. The proposed platform adopts the main control circuit boards used in the three types of professional ability certifications as the simulation examples. Specifically, the microcontroller ability certifications adopt wireless remote control robot and tracking self-propelled vehicle as the technical subjects for the practical level and professional/expert level respectively; the digital logic design ability certifications adopt the CPLD (Complex Programmable Logic Device) chip design and 24 hour-timing counter as the technical subjects for the practical level and professional level; electronic component de-soldering/soldering ability certifications adopt Bluetooth tracking self-propelled vehicle, guessing number, and jumping up, down, left, and right moving control as the technical subjects for the practical level, professional and expert levels. Figure 2 shows the pictures of the main control boards for the microcontroller ability certifications. Figure 3 shows the pictures of the main control boards for the digital logic design ability certifications. Figure 4 shows the pictures of the main control boards for the electronic component de-soldering/soldering ability certifications.

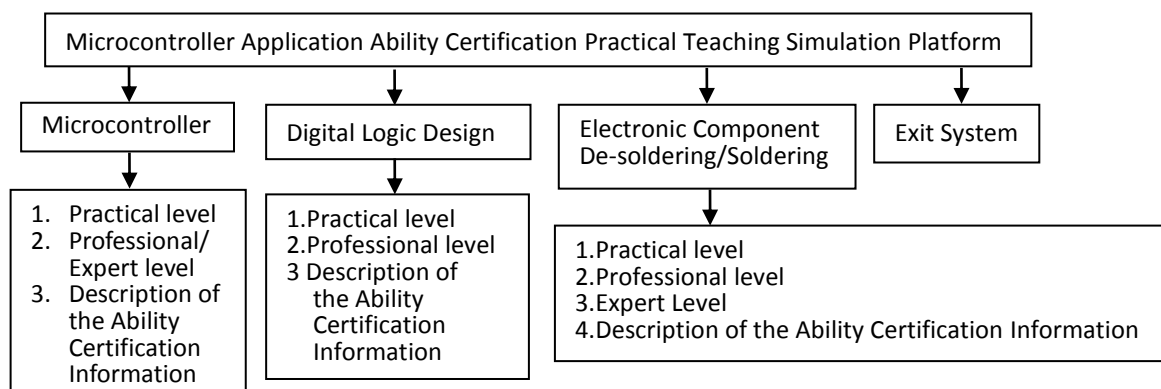


Figure 1 : structure of the designed practical teaching simulation software.

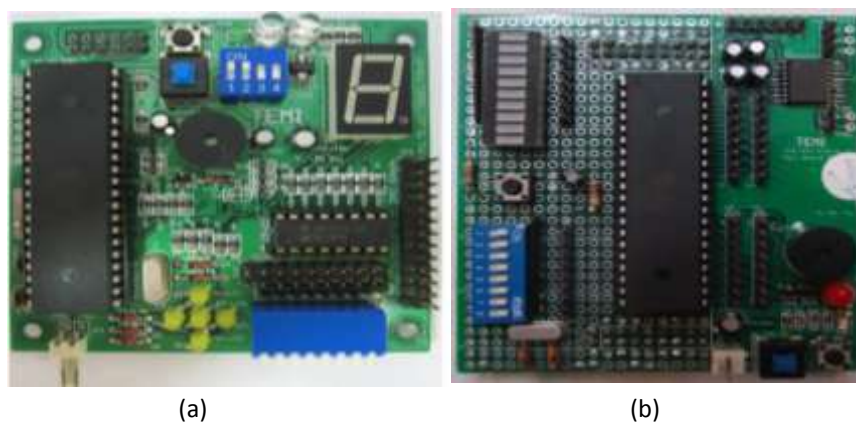


Figure 2: Main control boards for the microcontroller ability certifications; (a) practical level; (b) professional level.

As shown in Figure 2, both practical and professional levels of the microcontroller ability certification mainly evaluate the ability of soldering SMD (surface mount device) and DIP (dual-in-line package) technology, components' identification, and wireless control robot assembly and testing capabilities. The architecture of both main control circuit boards mainly uses 89S51 microcontroller to transmit the control signal. Specifically, in Figure 2(a), the main control circuit board with wireless robot control for the practical level ability certification has five module functions, including power detection module, 89S51 chip drive module, step motor trigger signal, and wireless channel control signal as well as the LED, 7-segment, and buzzer output signal. As for Figure 2(b), the main control circuit board with tracking self-propelled vehicle control for the professional level ability certification contains ten module functions, including serial transmission, buzzer, LED, 7-segment, memory read/write, analog/digital signal converting, step motor trigger, LCM display, keyboard, and optical sensor control.

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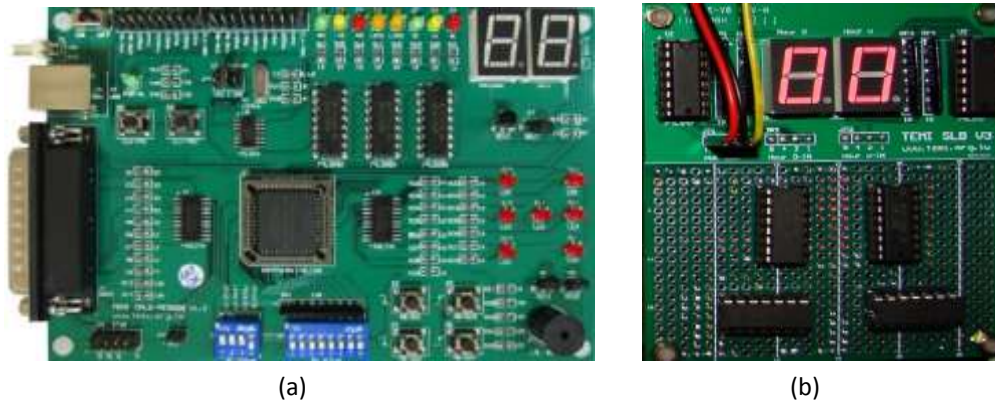


Figure 3: Main control boards for the digital logic design ability certifications; (a) practical level; (b) professional level.

Figure 3(a) is the complex programmable logic device (CPLD) based commercial peripheral board. As shown in Figure 3(a), the peripheral board supports several functions, including selecting multi-clock inputs, four specific DIP switches for functional setting, 8-pin DIP switches for inputs, 4 pushbuttons for inputs, 8 LEDs for outputs, two 7-segment displays for outputs, 7-dice LEDs for outputs, and the buzzer for the sound output. The practical level of the digital logic design ability certification mainly evaluates the ability of specific digital logic integrated circuit design and peripheral interface control skills. The architecture of the CPLD based commercial peripheral board mainly uses EPM 7064SLC44-10 chip to develop different CPLD based applications. Specifically, the practical level ability certification contains five combinational and sequential logical circuit design respectively, including 2-bit half adder/subtractor, 4X2 coder, 2X4 decoder, 4X1 multiplexer, and 1X4 de-multiplexer combinational circuit design as well as including module-8 ripple counter, synchronized module-6 up counter, module-5 down counter, module-4 loop counter, and module-7 Johnson counter sequential logical circuit design. In addition, the professional level of the digital logic design ability certification mainly evaluates the ability of both software and hardware digital logic application design. The software digital logic application design includes dice randomly display, left/right shift control, 0-99 two-digit up counter design, and red-green traffic sign control by using the CPLD based commercial peripheral board as the test target. As for the hardware digital logic circuit design shown in Figure 2(b), the architecture of the main control circuit board mainly adopts 4027, 4029, 4069 and 4081 integrated chips to decode mode 12, 15, 18 and 24 different hour-timing counter design and uses two 7-segment displays for outputs.

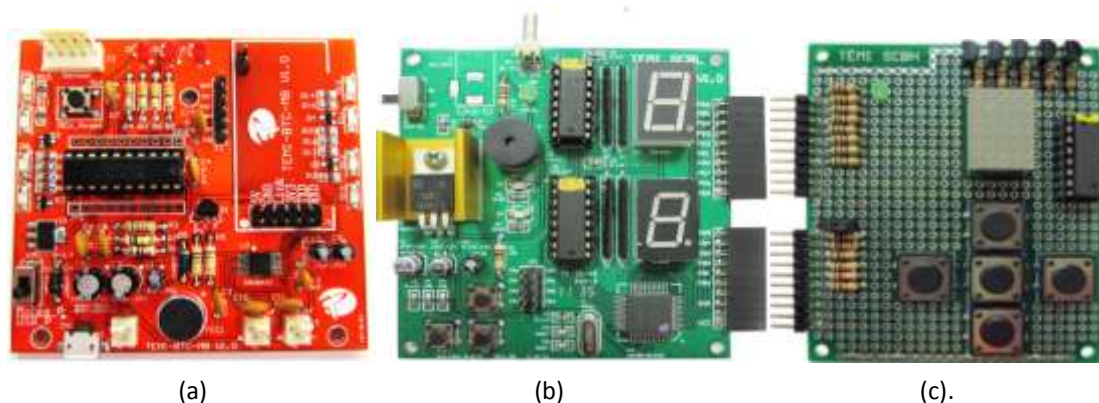


Figure 4: Main control boards for the electronic component de-soldering/soldering ability certifications; (a) practical level; (b) professional level; (c) expert level.

Figure 4 illustrates the pictures of the main control boards for the electronic component de-soldering/soldering ability certifications, which mainly evaluates the ability of soldering SMD (surface mount device), QFP (Quad-flat package), and DIP (dual-in-line package) technology, components' identification, and the functional test capabilities. Figure 4(a) is for the practical level of electronic component de-soldering/soldering ability certification with the function of Bluetooth voice-activated tracking self-propelled vehicle. The architecture of the main control circuit board mainly uses TI MSP430G2553 microcontroller to transmit the control signal and drive six module functions, including DC power input (via Micro USB or power socket), microphone signal input, masked sensor signal input, Bluetooth wireless signal input, LED output display, and DC motors trigger

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signal. Figure 4(b) is for the professional level of electronic component de-soldering/soldering ability certification with the function of the number guessing game. The architecture of the main control circuit board mainly uses ELAN EM78451 microcontroller in QFP (Quad-flat package) to drive five module functions, including DC power input (via power socket), push button signal input, system reset signal input, the 7-segment display signal output, and buzzer signal output. Figure 4(c) is for the expert level of electronic component de-soldering/soldering ability certification, which is required to connected to the main control board, as shown in Figure 4(b), to test the function of jumping up, down, left, and right moving control.

As described above, the main control circuit boards applied in three types of microcontroller related ability certifications are the key points for the user passing the subject examinations. Therefore, the proposed platform adopts these main control circuit boards as the simulation examples. The designed main control circuit board and discipline ability certification training simulation platforms are described as follows.

A. Main control circuit board simulation platform

Figure 5 illustrates the structure of the initial user interface for the main control board simulation. As shown in Figure 5, the main control circuit board simulation platform includes four parts. They are the display of the simulation score, setting/displaying the connection status of a component, executing the simulating functions, and showing the unwired main control circuit board picture on the right side of the screen. The displays of the simulation scores include the initial, undo, failed and total scores. The connection status of a component includes setting two nodes for a component, displaying the connection status for failure or success, and the number of connected, failure, success, and undone components. The simulation functions are such as start, calculating score, auto-simulation, re-run, and exit. In addition, the specific blank main control board pictures with different color marked for the microcontroller, digital logic design, and electronic component de-soldering/soldering practical/professional /expert level ability certifications are shown on the right side of the screen.

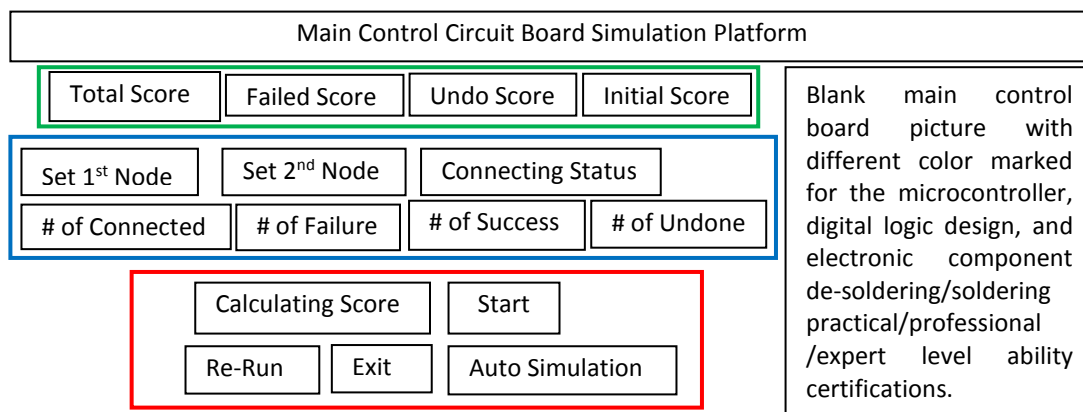


Figure 5 : Structure of the initial user interface for the main control board simulation.

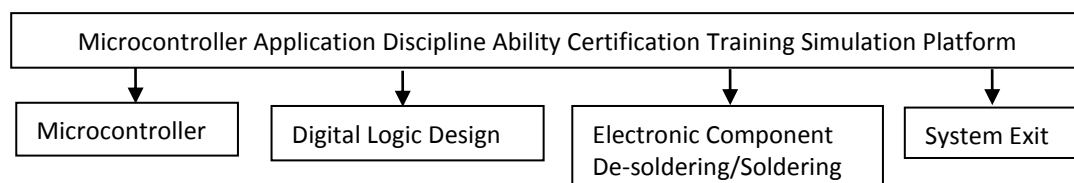


Figure 6 : Structure of the microcontroller application discipline ability certification training simulation platform.

B. Discipline ability certification training simulation platform

Figure 6 illustrates the structure of three different microcontroller application discipline ability certification training simulation platform. A user can start any discipline training simulation by clicking the icon of the microcontroller, digital logic design, or electronic component de-soldering/soldering discipline ability certifications. Figure 7 shows the software flow chart. As shown in Figure 7, each discipline ability certification simulation is divided into several sections and each section only contains 50 questions. When a user finishes the test, he/she can click "Finish" icon and then the score will be shown on the screen.

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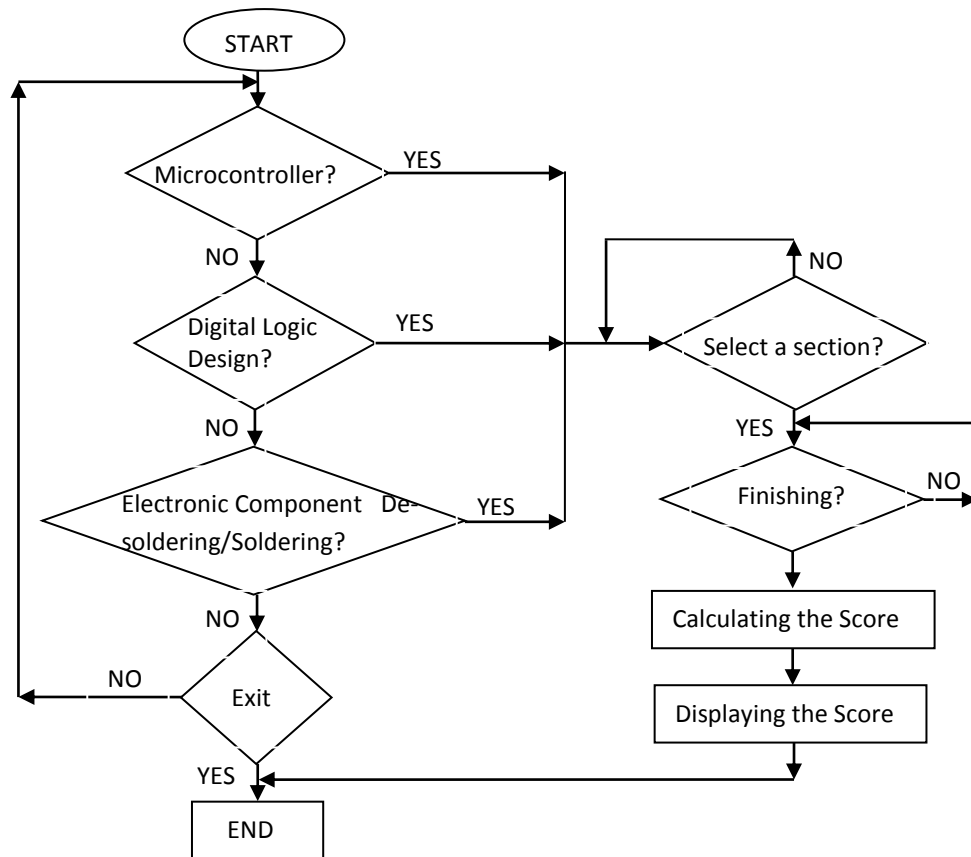


Figure 7 : Software flow chart of the microcontroller application discipline ability certification training simulation platform.

III. EXPERIMENTAL RESULTS

This paper has proposed a teaching simulation platform to help students learning three different microcontroller application ability certifications, including microcontroller, digital logic circuit design, and soldering/de-soldering of electronic components. The proposed learning ability certification simulation platforms adopt the Visual Basic for developing practical main control board simulating tests and apply Visual C for programming online simulating discipline tests. Figure 8(a) illustrates the initial user interface for the practical main control board simulation with "Microcontroller Application Ability Certification Practical Teaching Simulation Platform" on the up-left window. Users can click "Exit" button to exit the system. As shown in Figure 8(a), a user can choose the "Microcontroller" function to start the practical main control board simulation by clicking the "practical/professional/expert" icon. A user also can click the "Description of the Ability Certification Information" icon to display the main control board circuitry, discipline test questions, technical test questions, and ability certification guide as illustrated in Figure 8(b). Figure 8(c) presents the simulation sequences for the practical level ability certification in the order of the green, blue, red, and yellow colour, respectively. The components with smaller SMD parts are in green colour, larger SMD and smaller DIP parts are in blue and red colour, and larger DIP parts are in yellow colours. Figure 9(a) illustrates the main control board simulation user interface for the digital logic circuit design ability certification with MOD 12, 15, 18, and 24 different counter circuit simulation selections. Figure 9(b) demonstrates the auto simulation of the MOD 15 counter main control circuit board picture. As shown in Figure 9(b), the displays of the simulation scores include the initial, undo, failed and total scores. The connection status of a component includes setting two nodes for a component, displaying the connection status for failure or success, and the number of connected, failure, success, and undone components. The simulation functions include start, calculating score, auto-simulation, re-run, and exit. Figure 10(a) illustrates the initial user interface for the discipline test ability certification simulation with "Microcontroller Application Discipline Ability Certification Training Simulation Platform" on the up-left window. Figure 10(b) and Figure 10(c) show the discipline test ability certification simulation interfaces for microcontroller and electronic component soldering/de-soldering. As shown in Figure 10(b) and Figure 10(c), each discipline test ability certification simulation is divided into ten sections for microcontroller and six sections for electronic component soldering/de-soldering respectively, in

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which each section only contains 50 questions. In addition, when a user finishes the test, he/she can click “Finish” icon and then the score will be shown on the screen.

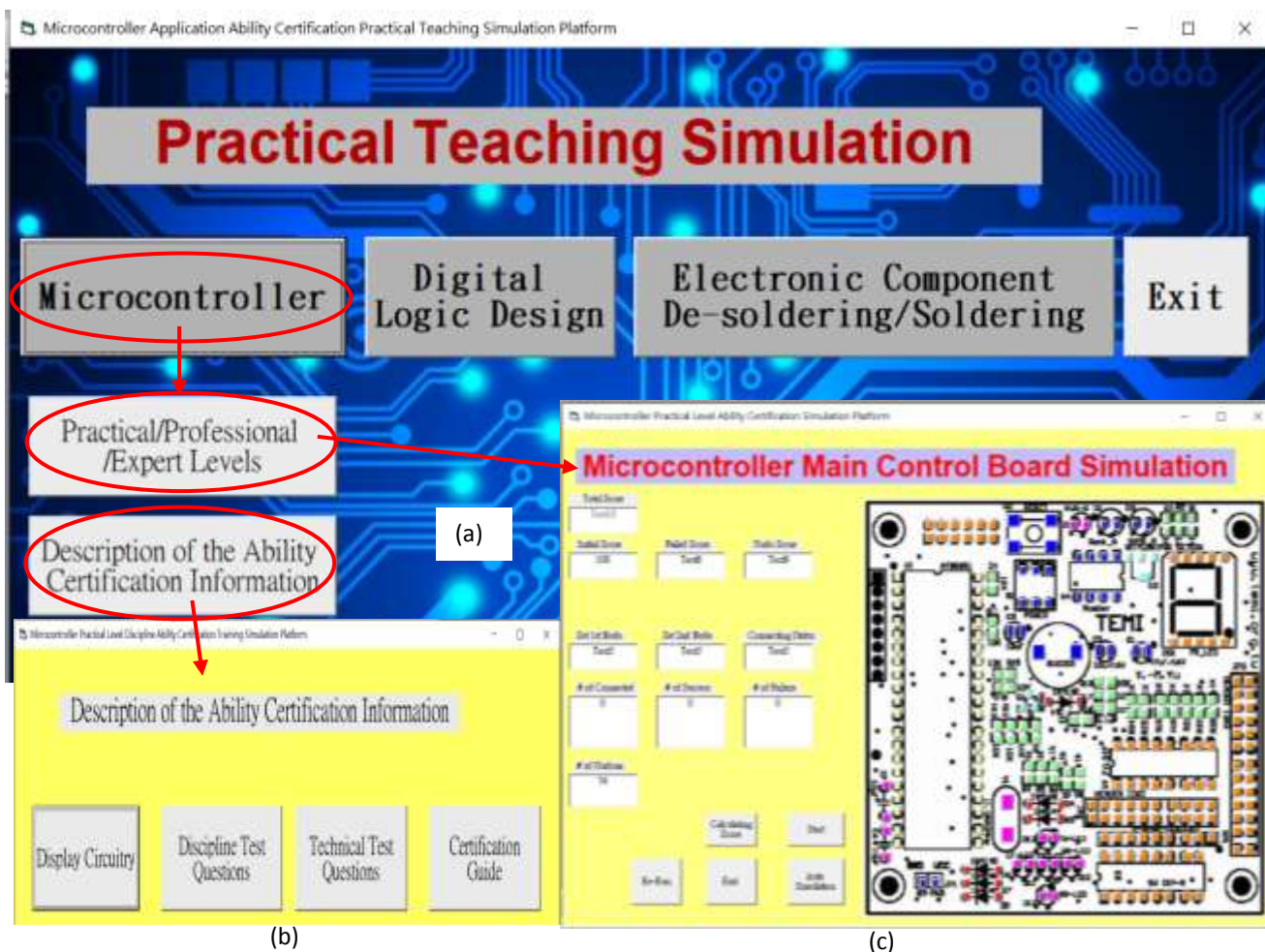


Figure 8 : Interface windows for the microcontroller practical main control board simulation; (a) Initial interface, (b) description of the ability certification information; (c) simulation sequences.



Figure 9 : Main control board simulation user interfaces for the digital logic circuit design ability certification; (a) initial interface; (b) auto simulation.

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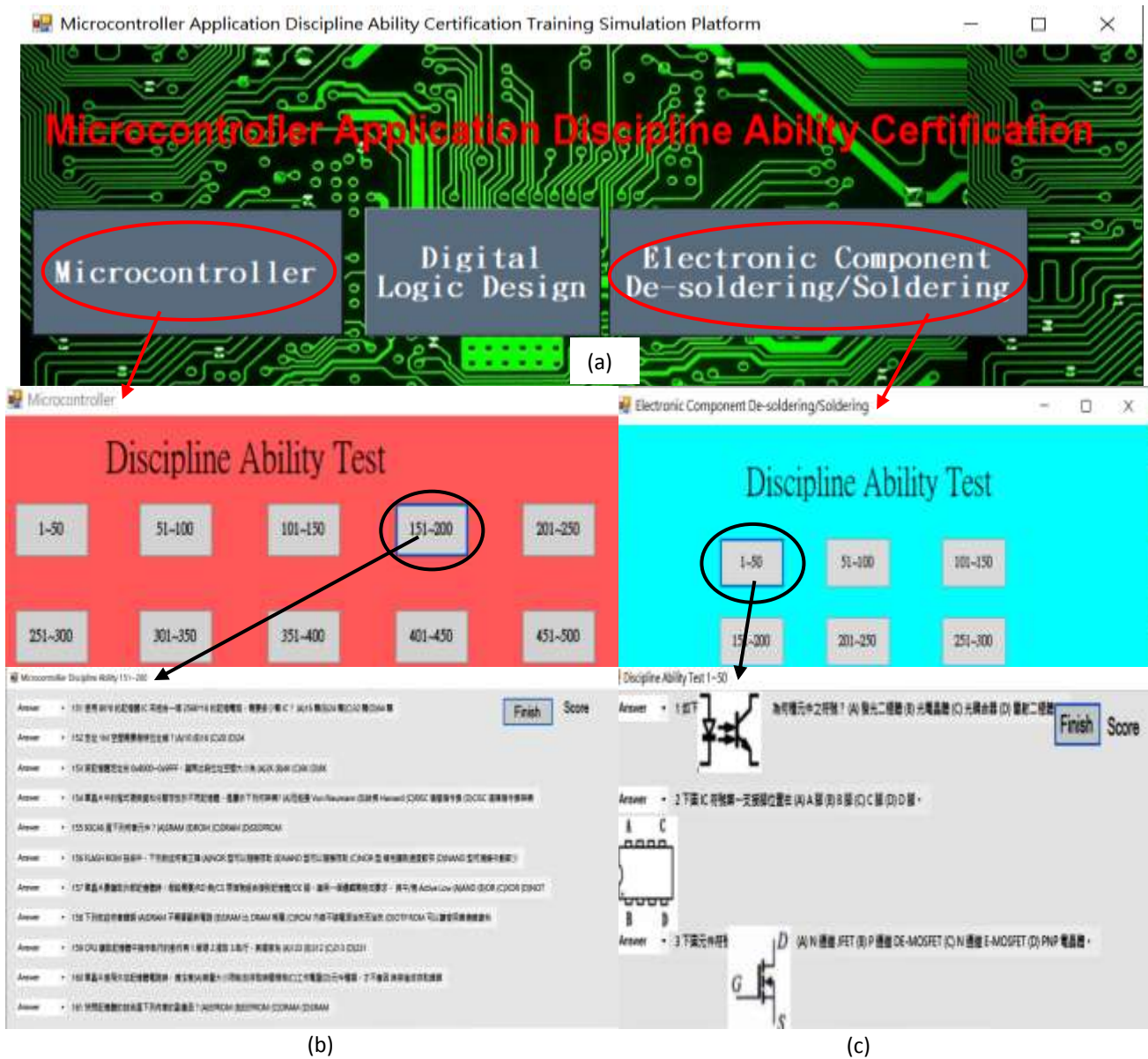


Figure 10 : User interface windows for the discipline test ability certification simulation; (a) initial interface; (b) microcontroller; (c) electronic component de-soldering/soldering.

The proposed simulation tool has been used as the learning exploration with the students at Kao Yuan University in Kaohsiung City, Taiwan. Table 1 illustrates the pass rates for students taking the practical level of different types of the ability certifications on the condition of whether students are with/without extra training the platform before taking the examinations. As shown in Table 1, two digital logic design ability certification examinations were held on Jan. 09, 2016 and Nov. 26, 2016, respectively. Two electronic component soldering/de-soldering ability certification examinations were held on June 05, 2017 and May 07, 2018. One microcontroller ability certification examination was held on Dec. 23, 2018. According to Table 1, the pass rate is around 50% for students without extra training the platform and the pass rate is about 75% for students with extra training the before taking the examination. Conclusively, the proposed simulation software can increase about 20% pass rate for students taking extra training courses on electronic component soldering/de-soldering ability certification. In addition, about 90% of students agree that the proposed learning tool is of great help for passing the certification examinations and for increasing the microcontroller application professional skills. In addition, the proposed platform also applies the picture-oriented lecture notes and auxiliary learning materials to help students finishing the microcontroller application ability certifications. Therefore, it allows students quickly understanding the microcontroller applications while participating the specific training courses.

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Table 1 : Pass rates with/without using the proposed learning platform before taking the examination.

Types of Ability Certifications (Practical Level)	Date	Number of Students				Extra Training Course
		Taking Exam.	Passing Exam.	Falling Exam.	Passing Rate	
Digital Logic Design	Jan. 09, 2016	24	12	12	50%	Without
Digital Logic Design	Nov. 26, 2016	33	18	15	54.5%	Without
Electronic Component	June 05, 2017	48	25	23	52.1%	Without
De-soldering/Soldering	May 07, 2018	36	27	9	75.0%	With
Microcontroller	Dec. 23, 2018	31	16	15	51.6%	Without

IV. CONCLUSIONS

This paper mainly develops a set of microcontroller application ability certification practical training simulation platform. The goal is to help students developing intelligent information and microcontroller application practical skills as well as assist teachers in teaching and increase students' learning quality. The proposed simulation platform can allow students to learn wireless remote-control robots, tracking self-propelled vehicles, digital circuit design and electronic component de-soldering /soldering related technology as well as can be used as the teaching tool for the certification training characteristic courses. The developed practical training simulation platform adopts the microcontroller, digital logical circuitry design, and electronic component de-soldering/soldering ability certification main control circuit boards, which are developed by TEMI (Taiwan Embedded Microcontroller Development Institute) association. In addition, the proposed approach applies information technology in designing teaching materials and teaching tools for guiding students on their hands-on experience to inspire students' interest in technology research and enhance students' learning effects. Conclusively, the designed training tool can benefit students with three aspects. First, it can increase the passing rates of obtaining three types of microcontroller application professional competence certification examinations. Second, it can assist teachers in understanding students' learning performance, thereby proposing related teaching strategies for improvement. Third, it can increase students' professional skills and employment competitiveness, thereby cultivating more professional and technical talents to meet the needs of the microcontroller application industry.

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