Design of Portable Industrial Automation Education Training Kit Compatible for IR 4.0

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***Abstract*—A myriad of existing education training kits are easily accessible, however lacks practicality as they require a large space to operate. This calls for a more portable and smaller training kit to facilitate the teaching and learning experiences. It is also necessary to ensure that the new design meets the requirement of the fourth Industrial Revolution besides assisting teaching and learning. A study was conducted using the results of students undertaking Industrial Automation Course in UNITEN. The data was obtained from assessment results when only simulation software was used, and simulation software is complimented by a training kit. The results indicated 1.6% and 18.0% increment in the number of students obtaining A+ respectively. This shows that students who are exposed to both simulation and also sensors and actuators wiring learnt better compared to the control group. Ultimately, this paper presents the development of a portable programmable logic controller (PLC)-based training kit for industrial automation course. This portable PLC training kit is only 470 x 370 x 270 mm in dimension, which is equivalent to a cabin size baggage, and weigh below 10 kg, making it the most suitable to teach smart sensor application for IR 4.0.**

Keywords—PLC Trainer, Portability, Intelligent Sensor, Teaching and Learning, Industrial Automation Training kit

I. INTRODUCTION

Programmable Logic Control (PLC) programming is learned best by practicing with real devices and face-to-face demonstration, using an automation system [1]. Nevertheless, due to some constraints such as timing, budget and workshop location, this type of learning experience is limited. Most institutions opt for more theoretical and simulation approach which limit the students from authentic hands-on experience.

Therefore, this indicates a need to reform teaching method and assessment tool, laboratory equipment and experiment in enhancing students' practical skills, laying a good balanced foundation for a job and improving their social competitiveness and the quality of personnel training [2].

PLC-programming is normally taught in Industrial Automation course in Universiti Tenaga Nasional (UNITEN) with students receiving hands-on experience through PLC devices as well as other actuator and sensors components. This is aligned with the Engineering Technician Accreditation Council (ETAC) requirements, which require a student to have more than 50% hands-on experience.

An option has been given to students to bare PLC devices with separate controller, wires, input devices and output devices which is more cost effective [3,4]. However, through this option, students are exposed to wiring complications. Another option is in the form of prebuilt hardwired kits and simulators which is more expensive and not portable. On top of that, the prefabricated PLC Training system is built in a casing, which makes the wiring connection between the PLC and I/O module to be unobservable and hidden.

Thus, this paper presents the design of a portable PLC training interface that covers the gaps between the industry and academicians, to enable students to be taught through PLC-programming and also PLC to I/O wiring. As a complement, this design is compatible with future improvement towards Industry 4.0 (IR4.0).

Moreover, this paper also incorporates students' feedbacks and scores when they were exposed to theoretical and simulation software only and when there is a combination of simulation and practical experiment throughout the years to justify the reason of why the new design is proposed.

II. MATERIALS AND METHODS

The proposed PLC-trainer kit design and demonstration methodology are presented schematically in Figure 1. Each phase is presented in the following subsections.

A. Product Planning and Early Feedback

At this phase, a clear definition of the project goal(s), objective(s) and timeline of the project are proposed. The objective of this project is to produce a smaller and lighter, interactive and programmable training kit for Industrial Automation course in an education institution. The advantage of this product is its portability for any presentation purposes. Once the objectives and goals are

clear, a Gantt chart is developed to monitor and plan the timeline of this project.

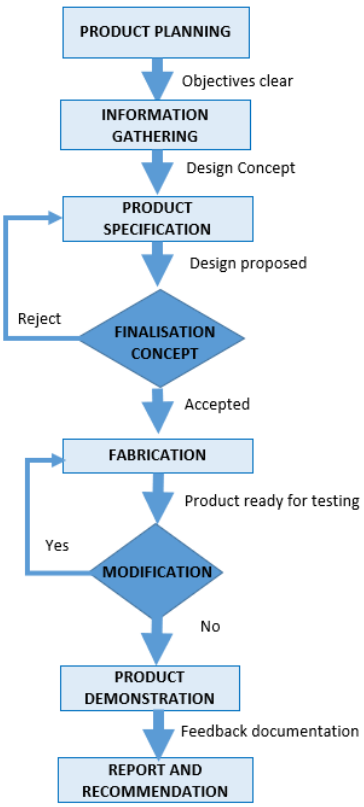

Fig. 1. Design and demonstration methodology flow chart

To support the product planning, an evaluation has been made by comparing the students' results based on simulation of PLC testing software (Year 2015 and 2016) with the ones using both simulation and training kit (Year 2017-2018) as shown in Figure 2. The year 2017 training kit was comprised of a PLC model, push button and LED. The year 2018 kit included sensors and motor on top of the 2017's kit. Figure 2 illustrates the total number of student enrolments per year and the evaluation was made based on students' grades from A+ to E, quantifying the best grade to the worst. The grades varied over the year, but the number of students scored C- and below showed a steady decrease. Figure 2 shows a normal distribution graph of student performance using simulation, with and without training kit. The distribution is distinguished in 4 colors.

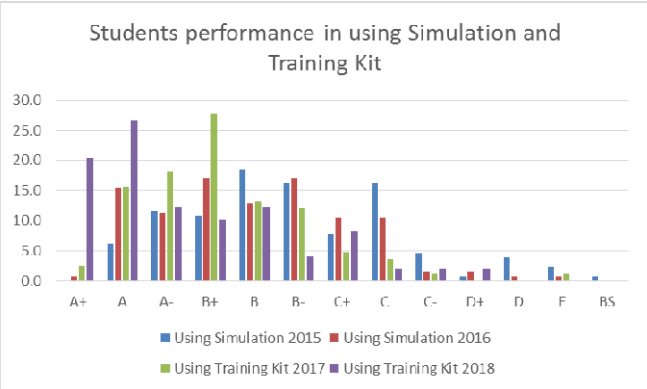

Fig. 2. Trend of students' performance using simulation vs training kit

B. *Information Gathering*

Data pertaining to sizes and weight of the existing kit is obtained in this phase. The information helps in providing the physical characteristics of the kit and estimation on the cost of fabrication, which could leverage the new design. Three existing training kits that are normally used in any Industrial Automation Lab in the market have been observed. Specification of chosen existing products can be referred to in Table I.

TABLE I. PREVIOUS DESIGN AND EXISTING PRODUCT SPECIFICATION

Characteristic	Specification		
	GTPLC-0003	XK-PLCS1	"Lab"
Dimension	500x340x160 mm	400x250x120 mm	370x370x50mm
Weight	3 kg	2.5 kg	4 kg
Power Supply	single-phase AC220V voltage, frequency 50/60Hz, power<150VA	single-phase AC220V voltage, frequency 50/60Hz, power<150VA	single-phase AC220V voltage, frequency 50/60Hz, power<150VA
Components	PLC, toggle switch, NO push button, dc motor, fan, led		
Experiment Power Supply	DC24V voltage source 1 way, capacity 1A.	DC24V power output: Capacity 1A;	
Portability	Yes	Yes	No
Price	USD1500	USD700	-
Critics	Relatively large and heavy	Smaller size, portable but not supported by wheels	Not portable

The revolutionary of Internet of Things (IoT) had brought our everyday devices to their better potential by transforming them into an automated informative system with intelligent means of communicating protocols which is one of the components that is relevant to Industry 4.0. The high pace escalation of technology is assisted by various development boards to deploy Internet of Things system. Engineers have spectacular variation to choose from between these boards depending on their preferences. For this project, a comparative study by [5], it can be concluded from Table II NodeMCU - ESP8266 stands out the most when comparing device level sensor networking abilities with other IoT development boards due to wireless connectivity, costing [6] and its small form.

TABLE II. COMPARISON OF NODEMCU – ESP8266, ARDUINO UNO AND RASPBERRY PI-3.

Parameters	NodeMCU - ESP8266	Arduino Uno	Raspberry Pi B+
Processor	-	ATMega328P	Quad-core ARM Cortex A53
GPU	-	-	Broadcom VideoCore IV with 400 MHz
Operating Voltage	5v	5V	5v
Clock Speed	26 MHz – 52 MHz	16 Mhz	1.2 Mhz
Flash Memory	<45 kB	2 kB	1 GB
System Memory	Up to 128MB	32 kB	-
EEPROM	-	1 kB	-
Communication Supported	IEEE 802.11 b/g/n	IEEE 802.11 b/g/n IEEE 802.15.4 433RF BLE 4.0 vi Shield	IEEE 802.11 b/g/n IEEE 802.15.4 433RF BLE 4.0Ethernet Serial
Development Environments	Arduino IDE, Lua Loader	Arduino IDE	Any Linux compatible IDE
Programming Language	Wiring, C, C++	Wiring	Python C C++ Java Scratch Ruby
I/O Connectivity	UART, GPIO	SPI I2C UART GPIO	SPI DSI UART SDIOCSI GPIO

III. RESULTS AND DISCUSSION

The expected results have been achieved when the proposed kit is used. The percentage of the students getting high scores increased every year as presented in Table III. The apparent achievement was in 2018 with 18.0% increment. This shows that students experienced effective learning when using simulation software as well as the training kit as complement. There was only 1.6% increment from 2016 to 2017 which can be attributed to the adaptation of the previous approach with the new one. It still shows success where students are more interested on hands-on project compared to the simulation process only.

Previously in years 2015 and 2016, students only applied their theoretical skills into the simulation software without conducting practical wiring skills. Students need to imagine the PLC process by themselves if they use simulation software. The results indicate that the students displayed high performance when handling hands-on project compared to the imagination per say. It helps students to better understand the topic if they stimulate the real project on circuit designing, installation, wiring, and troubleshooting by their own. It also enhances the students' psychomotor skills. At least from that particular aspect, students are able to determine the problems during the handling process compared to the simulation process. A new design which integrates more components is proposed to enhance the practical experience.

TABLE III. COMPARISON OF STUDENTS GRADE PERCENTAGE WHEN USING SIMULATION SOFTWARE AND TRAINING KIT

Grade	Using Simulation Software ONLY		Using Simulation and Training Kit	
	2015 (%)	2016 (%)	2017 (%)	2018 (%)
A+	0.0	0.8	2.4	20.4
A	6.2	15.3	15.7	26.5
A-	11.6	11.3	18.1	12.2
B+	10.9	16.9	27.7	10.2
B	18.6	12.9	13.3	12.2
B-	16.3	16.9	12.0	4.1
C+	7.8	10.5	4.8	8.2
C	16.3	10.5	3.6	2.0
C-	4.7	1.6	1.2	2.0
D+	0.8	1.6	0.0	2.0
D	3.9	0.8	0.0	0.0
E	2.3	0.8	1.2	0.0
Student Number	129	124	83	80
C- and Below	11.63	4.84	2.41	4.08

A. Product Specification

Summary of final design specification is as illustrated below. This design proposes the addition of a wheel-based moving case to make the portable kit more user-friendly (Refer Figure 5).

TABLE IV. FINAL SPECIFICATION

Characteristic	Description
Dimension	470 x 370 x 100 mm
Weight	4 kg
Components	PLC, HMI, Conveyor, Electric Solenoid, LED, NO and NC Push Button
Number of IO	I: 8 O: 6
IoT Development Board	NodeMCU ESP 2566
Communication	Ethernet
Portability	Movable by wheel mechanism

* LED: light emitting diode, HMI: human machine interface, NC: normally closed, NO: normally open

B. Final Product Design

Figures 3, 4 and 5 are the proposed designs for the new Industrial Automation Training Kit. All the components and their description are listed in Table 4.

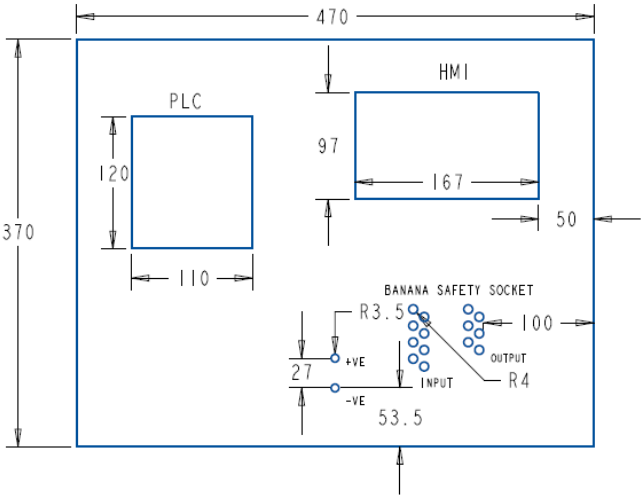

Fig. 3. Design of PLC (on the cover)

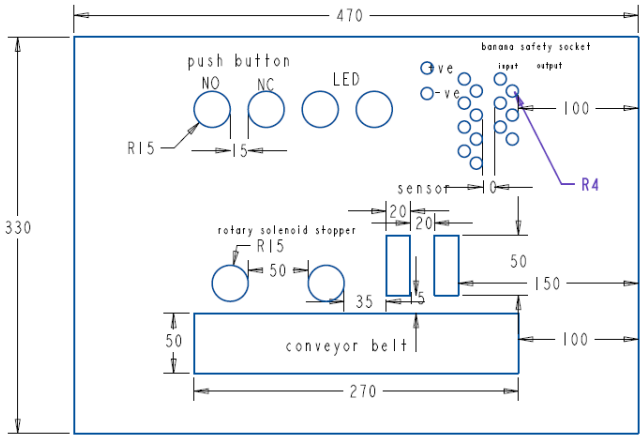

Fig. 4. Proposed actuator, LED and conveyor system (on the main board)

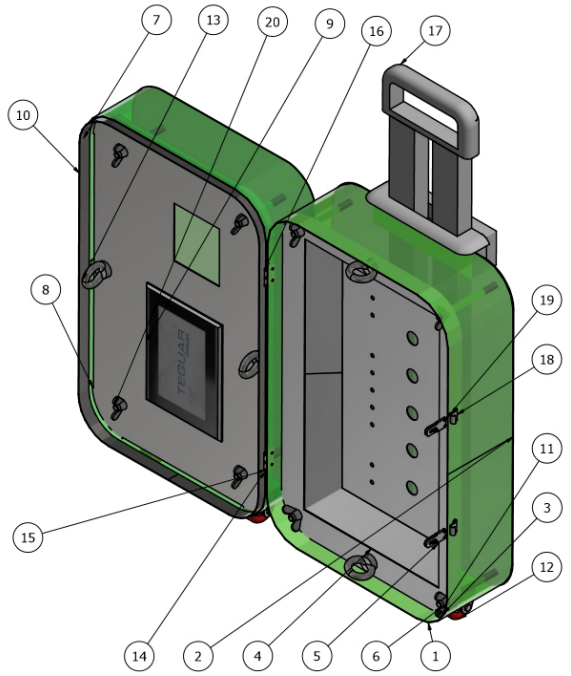

Fig. 5. Proposal of the overall design

TABLE V. PART LIST OF OVERALL DESIGN

Part List			
Item	Quantity	Part Number	Description
1	1	Cover Surface	
2	2	Front Cover	
3	1	Plate Button 1	
4	1	Plate Button 2	
5	1	Plate Button	
6	4	DIN 835 – M10 x 100	Double End Stud
7	1	Cover 2	
8	1	Cover In	
9	1	TP-1645-07	
10	1	Retainer	
11	8	CNS 4373 – M 8	Wing Nut
12	4	Rolling	
13	4	Bolt GB 825 B M10	Eyebolts Type B
14	2	Bracket	
15	2	Bracket 2	
16	1	ISO 2430–A–3x 30(1)	Clevis Pin Without Head
17	1	Handle	
18	2	Lock	
19	2	Bracket Lock	
20	4	DIN 835 – M10 x 80	Double End Stud

IV. Conclusion

The proposed design combines the PLC control system, actuators and sensors to become a portable PLC Training Interface that can be used together to teach anything related to IR 4.0. The portable industrial automation system training kit weighs less than 10 kg, which is suitable for air transportation and can be used anywhere as long it has a computer with the right software and power source. To improve the portability, the design includes wheels.

The usage of previous training kits already proved that the students achieved better results due to better comprehension of the system because they can learn the software, wiring, and automation system through hands-on experience and not only depending on simulation. Hence, this proposed design is believed to further enhance the achievement of the students in their training experience.

Acknowledgment

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