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Learning Element Package in Electrical Technology using Portable Automation Trainer

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Abstract: The main intention of this study was to design, develop and evaluate the performance of the trainer and ascertain its effectiveness as a learning tool for instruction. The trainer is intended to improve the efficiency of the teaching process for the proper installation and programming of data languages. As a result, learners are able to build competence in the areas of automation and control system operation, programming, and troubleshooting. The study was conducted at Bohol Island State University Main Campus, Tagbilaran City during the Academic Year 2015-2016. The study employed the experimental method of research in testing its effectiveness and descriptive design in determining the performance of the trainer. The performance of the trainer was evaluated by experts from the academe and private industry. The respondents of the study who took the pre-test and post-test were the third year Bachelor of Science in Electrical Technology students. The results revealed that the trainer's performance was found to be functional and performs to its full potential. In terms of effectiveness, it was found that an increase of learning took place after students experienced a hands-on demonstration on the trainer. This was obvious in the students' post-test results, where they earned higher ratings than their pre-test results. Based on the result, Portable Automation Trainer is an effective tool for instruction in Bachelor of Science in Electrical Technology.

Keywords: Learning Element, Portable, Automation Trainer, PLC, Performance, Effectiveness

I. INTRODUCTION

Currently, the world is entering the fourth industrial revolution, also known as "Industry 4.0". "Industry 4.0" was promoted as an approach to strengthening the competitiveness in the manufacturing industry [3]. It is an age marked by " more ubiquitous and mobile internet, smaller and more powerful cheaper sensors, and artificial intelligence and machine learning". As previous industrial revolutions have shown, it is clear that working in "Industry 4.0" requires higher levels of education and cognitive abilities. Schwab underscored that "Industry 4.0" is not only about the "ubiquitous and mobile internet", or smart factories but also about the integration of technological advances (i.e. Artificial Intelligence (AI), Automation, robotics, Internet of Things (IoT), 3D printing, nanotechnology, biotechnology, materials science, etc.) and their interaction with the physical, digital and biological realms. Schwab proposed that scenarios in which AI and machine learning could replace humans in the labor market. However, at the current stage, technologies serve simply to augment and assist human labor. The eventuality of such world requires that workers are equipped with skills that enable them to engage with and work alongside with increasingly more comprehensive, capable, and intelligent machines [13].

The transition of industrialism is closely connected to the Theory of Modernization which states that societies are developed in fairly predictable stages through which they become increasingly complex [12]. This development depends primarily on the importation of technology as well as a number of political and social changes. These changes are inevitable making it necessary to prepare adequate human resources adaptable and competitive on a global scale. Improving the quality of human resources through education is a way forward with the developments brought by the Industrial Revolution 4.0. To thrive in the 4th Industrial Revolution, a learning revolution is necessary. Throughout time, the purpose of education has evolved based on the needs of society and it continues until at present. In the advent of the 4th Industrial Revolution, a new vision of learning promoting that learners not only learn skills and knowledge but also identify the sources of the skills and knowledge to be learned [8]. As we move further into the future, education needs to support learners in developing the skillset and mindset necessary to do anything in the future. Hence, educators play a crucial role in preparing learners for opportunities in the 4th Industrial Revolution. Hence, the education sector needs to ensure that new graduates are well prepared for their initial work. Anecdotes from industrial technicians and technology instructors prove that teaching theory alone is insufficient in developing skills among students. Akay claimed that to be successful, cooperative and productive learners must learn and succeed through a well prepared and supplied background based on hands-on experience. However, bringing the real industrial set-up to classroom setting is challenging [1].

Bohol Island State University (BISU), as one of the premier institutions in the country, has mandate to form world class professionals in the field of engineering and technology focused on adapting technology ensuring that the knowledge generated within is geared towards industry practices. As the prime mover of education, the institution's role is to create

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opportunities for its leaners to engage in new technological tools that provide the necessary skills and knowledge to prepare them for their future careers. American philosopher John Dewey said, “If we teach today’s students as we taught yesterday’s, we rob them of tomorrow.” Instead of teachers distilling information to students to memorize, teachers have to become guides facilitating their student’s own learning and lines of inquiry. Failure needs to be embraced as an essential step to learning. Moreover, teaching will be more personalized through the support of technologies such as AI and machine learning.

As a response, schools, higher educational institutions in particular, must provide sufficient and efficient educational facilities including technological tools that must be modeled after the type of learners they would produce based on the demands of Industry 4.0. These facilities must allow the use of advance technologies including robotics, IoT, digitalization, automation, and teleconferencing in order to produces competent workers for the modern world. Having an edge in educational facilities empowers the learners, facilitators, and the educational system. However, this means that teachers in higher education is no longer the prime source of learning, the environment, which is the educational facility is what primely nurtures learner with the teacher, a mere facilitator. According to Nacorda in his study, "PLC-Based Intelligent Traffic Light Control Simulator", stressed that learning by discussing theories, giving schematic diagrams, or making projects are insufficient [9]. Educating and training the learners in their field of study are important aspects to focus on. In order for them to perceive the actual job situation. It was emphasized that teaching and learning pattern will not be merely based on exams, but also on the practical and experiential learning-based projects or field work suited for future employment. Furthermore, a research conducted by Pateña shows that schools were ineffective in preparing students because of insufficient teaching tools in the classroom [11]. Hence, students cannot cope with the ever changing working conditions in the industry. Industry 4.0 will require schools to properly prepare learners with the right tools and to come up with new and innovative solutions to present and future problems faced by society. This revolution can lead to greater inequality if essential skills are not taught to students.

Technology has always been a supportive part in the teaching and learning environment. However, Johnson et al., argued that choosing the best technological tools can be a challenge for an educator [6]. The Situated Cognition learning theory believes that learning takes place in a learning community or community of practice where the learners take an active role in the learning community [7]. It involves a process of interaction between the learners within the community, the technological tools available within the specific situation, and the physical world. It is within this active participation and interaction, whether with technological tools, artifacts or other people, where knowledge is located. Although today’s students understand connected devices and their benefits, many still lack the skills necessary to thrive in an Industry 4.0 environment. They see the benefits of advanced technology, but lack real-world exposure to manufacturing equipment and processes. To realize this learning condition, using appropriate teaching aids is necessary. Teaching aids are defined as all physical tools or equipment that can be used to deliver lessons which include text books, miniatures, prototypes, dummy objects, and multimedia devices.

Portable Automation Trainer is a teaching aid designed to facilitate the insufficiency of the knowledge about programming simulation with the use of PLCs. It integrates control programs into various types of industrial control applications found in the trainer. The trainer has eight (8) plc input and output address terminals. The input electrical devices such as sensors (inductive proximity) and switches (pushbuttons) are connected to the PLC input. The trainer also equipped with a computer system interfaced directly to a PLC used for simulating the programmed input and output instruction. The computer is a programming device interfaced to the trainer for storing and processing the ladder diagram of the trainer. It is used to simulate the created program before it is downloaded to the PLC.

The researcher incorporated a built-in monitor to display all the programmed language for the simulation. A wireless internet dongle was integrated also in the trainer that will enable students to have a quick access to internet to supplement their learning. An electronic sensor was linked also to the trainer as an input signal. The proximity sensor has the ability to detect metal object approaching to the sensor without any physical contact. It opens and closes the electrical circuit when an object makes contact within a certain distance. By integrating the sensor, students may identify the basic operation of this sensor during a hands-on activity. Binary Coded Decimal (BCD), traffic light and light sequence are the applications found in the trainer. The BCD either counts up or counts down and the light sequence switches on and off after pressing the switch button twice depending on the situation or problem provided. Through these applications, students’ capability to incorporate timer program is developed because the BCD counter, traffic light and light sequence are connected to a timer program circuit. The researcher believes that developing the Portable Automation Trainer addresses the diverse needs of learning in the field of automation and industrial process control.

II. METHOD/S

The study employed the experimental method of research in developing the trainer. The trainer was tested in terms of performance using observation guide. A pre-test and post-test was designed to test its effectiveness in enhancing the

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knowledge of the students. The researcher selected forty (40) respondents composed of ten (10) technology experts coming from different vocational institutions and training enterprises in the province of Bohol to test and validate the level of performance of the trainer and thirty (30) third year Bachelor of Science in Electrical Technology students of BISU Main Campus who were purposively chosen to evaluate the effectiveness of the trainer.

In gathering data, the researcher prepared questionnaire and observation guide to assess the effectiveness and validate the performance of the trainer. An observation guide was made to describe the minute details of the specific parts of the trainer. It includes also the specific components algorithms and how it worked. An achievement test was administered to students to determine the significant level of effectiveness of the trainer.

III. RESULTS AND DISCUSSION

This presents the findings, analysis, interpretation of the study. It also presents the data gathered, collated, and tabulated in accordance to the appropriate statistical treatment.

3.1 Ladder Diagram

The ladder diagram of the trainer is a representation of two vertical rails and a series of horizontal rungs that connect the input devices to the output devices.

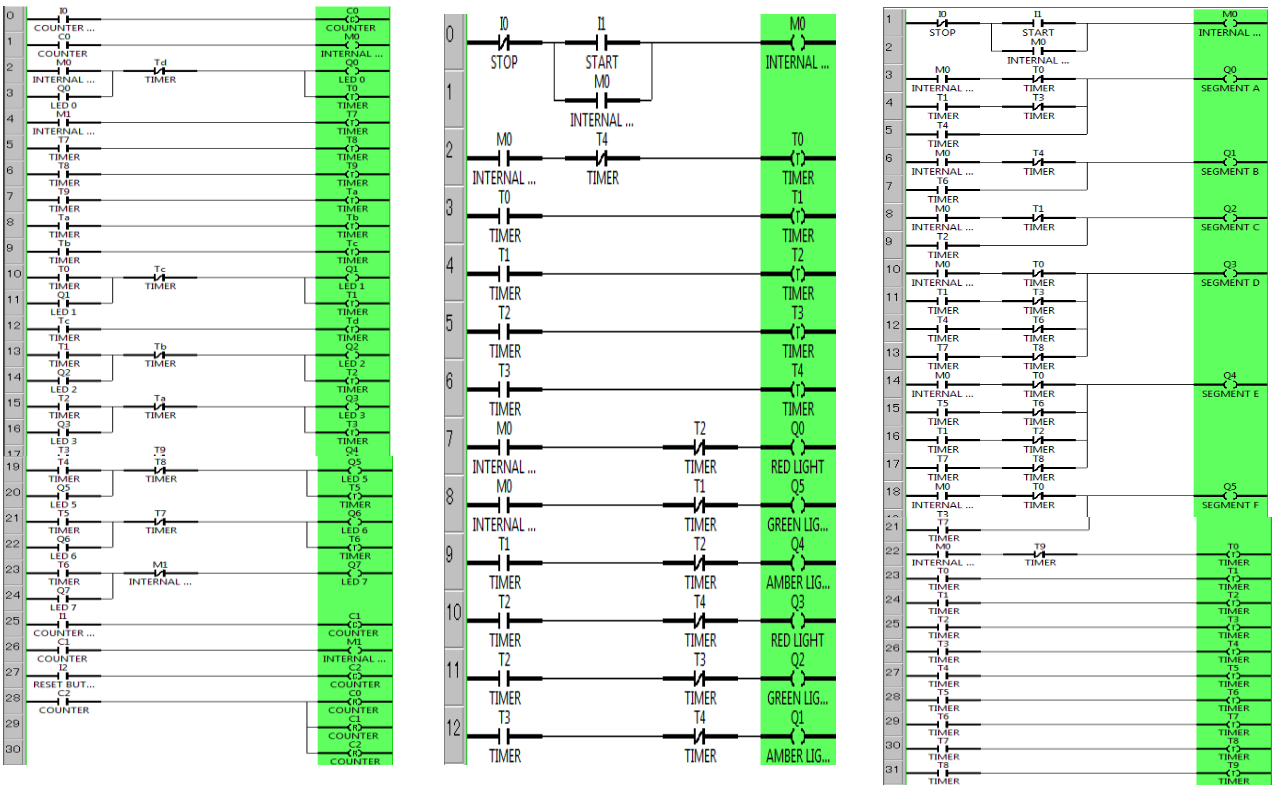

Fig 3.1 Ladder diagrams of the different applications of the trainer

3.2 Performance Level of the Portable Automation Trainer

Table 1 Multi-Function of Operations

Function	Operation	Output	Description
Binary Coded Decimal (BCD) Counter	Connect to PLC	Light decimal consecutively executes (0-9 digit)	Functional
Light sequence	Connect to PLC	Output lights sequentially turns on and off	Functional
Traffic light	Connect to PLC	Traffic signal light perform repetitive cycles (on/off)	Functional

As illustrated in the first table, the researcher tested the function of controlling the Binary Coded Decimal (BCD) Counter. A program was written for PLC which turns the BCD counter on and off based on input

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conditions and internal programming. For this aspect, a time delay timer was tested and configured for specific time setting for the output. It was observed that the operation of the BCD Counter function when the input was enabled, commencing the count up or countdown of the digital display. During the operation, the timers were energized and de energized. The output switches off based on the language program input. In turn, the BCD counter displays a number sign. The cycle of events continued until the set points were accumulated and the preset values of the timer were reached. The test was successful and found to be functional.

Sensors were linked to the trainer, particularly the inductive proximity sensor. It was solely designed for the detection of metal objects without any physical contact. This was used to serve as an input signal of the trainer. This was done to conform to the Theory of Detection which is about the extraction of particular pieces of information particularly metal from a larger stream of information without specific cooperation from or synchronization with the sender [2]. After building a ladder diagram and uploading it to the PLC, it was observed that the problem situation matched with the actual sequencing of light indicators during simulation. This part of the trainer was fully functional.
The last item tested was the function of the traffic light. This test aimed to prove whether the program ladder diagram will run through simulation. The programs were uploaded to the PLC then simulated to be able to determine if the program uploaded was able to communicate from the diagram inputted. Ohms Law explains the working principle of the programmable logic controller used to control the execution of light signals on the traffic light of the trainer. PLC are relay based controllers which function through induction, meaning input and output are all relays which are triggered when there is enough amount of current passes through it thus achieving a complete circuit. Ohms Law is also related to the Law of Electromagnetic Induction. It states that when a conductor is placed in a changing magnetic field (or a conductor moving through a stationary magnetic field), it causes the production of a voltage across the conductor. This process of electromagnetic induction, in turn, causes the production of a voltage across the conductor [5].

After a series of tests, the researcher found that the cycle of events of the traffic light continued until the set points were accumulated and preset values of the timer were reached. The test was successful and found to be functional. PLCs allow performing several different types of tasks including: logic, timing, counting, arithmetic, and special functions. Most PLCs support many extended instructions to perform more complicated tasks [4]. As a result, the researcher was able to run various functions that utilizes programmable logic controller which were resulted to fully functional of the Portable Automation Trainer.

3.3 Level of the Effectiveness of the Portable Automation Trainer

To determine the degree of the effectiveness of the Conventional and Portable Automation Trainer, a pretest and posttest were administered to 30 students. Fifteen (15) students composed the control group and the other fifteen (15) composed the experimental group. A t-test was done on the means of two groups, the experimental group used the Portable Automation Trainer and the control group used the conventional model.

Table 2
Pretest Performance of the Students under Control Group and Experimental Group
N = 15

Scores	Description	Control Group			Experimental Group		
		f	%	Rank	f	%	Rank
23-30	Very Good	0	00.00%		2	13.33%	3
15-22	Good	7	46.67%	2	5	33.33%	2
07-14	Fair	8	53.33%	1	8	53.33%	1
00-06	Poor	0	00.00%		0	00.00%	
Average Rating		**14.23 Fair**			**15.3 Good**		

Table 2 shows the frequency percentage of the performance of the students before the use of the trainer. It reveals that 8 out of 15 or 53.33% of the student's pretest performance under control group were described as "fair". While only 7 or 46.67% of the respondents were described as "good". Likewise, none were described "Very Good" and "Poor". The average rating of this group is 14.23 which is described as "Fair". Meanwhile, the experimental group got the same results of the control group, 8 out of 15 or 53.33% of their performance rated "Fair" and 5 or 33.33% of the respondents were described "Good". There were 2 or 13.33% of the students whose grades were described as "Very Good". Similarly, none were described "poor" with the average rating of 15.3 which was described "Good".

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Noticeably, both groups have relatively similar performance before the Portable Automation Trainer was introduced to them. Cognitive Load Theory suggests that effective instructional material facilities learning by directing cognitive resources towards activities that are relevant to schema acquisition [14]. Prior to the introduction of the Portable Automation Trainer, there was evidence that both groups have similar performance since both of the groups have the same knowledge and manipulative background in the area of electrical technology.

Table 3
Posttest Results of the Control and Experimental Group
N = 15

Scores	Description	Control Group			Experimental Group		
		f	%	Rank	f	%	Rank
23-30	Very Good	0	00.00%		13	86.67 %	1
15-22	Good	10	66.67%	1	2	13.33%	2
07-14	Fair	5	33.33%	2	0	00.00%	
00-06	Poor	0	00.00%		0	00.00%	
Average Rating		**15.83 Good**			**25.43 Very Good**		

Table 3 shows the performance of the students after exposing them to the different types of instructional media. It specifies that 10 or 66.67% of the students of the posttest performance under the control group were described "Good". Whereas, 5 or 33.33% of the student got the lowest score and were described as "Fair". The average ratings of this group are 15.83 and were described as "Good". On the other hand, there were 13 or 86.67% of the students of the posttest performance under the experimental group were described "Very Good" and were ranked first in the group. 13.33% or 2 of the students were described "Good" with an average weighted mean of 25.43 with the description of "Very Good".

It was found that the experimental group who used the Portable Automation Trainer obtained higher scores and was shown to be effective for the improvement of learning competencies of students through actual and hands-on demonstration. However, it was evident that learning took place in both groups although they were subjected to different instructional learning media.

According to the theory, "Learning by Doing" productivity is achieved through practice, self-perfection and minor innovation [15]. Based on the results shown in table 3, the experimental group who used actual and hands-on demonstration gained a rate of 25.43 which is significant compared to 15.83 of the control group. Thus, using the trainer is vital in the learning process of the students seeing that it can increase the ability and skills of the students rather than verbal discussion alone.

Table 4
Difference between the Performance of the students under Control and Experimental Group
N = 15

Difference	t computed value	t tabular value	Description	Interpretation
	at 0.05 level of significance, df 14			
Pretest of both Control and Experimental Group	-0.43	±2.145	Insignificant	Accept Null Hypothesis
Pretest and Posttest of Control Group	-8.33	±2.145	Significant	Reject Null Hypothesis
Pretest and Posttest of Experimental Group	-10.39	±2.145	Significant	Reject Null Hypothesis
Posttest of both Control and Experimental Group	-5.39	±2.145	Significant	Reject Null Hypothesis

Table 4 illustrates the differences between the performances of the two groups. The first row presents the difference of pretest results of the control group and the experimental group. The computed t-value of -0.43 was not within the absolute tabular value of ± 2.145 at 0.05 level of significance, therefore the null hypothesis was accepted. There was no significant difference between the scores of the students on both groups. The result shows that the student's average rating on both groups was closely equal on the topics tested because students are not expected to know the answers of the pretest questions; however only their previous knowledge was the basis for them to predict rational answers.

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The second row shows the pretest and posttest performance of the students under the control group. The computed t-value was -8.33, which was above than the absolute tabular value of ± 2.145 at 0.05 level of significance. Students have increased knowledge and understanding, thereby indicating that there was a significant difference in the performance after exposing the learners to various methods of instruction. Therefore, the null hypothesis was rejected. Furthermore, according to the theory of Higher Level Instructional Design, to support this ever-increasing need to be able solve problems and think critically in order to function well in society, we need to focus more on instructional simulators in our classrooms – whether they are in schools, conference rooms, or delivered digitally to home computers [10].

The third row shows the pretest and posttest performance of the students under the experimental group. The computed t-value was -10.39, which is above than the absolute tabular value of ± 2.145 at 0.05 level of significance. As a result, the null hypothesis was rejected. This implies that learning was enhanced when the Portable Automation Trainer was used as an instructional media.

The fourth row presents the posttest difference of both the control and experimental group. The computed t-value was -5.39, an absolute tabular value of ± 2.145 at 0.05 level of significance. It denotes that there is a significant difference in the performance of the students between the posttest of the two groups thus the null hypothesis was rejected.

Indicators reveal that the experimental group performed better than the control group although learning was also evident in the control group. The application of the Portable Automation Trainer as an instructional tool has shown to improve students' knowledge retention and assist effective learning acquisition in electrical technology.

3.4 The results of the study revealed the following findings:

1. The Portable Automation Trainer is a PLC-based with multi-functional operations trainer using Zen software. Furthermore, it is a teaching aid designed to facilitate the insufficiency of the knowledge about programming simulation with the use of PLCs. It integrates control programs into various types of industrial control applications found in the trainer. The materials of the device were carefully selected with guaranteed high quality. The total cost of assembling the Portable Automation Trainer is fifty thousand and nine hundred four pesos (₱50,904.00).

2. The performance of the Portable Automation Trainer was found to be functional and performs to its full potential. This was noticeable when the functions of the Binary Coded Decimal (BCD) Counter, light sequence, and traffic light follows the order of timing precisely based on the input program.

3. The results of the student’s performance were computed with the aid of statistical treatment. It was found that an increase of learning took place after students experienced a hands-on demonstration. This was noticeable in the post-test results of the students who used the Portable Automation Trainer got higher ratings in comparison to pre-test.

4. The pre-test scores of the control group and experimental group was revealed that the t-computed value of -0.43 was not within the absolute tabular value of ± 2.145 and was deemed insignificant, thus the null hypothesis was accepted. The participants of both groups were selected according to their class performance. Both groups increased their average rating after they were subjected to different instruction techniques. There was a significant difference in the performance of the students for acquiring -10.39 as the t-computed value which is above than the absolute tabular value of ± 2.145 thereby rejecting the null hypothesis. It can be seen that the realistic representation of materials provides a better understanding about the discussion.

IV. CONCLUSION

Based on the study’s findings, the following conclusions were drawn:
The Portable Automation Trainer is an effective tool for instruction in electrical technology given that the performance of the trainer improves the learning competencies of the students and provides relevant insights among instructors in the modern world of automation. Furthermore, the trainer helps the teachers in enhancing the learning of the students by letting them experience the real world of work.

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