A Practical Learning Simulation Software with Specific Applications for Printed Circuit Board Soldering/De-soldering Ability Certifications

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ABSTRACT:
This paper mainly develops a practical learning printed circuit board (PCB) soldering/de-soldering simulation software to be the reference of the specialized characteristic curriculum for a school. The proposed learning simulation software can train students with the soldering knowledge, the soldering technology, the electronic component identification, and the usage of the instruments. The research aims at inspiring students to be interested in circuitry soldering technology and have different thoughts on electronic/information/mechanical related technology applications. In this paper, the developed practical learning simulation software utilizes Visual Basic programming language as the developing tool and adopts the Bluetooth voice- activated tracking self-propelled vehicle and the number guessing game main control PCBs as the circuitry soldering training targets which was developed by Taiwan Embedded Microcontroller Development Institution (TEMI).
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, the developed simulation tool could provide three contributions. First, it can be an interactive- and interesting-oriented learning tool. Second, it can cultivate and inspire students learning soldering technology efficiently and effectively to meet the needs in the industry. Third, it can cultivate more professional and technical students actively participate in seeking solutions to problems.
Keywords-Soldering technology, specialized characteristic curriculum, and learning simulation tool.

I. INTRODUCTION

In nowadays, soldering applications cover various fields, such as machinery, vehicle, chemical, shipbuilding, aviation, space, construction, and semiconductor electronics [1]. This implies that good soldering is an important guarantee for the success of electronic manufacturing because electronic components must be supported and fixed with reliable electrical connection through soldering. The American Welding Society (AWS) has defined that the soldering process is to use an electric soldering iron to melt the solder and to firmly combine the end points of the electronic components with the wires or printed circuit boards (PCBs). The author Zhu [2] pointed out that the soldering uses a piece of metal heating the part to be joined at an appropriate temperature so that it is melted and then solidified and combined into a whole. Another author Lee [3] also stated that the purpose of the soldering is to mutual fusion two objects by heating to a certain temperature. Therefore, how to learn and how to use an electric soldering iron to solder electronic components is one of the basic skills in the entire electronic production.

With soldering technologies growing steadily in the industry, Almit Technology Ltd opened a hand soldering training course which reviewed the whole soldering process to improve soldering quality and increase the first time pass rate [4]. Metcal, a brand of OK International, also issued technical notes for hand soldering basics [5], the white paper for hand soldering with lead free alloys [6], discussed the risk mitigation in hand soldering [7], and developed a robotic soldering to increase productivity [8]. In addition, many educational institutes have provided soldering related training courses. For example, University of Technology Sydney provided a course to introduce the different types of solder and soldering irons, the tips of soldering, the methods and utilities of de-soldering as well as the hazards of soldering, including heat, toxic materials, spattering, and electrical safety [9]. Department of Engineering Health & Safety at University Cambridge gives the soldering safety induction and training overview [10]. In Taiwan, Kao Yuan University also opened the expand learning courses for training soldering techniques on passing the examinations of the circuit board soldering/de-soldering ability certifications [11]. In the reviewing some researches, the literature [12] introduced the issue of soldering failures during reflow soldering Surface Mount Device (SMD) components with the large size of the panelized Printed Circuit Boards (PCBs) and proposed a method for measuring and investigated PCB shrinkage during reflow soldering. A soldering process model has been developed and implemented as a software-tool for computing the temperature profiles in different sectors of the solder joint, which describes the process of single point soldering and allows predictions of its behavior [13].

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In the reviewing some related simulation references using JAVA language for online learning, the literature[14] 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 [15] designed a microcontroller named Komodo, which acted as an interrupt service to simulate the multi-thread processing of the microcomputer hardware. The literature [16] developed an ad hoc wireless network simulation software called ANEJOS which can be applied to various routing protocols. In the reviewing some related simulation references for students in skill training and teaching applications, the research [17] developed an interactive teaching virtual laboratory named simPHYSIO for psychology-related courses, which can be applied to the Internet platform for users to learn online. The thesis [18] proposed a computer simulation technology to analyze the performance of learners in computer simulation learning and skill abilities. Another thesis [19] explored the problem-solving strategies in a computer simulation environment, which used web pages and database platforms to collect students' answers based on the "hypothesis-observation-interpretation" process that can be automatically loaded into the database platform. The paper [20] investigated the acceptance and impact of integrated computer simulation technology into Visual Basic programming curriculum for college students, teachers, academia as teaching references. The thesis [21] discusses the effectiveness of applying the computer simulation software to the "Single Chip Experiment" course for students in the comprehensive high school information technology program. This study adopted self-edited single-chip basic ability tests coupled with pre-test and post-test respectively. The paper [22] studied the impact of using computer simulation software on the learning effectiveness of the "digital logic" course. This research adopted multi-factorial orientation tests with self- developed professional pre-test and post-test respectively.

With soldering technologies growing steadily and cooperating with the Ministry of Education's promotion on the concept of "education popularization" and "elite education" in Taiwan [23], students need to learn the basic knowledge of the electronic productions and familiar with the hands-on operating skills as well as brainstorm related electronic technology. Therefore, this study, the extend work of the authors' previous research [11], develops a set of learning simulation software platform for training PCB hand soldering/de-soldering technology in order to stimulate students to be interested in electronic component soldering technology and related applications. In addition, Taiwan Embedded Microcontroller Development Institute (TEMI) [24] has issued the circuit board soldering/de-soldering ability certifications which have been recognized by the industry, universities, and ministry of education in Taiwan. The proposed practical learning simulation platform allows students to learn about the intention of soldering, the correct method of soldering, the identification of components, and the knowledge of soldering tools. Conclusively, the proposed technology can not only inspire students to develop professional skills in an orderly manner, but also cultivate beginners to master the basic soldering skills, hands-on practical abilities, and less waste of component materials as well as increase the success rate of passing the PCB soldering/de-soldering ability certifications.

II. MATERIAL AND METHODS

Figure 1 is the block diagram of the proposed practical learning printed circuit board (PCB) soldering/de-soldering simulation platform. The system initially displays "Printed Circuit Board Component Soldering/De-soldering Ability Certification Learning Simulation Software" on the screen. The menu of the learning-tool user interface includes simulating practical/professional PCB electronic component soldering ability certifications, soldering/de-soldering tips, describing the ability certification information, displaying the circuitry schematic diagrams, illustrating the technical question examples, and system exit. In this study, the practical and professional PCB soldering/de-soldering learning platform adopt the Bluetooth voice- activated tracking self-propelled vehicle and the number guessing game main control PCBs as the circuitry soldering training targets which was developed by Taiwan Embedded Microcontroller Development Institution (TEMI). A user can click either the practical level or the professional level ability certifications icon to access the corresponding soldering simulation learning platform. In addition, a user can click the "Help" icon to illustrates the PCB circuitry schematic diagram. For example, the practical level PCB circuitry schematic diagram is divided into three parts. One part is such as SMD resistor/LED/transistor; the other part includes DIP (dual in-line package) diode, ceramic capacitor, resistor, electrolytic capacitor, and LED; Another part includes the switch, power socket, condenser microphone and header pins.

The practical level of the PCB component soldering/de-soldering ability certification using the main control circuit board of Bluetooth voice-activated tracking self-propelled vehicle mainly evaluates the ability of soldering/de-soldering SMD (surface mount device) and DIP (dual-in-line package) technology, components' identification, and self-propelled vehicle assembly and testing capabilities. The architecture of the main control circuit 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 signal.

The professional level of the PCB component soldering/de-soldering ability certification using the main control circuit board of the number guessing game mainly evaluates the ability of soldering/de-soldering SMD, QFP (Quad-flat package) and DIP technology, components' identification, and the number guessing game assembly and testing capabilities. The architecture of the main control circuit mainly uses ELAN EM78451 microcontroller 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.

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As shown in Figure 1, the learning platform for the ability certification provides six functions including showing the printed circuit board picture, setting component connecting nodes, autoing soldering simulation, rerunning the simulation, and displaying the elapsed time.
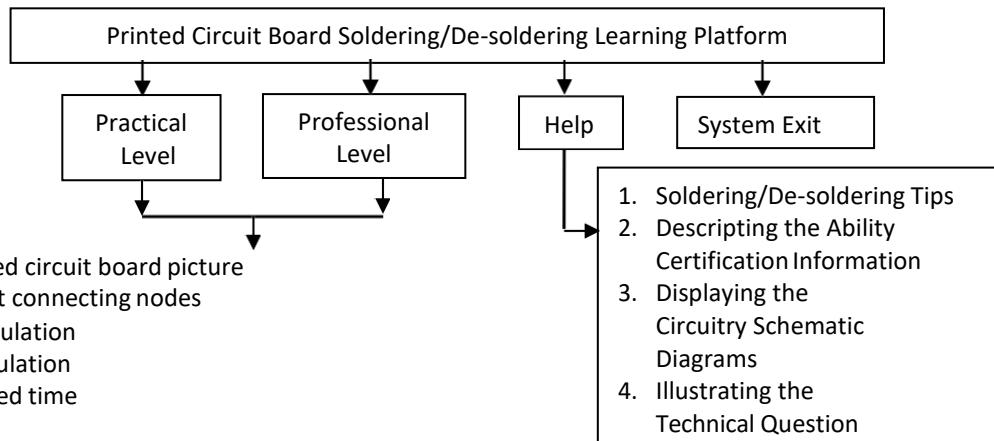

Figure 1：Block Diagram of PCB Soldering/De-soldering Learning Platform.

A. *Showing the Printed Circuit Board Picture*

Figure 2(a) is the blank PCB picture of the practical PCB soldering/de-soldering ability certification. Figure 2(b) is with electronic components. Figure 3(a) is the blank PCB picture of the professional PCB soldering/de-soldering ability certification. Figure 3(b) is with electronic components.


(a)   (b)
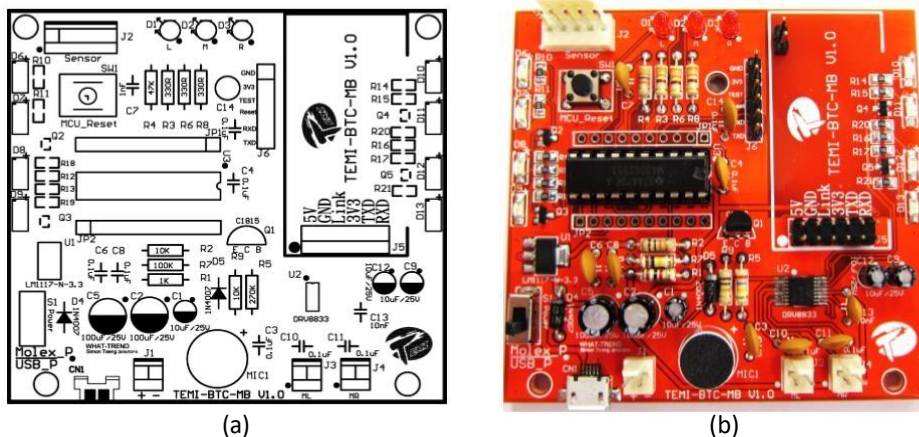
Figure 2：**(a)** Blank PCB picture of the practical PCB soldering/de-soldering ability certification; (b) with electronic components.

(a)   (b)
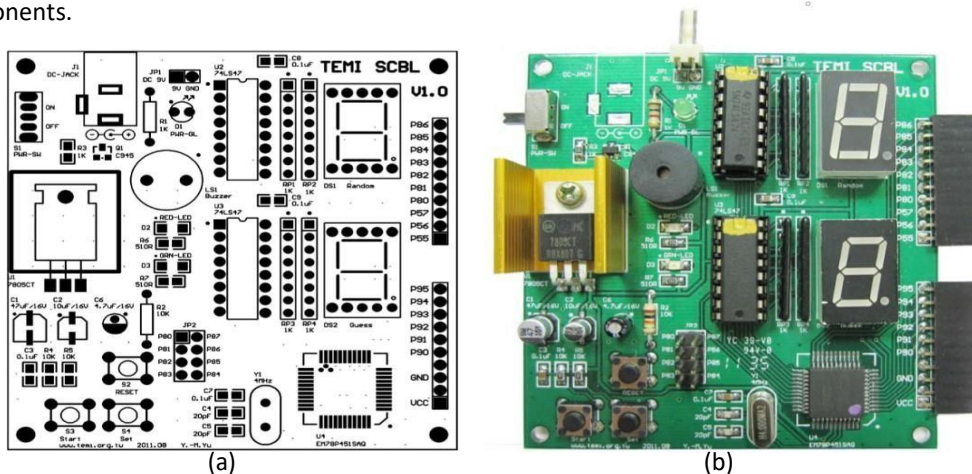
Figure 3：(a) Blank PCB picture of the professional PCB soldering/de-soldering ability certification; (b) with electronic components.

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B. Setting Component Connecting Nodes

Figure 4 illustrates the layout of the initial user interface for the PCB soldering simulation learning platform. As shown in Figure 4, when a user can set the component connecting nodes shown on the blank PCB picture, the corresponding information, such as 1st node, 2nd node, component, # parts completed, # parts succeeded, # parts failed, # parts undone, and elapsed time, will show on the right hand side of the Figure 4 where each function is described as follows.
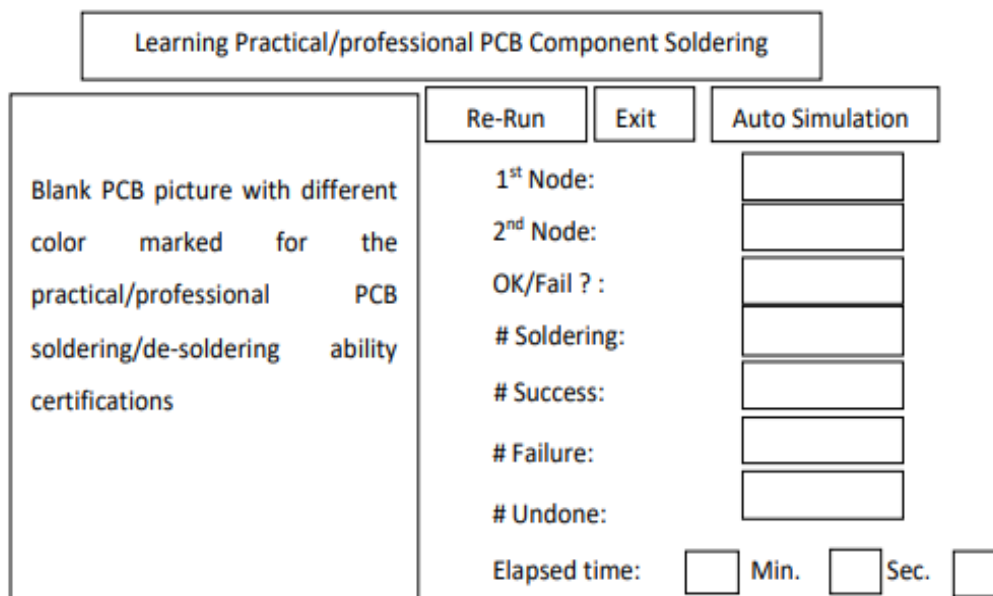
Figure 4 ：Layout of the initial user interface for the PCB soldering simulation.

C. Auto Soldering Simulation

A user can click the "Auto" icon to initiate automatic PCB soldering simulation. The soldering simulation starts from inside and the small components, such as the surface mount device (SMD), to the outside larger parts of the components, specifically.

D. Rerunning the Simulation

If a user wants to re-start the soldering simulation, he/she can click the "Re-Run" icon and the system will clear all the related information of setting component connecting nodes.

E. Showing the Elapsed Time

Once a user starts setting the component connecting node, the timer will count and show the elapsed time on the screen.

F. Exiting the System

A user can click the "Exit" icon to exit the learning simulation platform.

## III. ExpERIMENTAL RESULTS

In this paper, the authors adopt two commercial printed circuit boards (PCBs) named the Bluetooth voice-activated tracking self-propelled vehicle PCB and the number guessing game PCB as the experimental targets to train students for learning the soldering technology, the electronic component identification, and the usage of the practical instruments. The developed practical learning PCB soldering/de-soldering simulation software uses Visual Basic programming language as a development tool. Figure 5 illustrates the initial interface window which displays "Printed Circuit Board Component Soldering/De-soldering Ability Certification Learning Simulation Software" on the screen. As shown in Figure 5, the screen shows the practical and professional level of PCB component soldering/de-soldering ability certifications, respectively. The main functions of the proposed learning platform include user interface design, location layout, auto soldering simulation, and circuit schematic diagram display. Users can directly click the learning practical/professional ability certificate button to enter the simulation. If users want to leave the teaching simulation software system, they can click the "Exit" button. Figure 6 illustrates the success and failure settings of the PCB soldering component for the practical and professional ability certifications, specifically. As shown in Figure 6, the PCB soldering interface window contains the top side of the main control circuit board, the setting soldering component parts, automatic soldering simulation, circuitry schematic diagram display, timer exhibition, re-running, and exiting the system. Figure 7 shows the execution of the sub-functions of "Exit" and "Rerunning" interface windows.
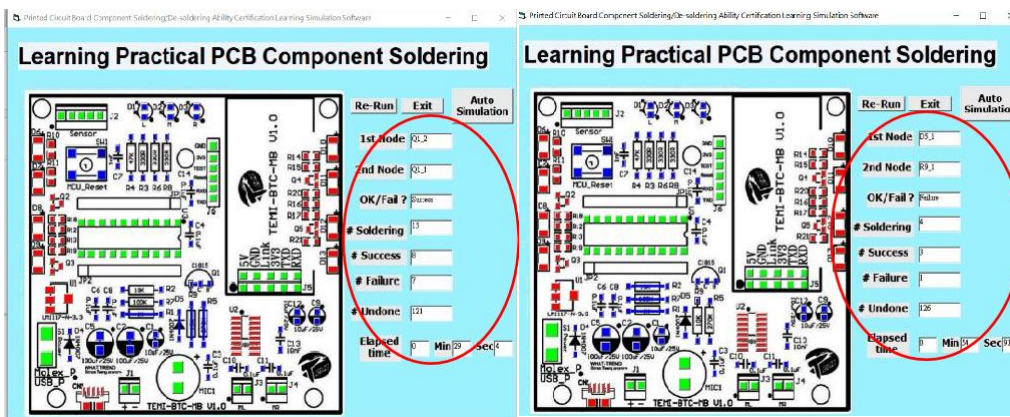
Figure 8 gives the results of executing automatic soldering simulation for practical and professional ability certifications, respectively. As shown in Figure 8(a), the PCB soldering sequences for the practical ability certification is in the order of the red, blue, and then green colour. The components in red is SMD related parts where the others are related to DIP components. In

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Figure 8(b), the PCB soldering sequences for the professional ability certification is in the order of the red, blue, and then green colour. The components with smaller SMD and QFP parts are in green colour, larger SMD and smaller DIP parts are in blue colour, and larger DIP parts are in green colours.
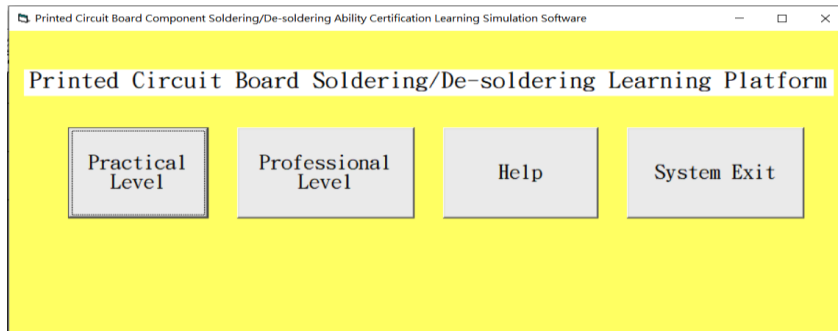
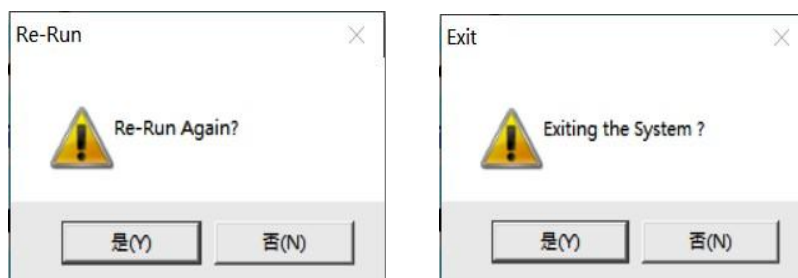**Figure 5**：Initial interface window of the learning simulation tool.

(a) Practical level of Success and Failure interface windows.
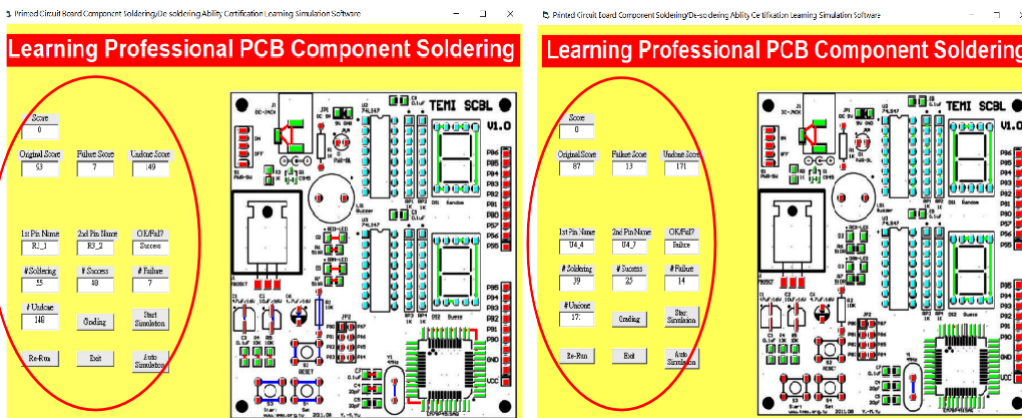


(b) Professional level of Success and Failure interface windows.

Figure 6：Success and failure settings of the PCB soldering component for (a) the practical and (b) professional ability certifications.

Figure 7：Execution of the sub-functions of "Exit" and "Rerunning" interface windows.

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(a)   (b)
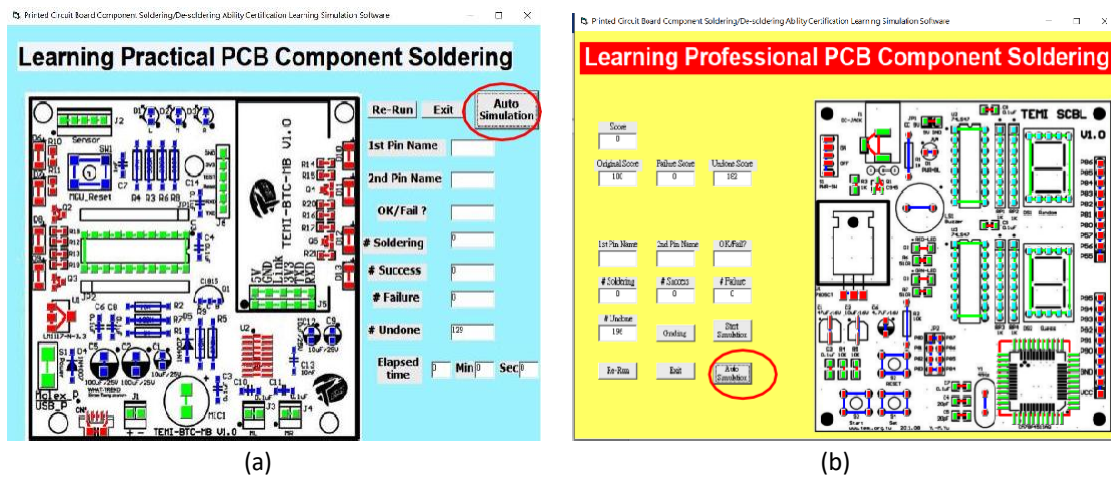
Figure 8：Results of executing automatic soldering simulation for (a) practical and (b) professional ability certifications.

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 the ability certification on the condition of whether with/without using the proposed learning soldering platform before taking the examination. According to Table 1, the pass rate is 52.1% for students without using learning soldering platform, where the pass rate is 75% for students with using learning soldering platform before taking the examination. Conclusively, the proposed simulation software can increase about 20% pass rate for students taking the PCB 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 examination and for increasing the soldering professional skills. However, the students also suggested that it would be better for the proposed simulation platform with the grading and starting simulation icons. Therefore, as shown in Figure 6(b), the grading and starting simulation icons are added in the interface window for the professional level of the ability certification.

According to the experimental results, the proposed platform applies the picture-oriented lecture notes and auxiliary learning materials to help students finishing the wireless Bluetooth based self-tracking vehicle production. Therefore, it allows students quickly and accurately understanding the production and finishing the exclusive voice-activated wireless self-tracking vehicle individually while participating the training courses specifically.

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

Date	Number of Students			
	Taking Exam.	Passing Exam.	Falling Exam.	Passing Rate
June 05, 2017	48	25	23	52.1%
May 07, 2018	36	27	9	75.0%

IV. CONCLUSIONS

This paper develops a practical learning simulation software for circuit board soldering/de-soldering ability certifications to increase students' learning quality, professional hand soldering skills, and employment capability. According to the experimental results, the proposed simulation software is an interactive- and interesting-oriented learning tool with the advantages in three aspects. First, when students practice the proposed platform before actual soldering PCBs, the first-time pass rate on soldering the PCB is increased and the cost of laboratory equipment and supplies is reduced. Second, it can cultivate students learning soldering technology efficiently and effectively and inspire students actively participate in seeking solutions to problems to meet the needs in the industry. Third, it can strengthen students' professional and technical aptitude thereby increasing the passing rate in obtaining circuit board soldering/de-soldering ability certificates.

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