Development of Education Kit Prototype Based on Internet of Things (IoT)

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ABSTRACT

In answering the challenges of industrial revolution 4.0, robotics and the Internet of Things (IoT) should be used as one of the learning curricula at all educational stages, especially at the high school level. Furthermore, robotics and IoT education are now becoming an important aspect to implement and learn about Science, Technology, Engineering, and Mathematics (STEM) education. To support robotics and IoT education, an easy and user-friendly education kit as a learning medium is required. This work aims at developing a prototype of a robotics and IoT education kit that is suitable for senior high school students. The education kit is designed to be interesting and challenging enough to increase the student's interest in learning robotics and IoT. The kit is developed by using various independent and unattached sensors so that the users, *i.e.*, high-school students can choose their sensors and can investigate the microcontroller pins that are used for these components. In addition, users can also learn to connect an electronic component with other electronic components on the kit to be able to produce various logical embedded systems that can be connected to the internet.

Keywords: Internet of Things, kit education, robotics, senior high school, STEM education.

1. INTRODUCTION

Internet of things is a technological revolution that represents the future of computers and communications. Its development depends on the dynamics of technological innovation in various fields, ranging from wireless sensors to nanotechnology [1]. With the presence of IoT technology and embedded system intelligence, an object can be transformed into an intelligent object that can respond to its surroundings through the internet network. IoT and embedded systems can be applied in various applications such as for a simple agricultural application [2].

IoT consists of four main parts, namely objects, people, processes, and data [3] so that an IoT device can send data obtained by sensors to a gateway through the network [4]. The application of the IoT concept to the world of teaching and education is a new paradigm that has good potential in improving the quality of education [5], as has been studied for higher education [6]. IoT has an important role in realizing STEM education (Science, Technology, Engineering, and Mathematics) in improving learning processes and academic achievement [7]. Teaching methods using STEM emphasize the application of science in real-life conditions by solving problems and finding the best solutions that can be used [8]. As mentioned in [9], an effective way to introduce STEM to the younger generation is to use educational kits, which will increase the students' creativity. One example of an educational kit is a kit developed by Kamal, *et. al.* [10] in 2012 using an object-based teaching method which is divided into three main parts namely thinking, power, and cloud storage. The next example is a study of educational kits conducted by Chaudhary, *et. al.* [11] in 2016 using Lego robots to conclude that teaching by using examples is more effective than teaching by explaining only theories. The education kit that has been proposed in this research is a solution for learning applications using the STEM approach which making it easier for users to learn about STEM.

In this paper, we describe our work in developing an educational kit that is suitable for high school students to studying IoT and robotics. Although the kit has not been tested yet, the education kit is designed to be interesting enough to increase one's interest in learning IoT and robotics. The kit is also expected to be interactive with its users. This is achieved by installing sensors independently from the main controller so that users can choose their sensors as well as studying what pins are used for these components. Furthermore, the kit is also designed such that the users can also learn about how to connect some electronic components to produce a desired and well-designed system that can be connected to the internet.

The rest of the paper is organized as follows. In the next section, we explain the methodology adopted to develop the education kit. Then, section third discusses the development of robotics and IoT education kit. Section fourth describes the testing of the kit and section fifth summarizes the work.

2. METHODS AND EXPERIMENTAL DETAILS

The methodology used in the process of making educational equipment is divided into 4 stages as shown in Figure 1.

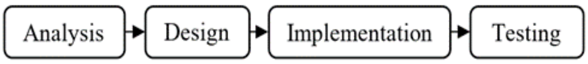

Figure 1. Educational Kit Development: Methodology

1. The analysis phase is the stage carried out to find out or identify problems that occur in the surrounding environment and find out the needs that will be needed in the manufacture of educational prototype kits.
2. The design phase is the stage that is carried out after knowing the needs needed so that it can make the design of the box kit and the design of the program to be used.
3. The implementation phase is carried out by applying all the parts at the design stage to produce a good educational kit.
4. The testing phase is carried out after the implementation phase to get the final results in accordance with the expected functions and conditions.

3. ROBOTICS KIT FOR SENIOR HIGH SCHOOL

The requirements of the developed educational kit are determined by Interactive Robotics as a company that works in robotics education. It is then expected that the developed kit can be utilized in a real teaching and learning process of an IoT and robotics course for the high-school level, where further comments on the kit can be obtained. We are planning to improve the design of the kit continuously by using feedback from the targeted users. Based on the initial requirement analysis, the first prototype of an educational kit for a high-school students is developed by using the ESP6288 internet module to receive input values from various sensors. The sensors utilized are Accelerometer GY521, MAX30102, RFID RC522, Fingerprint DY51, Touch sensor, Ultrasonic HC-SR04, Infrared sensor, LDR sensor, DHT11, and GSM SIM800l. This sensor data is then sent to the raspberry pi 3 which has been connected to the appropriate WiFi as configured on the ESP8266 module. The MQTT broker is used to send the input value that has been received by the raspberry pi 3 to be displayed on the LCD monitor using the node-red tool. Buzzer, LED, LCD I2C, 16x2 and OLED 0.96" function as outputs which act as additional notifications for educational kits. Figure 2 shows the block diagram used to make the educational prototype kit.

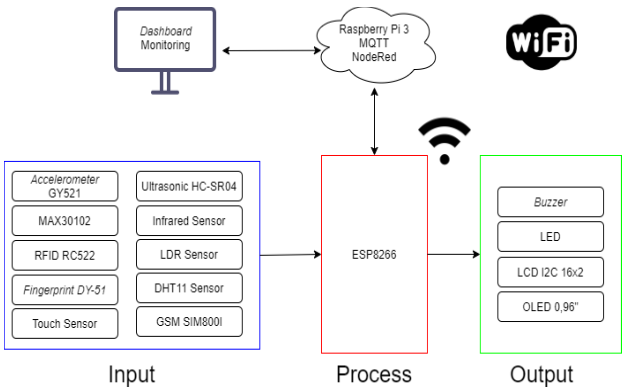

Figure 2. Block Diagram of an Educational Kit

The functional principles of the educational prototype kit are shown in Figure 3. This will also be explained to the high-school students in a classroom when using this kit. The workflow begins with reading the sensors' input values. Then, ESP8266 which has been connected to a certain WiFi network will take the values from the sensor. If the ESP8266 reads the sensor values, it will send the data to the Raspberry Pi 3. If the ESP8266 fails to read the sensor values, the reading stage will be repeated. If the raspberry pi 3 manages to retrieve the data sent by the ESP8266, it will display the data on the monitoring dashboard page, *e.g.*, the LCD matrix. On the other hand, if the raspberry pi 3 fails to retrieve the data values, then the data reading by the ESP6288 will be repeated.

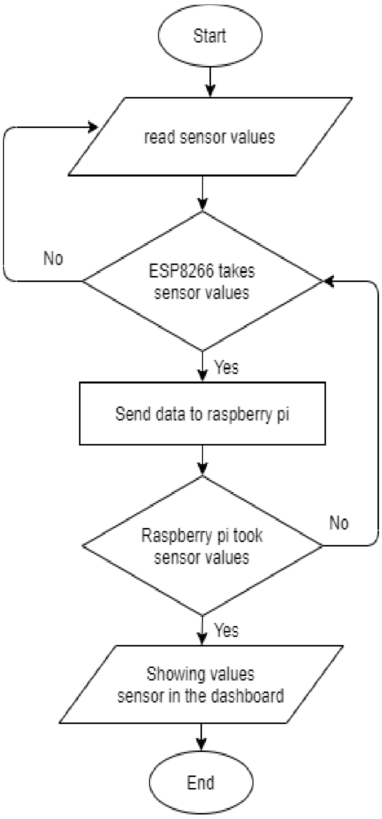

Figure 3. Educational Kit: Working Principle

The educational kit has a circuit board that functions as a circuit for the desired components as shown in Figure 4. The VCC pin on the ESP8266 functions as a pin that will power all sensor components connected to it. The GND pin on the ESP8266 acts as a pin that can connect all negative pins of the sensor component and form a path with a negative current. The SDA pin and SCL pin are the I2C communication serial lines used on 0.96 "I2C LCDs, accelerometers, and OLEDs. The I2C communication serial line acts as both transmitter and receiver.

The fingerprint sensor RX pin is connected to the TX pin on the ESP8266, which where is pin D6. The TX pin on the fingerprint sensor is connected to the RX pin on the ESP8266. The TX pin on the fingerprint sensor is connected to the RX pin on the ESP8266, namely pin D5.

The 3D education kit box design can be seen in Figure 5. On the front side of the circuit board, there is a hole in the USB port of the ESP8266 microcontroller. The USB port and HDMI cable for raspberries are on the backside of the circuit board. The USB ESP8266 port functions to connect the ESP8266 microcontroller with the raspberry as a server so that it can compile and upload programs. The USB port on the back serves to provide a power supply for the raspberry, while the HDMI cable port functions as a link between the raspberry and the LCD monitor.

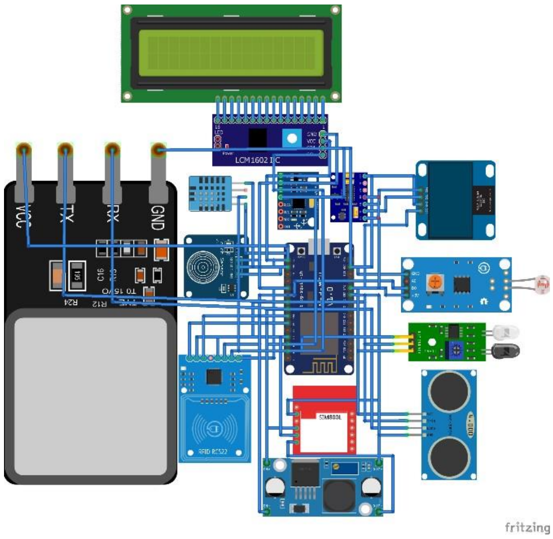

Figure 4. The Whole Circuit Used on the Circuit Board

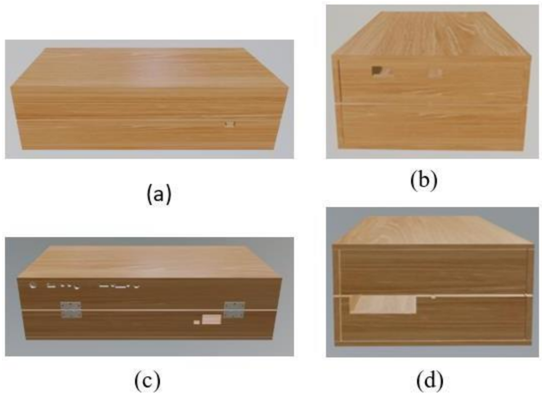

Figure 5. Educational Kit Box Design: (a) Front View, (b) Right View, (c) Back View, (d) Left View

After the 3D design on the box has been completed, the next step is to design the placement of an LCD. Figure 6 shows the kit box design when the LCD has been installed. Figure 6a shows the front view with the addition of an LCD controller connected to the button controlling the monitor. Figure 7 shows a complete kit box with an LCD monitor and circuit board.

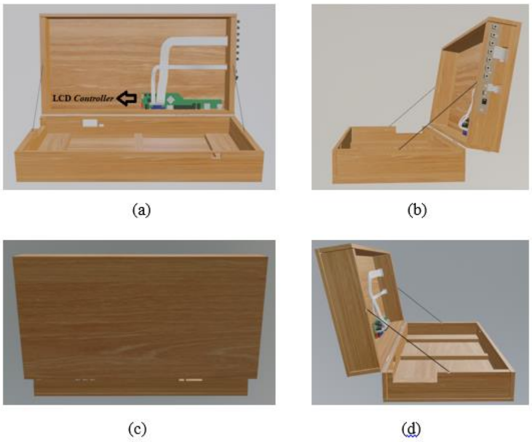

Figure 6. Box Kit Design with Additional LCD: (a) Front View, (b) Right View, (c) Rear View, (d) Left View

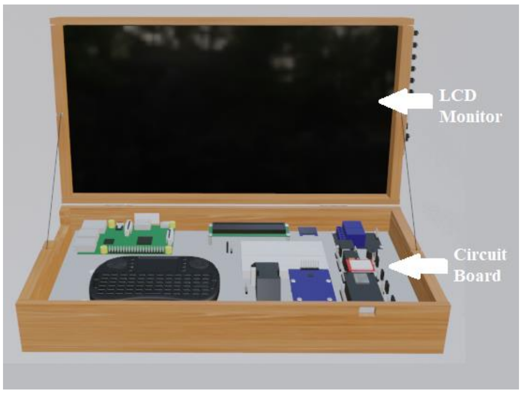

Figure 7. Box Kit with LCD Monitor and Circuit Board

The next step is to add a capability to the components to connect to the internet. Here, we utilize Node-Red which is a browser-based visualization tool for creating Internet of Things (IoT) applications [12]. Node-Red uses a system using a node represented by an icon that corresponds to its function. The system can operate in several ways, namely drag, drop, and connect nodes, or import JavaScript code [13]. The use of Node-Red as a GUI to guide the users will make it easier for high-school students to understand the basic principle of IoT. Here, Node-Red is simply used to display the sensor data values that have been sent by ESP8266 to the LCD. By further enhancement, however, some interested students can also try to store the sensor values in a cloud database and can retrieve the data elsewhere.

The reading of the value on the Node-Red to display data on the LCD monitor is done by running the publish and subscribe functions. Publish function is used to send the data and subscribe function is used to receive the data. When the sensor reads the sensor input value then the value will be processed on the ESP8266 and will be sent to the raspberry server. The sensor values received by the server are then published to MQTT, then node-red will subscribe to MQTT using the topics configured on the MQTT input node. The topic that is configured on the MQTT input node is a function used to call the sensor data values that match what is contained in the reading function in the Arduino programming. This way, the sensor value will be displayed on the LCD monitor.

Programming using Node-Red is done by accessing the raspberry IP address (1880). Next, the necessary nodes are arranged to form a simple flow. In its arrangement, there are several main nodes needed, namely the input node and the display output node. An example of an application that can be developed by the students are the utilization of the DHT11 sensor to obtain the temperature (°C) and room humidity (%) values. Figure 8 shows a Node-Red display created to display the DHT11 sensor data values.

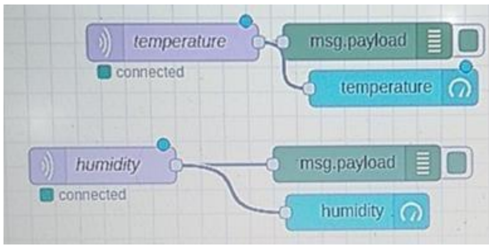

Figure 8. Node to Display the DHT11 Sensor Data Value

After the flow is complete, the design can then be seen using the Deploy function in Node-Red, which has a role to connect nodes. Then, the sensor values can be viewed by accessing the raspberry IP address via the Node-Red port (raspberry IP address: 1880/ui). Figure 9 shows the final appearance of the DHT11 sensor.

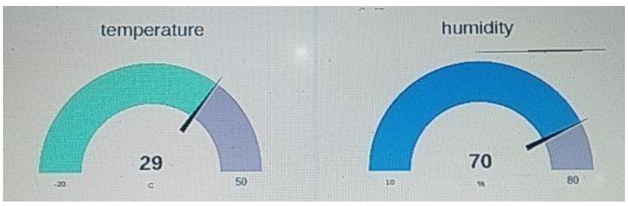

Figure 9. The DHT11 Sensor's Final Display

Another example of using this kit is by utilizing an HC-SR04 Ultrasonic sensor as can be seen in Figure 10. This figure shows a simple flow used to display the distance value in centimeters (cm) using the sensor, which will measure the distance between the sensor and the obstacle in front of the sensor. To obtain the distance value, an object is placed in front of the sensor. Figure 11 shows the final display of the HC-SR04 ultrasonic sensor on the LCD monitor.

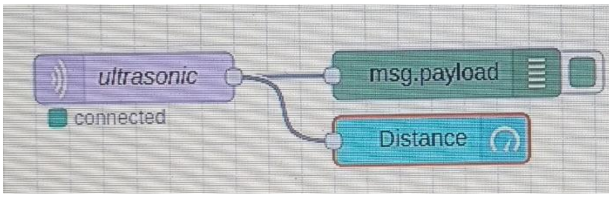

Figure 10. Node to Display the Ultrasonic HC-SR04 Sensor Data Value

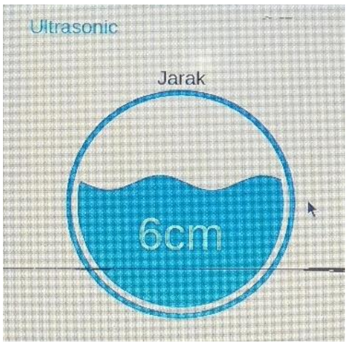

Figure 11. Ultrasonic HC-SR04 Sensor's Final Display

The use of other sensors such as the Accelerometer sensor GY521, MAX30102, RFID RC522, Fingerprint DY51, Touch sensor, infrared sensor, and LDR sensor can be used and applied using the same steps as the DHT11 and ultrasonic HC-SR04 sensors. Accelerometer GY521 can be used to determine the value of the slope of an object. The MAX30102 sensor can be used to determine the value of heart rate in units of bpm (beats per minute). The RFID sensor can be used to measure the intensity of infrared rays. Whereas the LDR sensor can be used to detect the amount of light intensity.

From this stage, we test the kit by testing each sensor component with a program that has been created and send the sensor value data to be displayed on the LCD. Table 1 shows the results of the tests.

Table 1. Sensor Testing Result

No	Sensor	Expected Condition	Expected Output	Remarks
1	DHT11	The sensor detects the temperatur e andhumidit y of the room.	The sensor values are displayed on the Node-Red graphical display	Succeeded
2	MAX3 0102	The sensor detects the heart rate in bpm (beats per minute)	The heartbeat values are displayed on the OLED display	Succeeded
3	*Acceler ometer* GY-521	The sensor detects the tilt angle	X, Y axis values are shown on the I2C 12x2 LCD and Node-Red user interface display	Succeeded
4	Module GSM SIM80 0 L	The module captures GSM networks and signals	Notification on the 16x2 LCD provides information that the SMS was successfully sent Notification on the 16x2 LCD provides information that the SMS was successfully sent	Succeeded
5	*Touch* Sensor	The sensor detects the Touch that The sensor receives	The sensor value will display Node-Red graphics	Succeeded

4. RESULTS AND DISCUSSION

Testing this educational kit is done by making a circuit by connecting the pinout components or sensors needed by the ESP8266 microcontroller pinout using a jumper cable can be seen in Figure 12. Pinout D0 DHT11 with a purple cable is a digital din sensor connected to the GPIO pin ESP8266, which is pin D1 ESP8266. The blue cable is the cable that connects the VCC DHT11 pinout to the VCC ESP8266 pinout. The white cable is the cable that connects the GND DHT11 pinout to the GND ESP8266 pinout.

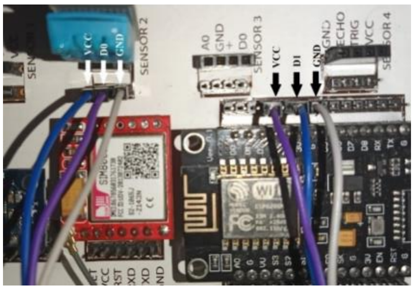

Figure 12. The Circuit on the DHT11 Sensor with ESP8266

Programming using the Arduino IDE application is carried out to create a circuit that has been made to carry out its function and can send sensor data values to the ESP8266 which will then be processed and sent to Raspberry using the same network as the ESP8266. Library DHT.h is used to read the temperature and humidity values from the DHT11 sensor. In addition, ESP8266WiFi.h and PubSubClient.h libraries are also used to enable data to transmit via the internet or WiFi network. The algorithm of the Arduino program is as follows:

1. Include libraries: DHT.h, ESP8266WiFi.h and PubSubClient.h
2. Define the pinout of the components according to the hardware construction. There are two initialized pinouts, namely the pinout to get the sensor input value and the pinout to state the type of DHT sensor used.
3. Configure the SSID, password, and the MQTT server address of the WiFi network that is used to receive and send sensor values to the raspberry server.
4. Read the sensors' values: ambient temperature and ambient humidity.

Node-red programming is carried out after the Arduino program has been successfully executed, to display the temperature and humidity data values as an easy-to-understand interface. The result of the node-red programming is shown in Figure 13. The node-red page can be accessed by typing the raspberry address and using the MQTT port (raspberry IP tool: 1880), followed by /ui (raspberry IP address: 1880/ui). This functional testing showed that the developed education kit prototype can function properly and is ready to be tested to real users.

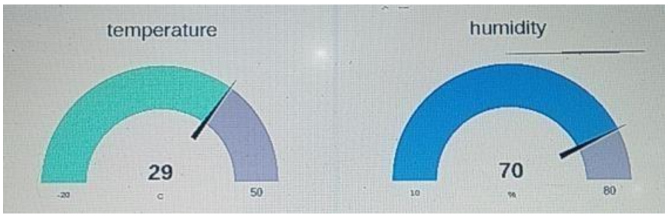

Figure 13. User Interface Display on DHT11 Sensor

5. CONCLUSION

This research has succeeded in developing an IoT-based educational kit for high school students. The education kit has a variety of sensors, namely infrared sensors, LDR sensors, touch sensors, ultrasonic sensors, DHT11 sensors, RFID, SIM800l, MAX30102, accelerometer sensors, and fingerprint sensors. To support the learning process, sensors can be selected and set by the user. Then the sensor value can be displayed on the LCD monitor by accessing the raspberry IP address. This kit is tested by testing all available sensors on the circuit board and displaying the sensor values on the monitoring page on the LCD monitor. The test results show that the developed educational kit can function properly in accordance with the needs analysis.

The next work is to test this kit to the targeted users, that is, the high school students, through direct teaching and learning process. Their input will be considered to improve the design of this prototype

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