A LOW-COST EDUCATIONAL ROBOT AS A TOOL FOR TEACHERS IN TEACHING MATHEMATICS AND PHYSICS

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ABSTRACT: Educational robots can act an immense part in adopting some of the challenges in the education system in the Philippines. Hence, this project study focuses on the design, mechanisms, and applications of robotics that can be suitable as educational aid to improve the teaching methods in secondary schools. In this robotic project, the Atmega168 P-Bot Jr microcontroller is the brain of the robot with DC motor, line sensor and an ultrasonic sensor connected to create a customized educational robot. Once operational, one of the key purposes of these robots is to reinforce the inadequacy of the K to 12 program of Department of Education, Misamis Oriental Division in using technology such as robotics in the classroom. Furthermore, these prototype robots needed a pilot school to test and implement the integration of Grade 9 curriculum module in mathematics and physics subjects aligned to the Department of Education (DepEd) standards. Teachers were trained to the operation of the robots, which included developing programs and activities related to their various lessons. This paper presented the importance of the integration of the customized educational robot as a tool in the classroom, the lessons that had been learned through its implementation, and the future directions of the project.

KEYWORDS:*Educational Robot; Robotics; Technology; Atmega168 Microcontroller; Line Sensor*

1.0 INTRODUCTION

Robotics was widely used in the classroom as an educational tool in the countries like the United States, South Korea, Japan, Taiwan, Germany, and the United Kingdom. Teachers used educational robots as a motivational and creative medium to promote a diverse and more active experimental

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approach to learning. Many studies were also interested in the field of robotics as an educational tool, but few researchers focused on using educational robots in an early childhood education suchforesees a big impact to learners with lower costs and more durable effects than those that begin in the later years [1] [2].

In Taiwan, the assessment result in using educational robot-based in the classroom showed that students were motivated and that the use of robots exerted a significant impact on their learning activities and performances. The experimental study recommended to develop an inexpensive educational robot for the students in the classroom. It also provided rigid training to teachers on the operation of the robot as well as to upgrade their skills [3]. An American teacher who introduced robotics in her classroom believed that introducing robotics at an early age would provide opportunities to learn coding and would serve as a foundation for learners, digital citizens, and leaders [4]. A co-chair of Robot & Automation Society’s Education Committee also described that the use of robots for educational purposes as an "intriguing mix of theoretical and practical experience", will be the bases for cross-curriculum activities that can be used to teachMathematics (Spatial concepts and Geometry), Scientific principles (Physics), Design & Technology (Electronics, sensors, and actuators), and ICT (Computer programming) [5].

In the Philippines, only a few secondary schools introduce robotics in their classroom, mostly from private schools since it costs time, effort, and funds. According to the supervisor of Department of Education (DepEd), Cagayan de Oro City Division, 60 public high schools are not applying robotics as an educational tool. Among the reasons were the following, namely: Robotics was not introduced in their curricula, teachers had no educational background and training about robotics and programming, and schools do not prioritize the expensive commercial robots available in the market. These are some reasons that made our education quite behind in terms of technology as compared to other countries [1] [6] [7].

In line with this, this project study was created to helppatch the gap of the inadequacy of the K-12 program of DepEd in providing an educational tool named,EduR, as a medium of instructions for teachers who are teaching Mathematics and Physics subjects. Using a customized and low-cost robot with Atmega168 and different sensors as an educational tool, teachers and Grade 9 students would learn robotics and programming that will develop their critical thinking and metacognitive skills. The project was to create manual and workbook intended for Mathematics and Physics experiments to use in preforming various activities. Andalso conduct various testing of the functionality of components that is suited for educational robot.

The educational robot was made in light materials since there were no bumping and collision in performing activities. This study was performedduring the 4th Quarter of the Grade 9 students in Misamis Oriental General Comprehensive High School (MOGCHS). The assessment of teacher's skills and student's grades was not included in this study.

2.0 METHODOLOGY

This study used an Action Research Design for it assessed the relevance of improving the practice and support for a change in the educational system of Department of Education, where the K to 12 programs has been already implemented. The study was to enhance the usage and operation of the existing educational robots called LISER from University of Science and Technology of Southern Philippines (USTP). Although the hardware and software of LISER were the bases, there were necessary variations made inorder to address the objectives and to answer the problems of the study.

There were five stages in developing the educational robot: First, the system requirement supported in producing the educational robot between the researcher and the needs of the users. The users were Mathematics and Physics teachers, and students in MOGCHS.Second, the system design was composed of three components as shown in Figure 1: (1) The open-source programming called Minibloq, where the block codes performed in the working area. The codes from Minibloq were transmitted and sent to the action data via USB-to-Serial cable to the Atmega168 P-bot Jr microcontroller. One of the best features of Minibloq was its "real-time generator," leaping from graphic programming languages to text-based programming. (2) The Atmega168 Pbot Jr board was the brain of the system in which the components like sensors and motors were connected to this board. (3) The educational robot was a unit that would demonstrate the result of the block codes transmitted to the P-bot Jr board.

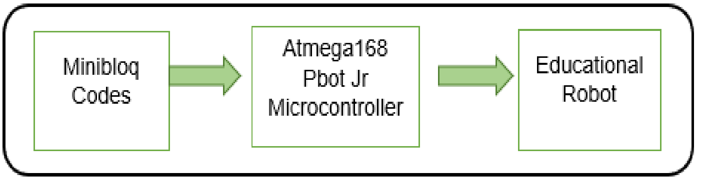

Figure 1: System Block Diagram

Figure :
Atmega168 board as the heart of the robot. This microcontroller can be

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programmed by the AVR assembly language for the bootloader to communicate using the USB to serial port; Line follower sensor and Ultrasonic sensor; two DC motors; re-chargeable battery, and a charger. All components were available in the local market and cost as cheaper compared to other components.

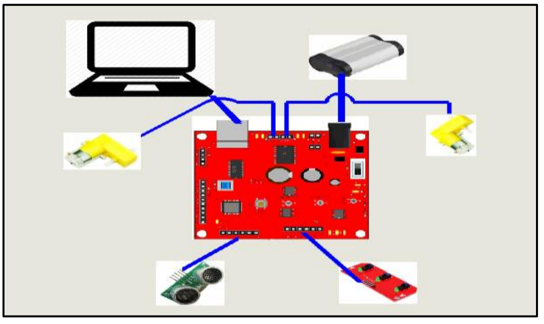

Figure 2: Hardware connections from Atmega168

Third is the System development stage wherein the integration of hardware and software were performed. There were two phases to consider. The first is Testing. It will be conducted in MOGCHS on the 4^{th} Quarter of their curriculum. The Minibloq program was installed in the PC and necessary settings were made for default. The program was loaded to the Atmega168 board to make the educational robot perform an activity. (See Figure 3 on the working flow during testing integration). The other part of system development was creating the User's manual and workbook that was based on the capability of the educational robot, this served as the guide for teachers in integrating the robot to their lessons.

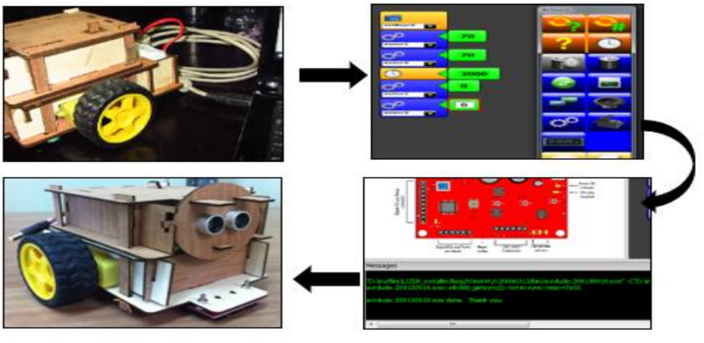

Figure 3: Sample photos during testing of Educational Robot

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Table 1 shows the list of topics that the educational robot can execute. The users performed it during the workshop conducted in the classroom.

Table 1: Feasible topics in Mathematics and Physics subject that the educational robot can execute.

Physics Topics	Mathematics Topics
Force and Motion	Measurements
Gravitational and Frictional Forces	Ratio and Proportion
Laws of Motion	Distance
Motion in One Direction	Angles
Motion in Two direction	Number sense
Acceleration	

Thefourth stage is Feedback. The teachers and studentswere given a questionnaire that served as their response and suggestions for using the educational robot and user's manual after the performance of activities. The data were collected, measured and analyzed using the statistical tools that gave an assistance to improve the system design and activities intended for the two subjects.Lastly, the maintenance. With the result of the responses from the users after using the educational robot, the proponent vowed to improve the development of the educational robot and modification of the physical and hardware design, create additional activities, and update the necessary components as well as the software application.

2.1 Statistical Tool

A Descriptive Statistics was used to test the result of the functionality, usability and the software function codes that were significant in using the educational robot and user's manual/workbook. It managed the statistical data to measure the value of the Mean, equation 1, and in obtaining the average result of the respondents. Average was calculated by adding all scores from the respondents and dividing it to the number of questions. The respondents were given a questionnaire to answer "YES" =2 or "NO" =1 with its equivalent score to place the factuality of the data.

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$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N} \quad (1)$$

Where,
$\overline{x}$ = mean, average
X = values of the data / scores from the respondents
N = population /number of questions

In the statistical tool used, there was a need to solve the interval value to determine the distances in each range so that there would be no overlapping between the ranges (equation 2). The 0.5 was the interval value that was added to the lowest score up until the next value ending to the highest score. Because of the interval value, the range was formed and it presented the description of the remarks in the evaluation, either “Good” or “Not Good”, see Table 2.

$$\text{Internal value} = \frac{(\text{highest score - lowest score})}{\text{no. of choices /options}} = \frac{(2-1)}{2} = \frac{1}{2} = 0.5 \quad (2)$$

Table 2: The range of the value of mean and its equivalent remarks

RANGE	REMARKS
1.0 - 1.49	NOT GOOD / FAIL
1.5 – 2.0	GOOD / PASS

The respondents were composed of 17 teachers teaching in Mathematics and Physics, and 98 Grade 9 students in Misamis Oriental General Comprehensive High School (MOGCHS).

3.0 RESULTS AND DISCUSSIONS

3.1 Components testing

The components were already connected after series of trial and testing to obtain the desired arrangement. (The diagram of components was shown in Figure 4). The motor driver on the board was an A3966 IC wherein the output was inverted. The assigned pin numbers for the motors were 8,9,10, and 11. Motor 1, M1, was connected to pin number 10 and 11, where pin number 10 gave direction, and pin number 11 would move the motor. Motor 2, M2, was assigned to pin number 8 and 9, where pin number 8 would give direction and pin number 9 would movethe motor.

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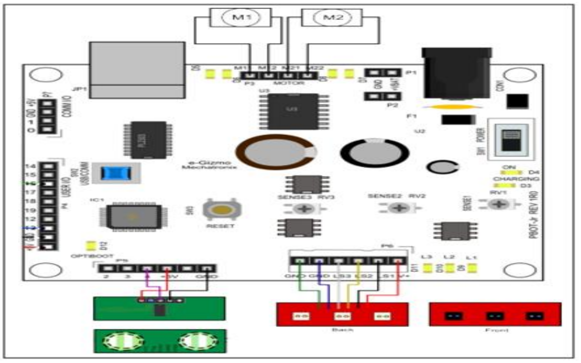


Figure 4:Schematic Diagram

As shown in Table 3, the assigned pin numbers in the motor correspond its direction to its output signal.

Table 3: Direction and output signal of pin numbers of the motor

Pin	Forwa	Backwa	Left	Right	Stop
8	Low	High	Low	Low	Low
9	Low	Low	High	Low	High
10	Low	Low	Low	High	High
11	Low	High	Low	Low	Low

The DC motor used for the educational robot was Dagu 125 rpm DC motors. It was tested 20 times for different directions within 50-cm distance. For the measurement of the angles, it was a trial and error activity to get the correct value of time and speed of the two motors in achieving the desired angles. After the testing, the proponent confirmed that the Dagu 125 rpm DC motor was OK and could be used as one of the components for assembling the educational robot.Table 4shows the result during the testing of the two motors.

Table 4: Results of the two motors during testing

Motor numbe	No. of times	Direction in 50cm	Remar ks	Degre es	Remar ks
M1	20	Forward Backward Stop Turn Left Turn Right	OK OK OK OK OK	30° 45° 90° 180 360	OK OK OK OK OK

M2	20	Forward	OK	30°	OK
		Backward	OK	45°	OK
		Stop	OK	90°	OK
		Turn Left	OK	180°	OK
		Turn Right	OK	360°	OK

Another components were two (2) sensors connected in the educational robot, the line sensor, CNY70 and the ultrasonic sensor, US100 ultrasonic.

A CNY70 line sensor has 3-channel infrared optical line following sensor. It detected dark lines printed over the white color surface. The 3-channel represented a Boolean number to detect the dark colors. Figure 5showed the graph result of the performance of the line sensor during the testing in 15 times. It is described from the graph that at distances from 0 to 9-millimeter, having straight lines signified that the reading of dark spots was distinct even in the curve areas (left and right turn). Starting at distance 9-mm to 15 mm, having broken lines, implied that the reading of the dark spots was not so distinct and that made the movement of the motors in different direction. After 15 times of testing per channel, the proponent confirmed that the CNY70 Line sensor was good to use as one of the components for assembling the educational robot.

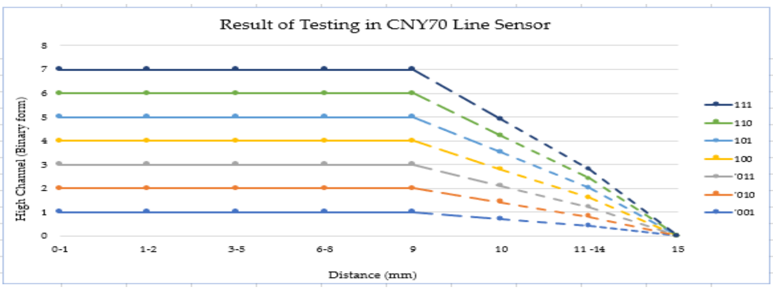
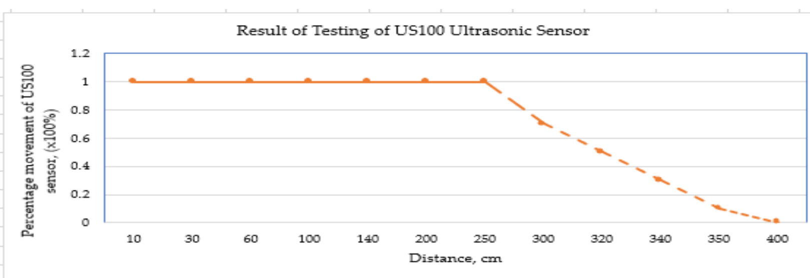


Figure 5: Graph of the result of testing of the CNY70 line sensor

The other sensor used was the US100 ultrasonic sensor. Figure 6showed the graph of result of performance of the ultrasonic sensor during the testing. The straight line implied that detecting of the obstacles was 100 % clear (means 1) from the given distances. The broken lines signified that detecting of obstacles was deteriorating in its percentageof clearness. After it tested 30 times, the proponent confirmed that the US100 ultrasonic was good or OK to use as one of the components for assembling the educational robot



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3.2 Evaluation result of using the Minibloq program, manual and the educational robot

The evaluation survey questionnaire was validated by an expert on this field.Questionnaires that consisted of 37 questions were given to teachers and 20 questions to students to evaluate the different factors in using the educational robot which includes: the Minibloq programming, using the manual, and the integration of activity using the robot. By using the statistical tool, the result of the survey for teachers and students was presented the graph. As shown in Figure 7 and Figure 8, there were problems encountered by the users, but they were minimal and were solved by the proponent. Table 5 shows the summary of the problem encountered by the users and its action taken. Table 6 shows the factors that were evaluated by the users with a remark "GOOD". This means that all factors have passed the evaluation by the users.

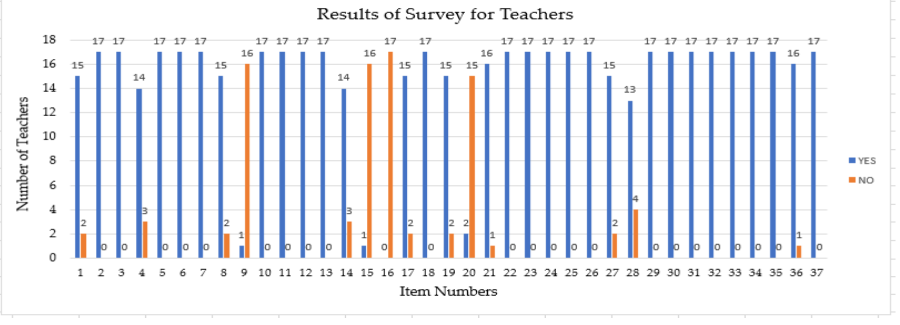

Figure 7: Graph of summary report of survey for teachers

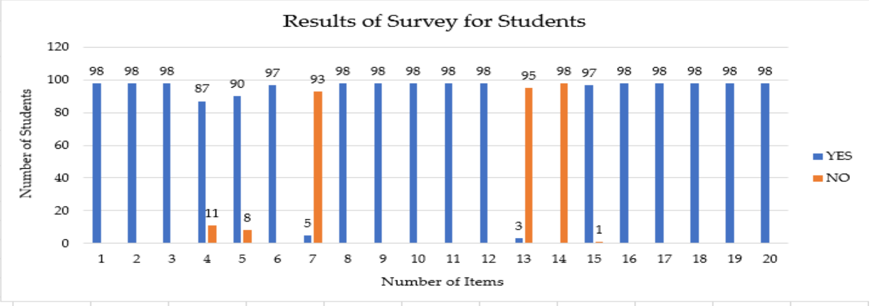

Figure 8: Graph of summary results of survey for students

Table 5: Problem encountered and its action taken.

Problem	Action Taken	Remarks
The mouse connected was not working properly	Checked the connection of the mouse. Changed the mouse used to another mouse.	Passed
The codes were wrong	Checked the codes and corrected the formula	Passed
The teacher attempted to make a function code using C++ in the Minibloq program	Informed the concern teacher that creating function code using C++ had not been lectured during the workshop. It is not included in the user's manual also.	Passed
The connection of the wire for motor was in reverse position.	Reversed the connection of the wire	Passed
The time in the program is not enough for 1-meter in a rough surface.	Adjusted the time in Minibloq program.	Passed
The battery is low that makes the speed of the motor slow	Charged the battery	Passed
The robot runs in different direction	Reversed the connection of the wire for motors	Passed

Table 6: Summary result of factors being evaluated by the users

Factors	**Mean**	**Remarks**
The order of instruction is clear	2	GOOD
The instructions are understandable	2	GOOD
The user's manual is helpful	1.980	GOOD

Performance of the educational robot	1.9638	GOOD
Design of the educational robot	1.922	GOOD
Learning Minibloq programming	1.912	GOOD
Usefulness of educational robot in the classroom	1.988	GOOD

4.0 CONCLUSIONS AND RECOMMENDATIONS

The proponent obtained the following conclusions and recommendations based on the results of the testing conducted:

1. The use of Atmega168 P-Bot Jr boardas the main brain of the educational robot was good for it had 13 I/O pins that the line sensor and ultrasonic sensor can be placed together.Also, there was a built-in A3966 IC for the motor driver that would not need to be assembled to another circuit;
2. For US100 ultrasonic sensor, CNY70 line sensor and DC motors of this project, had a good result which meant that the mentioned components used were capable of performing activities as a tool for understanding visually certain topics of the two subjects;
3. Using wood as physical frame for the design of the educational robot was enough and compact to hold the components inside besides, there were no bumping and physical fighting activities.
4. Based from the result of survey conducted to the users who were using the User's manual, Minibloq programmingand the robot during workshop, the programs were helpful, useful, and easy to learn particularly for those who were the first-time integrating robotics in the classroom.
5. Six (6) robots were not enough for 45 students in the classroom. A ratio of 1:3 is recommended.
6. It is convenient to have a modular design to have an easy assemble of the components.

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