The Development of a Real-Time Supervision-less Arduino's Trainer Board for Engineering Technology Undergraduate Program

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.909000183

Received: 29 August 2025; Accepted: 04 September 2025; Published: 04 October 2025

ABSTRACT

Arduino has been widely used as the default microcontroller for teaching and learning due to its cost-effective and user-friendly features. This is evident from the many commercial Arduino trainers available on the market. Unfortunately, all these trainers require supervision, limiting the teaching and learning sessions to a small number of students. This project aims to create a proof-of-concept for an Arduino Trainer that can provide automatic feedback on whether students correctly connect the components. This trainer consists of an Android app and a trainer board. The Android app will display the required component connections in the form of questions and provide feedback by automatically checking the connections made by the students. The trainer board includes eight of the most commonly used electronic components. The proof-of-concept is then verified by comparing the expected results with the actual results obtained from the trainer. Additionally, a survey among the students is conducted for the validation process. The survey results indicate the potential use of the trainer to aid teachers in teaching and learning sessions.

Keywords*:* education kit; trainer; quiz board; Arduino trainer; Arduino quiz board.

INTRODUCTION

Arduino is an open-source microcontroller that has been widely adopted as the go-to microcontroller for teaching and learning (T&L). Its adoption spans from primary to tertiary education, demonstrating its versatility. This widespread use is attributed to its open-source nature, making it inexpensive and easy to use, with numerous references available online.

The T&L process with Arduino typically involves two components: writing a program and constructing an electrical circuit. While various tools are available to support students in programming, equivalent tools for circuit construction are lacking. This project aims to address that gap through two tactical objectives. The first is to develop a trainer capable of providing automatic feedback on students' circuit connections, indicating whether they are correct or incorrect. The success of this objective is measured through a verification process in which the expected outcomes for all possible scenarios are compared with the actual outcomes produced by the trainer. The second objective is to ensure that the trainer effectively supports the T&L process, particularly during laboratory sessions, with minimal supervision from educators. The success of this objective is evaluated through a validation process, in which the target audience is surveyed regarding the trainer's effectiveness in T&L.

The proposed trainer consists of hardware and an Android application. Its general operation is as follows: (1) the application presents circuit connection tasks in the form of questions, (2) students attempt to answer by making the corresponding Arduino connections on the trainer's board, and (3) the application provides feedback on the students' circuit connections. The trainer incorporates eight commonly used components: an Arduino UNO, red Light Emitting Diode (LED), blue LED, green LED, 16×4 Liquid Crystal Display (LCD), humidity and temperature sensor (DHT11), buzzer, and potentiometer. The components selected for the trainer covered 75% of the commonly used in the introductory course of microcontroller subject for Engineering Technology field in Malaysia. Designed to be both affordable and portable, the proposed trainer has a material cost of under RM200 (USD 50), measures 25.7 cm × 20.5 cm × 10 cm, and weighs less than one kilogram.

The inspiration for the trainer is drawn from various past academic literatures [1-10]. M. A. Hairuddin et al. suggested using LabVIEW integrated with an Internet of Things (IoT) platform, referred to as a Computer Assisted E-Laboratory, to train instructors in Industrial Instrumentation [1]. This interactive instructor was designed for remote access to the LD-Didactic temperature system, incorporating LabVIEW, Arduino-Espresso8266, and Blynk Software to control a PID temperature management system. M. H. A. H. A. M. Faseh et al. developed a low-cost version of the Programmable Logic Controller (PLC) Mnemonic Code translator [2]. This project utilizes the detection method by M. H. A. H. A. M. Faseh et al. [2] in order to detect specific pin connection made by the user of the trainer. R. Rifin et al. advanced a mobile application called ExamWhiz to simplify traditional exam processes, including creating examination questions, labelling results, and avoiding conventional exam papers [3]. This project adopts the best practice implemented by R. Rifin et al[3]. In designing the application's Graphical User Interface (GUI).

The concept of computer–human interaction in this project is adapted from several studies [4, 6, 7]. A. F. Hafizan et al. proposed a traditional board game educational package, known as Congkak, which was digitized and called E-Congkak [4]. This project adopts their electronic feedback mechanism, in which the coordination of a buzzer and LEDs on the trainer serves as visual and audio cues to complement the feedback provided by the application's GUI. M. R. Yaacob et al. created an innovative electronic quiz board called e-Flowchart to assess students' understanding of basic flowchart concepts [6]. The ease of the maintenance when designing the kit are adopted in this project. While, I. A. Rozani et al. developed an interactive hardware version of the classic Othello board game, encouraging younger children to engage with traditional games in an interactive format while retaining the tactile element absent in computer games [7]. The tactile interaction concepts implemented by M. R. Yaacob et al. and I. A. Rozani et al. [6-7] are studied and incorporated into this project.

The inspiration for the instructional design in this project is drawn from several studies [5, 8, 9, 10]. M. F. Z. M. Zakaria developed an educational quiz board to test students' knowledge of control systems, specifically the time-domain analysis of second-order principles using DC motor speed control [5]. The quiz board employed DC motor velocity control, with questions based on the system's response curve. The approach of M. F. A. M. A. Halim et al., who developed a set of questions to assess student's understanding of resistor connections is also applied in this project [9]. A. F. Hassan et al. proposed a visual gamification program to enhance physiotherapy sessions, and the gamification elements from their work are incorporated into this project [10].

In terms of project management for designing and constructing the prototype, the Conceive–Design–Implement–Operate (CDIO) methodology proposed by Mustapa et al. [8] is employed. The authors incorporated the CDIO framework as the project management guideline for developing a product in the university technology MARA's Capstone project. In the article, the authors presented a successful case study where a group of students successfully developed a tactile electronic board game—based on Hasbro's *Mastermind*—using the CDIO methodology.

The questionnaires used to assess the effectiveness of the kit are adapted from previous studies [11–17]. Based on these works, 13 questions were modified to suit the context of this study. A five-point Likert scale was employed, as the majority of these studies used it as the standard. The results are presented in a multi-scale bar chart, in line with the common practices reported in [11–17].

METHODOLOGY

Block Diagram of the Trainer

The functionality of the proposed trainer's hardware can be easily illustrated using a block diagram. Figure 1 shows the main components of the proposed trainer, which can be divided into four main categories: inputs, outputs, controller, and communication.

Inputs are components that accept responses from the user and translate them into relevant electrical signals for the controller to process. The proposed project uses simple female pin headers, jumper wires, a DHT11 sensor, a potentiometer, and a dummy Arduino UNO as inputs. The electronic components are the components used by the user to perform circuit connection on the trainer.

The second category is the controller, which in this project is an Arduino MEGA. It stores the program that detects the connections made by the user and verifies their correctness by comparing the energized pins with a lookup table stored in the code. Once verified, it sends the relevant information to the Android app via a Bluetooth connection.

The communication medium used in this project is Bluetooth, with the HC-05 module selected for its bi-directional capabilities. Bluetooth was chosen for its simplicity and suitability in rural areas where internet coverage may be limited.

The last category is the outputs, which include the buzzer, LCD, and LEDs. These three components are provided as selectable options for the user as part of the Arduino circuitry connection.

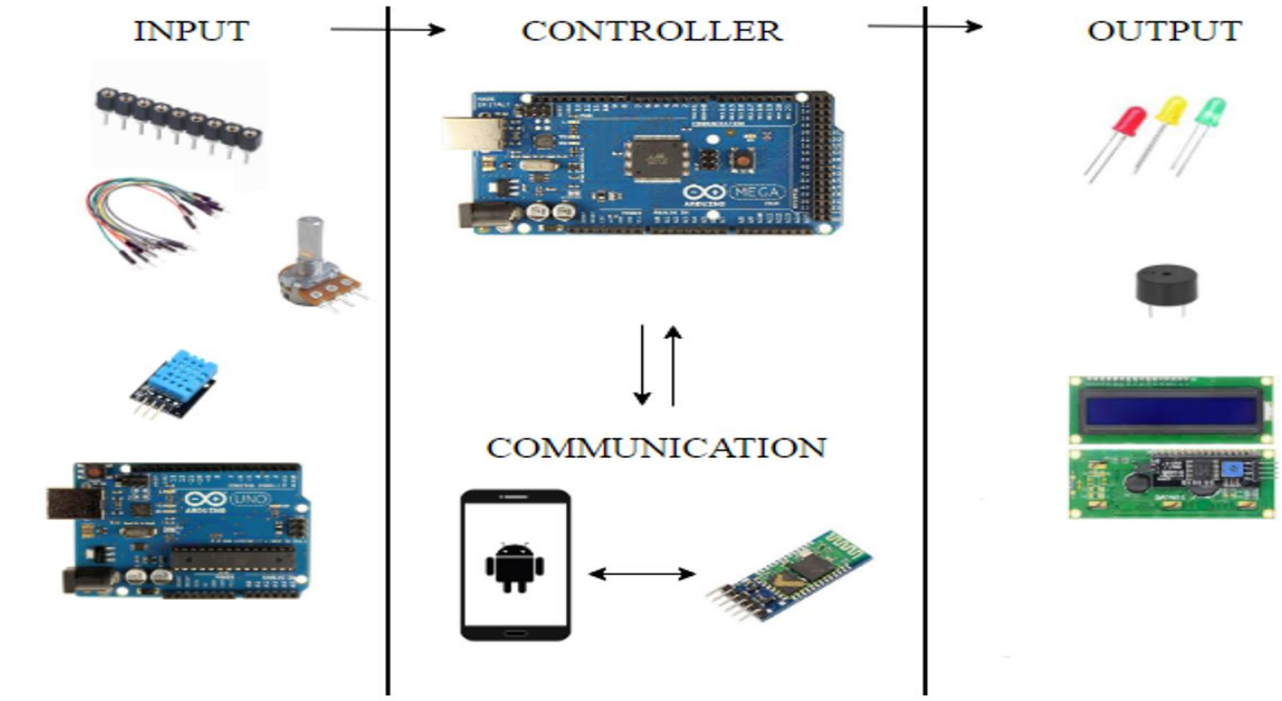


Figure 1: Block diagram of the proposed trainer

Trainer's Layout

The top of the trainer board will be equipped with several electronic components that users need to connect to the Arduino UNO, based on the figure displayed on the Arduino smartphone app. Female round pin headers are attached to every pin available for the electronic components. Users need to use jumper wires to connect the components to the Arduino UNO. The electronic components attached to the top of the trainer board include LEDs, a potentiometer, a buzzer, a DHT11 sensor, and an I2C LCD. The controller used is an Arduino UNO. Figure 2 shows the expected project layout for the trainer board, drawn using Paint 3D software, while

Figure 3 shows the actual project layout. There is a slight deviation in the arrangement of the components due to the different sizes of the housing that encases the trainer.

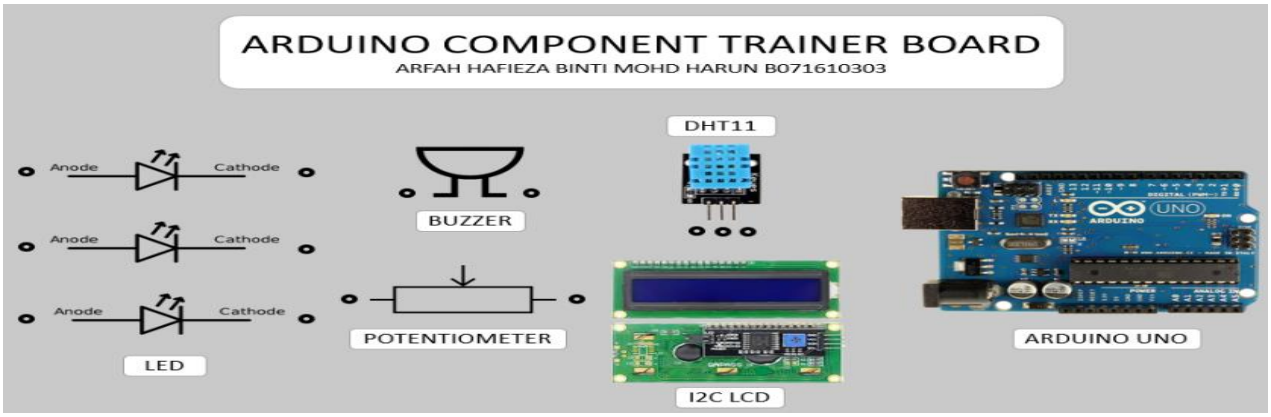


Figure 2: Expected project layout

Figure 3: Actual project layout

Flowchart Of the Trainer

Figure 4 illustrates the general flowchart of the project's operation. First, the Android smartphone displays a welcome message for the user. The user then needs to connect the smartphone's Bluetooth to the trainer's Bluetooth module to allow the app to display the questions. Once the Bluetooth connection is established, the question is displayed, and the user can start performing the circuit connection. After completing the connection, the user can click to check the answer. The Arduino will verify the connection and send the corresponding information to the app. The app will then display the appropriate feedback. The question will increment by one until all questions have been answered. Table 1 shows the expected and actual display of the app, given the scenario described in the flowchart.

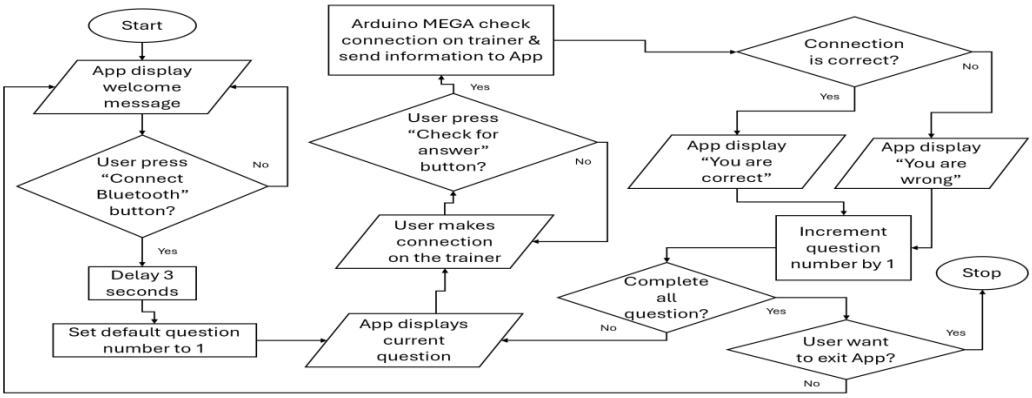
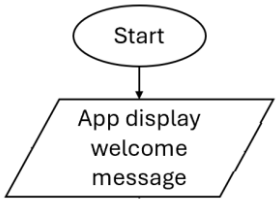
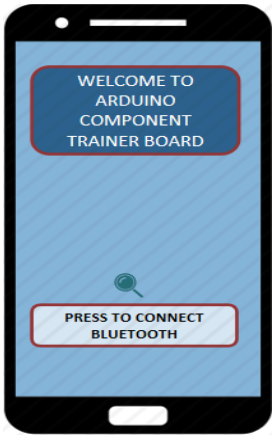
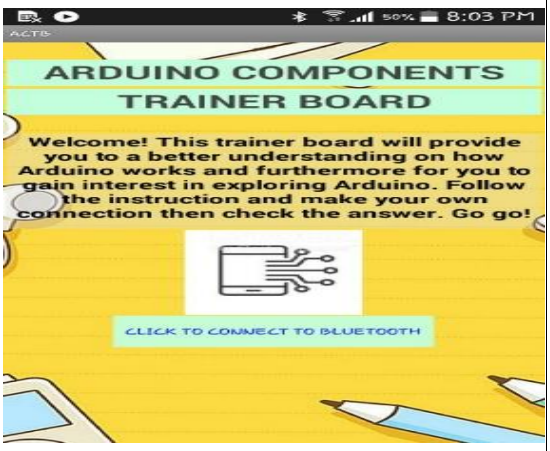
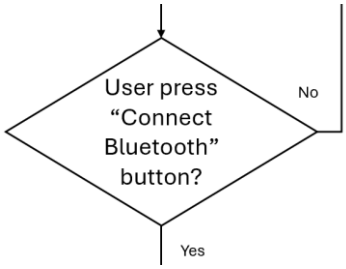
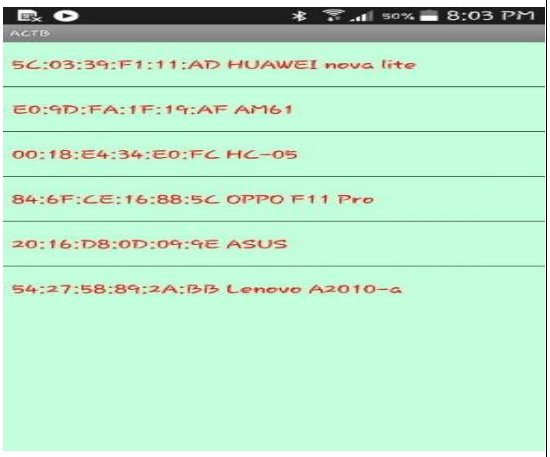
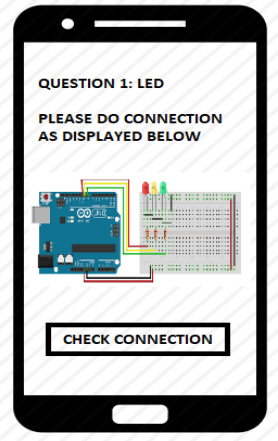
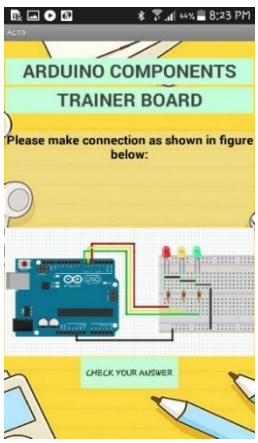
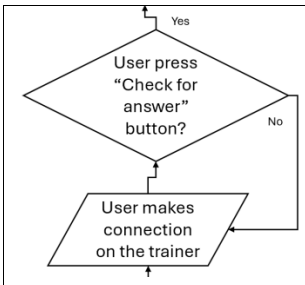


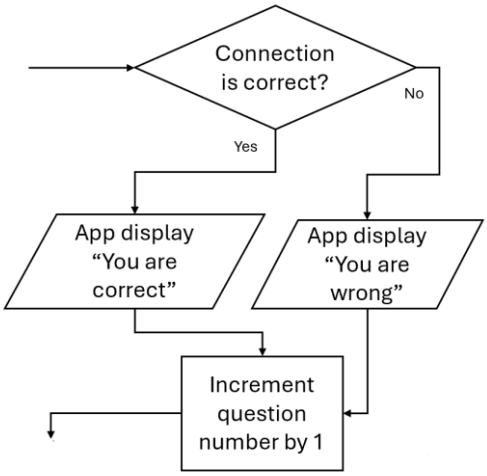
Figure 4: Flowchart of the general operation of the App.

Table 1: Expected and actual result based on flowchart of the project

Scenario	Expected result	Actual result
As the kit is connected to the power supply, and the App is open, the main screen will display the welcome message. The screen also displays an option button for user to connect Bluetooth to start operating the kit. 		
After the user press the Bluetooth option button, the screen displays all the paired Bluetooth devices with the phone. To proceed in using the kit and for the MIT App to start display the questions, user must select HC-05. 		
After the Bluetooth successfully connected to the phone, MIT App starts to display question for user to make connection on the kit. The screen also included the "Check Connection" option, so user can check the answer for the connection they made.		



As the user pressed the option button to check the connection, the screen will display whether the connection user made is correct or wrong. Then, the screen displays an option button for user to proceed to answer the next question. As the question incremented, there are a number of questions for user to do connection.



Correct answer

Wrong answer

Correct answer

Wrong answer

RESULT AND DISCUSSION

Trainer's Verifiction

Verification is the process of ensuring that the prototype meets the technical specifications. This project employs a straightforward yet commonly used verification method by comparing the simulation results with the actual results. Table 2 shows some sample the correct connections, while Table 3 displays sample of the incorrect connections. From these two tables, it is evident that the expected outcomes match the actual outputs produced by the prototype. The trainer has a database of 30 questions which create a set of 60 possible scenarios to be tested.

Table 2: Sample of scenario testing of the correct connections

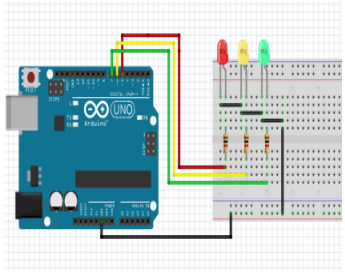
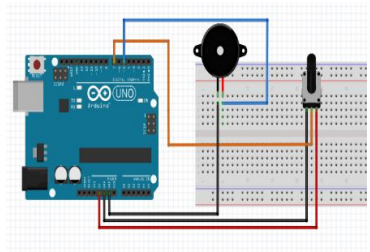
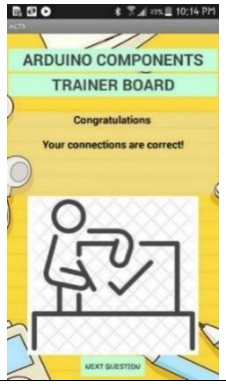
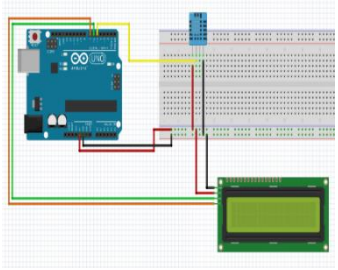
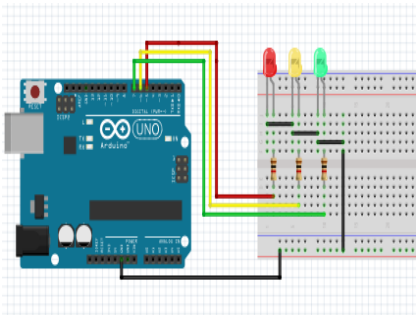
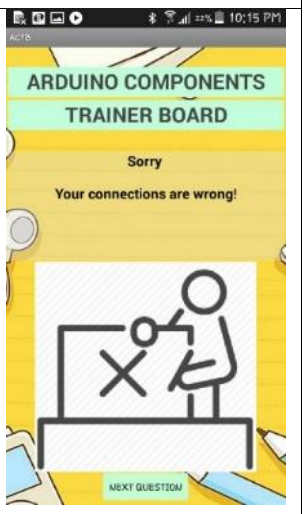
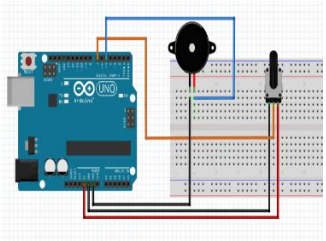
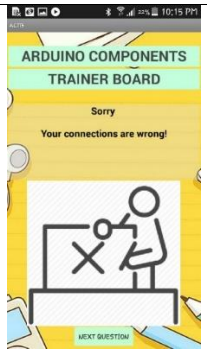
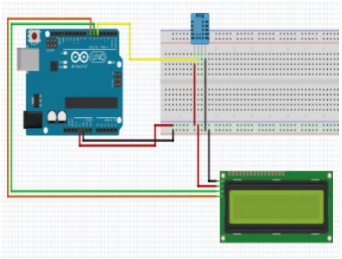
No.	Question	Circuit Construction	Actual Outcome
1.			
2.			
3.			

Table 3: Sample of scenario testing of the wrong connections

No.	Question	Circuit Construction	Actual Outcome
1.			

2.			
3.			

Trainer's Validation

Validation is the process of determining whether a product meets the needs of the user. This project employs a simple survey targeted at tertiary Engineering Technology (ET) students. The survey consists of 13 questions answered by 100 respondents, all of whom are first-year Electronic & Computer ET students from university Technical Malaysia Melaka (UTeM). All questions use a 5-point Likert Scale. Table 4 lists the questions used in the survey, and Figure 4 summarizes the survey results.

Table 4: List of Survey's Questions

Question No.	Question / Statement
Q01	Is Arduino an interesting lesson?
Q02	Is Arduino easy to comprehend?
Q03	Is constructing any Arduino-based circuit easy?
Q04	Is the trainer board easy to operate?
Q05	Do you think this trainer board can saves time?
Q06	Is the trainer board in a convenient sequence?
Q07	Does the instructions displayed on the application easy to comprehend?
Q08	Is the trainer board portable and can be carry around?
Q09	Is the cost of the trainer board affordable?
Q10	Is the trainer board functions perfectly as a whole?
Q11	Do you think the trainer board is important in learning process?
Q12	Does the trainer board be operated by yourselves without any guidance and help from lecturers and lab engineer?
Q13	Do you think the trainer board can help improve your hands-on skills?

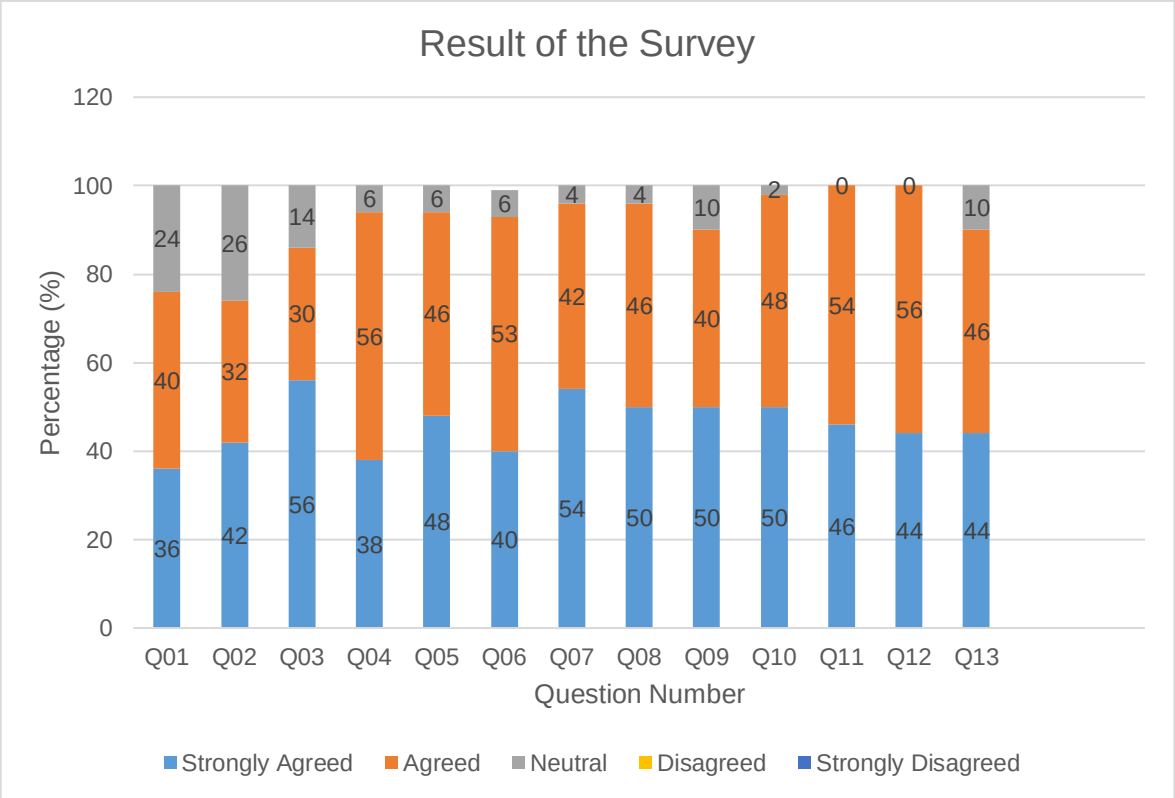


Figure 4: Result of the Survey

The first three questions gauge the respondents' opinions on using Arduino as a tool for teaching and learning (T&L). The first question is, "Is Arduino an interesting lesson?" Only 36% of the respondents strongly agreed that Arduino is an interesting lesson, while 40% agreed with the statement. The remaining respondents were neutral. The second question is, "Is Arduino easy to comprehend?" The majority of respondents strongly agreed that Arduino is easy to comprehend, likely due to its straightforward instructions and interface compared to other microcontrollers they had experienced (such as PIC). As Arduino is open-source, users can find many resources online when they face difficulties. Another 32% of respondents agreed, while the rest were neutral. The third question is, "Is constructing Arduino-based circuits easy?" According to the results, 56% of respondents strongly agreed that constructing an Arduino-based circuit is easy, which is unsurprising given the abundance of tutorials and guides available.

The following seven questions gauge user satisfaction with the prototype's functionality. For Q04, while no respondents rated below neutral, only 38% strongly agreed that the trainer board is easy to operate, indicating a need for further investigation to improve the prototype interface. For Q05, all respondents rated neutral or above, suggesting that the trainer board reduces circuit construction time because all components are properly placed, eliminating the need for students to install them on a breadboard. For Q06, only 6% felt neutral, with the rest expressing positive sentiments. According to Figure 4 (Q07), 54% of respondents strongly agreed that the instructions displayed on the app are easy to comprehend, with another 42% agreeing and the remainder staying neutral. The app's interface was designed to be as minimalistic as possible to create a foolproof experience. For Q08, half of the respondents strongly agreed that the trainer is portable, with none disagreeing. For Q09, although none felt the trainer was expensive, 10% of respondents were neutral regarding the cost of producing the trainer. Overall, as indicated in Q10, 98% agreed that the trainer fulfils its intended functionality.

The remaining three questions focused on gauging respondents' opinions on the trainer's effectiveness. In Q11, respondents were asked whether the trainer board is helpful in the T&L process. The results showed that 100% of respondents agreed, aligning with the second objective of the project. In Q12, respondents were asked whether the trainer board reduces the supervision required by educators during T&L, with 100% agreeing, proving the project achieved its second objective. For Q13, 90% of respondents agreed that the trainer is helpful in improving their psychomotor skills.

CONCLUSION

This paper presents the development of an automatic Arduino trainer designed to display questions related to circuit connections and verify their correctness using an Arduino MEGA microcontroller. A companion app serves as the user interface, delivering questions and feedback, while the methodology outlines the hardware and software development processes. The prototype's functionality is validated through a verification method, and user satisfaction is assessed via a survey, which confirms that the trainer meets its intended objectives. However, the survey also highlights concerns regarding maintenance and scalability. Based on this feedback, future improvements include packaging the trainer as an IoT device integrated with existing Learning Management Systems, and introducing a troubleshooting mode that offers hints or step-by-step correction guidance to enhance pedagogical effectiveness.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to the Ministry of Higher Education Malaysia (MoHE) and University Technical Malaysia Melaka (UTeM) for providing the funding necessary to accomplish this study.

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