Development of Micro:Bit Robot Kit as a Tool in STEM Education Enrichment for Primary School Students

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ABSTRACT

The integration of robots in education has risen in popularity in the past few years. Their most significant issue is the most commonly used microcontroller that is hard for primary school students to understand and costly, making it almost unfeasible for schools to have one robot for every pupil and lack of research on micro:bit as a microcontroller for robot kit. An additional drawback of commercial systems is their proprietary character, this inhibits the robot's ability to evolve or adapt to educational demands. This research presented a new low-cost micro:bit educational robot kit and open-source software-based platform that may fulfill the needs of STEM enrichment for primary school students. The detail about the micro:bit robot kit components, design, software, and its list of hardware, which enable it to handle a wide range of instructional activities, as well as its simple and easy software stack were described. The research integrates the robot kit and 3 exercises in the micro:bit; the light sensor, temperature sensor, and magnetometer sensor. This research helped primary school students to learn about programming and hardware more easily by using block code as a medium to write the code. Results from the three exercises show high accuracy of output in which the data collected 100% tally with the experiment done. The robot has successfully utilized the open-source software and ease of understanding. Students can build the system by themselves successfully and assist researchers and educators.

Keywords: Education robot, Micro:Bit, Robotic

1. Introduction

Robotics has become the most recent advancement in education. In addition, robotics was introduced into classes ranging from kindergarten to high school institutions which one of the ways to enrich the learning level and encourage activities for increasing knowledge in robotics is to increase understanding. Educational robotics is a crucial part of the evolution to Education 4.0 [1]. Educational robotics is a relatively recent academic topic that provides students with several options for learning and development [2-3]. Education robots helped many instructors and students worldwide reconsider their function in the education field.

Robotic kits enable the creation of various robot models as well as the use of specialized programming tools. This allows you to examine the mechanical parts of robots while also programming them. On the global market, a variety of robotic kits are available. An essential attraction for students in this robotics kit is the opportunity for students to build their robot by themselves using arbitrarily hardware and software. Building a robot involves knowledge of mechanics, electronics in hardware parts, and programming block-based code. As a consequence, incorporating self-made robot development into the education program curriculum is beneficial for students' creative, critical thinking, self-realization and it also includes a thorough examination of robotics' fundamentals. There are currently numbers of methodological methods for integrating robotic kits with low-cost, simple coding language that are suitable for education purposes; nevertheless, there is a clear lack of instructional and research resources regarding robotic kit construction that may be utilized for pupils in primary schools.

Educational robotics is a crucial part of the evolution to education 4.0. Robotics in education is now being developed a lot for the use of primary school students especially in Malaysia. Robotics technology is evolving at a breakneck pace, but Malaysia has not yet felt the full effects of this progress. Arduino is the most common microcontroller used in primary school as a teaching tool to control the robot motions. However, the Arduino is mostly written in text-based languages that can be challenging for primary school pupils to understand, meanwhile the micro:bit is programmed in block-based languages that tend to be more suitable and easier for children to understand. For advance projects, Arduino need to be connected to numbers of different expansion boards, which might be expensive and complex. In association with more advanced hardware (such as Arduino and Raspberry Pi), the micro:bit extremely capable regardless of its complex built-in sensor and uncomplex extension [4].

Chronis et al. developed FOSSBot which was a do-it-yourself robot, with 3D-printable parts and a modular design. Arduino UNO microcontroller board was utilized in the research [5]. In 2022, Passault et al. introduced Robot Soccer kit, an educational holonomous robot kit that comes with an external tracking system which lightens the constraint on embedded systems. Python language is applied in the research where it focuses on the development and use of omniwheel robots designed for educational purposes highlighting their potential to inspire interest in STEM fields [6]. Saar et al. presented a low-cost robot science kit for education. LEGOLAS is an easy-to-use, modular system based on modular toy parts, 3D printed parts, Raspberry Pi components, and aluminum extrusions. They discussed its use and its greater capability to teach the dual tasks of autonomous model exploration, optimization, and determination, with an example of autonomous experimental "discovery" of the Henderson-Hasselbalch equation [7]. In the research by Luo et al., they instructed the students to build a wireless communication and control system that links a computer to a wheeled robot using the micro:bit platform. This platform features a microcontroller equipped with a Python interpreter and an extension board that includes motors and sensors [8]. Research by Lidia discussed informal activities designed for elementary school students to introduce them to basic sensors, actuators, and BIT microcontrollers, which can be programmed using Microsoft MakeCode [9]. In 2022, Ruch outlined why the micro:bit is an excellent option for coding education in Türkiye. One exercise has been presented as an introductory overview of the potential that the micro:bit brings to STEM education in Türkiye [10-11]. Many other researchers worldwide have explored the potential of micro:bit in education since it is more low cost and involves simple coding [12-20].

The purpose of this research is to develop a robotic kit that allows students to learn and apply three exercises in micro:bit as well as to increase their skills to design the robot based on their creativity and critical thinking in coding block-based and measure the accuracy of the robot kit by control it with micro:bit. This research will assist students in gaining fundamental knowledge and abilities in a variety of robotics-related areas. The accuracy of the light sensor, temperature and magnetometer which are internal sensors or built-in sensors at the micro:bit, will be the focus of this research three exercises to test the accuracy of the robot kit. Furthermore, all data measured were recorded and stored in micro:bit data logging.

2. Methodology

In this research, the robot applied micro:bit as the microcontroller which used the block-based code as a programming language. There were three exercises from the micro:bit that has been chosen; the light sensor, temperature sensor, and magnetometer sensor. This research use BBC Micro:bit Version 2. The board has built-in sensors that allow users to start experimenting without the need to attach to third party hardware. The micro:bit's light sensor measures light from diversity light souce in a range from 0 (very dark) to 255 (very bright). The temperature sensor tracks the highest and lowest temperatures by leaving this program running on a micro:bit. It uses the temperature sensor inside the micro:bit's CPU (central processing unit) to measure the temperature in °C (Celsius). Moreover, the micro:bit can turn into a simple magnetic detector from magnetic force in μT.

The measurement of the light sensor starts with the light sensor detecting the light intensity level. Dark places will provide as low as 0 value for total darkness. For a very bright area, micro:bit will provide values of 255. If the sensor detects the light, the micro:bit will display the number of light intensity level and the bar graph of sensor reading at the micro:bit module 5x5 matrix LEDs. The micro:bit will store the data of light intensity level towards hours in a day in the data logging. The data will be display in the laptop after transfer the data from micro:bit via USB cable. The process is shown in the flowchart as in Figure 1.

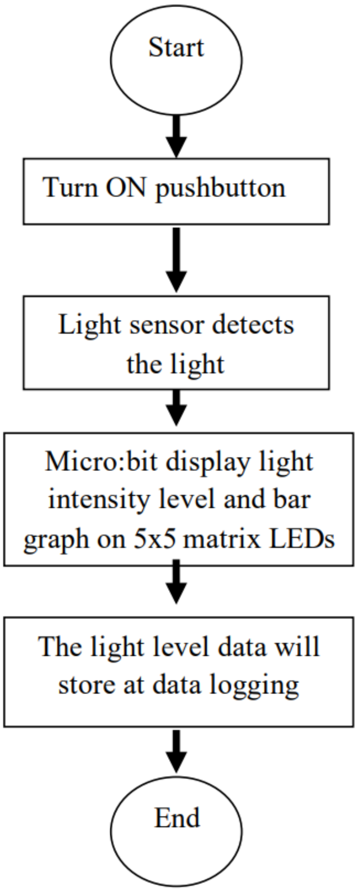

Figure 1. Flow chart for light sensor accuracy measurement in light intensity level

Figure 2 shows the implementation of the temperature sensor in the micro:bit which starts with the temperature sensor detecting whether the temperature ranges between 21 ºC to 32 ºC indicating a comforting temperature. If it is yes, then the LED will display a smile icon. Meanwhile, if the sensor detects the temperature is out of the range, the LED will display a sad icon. This is to indicate that the temperature is either too hot or cold. The micro:bit will store the data of temperature level in degrees Celsius(ºC) towards the time of the day in the data logging. The data can be displayed in the laptop after transferring the data from micro:bit via USB cable.

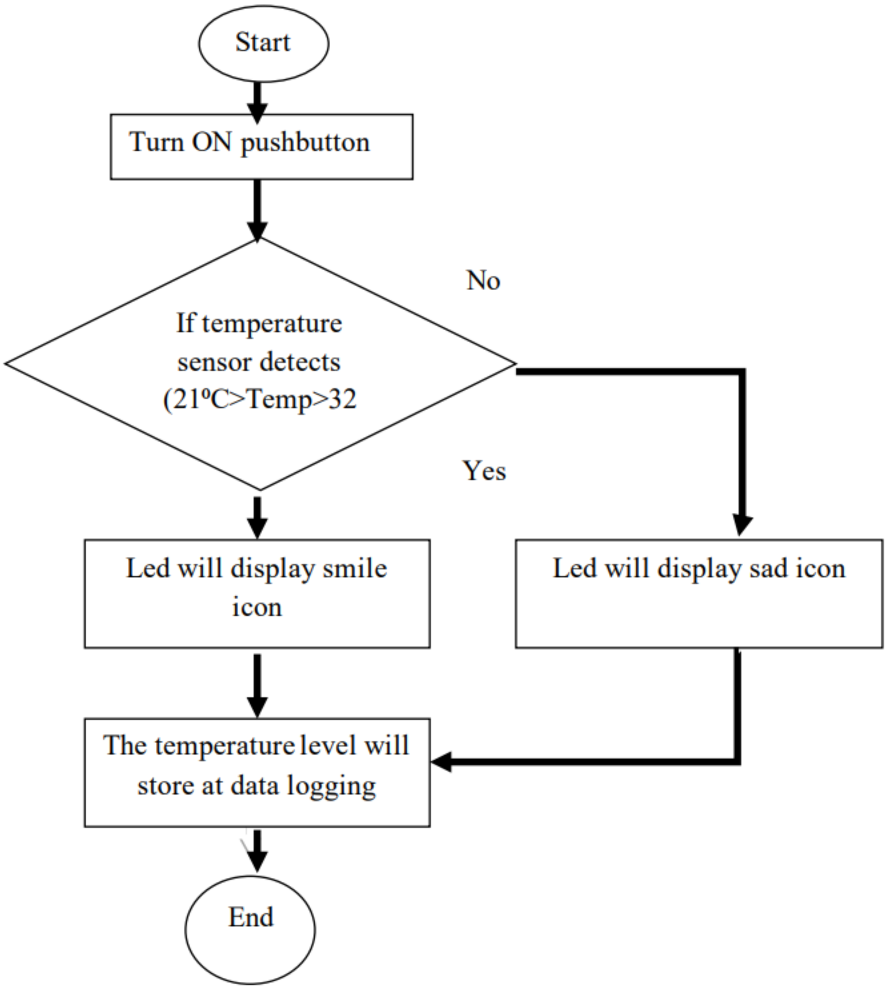

Figure 2. Flow chart for temperature sensor accuracy measurement

For Magnetic Detector Exercise, the measurement of magnetometer sensor starts with the magnetometer sensor detecting the magnetic force in micro-Tesla, $\mu\mu$T of the object or materials, and then the micro:bit will show the number of magnetic force and bar graph of the metal or non-metal strength in range 0 till 1024 which is the range of micro:bit magnetic force value. Then all the data of the magnetic force based on the experiment objects like coins, iron, and others were recorded. The flowchart for this exercise is shown in Figure 3.

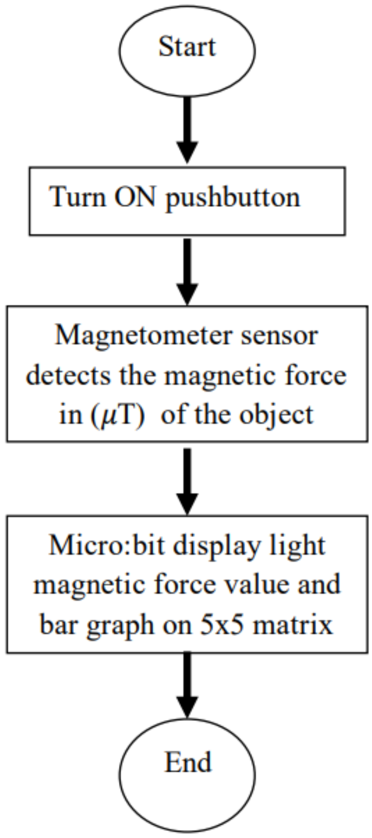

Figure 3. Flowchart for magnetometer sensor accuracy measurement with magnetic detector exercise

Figure 4 shows the project sketch of the robot kit that used the micro:bit V2, printed circuit board (PCB), DC motor, wheel and a few other components to complete the robot kit. The robot kit was designed in a simple way to help the students understand the hardware and connection easier. Moreover, by using this robot kit students were able to conduct all three exercises using built in sensor in micro:bit which were the light sensor for light intensity exercise, temperature sensor to measure the surrounding temperature, and a magnetometer sensor as magnetic detector.

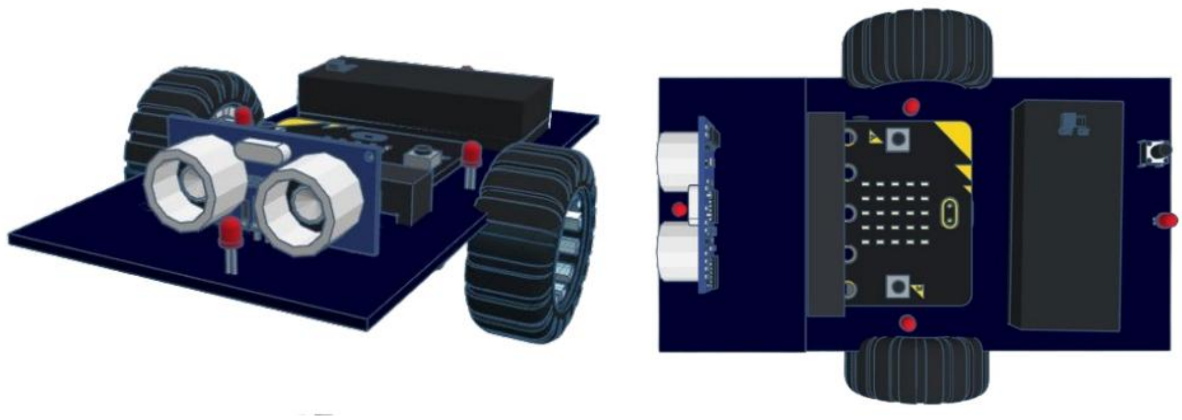

Figure 4. Robot kit sketch in Tinkercad 3D digital design

The BBC Micro:bit was loaded with a Python or block code interpreter of the 3 aforementioned exercises and connected to a Printed Circuit Board (PCB) integrated with motors and a few other components. With the PCB, students experienced the basics of robotics wiring too. The PCB consist of micro:bit edge, L293D motor driver, four of LEDs, female headers for ultrasonic sensor, motor connection and port for external sensor or components and voltage regulator that convert 5V DC power supply to 3.3V DC. The schematic design of the circuit connection and the 3D PCB design are as shown in Figure 5 and Figure 6 respectively.

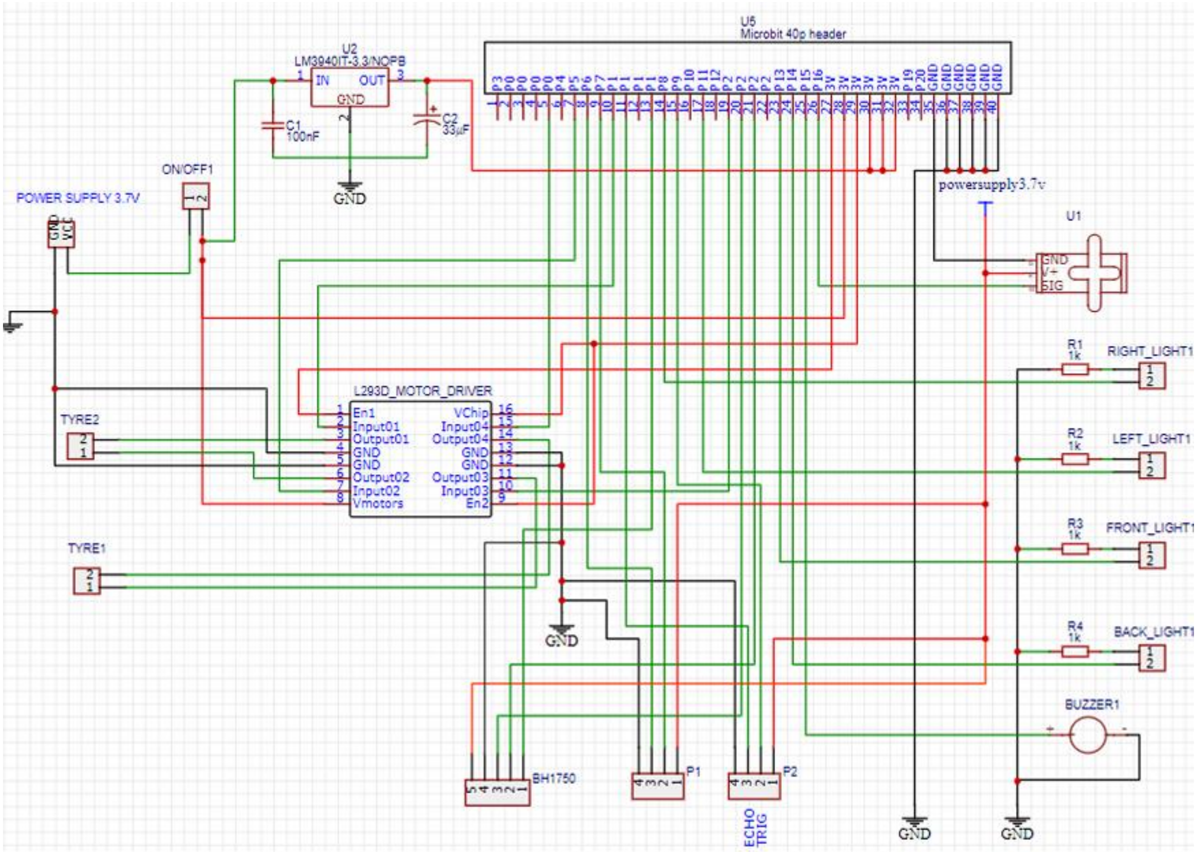

Figure 5. Printed circuit board (PCB) schematic design

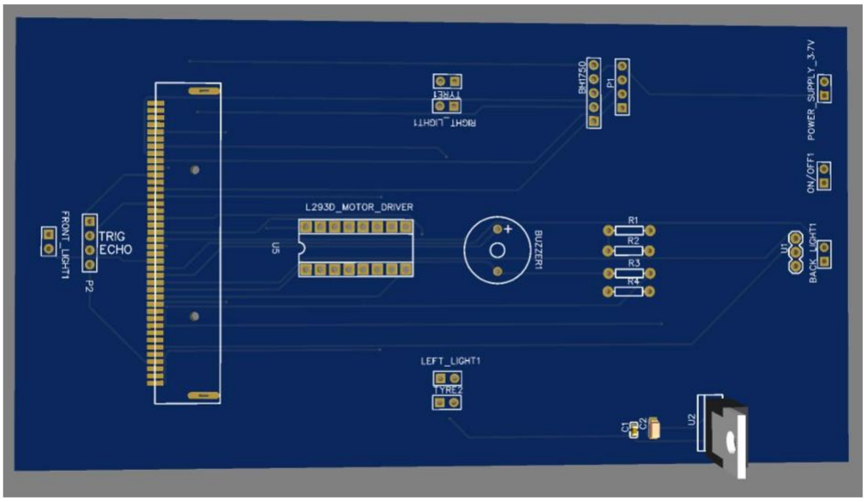

Figure 6. Printed circuit board (PCB) 3D design

The hardware for this project consists of Micro:bit, built-in sensor, printed circuit board (PCB), DC motor driver to control the dual shaft and wheels, ultrasonic sensor for obstacle avoidance and other miscellaneous components. The printed circuit board (PCB) was designed to help the students understand the wiring connection easier that only had 8 wires which were the power supply, switch and tyres wiring connection. The complete robot kit setup is as shown in Figure 7 where it consists of micro:bit version 2, micro:bit edge with 40 connection, ultrasonic sensor, LEDs, power supply header, switch header, voltage regulator, DC motor and wheel, L293D motor driver and batteries.

Figure 7. Top and front view of the education robot kit

For the connection between L293D, ultrasonic sensor header and LEDs with the micro:bit edge, and the power supply and switch, the connection was as shown in Fig. 5 which was on the printed circuit board (PCB) internal connection. The students just need to connect the positive and negative wires of power supply to the power supply female header on PCB. Hence, the positive and negative wires of switch need to be connected to female header of switch port on PCB. For the tyre connection, it needs to be connected at tyre 1 and tyre 2 female header port on PCB based on forward and reverse movement.

As for the programming part, the program is written by using MakeCode block-based coding. To run the exercise, the coding for all the exercises was programmed in the Microsoft MakeCode website. After that, the codes were downloaded into the micro:bit as a controller via USB cable. The coding used for the micro:bit on the three exercises are as in Figure 8, Figure 9 and Figure 10.

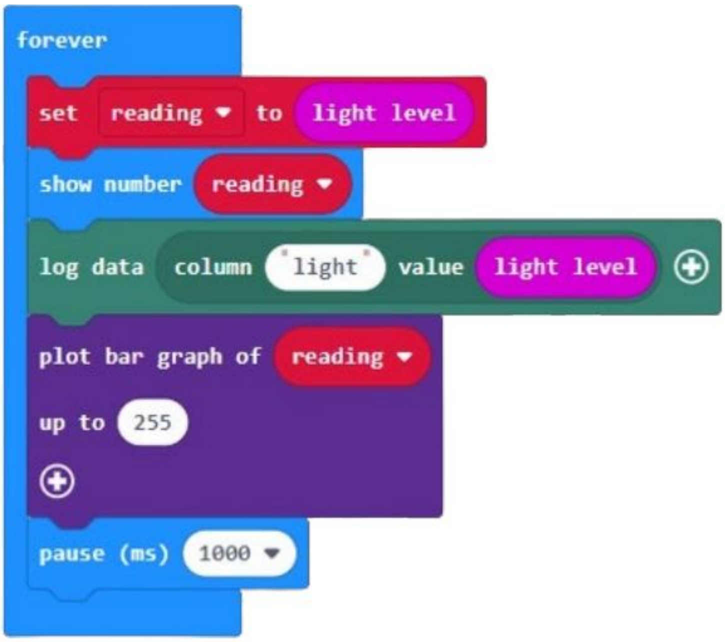

Figure 8. The light sensor code for light intensity measurement

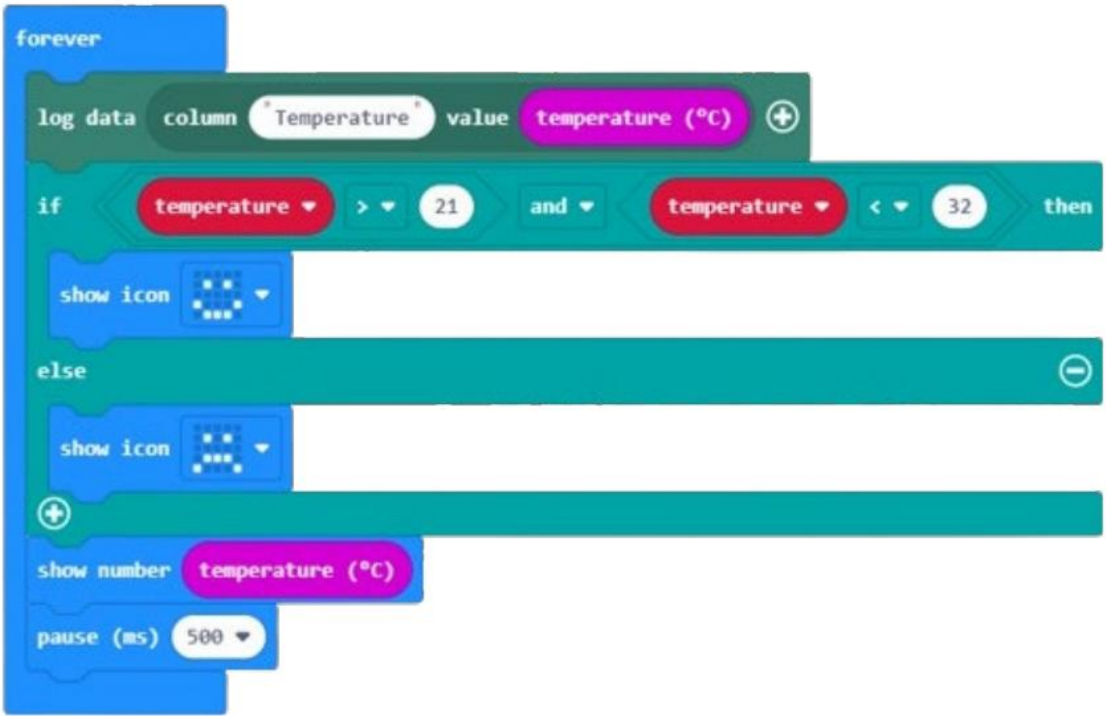

Figure 9. The temperature code to measure surrounding temperature

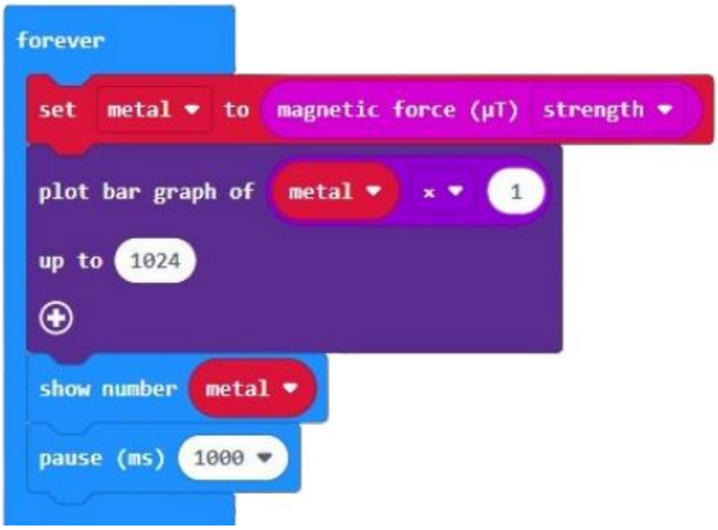

Figure 10. The magnetometer sensor code based on magnetic detector exercise

3. Results And Discussion

This section will only discuss on the results for the three exercises using micro:bit. Data collection for the exercises has been done to determine the efficiency of the micro:bit performance. The data are being monitored using data logging in micro:bit platform and can be monitored by using micro:bit LEDs display. For the first exercise; the light intensity level measurement, the amount of sunlight absorbed in the micro:bit light sensor based on light intensity when the micro:bit was covered, and subjected to sun and torchlight at 15 cm distance. Light sensor starts with light sensor detect the light intensity level; the very dark places have very low numbers as low as 0 for total darkness. Very birght places have values going towards 255. The micro:bit value is in digital number 8-bit which is in the range of 0 to 255. The light intensity was also being tested in illuminance (lux) unit by using the Photone-Grow Light Meter software with the same type of light source. This is as shown in Table 1. When there is no light source, both micro:bit and Photone software recode the 0 value. However, when tested under the sun, micro:bit record the highest value which is 250.8, and the software recorded 6250 lux in the midday. It explains the greater the intensity of light, the greater the brightness at that place or object.

Table 1. The data for light intensity with different types of light source

Type of light source	Light intensity (micro:bit value)	Light intensity (lux)
No Light source	0	0
Torchlight (15cm distance from micro:bit)	210.8	180
Sun	250.8	6250 (midday)

The light intensity at different times of a typical cloud's day on 6 January 2024, Saturday at Paka, Terengganu has also been collected in determining the amount of light that hit on the light sensor at the micro:bit. Table 2 shows the data that were collected during that duration.

Table 2. The light intensity data measured at different times of a typical cloudy day

Time of a day	Light intensity (micro:bit value)
8 am	220
9 am	239
10 am	248.4
11 am	250.8
12 pm	252.6
1 pm	249.6
2 pm	205 (raining)
3 pm	227
4 pm	231

Figure 11 shows the graph of the light intensity detected by the light sensor at micro:bit versus time of a day from 8 am till 4 pm. The graph shows that the light intensity is increasing from morning to afternoon and starts to decrease from afternoon to evening. The amount of light that being absorbed by the micro:bit was the highest at 12 pm because of the high amount of light intensity at that hour, meanwhile the light intensity dropped at 2 pm because it is raining briefly at that time and the sky was cloudy (darker compared to 12 pm).

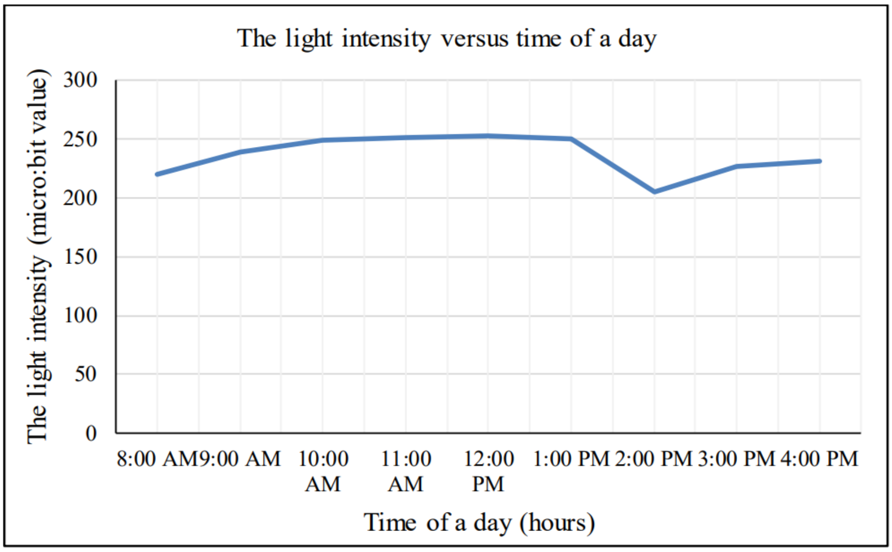

Figure 11. The light intensity versus time of a day

Next, the surrounding temperature that was detected using a micro: bit temperature sensor were collected. Figure 12 shows the graph for the data collection for the temperature sensor that measures the outdoor temperature towards the day from 8 am to 4 pm. Based on the result taken for a day, the temperature was maintained in the morning with 26 ºC and kept increasing till the afternoon and achieved 30 ºC at 1 pm. Meanwhile, the temperature decreased drastically to 25 ºC at 2 pm due to the rain and windy day. The rain stops between 2 pm to 3 pm and the temperature then rise to 28 ºC and stay constant after 3 pm.

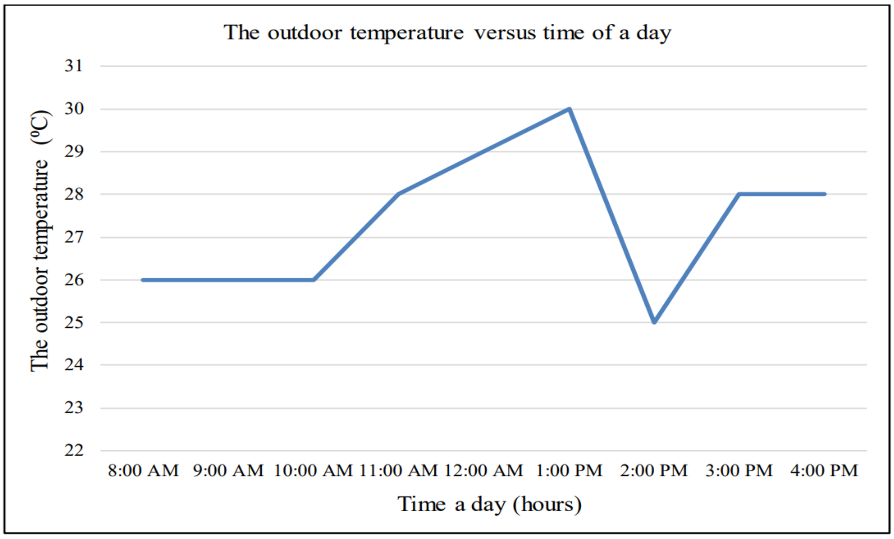

Figure 12. The graph of outdoor temperature versus time of a day

The data from the magnetometer sensor that was used as a magnetic detector to detect the magnetic force of metal or non-metal objects were recorded as shown in Figure 13. From the bar graph, it can be concluded that all the object even metal or non-metal has different value of magnetic force. Based on the five objects used in this exercise, iron has the highest value of magnetic force compared to others, and the lowest value of magnetic force is coin because of the magnetic moments and other factors. Metals' magnetic characteristics are controlled by many factors such as the atomic structure, electron arrangement, and the presence of magnetic moments inside the material. Varied metals have varied magnetic forces, owing to changes in these parameters. In metals, electrons in the outer energy levels are not closely connected to individual atoms and can travel freely throughout the substance. When exposed to an external magnetic field, these unbound electrons help produce a magnetic moment. When a metal is placed in a magnetic field, the free electrons align their magnetic moments in the direction of the field, resulting in a macroscopic magnetic effect.

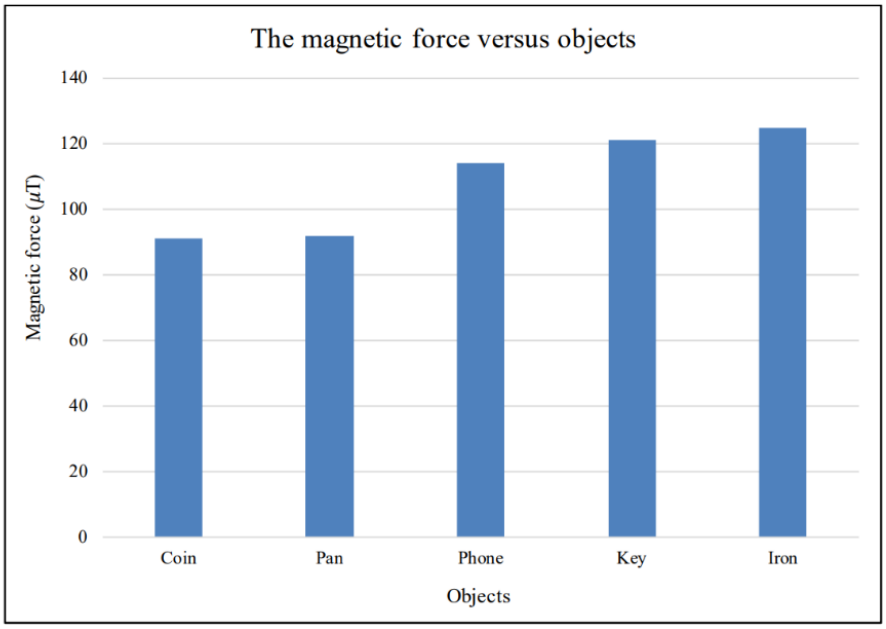

Figure 13. The magnetic force for the objects under test

4. Conclusions And Recommendations

This project integrates the robot kit and 3 exercises by using the sensor within the micro:bit which are the light sensor, temperature sensor, and lastly the magnetometer sensor. It can be concluded that the exercises provide a good accuracy which agrees well with the condition under test and the theory.

This research can help the primary students to learn about programming and hardware in a simpler way by using block code as a medium to write the code. In addition, by using micro:bit as a microcontroller for the robot kit make it easier for the students because micro:bit is using an open-source platform and students do not have to download external software to upload the code into the microcontroller. The block code is also easier for primary school students starting from grade 2 to grade 6 to learn.

As for recommendation, students or other researcher can explore other exercises using the internal sensors in the micro:bit. They can also explore the integration of external sensor to the micro:bit such as the ultrasonic sensor. Some tips and tricks need to be understood by students to use the external sensor. The ultrasonic sensor which is readily attached on the PCB is for future research where it is aimed to be used by secondary school students. Advance package will be used to program the ultrasonic sensor.

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