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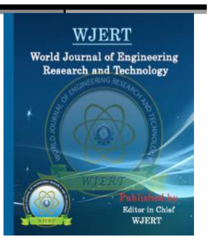

MOBILE MECHATRONICS SYSTEM TRAINER

***Jessie Nigparanon, Ph.D**

Bohol Island State University-Main Campus, Tagbilaran City, Bohol, Philippines.

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***Corresponding Author**
Jessie Nigparanon
Bohol Island State
University-Main Campus,
Tagbilaran City, Bohol,
Philippines.

ABSTRACT

The implementation of new curriculum in the educational system and the demand to produce a workforce that is responsive to the needs of the industry has become much more complicated with the entry of students who are considered as digital natives. Thus, there is a need for teachers' inventiveness in developing instructional materials that can provide real industrial set-up into a classroom setting. In response to the demands of learning in the digital age, the researcher developed a trainer called “Mobile Mechatronics System Trainer” which is a stand-alone, integrated technology containing multi-types of industrial sensors, pneumatic control unit, motor control unit, and programmable logic controller. It aimed to assess the performance of the trainer and ascertain its effectiveness as a learning tool for instruction. The study was conducted at Bohol Island State University Main Campus, Tagbilaran City during the Academic Year 2019-2020. The study employed the experimental method of research. The results revealed that the performance of the trainer was found to be functional and operates to its optimum capability. As to its effectiveness, it was found out that there was a significant increase in the students’ performance after being exposed to the trainer. This was noticeable in the post-skill test results wherein they obtained higher ratings in comparison to their pre-skill test results. Based on the results of the study, the researcher highly recommends the use of Mobile Mechatronics System Trainer in electrical technology and engineering laboratories and community-based training as an instructional tool for developing competencies in automation.

KEYWORDS: mobile, mechatronics, trainer, programmable logic controller, digital native.

INTRODUCTION

The industry and academe have found common cause in the development of a highly skilled workforce to sustain the competitiveness and economic prosperity of the country in response to rapid technological changes and increasing global competition. The relationship was generally understood that the higher education sector provides students with the information and skills required to meet the needs of the industry. However, for higher education institutions to deliver the right skill set and knowledge to future generations, questions on how higher education institutions are affected by the Fourth Industrial Revolution and how the delivery of education will be transformed have been raised.

According to Professor Klaus Schwab, founder and executive chairman of the World Economic Forum, developments in artificial intelligence (AI), machine learning (ML), big data, the Internet of Things (IoT), cyber-physical systems (CPSs), robotics, and automation is introduced in the Fourth Industrial Revolution (Lu, 2017). He underscored that in the Fourth Industrial Revolution, a range of new technologies combining the physical, digital, and biological create both huge promise and potential perils.

In an interview by the Philippine Chamber of Commerce and Industry (PCCI), a significant disparity between education and actual jobs was raised as an issue in the Philippine educational system. In fact, this is a major area of concern of tertiary level learning institutions in addition to the large scale shortages in facilities across Philippine public schools including infrastructure and educational technology. Moreover, it is also the cause of the persistent gap between those who were educated but unemployed or underemployed. According to Dean Salvador Belaro Jr., the 1-Ang Edukasyon Party-list representative, the “education gap”, which refers to the condition of those educated but remain unemployed, affects around 600,000 individuals annually. Hence, investment in research and in innovation in educational institution is constant in preparing the country’s future workforce for the Fourth Industrial Revolution (PIDS, the Philippine APEC Study Network (PASCN) and University of the Philippines (UP), 2018).

Bohol Island State University (BISU), as one of the top technical schools in the Philippines in engineering and technology, is faced with the challenged of responding to the changes in the industry brought by the Fourth Industrial Revolution. The demand to produce a workforce which is responsive to the needs of the industry is complicated with the entry of students who are considered as digital natives whose means of learning are inclined towards smarter learning tools which is characterized by an intricate montage of pictures, symbols, sound, video, recreational activity and diversions.

In response to the university's vision and the demands of learning in the digital age, the researcher developed a trainer called "Mobile Mechatronics System Trainer" which is a stand-alone, integrated technology containing multi-types industrial sensors, a pneumatic control unit, a motor control unit, and a programmable logic control (PLC). This technology trains students for pick and place operations, stamping operations, motor control operations, and teaches interfacing, problem solving, programming, and sequencing. The trainer also is fully configured with a comprehensive range of electrical, electronic, mechanical, pneumatic, and automated components for students to construct, operate, and troubleshoot.

The Mobile Mechatronics System Trainer is a teaching aid developed by the researcher inspired by the real-world feedback. It builds industrial competencies in areas like PLC programming and troubleshooting, motor control and motion control, as well as learning to program and operate a pneumatic robotic arm. Moreover, it is designed in a skill-based format that focuses on teaching industry-relevant tasks and fostering application of learning concepts. With the help of this trainer, students can practice hands-on skills that mimic real-world experience in the field.

METHODOLOGY

Design

The study employed the experimental research design in developing the Mobile Mechatronics System Trainer. The trainer was tested in terms of performance. The effectiveness in imparting the knowledge and skills to the students was evaluated using one group pre-skill test and post-skill test design. The researcher conducted a skill test with fifteen (15) respondents. They underwent the experimentation process to check the validity of effectiveness of the trainer.

A pre-skill test was given to the students before any discussion and after the assembly of the trainer. This evaluated the baseline skills requirement of the study in designing program construction. The test was composed of a set of instructions for installation, interfacing, and programming of the trainer. At this stage, students were not expected to know all the answers to the skill test situation problems given. However, students were expected to utilize previous knowledge to give sensible answers.

A discussion on mechatronics was conducted after the pre-skill test was done. Participants were allowed to experience hands-on application with a given situation. A post-skill test was employed after the discussion. The content of the discussion and the manner of conducting the post-skill test were similar to the contents of the pre-skill test. Students will be expected to answer more problem situation given correctly based on an increase in knowledge and understanding. The students' ratings in the post-skill test will serve as the basis in determining the degree of effectiveness of the trainer.

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.

The Performance of the Mobile Mechatronics System Trainer

On the first table, the ability of the computer to link with a variety of PLC modules was tested. During the test, the CPU was booted to run mode and a program was modified and executed to operate the desired process.

Table 1

Compatibility

Computer	PLC's	Operation	Result	Interpretation
Desktop	Mitsubishi	Modify input status and upload the program.	Light indicators, magnetic coils, internal relay and timers commence to initiate luminance, movement, and timing. Took 5 seconds to upload the program.	Functional
	Omron			
	Schneider			
	Allen Bradley			
	Logo 8			

It was found that the light indicators, magnetic coils, internal relay and timers commence to initiate luminance, movement, and timing for the different types of PLCs tested. Furthermore, uploading the created program only took 5 seconds. According to the Electrical Engineer's Reference book, 16th edition, Programmable Logic Controller (PLC) has a reliable processor that makes it intrinsically powerful, and its program instructions are executed at a speed of 42 ns/step (Kandray, 2010). This signifies that even if the program is composed of several complex rungs of instructions, the programmable logic controller can easily execute it.

All trials under compatibility were tested and the results were all described as functional because particular software application programs and hardware were installed and shared common convention such as performance, reliability or some other characteristics.

Table 2

Motion Control

Type of sensor	Range of detection	Operation	Result	Interpretation
Limit sensor	Not applicable	Upload the created program and press the button to start the simulation	Electric motor activates in forward direction	Functional
Inductive proximity sensor	3 mm	Upload the created program and press the button to start the simulation	Detect object and set timing for conveyor to energized	Functional
Magnetic reed sensor	10 mm	Upload the created program and press the button to start the simulation	Solenoid valves, relays, timers and counters actuated on and off	Functional
Diffuse-reflective sensor	30mm	Upload the created program and press the button to start the simulation	Initialize timing for stamping process to On	Functional

Table 2 shows the performance level of the Mobile Mechatronics System Trainer in terms of motion control. In the 1st item, a program was written and uploaded to the PLC which turns the electric motor to energize and initiate a forward rotation. For this feature, a limit sensor was tested to detect the presence and absence of an object. Moreover, a limit sensor is used as pilot devices to control the coil of relays and allowing conveyor to initiate rotation. This happens when the bumper arm of the limit sensor is impacted and causes the contact to change position. The test was successful and described as functional.

The inductive proximity sensors were designed solely for the detection of metal objects without any physical contact as illustrated on the second item. The object sensed is often referred to as the proximity sensor's target. The maximum distance that the sensor can detect is defined as the "nominal range". In the second item, the proximity sensor was tested in a graduated detection of a maximum of 3mm distance with a piece of metal as the target. The sensor was able to trigger the relay and set the timing for 2nd conveyor to be energized making the performance functional as designed.

Magnetic reed sensor and diffuse-reflective sensors are popular throughout the industry because of their reliability and flexibility. These sensors are used for high-speed operations in the Mobile Mechatronics System Trainer. In items 3 and 4, it was observed that both sensors functioned accordingly to actuate the valves, relays, timers, and counters and initiated the timing for the stamping process to operate. Furthermore, diffuse-reflective sensors were used to sense products on a conveyor line. Each time a product breaks the light beam, the conveyor line automatically stops the operation allowing stamping process to take over. The test was successful and described as functional.

Table 3

Product Handling

Process phases	**Operation**	**Result**	**Interpretation**
Product loading (1st Phase)	Transfer the program to the PLC and press the button to start	Actuates relay coil making electric motor to operate	Functional
Conveyor (2nd Phase)	Hit the lever of the limit sensor	Initiate timing for the internal relay coil to turn ON	Functional
Pick and place (3rd Phase)	Transfer the product near the magnetic reed sensor	Synchronized ON and Off conveyor line 1 and solenoids valves	Functional
Stamping (4th Phase)	Place the product in adjacent to the diffuse-reflective sensors	Initiate timing for stamping to turn On	Functional
Product counting (5th Phase)	Place the product in adjacent to the diffuse-reflective sensors	Set timing for internal relay coil to turn On and counter counts up	Functional

Table 3 illustrates the performance level of the Mobile Mechatronics System Trainer in terms of product handling. During the 1st phase, a program was written to the PLC which turns on the loading of the product to the conveyor. It was observed that the operation of the electric motor for loading the product function when the relay coil was enabled. The test was successful and described as functional.

The 2nd phase involved the conveyor operation. The initiate timing for the internal relay coil to turn ON was found when a product is placed adjacent to limit sensor and proximity sensor. Conveyor line operates and brings the product to the next phase of operation.

The Law of Electromagnetic Induction 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 (Galili et al., 2006). The law serves as the foundation in developing the conveyor of the Mobile Mechatronics System

Trainer. Relays and electric motors are the devices which function through induction and are vital components of the conveyor.

The 3rd phase involved pick-and-place operation. A variety of pneumatic actuators were installed together with the magnetic reed sensors and solenoid valves to develop a pneumatic robotic arm. During the test, the product was brought adjacent to magnetic reed switch via a conveyor. The robotic arm successfully picked and placed the product to the next phase of operation and synchronized the ON and OFF conveyor and solenoids valves. The test was successful and described as functional.

The 4th phase involved the stamping operation and it was tested by placing the product adjacent to the diffuse-reflective sensor. The stamping operation successfully initiated the timing that turns ON simultaneously when the sensor sensed the presence of the product. All the trials were successful and described as functional.

The last phase tested was product counting. This test aimed to prove whether the internal relay coil will energize after placing the product near the diffuse-reflective sensor and whether the counter counts up each time a product breaks the light beam of the sensor. During the test, the researcher set the values (2,4,6) which are equivalent to the number of products that bypassed the sensor. After obtaining the set values, the operation of the Mobile Mechatronics System Trainer stopped automatically.

In all the set values recorded, the researcher observed that during the testing of the first product, there were some delays and the counter sometimes failed in sensing the product. This caused the decimal counter to display the incorrect number of products that has passed. As a result, the trainer could not deactivate the operation. To correct this technical error, the researcher adjusted the potentiometer of the diffuse-reflective sensor to regulate the frequency. This was to ensure accurate and perfect time in sensing the product as it passes since the counting and deactivating of the operation were dependent in the sensor. After the adjustments, the sensing, counting of products, and deactivating operation were good. All the trials were successful and described as functional.

The Level of the Effectiveness of the Mobile Mechatronics System Trainer

To determine the degree of the effectiveness of the Mobile Mechatronics System Trainer as a tool for instruction, a pre-skill test and post-skill test were administered to fifteen (15) students. The purpose of the pre-skill test and post-skill test experiment was to determine if the treatment has caused a change in the performance of the participants.

Table 4

Pre-skill test and Post-skill test Result of the Students using

Mobile Mechatronics System Trainer

N = 15

Range Score	**Description**	**Pre-skill test**			**Post-skill test**		
		Freq.	**%**	**Rank**	**Freq.**	**%**	**Rank**
3.25-4.00	Excellent	0	0		12	80.00	1
2.50-3.24	Very Good	1	6.67	3	3	20.00	2
1.75-2.49	Satisfactory	4	26.67	2	0	0	
1.00-1.74	Needs Improvement	10	66.67	1	0	0	
Average Score		**1.67**			**3.61**		
Description		**Needs Improvement**			**Excellent**		

Table 4 illustrates the frequencies and percentages of the performance of the students before and after operating the trainer. The test determines the level of effectiveness of the Mobile Mechatronics System Trainer as a tool for instruction. It reveals that 1 out of 15 or 6.67% of the students' pre-skill test was found to be "Very Good", 4 out of 15 or 26.67% were "Satisfactory" and 10 or 66.67%, "Needs Improvement". No respondent rated "Excellent". The average score of the group was 1.67 described as "Needs Improvement".

On the other hand, the post-skill test showed higher results in comparison to the pre-skill test. Twelve (12) students or 80.00% rated "Excellent" and three (3) students or 20.00% were described as "Very Good" but none of them fall under "Satisfactory" and "Needs Improvement". The average score of the students was 3.61 denoted as "Excellent".

The result of the post-skill test showed that there is a noticeable change in the knowledge gained by the students. This is connected with the Experiential Learning Theory. This showed that students learn best when they have meaningful practice and repetition (Kolb, 2001). Hence, experiencing a situation, whether actual or simulated, contributes a great deal to the knowledge acquired by the students. Actual performance is needed to understand the theory; theory in effect serves as a guideline to improve a student's application.

Table 5

Difference between the Pre-Skill Test and Post-Skill Test Results of the Students

N=15

Difference	**Computed t-Value**	**Tabular t-Value**	**Interpretation**	**Decision**
	at 0.05 level of significance, df=14			
Pre-skill test and Post-skill test	-10.06	±2.14	Significant	Reject the null hypothesis

Table 5 presents the difference between the pre-skill test and post-skill test of the students. The result showed that the computed t-value of -10.06 is beyond the tabular t-value of ±2.14 at 0.05 level of significance with 14 degrees of freedom. Hence, there was a significant difference in the learners’ performance after being exposed to the Mobile Mechatronics System Trainer. Therefore, the null hypothesis was rejected. This is in relation to the Simulator-Based Theory which states that simulation is a technique for practice and learning that can be applied to many different discipline and types of trainees (Jha, 2001). Furthermore, actual approach contributes much to the development of students’ skills and ideas. In this connection, Ukoha (2007) encourages teachers to teach through practice as experience shows that students learn best by practice, especially with regard to psychomotor activities, as they advance.

The results of the study revealed the following findings

1. The assembly of the Mobile Mechatronics System Trainer was deemed feasible as it involved easy preparation procedure and design. The respondents readily identified the different parts and their corresponding functions. While the cost of the entire product could be considered a bit high, but it can also be regarded as reasonable considering the purpose and function the trainer is intended to perform. The assembly process is not complicated owing to the number of years that the researcher has experienced in the field. The unit is user friendly as one can easily manipulate it even with just basic knowledge on programming.

2. The Mobile Mechatronics System Trainer was linked to computer and a variety of PLC modules. Light indicators, magnetic coils, internal relays, and timers initiated luminance, movement, and timing with accuracy and functionality. The diverse functions of the sensors followed the order of timing precisely. The product handling in the aspects of product loading, conveyor, pick-and-place, stamping, and product counting in the Mobile Mechatronics System Trainer were mandatory step by step processes wherein the next

controls are programmed by the previous step. It was found that the behavior of the processes in every phase was properly executed due to the appropriate program installed.

3. The results of the students' 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 wherein they obtained higher ratings in comparison to their pre-skill test results after being exposed to the Mobile Mechatronics System Trainer. The post-skill test was rated 3.61 interpreted as "Excellent". Whereas, the average rating result of pre-skill test was 1.67 interpreted as "Needs Improvement".

4. The pre-skill test and post-skill test scores revealed that the computed t-value of -10.06 was beyond the tabular t-value of ±2.14 at 0.05 level of significance with 14 degrees of freedom and 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. Therefore, using the Mobile Mechatronics System Trainer proves that it has greatly enhanced the students' retention of knowledge.

CONCLUSION

Based on the findings, the following conclusions were drawn:

The Mobile Mechatronics System Trainer is an effective tool for instruction in Electrical Technology and Electrical Engineering since it provides a workplace experience in the field of process automation and enhances a graduate's employment prospects. Also, it can handle complex industrial control set-ups and deliver efficient and automated methods of programming.

RECOMMENDATION

Based on the results of the study, the researcher highly recommends the use of Mobile Mechatronics System Trainer in electrical technology and engineering laboratories and community-based training as an instructional tool for developing competencies in automation.

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