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Computer- Assisted Programmable Logic Controller Simulator

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***Abstract:** The main purpose of this study was to assemble and assess the performance of the Computer-Assisted Programmable Logic Controller Simulator and ascertain the level of effectiveness of the simulator as a tool for instruction. This was conducted at Bohol Island State University Main Campus, Tagbilaran City during the Academic Year 2015-2016. It was done for the improvement of instruction in electrical technology and electrical engineering courses. The PLC Technology Courseware featured in the Simulator enables learners to develop competence in operating, programming and troubleshooting a true industrial programmable logic controller (PLC). It includes a student activity manual enabling a novice to rapidly attain programming competency. The study employed the experimental methods of research and descriptive design in developing the simulator, particularly the one group pre-skill and post-skill test design, and testing its effectiveness in enhancing the skills of the students. The respondents of the study were third year Bachelor of Science in Electrical Engineering students and different experts from the academe and industry. The results of the study using the Simulator revealed that the students' performance rating was increased by 57.25%. The results proved that the simulator is suitable for the electrical laboratory as an instructional tool.*

***Index Terms:** Computer-Assisted, Effectiveness, PLC, Simulator, Performance.*

I. INTRODUCTION

Integrating technology in education results ease in teaching and learning. According to Albert (2000) [1], schools were ineffective in preparing students because of insufficient teaching instruments in a classroom. Hence, students cannot cope with the ever changing working conditions in the industry. Bohol Island State University as a technology-based institution employs theoretical and actual hands-on exercises. Thus, students are not only equipped with adequate education in their field of study but also armed with skills and the knowledge required to influence technology effectively in the workplace. The Experiential Learning Theory suggests that trying and doing contributes much to the development of student's skills and ideas [2]. Hence, experiencing a situation, whether actual or simulated, contributes much to the knowledge gained by students. According to Kolb (2014) [3], actual performance is needed to understand the theory, in turn theory serves as a guideline to improve a student's application.

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To ensure effective training performance of the students, laboratory facilities used in curricular offerings should be on par with the prevailing standards in the industry. Learning will be comparable with real work situations if the instructional technology used functions similarly with those used in actual work stations. This attests to one of the theories of vocational education which states that "the training environment is the working environment itself or a replica of the working environment" (Colley, 2003) [4].

Modern technology has brought a whole new lifestyle that has changed many aspects of day-to-day living [5]. Many inventions that function to augment the daily needs and wants of man continue to emerge in the industry. Programmable logic controllers (PLCs) are among the recent developments in process control technology and are widely utilized by industry. A programmable logic controller (PLC) is designed to be used in an industrial environment to control and automate complex systems. With its numerous positive effect brought by PLC in the industry, the researcher developed a multiple control simulation of the PLC intended for instructional purposes.

The Computer-Assisted Programmable Logic Controller Simulator is a device that integrates control programs into various types of control functions. This device is designed to facilitate the insufficiency of the knowledge about programming simulation. The Simulator has eight (8) input and output modules. The input electrical devices such as sensors (inductive proximity) and switches (pushbuttons) are connected to the PLC input module. The Simulator has 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 simulator for storing and processing the ladder diagram of the control simulator. 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 network enabling student's to have a quick access to internet to supplement their learning. An electronic sensor was linked also to the simulator 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 in the simulator, 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 simulator. 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 main objective of this study was to assemble and assess the performance of the Computer-Assisted Programmable Logic Controller Simulator in the aspects of programmability, multi-function of operations, and network connectivity and discover the effectiveness of the simulator as device for instruction by administering a pre skill test and a post skill test. Furthermore, the study sought to determine the acceptability level of the device in terms of performance, convenience, safety, durability and cost.

II. RESULTS AND DISCUSSION

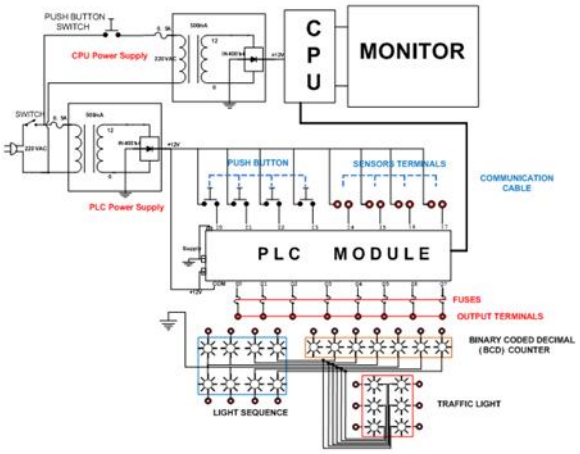

Fig 1: Schematic diagram of the Computer-Assisted Programmable Logic Controller Simulator

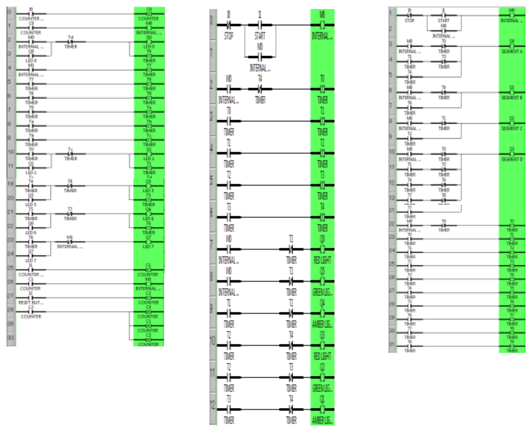

Fig 2: Ladder diagram of the Computer-Assisted Programmable Logic Controller Simulator

The Performance Level of the Computer-Assisted Programmable Logic Controller Simulator.

Table I

Multifunction of operation

Function	Operation	Output	Description
Binary Coded Decimal(BCD) Counter	Connect to PLC	Light decimal consecutively execute (0-9 digit)	100% functional
Light sequence	Connect to PLC	Output lights sequentially turns on and off	100% functional
Traffic light	Connect to PLC	Traffic signal light perform repetitive cycles (on/off)	100% functional

As illustrated in Table 1, researcher first 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 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 inputted. 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 is 100% functional.

Sensors were linked to the simulator, 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 device. 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 [1]. 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 simulator 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 Computer-Assisted Programmable Logic Controller Simulator. 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 [6]. 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 is 100% 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 [7]. As a result, the researcher were able to run various functions that utilizes programmable logic controller which were resulted to fully functional of the Computer-Assisted Programmable Logic Controller Simulator.

Table II
Network connectivity

Function	Operation	Output	Description
Firmware Update	Research through internet	PLC program version maintain its normal operation	100% functional
Program Extraction	Research through internet	Input(switch)/Output device (light) execute on/off	100% functional
Learning Channel	Research through internet	Illustrate program data	100% functional

During the process of firmware update, it was found that the method of updating PLC program was part of the normal operations of the PLC. Hence, the user can continue to generate and simulate program language into the PLC.

Program extraction was tested with users collating information from the internet to supplement their solution to the problem. After gaining the necessary information, it was constructed and simulated into the PLC. It was found that the input and output devices respond as designed in the circuit to its changing state from ON to OFF and vice versa. The use of social media increases an individual's learning ability [8] and was used effectively.

The last item tested for the network connectivity was the learning channel. It was tested through a series of trials. After conducting the trials, the researcher concluded that, the data searches illustrated the actual simulation and processes of the Computer-Assisted Programmable Logic Controller Simulator. Hence, the internet is a valuable asset in collecting important information to supplement the students' learning. There were multiple search engines that have made it easier for Internet users to find information about the deficiency of Computer-Assisted Programmable Logic Controller Simulator. All the trials utilizing internet connectivity were found to be 100 percent functional for the fact that it can send and receive swamped of information such as text, graphics, voice, video, and computer programs.

The Level Of The Effectiveness Of The Computer-Assisted Programmable Logic Controller Simulator

Table 3 illustrates the skill test results of the students before and after using the simulator. It was observed that in the pre-skill test, mostly, students fell under "poor" having a 66.67 % or 20 out of 30. Meanwhile, 10 out of 30 or 33.33% of respondents were described as "fair". The average rating of this group was 1.33 which is described as "poor".

Table III
Pre-skill Test and Post Skill Test Result of the Computer-Assisted Programmable Logic Controller Simulator
N = 30

Score	Description	Pre skill Test			Post Skill Test		
		F	%	Rank	F	%	Rank
3.25-4.00	Very Good	0	00.00%		25	83.33%	1
2.5 -3.24	Good	0	00.00%		5	16.67%	2
1.75-2.49	Fair	10	33.33%	2	0	00.00%	
1.00-1.74	Poor	20	66.67%	1	0	00.00%	
Average Rating		1.33 Poor			3.62 Very Good		

On the other hand, the post skill test relatively showed higher results to pre skill test. Twenty five (25) out of 30 or 83.33% rated "Very Good". Five (5) out of 30 or 16.67% of respondents were described "Good". The students' total average rating of 3.57 was interpreted as "Very Good".

The significant difference between the pre skill test and post skill test results of the students

Table 4 presents the difference between the pre skill test and post skill test of the students. The computed t-value was -25.24 with an absolute tabular value of ± 2.045 at 0.05 level of significance. Therefore, the null hypothesis was rejected.

Table IV
Difference between the Performance of the students under Pre skill test and Post skill test
N = 30

Difference	t computed value	t tabular value	Description	Interpretation
	at 0.05 level of significance, df 29			
Pretest and Posttest	-25.24	±2.045	Significant	Reject Null Hypothesis

Table V
Acceptability Level of the Computer-Assisted Programmable Logic Controller Simulator

Acceptability Level	WM	D	R
5.1 Performance of the Computer-Assisted Programmable Logic Controller Simulator			
As a Gadget:			
1. Replicates the behavior of electronic device and circuits used in ladder logic programming for simulator.	3.90	VH	
2. Scalable application program that works on different windows environment	3.85	VH	
3. Provides users with the ability to write edit and debug programs written using a ladder logic format	3.85	VH	
4. Compact input and output modules for connections of lights, sensors and switches	3.65	VH	
5. Ladder logic programs can be downloaded and uploaded from computer to PLC and vice versa	3.75	VH	
6. Can simulate programs in Computers before downloading to PLC	3.8	VH	
7. Can be interfaced to a desktop, laptop and tablet computers via USB (universal serial bus) port.	3.7	VH	

8. Provide identical function with regards to traffic light, BCD counter and light sequence.	3.75	VH	
9. Can access information through internet.	3.95	VH	
Average	3.80	VH	
As Device for Instruction:			
1. The post skill test rating of the student's shows very good performance with only good performance of the pre skill test rating.	4.00	VH	
2. Students were able to increase the efficiency from pre skill test to post skill test to 2.05%.	3.85	VH	
3. Provides different perspectives to the teacher's knowledge, and provide additional activities for students to develop skills in ladder logic programming	3.9	VH	
4. Students can interpret more PLC program language.	3.65	VH	
5. Provide better understanding for students in programming.	3.8	VH	
Average	3.84	VH	
Average	3.82	VH	1
5.2 Convenience			
1. Ports and terminals for input and output module is readily accessible	3.75	VH	
2. Programming language is user friendly with tutorials	3.7	VH	
3. The input language can be reprogrammed.	3.95	VH	
4. Movable from one place to another.	4.00		
5. The parts are replaceable when damage.	3.55		
6. Less hard wiring is use.	3.8		
Average	3.79	VH	2
5.3 Safety			
1. Fuse was used as over-current and short circuit protection for the gadget.	3.9	VH	
2. A rectified 12-24VDC was supplied to the simulator for operation.	3.7	VH	
3. The casing is non-conductor and the components were properly fitted.	3.95	VH	
4. Electrical and electronics components are properly rated according to voltage and current.	3.6	VH	
5. Terminal connections and joints have adequate mechanical and electrical supports.	3.6	VH	
Average	3.75	VH	3
5.4 Durability			
1. The gadget can stand through vibration.	3.9		
2. Designed to same level of tolerance to temperature.	3.55		
3. Longevity to its process control.	3.7		
Average	3.72	VH	4
5.5 Cost			
1. The Computer-Assisted Programmable Logic Controller Simulator has a total cost of ₱ 50, 904.00	3.65	VH	
Average	3.65	VH	5
Average WM	3.75	VH	

Table 5 shows the summary of acceptability levels of the Computer-Assisted Programmable Logic Controller Simulator in terms of its performance, convenience, safety, durability and cost. Using the Weighted Arithmetic Mean test, the Computer-Assisted Programmable Logic Controller Simulator "as a gadget" had an average rating of 3.80 and interpreted as "very high". This means that it can operate to its maximum level of efficiency devoid of any failure. The device garnered an average rating of 3.84 for "as device for instruction". It was interpreted "very high". The respondents found that the device provides better understanding and increases the knowledge through the additional activities given to the students attesting the Experiential Learning Theory.

To sum up, the average rating of the Computer-Assisted Programmable Logic Controller Simulator as a gadget and as a device for instruction under "performance" ranked highest with the average weighted mean of 3.82 was interpreted as "Very High".

Convenience was rated very high with an average weighted mean of 3.79. This means that the Computer-Assisted Programmable Logic Controller Simulator is suitable for instruction and requires less effort to operate as evaluated by the experts.

Safety was given a rating of "very high" and obtained an average weighted mean of 3.75. This implies that the simulator is a good electrical insulator and is properly equipped with short circuit protection. Moreover, the materials used were designed and selected to provide safety to users.

Durability had an average weighted mean of 3.72 and interpreted as "very high". Although it ranked fourth, the Computer-Assisted Programmable Logic Controller Simulator was seen to have the characteristics of low density, ease of fabrication, low thermal conductivity, high resistance to wear, and good corrosion resistance.

Cost was described "very high" and was ranked the lowest. The Computer-Assisted Programmable Logic Controller Simulator is rather expensive because the materials used were guaranteed to have quality to provide better performance during operation. Materials play a key role in the entire product design and manufacturing phase.

An erroneously selected material often leads to premature product failure causing loss of revenue and repute of the manufacturer. Selecting the suitable material for a specific application is always considered in constructing instructional tools for imparting knowledge to students (Dym, et. al. 2004) [9].

The overall weighted mean of the Computer-Assisted Programmable Logic Controller Simulator is 3.75 which is interpreted Very High. The respondents assessed the Computer-Assisted Programmable Logic Controller Simulator suitable to be used in the laboratory as a device for instruction in electrical technology.

The results of the study revealed the following findings:

The Computer-Assisted Programmable Logic Controller Simulator is a PLC-based with multi-functional operations simulator using Zen software. It is a type of multi-operational simulator that manages functionality according to the design problem. The materials of the device were carefully selected with guaranteed high quality. The total cost of assembling the Computer-Assisted Programmable Logic Controller Simulator is fifty thousand and nine hundred four pesos (₱50,904.00). The procedures were followed on how to operate each function of the device.

On the Performance Level of the Computer-Assisted Programmable Logic Controller Simulator in terms of programmability, multi-function of operations, and network connectivity.

The Computer-Assisted Programmable Logic Controller Simulator was able to link to various electronic gadgets and was able to simulate the program using a Windows operating system. The input and output states in the ladder diagram was able to transfer and run the program from computer to PLC with 100% success and functionality. The diverse of functions such as Binary Coded Decimal (BCD) Counter, light sequence, and traffic light follows the order of timing precisely and are 100% functional.

On the Level of the Effectiveness of the Computer-Assisted Programmable Logic Controller Simulator.

Pre skill test and post skill test of the students using Computer-Assisted Programmable Logic Controller Simulator. 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 skill test results of the students who used the Computer-Assisted Programmable Logic Controller Simulator got higher ratings in comparison to pre skill test. The post skill test was rated at 3.62 which was interpreted as "Very Good". On the other hand, the average rating result of pre skill test is 1.33 which was described as "poor".

The significant difference between the pre skill test and post skill test of the students using the Computer-Assisted Programmable Logic Controller Simulator.

The score differences of the students during pre-skill test and post skill test. The pre skill test and post skill test scores revealed that the t-computed value of -25.24 was not within the absolute tabular value of ±2.045 thus was deemed significant. Hence, the null hypothesis was rejected. It can be seen that the realistic representation of materials provided students a better understanding about the discussion.

The acceptability level of the Computer-Assisted Programmable Logic Controller Simulator.

The Computer-Assisted Programmable Logic Controller Simulator was found to be highly acceptable in the aspects of performance, convenience, safety, durability, and cost with a total average weighted mean of 3.75 and interpreted as "Very High". Performance was ranked highest with an average weighted mean of 3.82 and described as "Very High". Cost was ranked lowest with an average weighted mean of 3.65, although ranked lowest, it was described as "Very High" by respondents.

III. CONCLUSION

Based on the results of the study, the researcher concluded that since there was a significant difference in the performance of the students in pre skill test and post skill test, the Computer-Assisted Programmable Logic Controller Simulator is an effective tool in delivering instruction thus, enhancing the students' skills. The instructional tool can operate at the highest level of efficiency with guaranteed safety to the students.

IV. RECOMMENDATIONS

1. Researcher will introduce the Computer-Assisted Programmable Logic Controller Simulator to electrical technology and allied engineering courses as a tool for instruction.
2. Conduct trainings to teachers and instructors on the Computer-Assisted Programmable Logic Controller Simulator.

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