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Computer- Assisted PLC-Controlled Tower Crane System

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Abstract *- The application of Programmable Logic Controller (PLC) remains relevant to the globally competitive industry with every movement of the processing machines which were aided by the PLC. With its advanced usage, it is increasingly becoming an important part in the industry and academe as well. Thus, it is essential that this knowledge is effectively delivered to students with practical applications. For this reason, the researcher was motivated to design and assemble a Computer- Assisted PLC-Controlled Tower Crane System. This study describes a prototype of a tower crane equipped with a programmable logic controller. It aimed to assess the functionality of the system in terms of faster information flow with greater accuracy and improved driving efficiency. Furthermore, it aimed to ascertain the level of effectiveness of the instructional tool as an alternative solution to expensive and proprietary laboratory equipment for electrical technology and engineering courses especially in teaching control system automation for students and instructors. The study was conducted at Bohol Island State University Main Campus, Tagbilaran City and in different learning institutions and private industries in the province of Bohol during the Academic Year 2016-2017. The study employed the experimental method of research in testing its effectiveness. The functionality of the system was evaluated by experts from the academe and industry. The respondents of the study who took the pre- and post-skill test were the third year Bachelor of Science in Electrical Technology and Electrical Engineering students. The results revealed that the electrical and electronic parts of the Computer- Assisted PLC-Controlled Tower Crane System was found to be functional and operates to its optimum capability based on the evaluation made by the researcher and experts on the device. As to its effectiveness, it was found out that there is a significant increase in the performance of the students after being exposed to the instructional tool. Based on the results, the researcher highly recommends the use of the Computer- Assisted PLC-Controlled Tower Crane System as a tool for instruction in electrical technology and engineering laboratories and improve with provisions for various types of PLC and programming language.*

Keywords - computer-assisted, PLC-controlled, tower crane system, prototype, functionality

INTRODUCTION

Automation of many different processes, such as controlling machines or factory assembly lines, is done through the use of small computer called a programmable logic controller (PLC) [1]. PLC's have grown to be one of the widely used devices in all industries to simplify and automate processes. The use of PLC's significantly reduces the work for electrical modifications and provides flexibility to change the operation of a machine as desired [4]. For this reason, it is considered as one of the most important means in the technological and industrial sector today. With their advanced usage, it increasingly becomes a staple and important part of Engineering and Technology [2].

Although PLCs are heavily used in the industry, their use in teaching control theory concepts is uncommon in the electrical engineering and electrical technology programs in the Bohol Island State University, Tagbilaran City, Bohol, Philippines. Traditional control systems in technology and engineering courses focus on the theory and rarely involve the use of PLCs.

Researcher found that Programmable Logic Controllers can be effectively used in education to emphasize its importance in light of globalization. Recognizing the changes brought by technology, the researcher created a tool for instruction that may help them understand the different theories, operations and actual uses of PLC. For this study, the researcher developed a prototype of a tower crane controlled with a programmable logic controller.

Computer-Assisted PLC- Controlled Tower Crane System is an archetype which replicates the actual behavior of electronic/ electrical devices and circuits used in a real tower crane set-up. The project aims to integrate PLC as the main controller of the system that introduce the concepts of the software design for the PLC motion control that enables axes movement, ability to hoist, move, and lower the load, software interface and integrate system components. The Computer-Assisted PLC-Controlled Tower Crane System is also made with a tough design, speedy, and practical controllers in transferring loads from point to point in a short span of time. The system is also equipped with a built-in computer system interfaced directly to the PLC used for simulating the programmed input and output instruction through a built-in monitor whose display can also be extended for larger screens through an external video graphic array port. The device can be used as training equipment that would answer to the deficiency of training facilities in schools particularly in automation. It can be used by the instructors for simulation process and in conducting skill tests.

OBJECTIVES OF THE STUDY

The study aims to design and develop a Computer-Assisted PLC- Controlled Tower Crane System and determine its functionality of its parts. Moreover, it aims to evaluate its effectiveness as a tool for instruction and determine if there is a significant difference in the results of the pre- skill test and post-skill test ratings of students using the Computer-Assisted PLC- Controlled Tower Crane System.

MATERIALS AND METHOD

The study employed the experimental method of research in developing the Computer-Assisted PLC- Controlled Tower Crane System. The design is composed of pre-skill test, discussion, experimentation, and post-skill test. The result of the pre- skill test served as the basis in dividing the students into two groups. This study was conducted in different learning institutions and private industries in the province of Bohol, specifically at Bohol Island State University (BISU) - Main Campus, BISU Calape Campus, BISU Balilihan Campus, University of Bohol, Holy Name University, Bohol Institute of Technology - International College, Bohol Light Company Incorporated, Coca-Cola Bottlers Incorporated, and Geresonic Electronics and Communication System to test the functionality of the device. To obtain the necessary data, the researcher made use of the observation guide as an instrument to determine capacity of the system to test its functionality.

The researcher purposively selected thirty (30) third year Bachelor of Science in Electrical Technology and Electrical Engineering as respondents for the study. The students were grouped based on the results of the pre-skill test conducted wherein the scores were distributed fairly in each group. Scoring rubrics were employed to evaluate the learning improvement of the students in their pre- skill test and post- skill test.

RESULTS AND DISCUSSION

This contains the presentation of data gathered by the researcher out from the functionality of the device which was also personally interpreted by the researcher. The results of the study were presented according to the specified questions. The presentation of data was supported with tables which illustrated the responses of the study as to the functionality of the Computer- Assisted PLC-Controlled Tower Crane System.

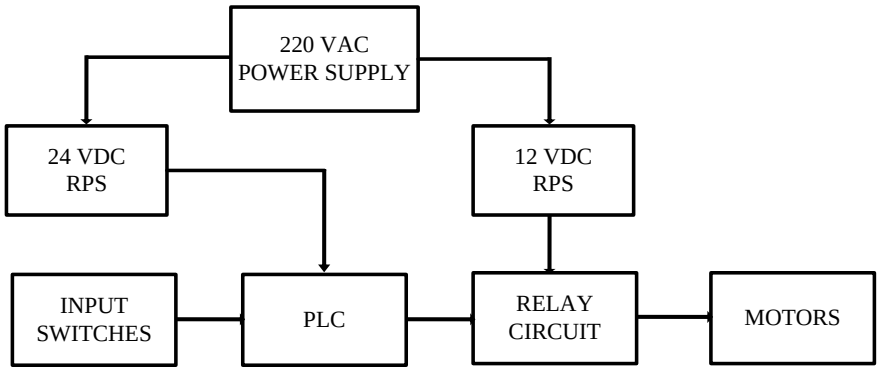

Figure 1. Block Diagram of the Computer- Assisted PLC-Controlled Tower Crane System

Figure 2. Perspective View of the Computer- Assisted PLC-Controlled Tower Crane System

Functionality of the Computer- Assisted PLC-Controlled Tower Crane System

Table 1. Software Interface

Phase	PLC	Operation	Response
1	Ladder Diagram (Input)	Formulate a basic program then upload.	It only took 3 seconds to upload the program.
		Formulate a complex program then upload.	It only took 3 seconds to upload the program.
		Formulate an advanced program then upload.	It only took 3 seconds to upload the program.
2	Ladder Diagram	Download the uploaded basic program from the PLC.	It took 3 seconds to download the program.

	(Output)	Download the uploaded complex program from the PLC.	It took 3 seconds to download the program.
		Download the uploaded advanced program from the PLC.	It took 3 seconds to download the program.

On the first table, the capability of the PLC module to download and upload a program is presented. It was found out that in working with different programs, it took only 3 seconds to upload and download the programs. Thus, a Programmable Logic Controller (PLC) has a reliable processor that makes it intrinsically powerful, and program instructions are executed at a fast rate [4]. The statement above signified that even if the program is composed of several complex rungs of instructions, the programmable logic controller can easily execute it.

Table 2. Axes Movements and Load Feedback

Movement	Operation	System Load	Time Response (s)	Output	Description
Panning	Pressing Left – Pan Push Button	Relay	1.00	Electrical/ Electronic devices actuated On and Off	Functional
		Pilot Light	0.95		
		Motor	1.03		
	Pressing Right - Pan Push Button	Relay	0.95		
		Pilot Light	0.95		
		Motor	1.01		
Jib-Section	Pressing Forward Button	Relay	1.00	Electrical/ Electronic devices actuated On and Off	Functional
		Pilot Light	0.95		
		Motor	1.02		
	Pressing Backward Button	Relay	1.00		
		Pilot Light	0.96		
		Motor	1.01		
Hoist Movement	Pressing Down Push Button	Relay	1.00	Electrical/ Electronic devices actuated On and Off	Functional
		Pilot Light	0.95		
		Motor	1.8		
	Pressing the Up Push Button	Relay	1.1		
		Pilot Light	0.96		
		Motor	1.3		

Table 2 presents the functionality of the Computer- Assisted PLC-Controlled Tower Crane System in terms of its axes movements and load feedback. It showed that the device operates within less than 2 seconds and was found to be functional in doing the panning, jib-section, and hoist movements with system load. In general, the researcher found out that the wholesome operation of the device covers a very short period of time due to the effectivity of the electrical and electronic devices used.

As stated in the Advanced Micro Control, a programmable logic controller has the ability to scan 100,000 step programs in one millisecond [6]. Through a programmable logic controller, hundreds to thousands of inputs and outputs may be interfaced. Hence, there is no reason for errors if the program was inputted properly. Thus, all the trials that utilized programmable logic controller were functional.

Level of Effectiveness gained by the students using Computer-Assisted PLC- Controlled Tower Crane System

Table 3. Pre- skill Test Performance of the Students under Control Group and Experimental Group
N = 30

Score	Description	Control Group N=15			Experimental Group N=15		
		f	%	Rank	f	%	Rank
3.25-4.00	Very Good	0	00.00%		0	80.00%	
2.50 -3.24	Good	0	00.00%		0	20.00%	
1.75-2.49	Fair	6	40.00%	2	6	40.00%	2
1.00-1.74	Poor	9	60.00%	1	9	60.00%	1
Average Rating		**1.73 Poor**			**1.67 Poor**		

Noticeably, both groups have relatively similar performance before the Computer-Assisted PLC- Controlled Tower Crane System was introduced to them. Cognitive Load Theory suggests that effective instructional material facilitates learning by directing cognitive resources towards activities that are relevant to schema acquisition [8]. Prior to the introduction of the Computer-Assisted PLC- Controlled Tower Crane System, 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. This was the result of the exact pairing of the students for each group.

Table 4. Post- skill test Performance of the Students under Control Group and Experimental Group
N = 30

Score	Description	Control Group N=15			Experimental Group N=15		
		f	%	Rank	f	%	Rank
3.25-4.00	Very Good	0	00.00%		15	100.00%	1
2.50-3.24	Good	6	40.00%	2	0	00.00%	
1.75-2.49	Fair	9	60.00%	1	0	00.00%	
1.00-1.74	Poor	0	00.00%		0	00.00%	
Average Rating		**2.35 Fair**			**3.93 Very Good**		

It was found that the experimental group who used the Computer-Assisted PLC-Controlled Tower Crane System obtained higher scores and was seen 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 [9]. Based on the results shown in table 4, the experimental group who used actual and hands-on demonstration gained a rating of 3.93 described as "Very Good" while the control group gained a rating of 2.35 described as "Fair". Thus, using instructional tool 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 5. Difference between the Performance of the students under Control and Experimental Group

Difference	t-computed value	t-tabular value	Description	Interpretation
	at 0.05 level of significance, df=14			
Pretest of both Control and Experimental Group	0.38	±2.05	Insignificant	Accept Null Hypothesis
Pretest and Posttest of Control Group	-6.97	±2.14	Significant	Reject Null Hypothesis
Pretest and Posttest of Experimental Group	-21.18	±2.14	Significant	Reject Null Hypothesis
Posttest of both Control and Experimental Group	-15.70	±2.05	Significant	Reject Null Hypothesis

Table 5 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. There was no significant difference between the scores of the students on both groups. The result shows that the students have similar performance in their pre-skill test before they were exposed to the Computer-Assisted PLC- Controlled Tower Crane System.

The second row shows the pretest and posttest performance of the students under the control group. It is shown that students have increased knowledge and understanding. Thus, learning takes place even with the conventional method of teaching.

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.

The third row shows the pretest and posttest performance of the students under the experimental group. It is evident that learning was enhanced when the Computer-Assisted PLC- Controlled Tower Crane System was used as an instructional media. As a result, the null hypothesis was rejected. Thus, there was a significant difference in the performance of the students before and after exposure to the instructional tool.

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 [5].

The fourth row presents the posttest difference of both the control and experimental group. 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 use of the Computer-Assisted PLC- Controlled Tower Crane System as an instructional tool proves that it has greatly enhanced the students' retention of knowledge and facilitates effective learning acquisition in electrical technology.

In relation to the Simulator-Based Theory, simulation is a technique for practice and learning that can be applied to many different discipline and types of trainees. It is a technique to amplify real experiences with guided ones that evoke or replicate substantial

aspects of the real world in a fully interactive fashion [3].

The statement above proves that teachers can boost the learning of the students by letting them experience the real world of work through simulators. Moreover, the improvement can be shown evidently through the data collected by having the students to undergo skill tests.

The results of the study revealed the following findings:

1. On the description of the Computer-Assisted PLC-Controlled Tower Crane System.

The designing and developing of Computer-Assisted PLC-Controlled Tower Crane System was deemed feasible as it involved easy preparation procedure. The respondents readily identified the different parts and their corresponding functions. The assembly process is not complicated owing to the number of years that the researcher have experienced in the field. The unit is user friendly as one can easily manipulate it even with just a basic knowledge on PLCs.

2. On the functionality of the Computer-Assisted PLC-Controlled Tower Crane System.

The Computer-Assisted PLC-Controlled Tower Crane System has a fast software interface as it only took 3 seconds to upload and execute the program from computer to the PLC module and also 3 seconds in downloading the program. Moreover, the electrical and electronic devices linked in the Computer-Assisted PLC-Controlled Tower Crane System were found to be functional and operates to its optimum capability.

3. On the Level of the Effectiveness of the Conventional and the Computer-Assisted PLC-Controlled Tower Crane System.

After conducting series of computations of the pre-skill test performance of students under experimental group and control group, the researcher found out they have similar performance both rated as "Poor" since both of the groups have the same knowledge and manipulative background in the area of electrical technology. This was the result of the exact pairing of the students for each group. Furthermore, the post-skill test result reveals that the experimental group who used the Computer-Assisted PLC- Controlled Tower Crane System obtained higher scores and was seen to be effective for the improvement of learning competencies of students through actual and hands-on demonstration.

4. The significant difference between the pre-tests and post tests scores of control and experimental groups.

There was no significant difference between the pre-skill test performance of the students before being exposed to different instructional techniques. Hence, the students are equally divided among the control and experimental groups. Furthermore, both groups increased their average rating after they were subjected to different instructional techniques. There was a significant difference in the performance of the students for acquiring after they were exposed to the conventional and the Computer-Assisted PLC- Controlled Tower Crane System thereby rejecting the null hypothesis. However, the results also reveal that the experimental group performed better than the control group although learning was also evident in the control group. Hence, the use of the Computer-Assisted PLC- Controlled Tower Crane System as an instructional media proves that it has greatly enhanced the students' retention of knowledge. It can be seen that the realistic representation of materials provides students a better understanding about the discussion.

CONCLUSION AND RECOMMENDATION

Based on the study's findings, the following conclusions were drawn:

The PLC is an effective controller for tower crane control system and other applications relevance in the industry since it can handle complex industrial control set-ups and deliver efficient and automated method of programming. Also, it enhances the traditional

way of controlling, troubleshooting and modifying the tower crane system to be quickly configured or reconfigured, and then quickly and automatically programmed due to its soft wiring advantage.

The Computer- Assisted PLC-Controlled Tower Crane System is an effective tool for instruction since it enhanced the knowledge and improves the learning competencies of the students and provides relevant insights among instructors in the modern tower crane control.

It is recommended that the researcher shall introduce the Computer-Assisted PLC-Controlled Tower Crane System to electrical technology and allied engineering courses as a tool for instruction and recommend the study to be patented for its protection. Also, the school administrator shall encourage their instructors to construct instructional materials that can replicate the actual functions of the machines or devices found in the industry and conduct trainings to teachers and instructors on PLC-based technology to broaden their competencies in control automation. Future researchers may improve the Computer-Assisted PLC-Controlled Tower Crane System with provisions for various types of PLC and programming language.

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