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An Interactive Tool to Learn the Sensors and Transducers Subject for Kinaesthetic Domain Students

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ABSTRACT

The main course learning outcome in the Sensors and Transducers subject is the ability of students to present the sensing mechanism for some specific sensors. This sensing principle is physical or chemical in nature and cannot be seen with bare eyes. Different teaching techniques have been used; however, all the techniques did not favour the kinaesthetic domain. Hence, an interactive tool has been proposed to motivate students to be more participate in class and increase their understanding. The proposed tool was the Arduino board, which was connected to five different sensors: water level sensor, infra-red sensor module, proximity sensor, pH sensor, and thermocouple. A graphical user interface (GUI) was developed using Visual Studio software as a monitoring system to show the sensors' outputs interactively. The tool can be re-developed by students from the circuit connection given in the menu of the monitoring system. The source code for the user-friendly Arduino board can be easily obtained from any related electronics website. The developed GUI can be installed by students on their laptops using the created setup file. Using the interactive tool, students can see in real-time the output of the sensors on the monitoring system by exposing them to their corresponding measurand. All sensors work as expected and the GUI correctly presents the data from the sensors. The setup file can also be installed and the tool can run successfully on the computer even without the Visual Studio software. The positive feedback from students and their performance also showed a positive trend. From the performance of the students, the developed tool has been proven to improve students' understanding of the sensors learned.

1. Introduction

Sensors and Transducers is a three-credit course and must be taken and passed by first-year students of the Bachelor of Applied Sciences (Electronics and Instrumentation), Universiti Malaysia Terengganu (UMT). This course is very significant as the sensors and transducers are two important components in any instrument used in industry from a simple type of measurement to a complex one. The course learning outcomes are to describe the effect of the sensing mechanism for various types of sensors, compute the value of electrical components involved in the sensor-interfacing

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circuits, and present the use of sensors in electronic applications effectively. To achieve the first learning outcome, the course covers five different types of sensors: radiation, magnetic, thermal, mechanical, and chemical. The students learn the sensing mechanism of sensors which is how the sensors convert different types of non-electrical energy (radiation, magnetic, thermal, mechanical, and chemical) into an electrical signal. All sensing principles of sensors are covered in Chapters 2 to 6.

In Chapter 1, students are first exposed to the definition of the sensor, transducer, and actuator. Students also learn six different ways to classify the sensors based on different sources in textbooks. Students also need to get familiar with sixteen static characteristics of sensors, so that they understand the information given in the datasheet. In the last chapter, students also learn how to interface the sensors to electronic circuits and calculate all parameters involved in a voltage divider circuit, the Wheatstone Bridge, AC bridges, six different configurations of operational amplifiers, and four types of passive filters. All the learning process is done in a 3-hour lecture per week for 14 weeks in a classroom. The teaching and learning of the subject are supported by the Sensors and Transducers books available in the university library by different authors [1-3].

The selection of specific sensors to be taught to students can be influenced by different factors. For example, for mechatronics students, the types of sensors may focus on the sensors widely used in the automotive industry. For electronics students, all sensors related to electronic devices and widely used in the electronics industry will be focused more. The specific sensors covered in this course can be categorized based on energy as in Table 1. In total, students have to understand nineteen different sensing mechanisms for this course. The conventional teaching method was used before to explain about all the sensing mechanisms. The use of texts, pictures, and videos are the most common ways to show how physical variables can be transformed into electrical parameters. However, from the theoretical aspects discussed by Othman and Amiruddin [4], the conventional method does not cover the need of kinaesthetic learners.

Table 1
List of sensors taught in the subject based on different energy domains

Energy domain	Types of sensors
Mechanical	Switch, potentiometer, pressure sensor, piezoelectric sensor, piezoresistive sensor, water level sensor
Magnetic	Hall effect sensor, Eddy current sensor, Magnetoresistive sensor
Radiant	Photoconductive cell, Photovoltaic cell, Photodiode
Thermal	Thermocouples, Resistance Temperature Detectors, Thermistors
Chemical	Electrochemical sensor (pH sensor, fuel cell), Thermo-chemical sensor, Optical-chemical sensor

Many factors contribute to the performance of students at the university level [5]. The factors can be controllable and uncontrollable by educators. The uncontrollable factors are gender, race, family income level, and family environment, receiving grant aid, completing advanced level classes, time allocation for studies, parent’s education, and parent’s age. Meanwhile, controllable factors are learning abilities, attitude toward attendance in classes, study habits, and academic interaction with teachers and peers. As educators, the teaching methods used in the class play a vital role in interacting with students, increasing students’ interest in learning and thus improving students’ understanding.

One of the incentives to encourage students to be interested in this course is to introduce an interactive tool as a teaching aid. The proposed tool is used to achieve the first-course learning outcome because it is the most difficult part to understand without a strong physics background and covers almost 60% of the overall contents. The movements of electrons, the magnetic field, and all effects involved in the sensing mechanism cannot be seen with bare eyes and is difficult to be imagined by kinaesthetic students. The best way to learn for this type of learner is by doing. They enjoy learning through hands-on methods [4]. That's the purpose of the development of this tool.

Many different learning models have been proposed in the literature such as David Kolb's model that has been introduced in 1984 and revised many times [6], Honey and Mumford's model [7], Visual-Auditory-Kinaesthetic (VAK) model [8,9], and Neil Fleming's Visual-Auditory-Reading-Kinaesthetic (VARK) model [4,10,11]. Among them, Neil Fleming's VARK model is the most widely used as it covers all levels of education. According to the model, there are four types of learners, which are visual domain, those who prefer to learn from graphs, charts, diagrams, etc.; aural who best learn from lectures, discussions, tapes, etc.; read/write who prefer to read from books and write notes, and kinaesthetic learners who learn best via explorations, projects, real experience, and experiments. To incorporate different learning styles, educators must vary teaching and learning activities in the classroom.

The sensors and transducers course are categorized under the Engineering, Science, and Technology subjects. For this category, different learning styles have been discussed thoroughly [11]. In most textbooks, the sensing mechanism can be explained using text with the aid of figures. Video animations explaining how certain sensors work by showing electrons' movement on YouTube make the concept easier to understand. According to Muda [12], it has been reported that the teaching method for the Sensors and Transducers subject at UMT has been improved from one-way teacher-centred learning to more interactive using video, question-and-answer method, more practical examples, mind-map, pictures, and E-book. However, those techniques are only for visual, audial, and read/write domain learners.

Different methods were discussed in the literature to include hands-on in this subject to meet the demand from kinaesthetic learners. To support the theoretical part that has been learned in class and help kinaesthetic learners to understand better, most educators use the sensor output to show the effects of the sensing mechanism. The simplest and low-cost way to show the effects of sensor output is by using a potentiometer and a fixed resistor to form a voltage divider circuit [13]. Using this method, the behaviour of sensors can be experienced even in a classroom. Advanced circuit sensors and transducers in the form of trainers were proposed [14,15]. The developed trainer [14] was equipped with different sensors and transducers, while the trainer proposed by Basri *et al.*, [15] only has an inductive sensor which is the most important component for automotive engineering students. Meanwhile, Sankaran *et al.,* [16] used a project-based learning approach to teach biosensors and transducers course. The project involved collecting and analysing the quality of the components, checking the functions of components, setting the required parameters, calibration, and testing, to increase students' performance and understanding. However, these methods must be executed in a physical environment which is now a big issue after the COVID-19 pandemic. The best teaching method should be transferrable to online classes as well. In addition, the use of trainer's limits students' understanding of the circuit connections of the sensors as they are all embedded under the printed circuit board (PCB) layers.

A software was used to teach the subject as implemented by Wang *et al.,* [17]. The technique is called CDIO, which stands for conceiving, designing, implementing, and operating. However, the objective of this subject is more on enhancing students' ability in computer graphics and design and it is suitable for Civil Engineering-based programs. Another software used for teaching this subject is LabVIEW [18]. The software is used to develop an interactive graphical user interface (GUI) and linked it with the hardware. The software is considered easy to use and does not need in-depth knowledge of computers and indeed programming languages. However, the software itself is expensive. Branzila *et al.,* [19] proposed a Laboratory Kiosk to attract students' interest in the practical work of the Sensors and Transducers course. The kiosk was developed as a website to present general information about the lab, teachers, students, and their working projects. Though, the kiosk cannot show directly the output from the sensors.

Post-COVID-19, many new methods were proposed in the literature especially those involved with hands-on [20,21]. Trudgen and May [20] proposed a remote lab to be used for both, offline and online teaching for the Sensors and Transducers course. The proposed remote lab was developed to ensure the outcome of the course which is to extract numeric values from experiments using laboratory equipment can be achieved. In addition, augmented reality-based software was used to support online learning in the practical course of sensors and transducers by developing learning media containing applications and animation storyboards to show how the sensors work and react in a specific situation [21]. Both papers suggested a very interesting method, however, it is to achieve a different course learning outcome.

Arduino is a very popular microcontroller as it uses simple programming and is very user-friendly [22]. Low-cost Arduino-based teaching aids are becoming popular and widely used to explore and understand the application of sensors and transducers [22-24]. According to Organtini [22], a few experiments related to physics subjects using Arduino were presented and the results showed that this method was suitable to increase students' engagement in the teaching and learning experience. Meanwhile, Suwondo *et al.,* [23] proposed a GUI system to display data from sensors connected to Arduino Mega 2560 in the real-time operating system (FreeRTOS) AVR environment. Although most of the actual systems were run in RTOS, most students had a laptop with a single-user multi-tasking operating system, such as Microsoft Windows and Apple's MAC, and using RTOS, they can only depend on the educators' computer without having a chance to run on their laptop. A concept of developing GUI to help undergraduate students was proposed to solve non-linear equations [24]. Another microcontroller-based project for educational purposes was proposed by Adam *et al.,* [25] to control the traffic light system using 68HC11 microcontroller.

To ensure the students have the experience of running on their own devices, Hatmojo and Azis [26] introduced an Android-based mobile application for the Sensors and Transducers subject. The proposed system was for vocational education, and they used Adobe Animate software to create the GUI before exporting it to the Android SDK platform. However, this method applies only to Android users. Another researcher who focused on the smartphone were Hendeby *et al.,* [27]. However, the sensor fusion thought in the subject was run in real-time MATLAB software and streamed from smartphones over Wi-Fi. The students must learn MATLAB software to implement this method, and it is also limited to Android users.

In this paper, the objective of developing an interactive tool is to improve students' ability to explain the effect of the sensing mechanism for various types of sensors, both verbally and in writing, especially for kinaesthetic students. Arduino-based method was used in this paper where five different sensors that represent five different energy domains were connected to the board. The GUI was developed to show the output of the sensors in real-time interactively. The paper is organized as follows. Section 2 presents a methodology of this work starting from the hardware and software parts of the Arduino board, and developing a GUI for the monitoring system. The results and thorough discussions for all sensors are presented in Section 3. The performance of the students is also discussed. Finally, Section 4 gives the conclusions of the paper.

2. Methodology

In the class, the lecturer cannot identify which students are dominant in certain learning style methods. So, variation of teaching techniques is needed to ensure all domains get the knowledge equally and not lack behind. The idea is to focus on the kinaesthetic learning style as a support to the existing conventional method. However, the complicated programming technique must be avoided for first-year students with no programming background. So, in this paper, an interactive tool was developed to include a simple hands-on that can be done in class physically and can also be shared using an online platform.

This Arduino-based system was connected to five different sensors to represent five energy domains covered in this course, namely a thermocouple (thermal), an infra-red (IR) sensor (radiant), a pH sensor (chemical), a proximity sensor (magnetic), and a water level sensor (mechanical). The proposed tool integrates the technology of Arduino and GUI. The programming for Arduino uses open-source Arduino IDE software that can be downloaded and installed for free, and the code is simple and accessible on any website. Although the programming of the GUI is quite complicated using the Visual Studio software, students do not have to develop their GUI from scratch because a setup file of the GUI can be created and installed on any computer. So, students can install the proposed GUI on their laptops and run it using their sensor and Arduino board, since the circuit connection is given in the GUI menu.

To present how the proposed system was developed, it can be separated into hardware and software parts. The hardware part focuses on the circuit connection of five different sensors to the Arduino board, as shown in Step 1 of Figure 1. Once the hardware connection was completed, the software development for the Arduino board was developed to measure the data from sensors to be sent to the monitoring system, as in Step 2. Then, the GUI of the monitoring system was developed using Visual Studio software to display the collected data from the Arduino board, interactively. The whole process is presented in Figure 1.

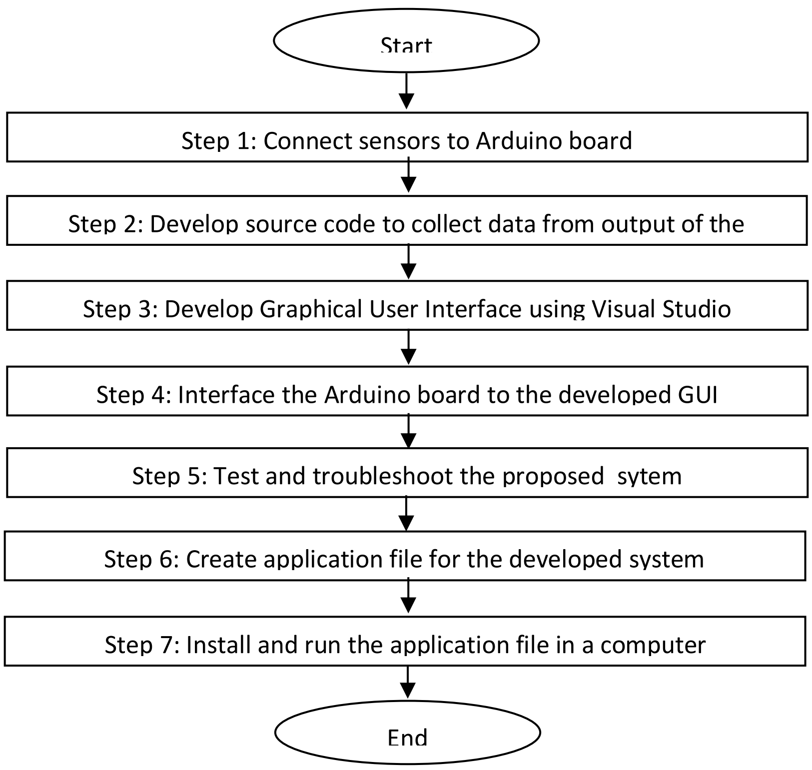


Fig. 1. Flowchart of the overall procedure in developing the system

2.1 Hardware Connection

All five sensors are connected directly to the Arduino board as shown in Figure 2 to Figure 6. Three common wires from sensors must be connected to the power supply, the ground, and the corresponding Arduino ports based on the analogue or digital signals produced by the sensor, except for the thermocouple, which has two extra wires.

Refer to Figure 5, due to the low voltage produced by the thermocouple, it must be connected to the MAX6678 amplifier to increase the amplitude of voltage generated by the sensor before connecting it to the Arduino board. Two additional pins from the amplifier are the chip select (CS) pin to select the device when needed, and the SPI clock (SCK) pin to synchronize the communication between the amplifier and the Arduino board.

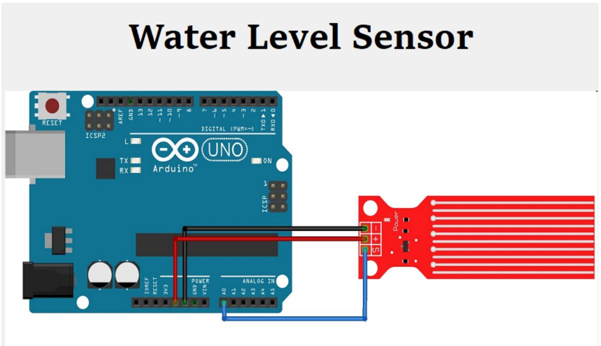


Fig. 2. Circuit connection for water level sensor

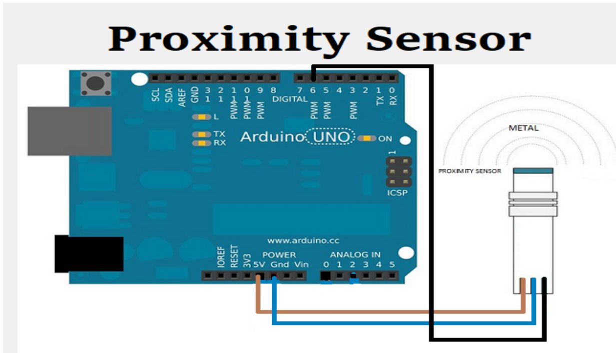


Fig. 3. Circuit connection for proximity sensor

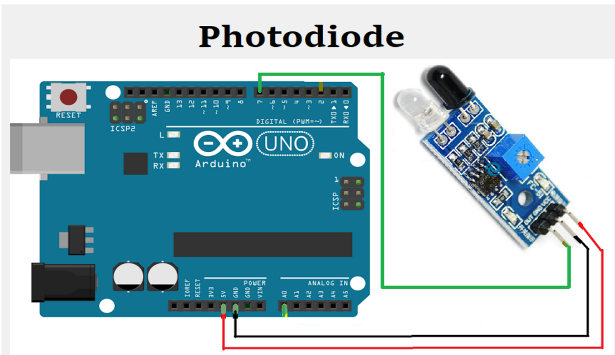


Fig. 4. Circuit connection for IR sensor with a photodiode as a receiver

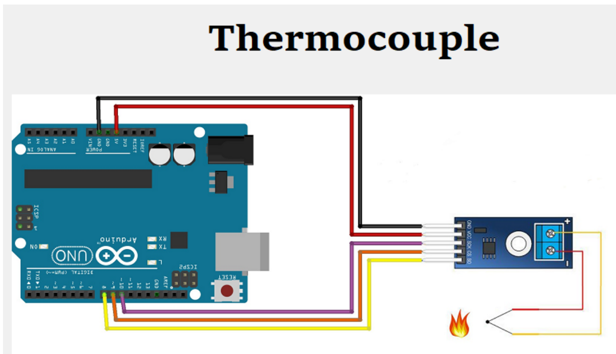


Fig. 5. Circuit connection for thermocouple

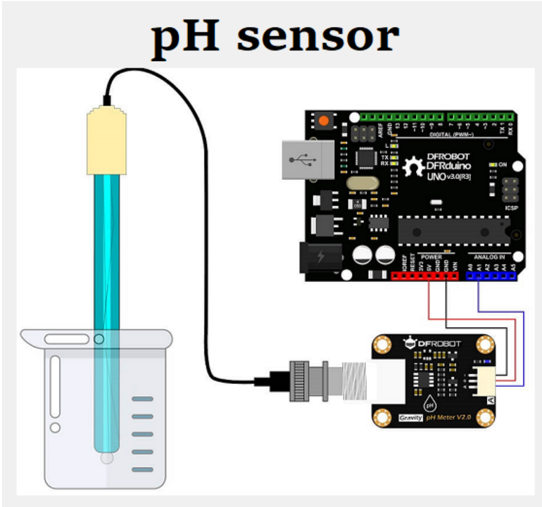


Fig. 6. Circuit connection for pH sensor

2.2 Software Development for Arduino Board

The source code for the Arduino board was written in Arduino IDE software. The flow of the source code can be represented in Figure 7. From the figure, the code can be written based on the circuit connection, either digital or analogue. For digital ports, which were connected to the IR sensor and proximity sensor, the retrieved value was either bit 1 or bit 0. However, for the analogue port, the obtained value was the corresponding analogue-to-digital (ADC) signal which must be converted to the actual value based on the information from the datasheet provided by the manufacturer or to develop a simple experiment to find the relationship between the actual reading and the obtained ADC value.

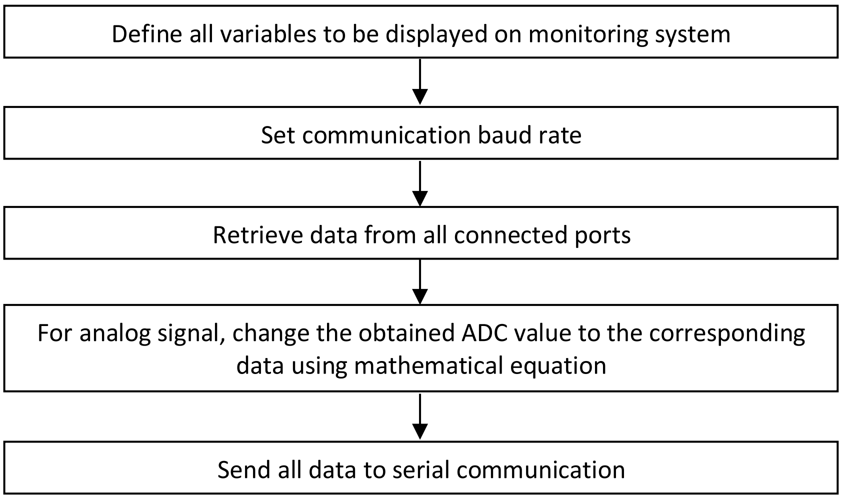


Fig. 7. The flowchart of the developed source code in Arduino IDE

A simple experiment was done for the analogue water level sensor to find the relationship between the ADC value and the actual water level. When the sensor was slowly sunk into a cup of water, the depth of the water was measured, and the corresponding ADC value displayed on the monitor was recorded. The relationship between the height of the water level, h_{wl}, and the ADC value, X_{wl}, can then be obtained as the following Eq. (1):

$$h_{wl} = \frac{X_{wl}}{X_{m,wl}} \times h_m \tag{1}$$

where the maximum height of the sensor used, h_m is 4 cm, and the maximum ADC value produced by the sensor, $X_{m,wl}$ is 630.

For the thermocouple, the library of MAX6675 can be included in the software, and the built-in function to read the temperature value in degrees Celsius, can be used easily. All related equations are included in the built-in function.

The last analogue sensor is the pH sensor, where the datasheet was used to find the relationship between the retrieved ADC value and the actual pH value that should be displayed on the monitoring system. From the relationship between the ADC value, X_{pH}, and output voltage, V_{pH}, of the sensor in mV, the following Eq. (2) can be obtained:

$$V_{pH} = \frac{X_{pH} \times V_{fullscale}}{X_{m,pH} \times n} \tag{2}$$

where full-scale voltage, $V_{fullscale}$, is taken as 5 V, the maximum ADC value of 10-bit ADC, $X_{m,pH}$, is 1023, and n is the number of samples taken in X_{pH} readings. From the V_{pH}, the actual pH value can be obtained from the following Eq. (3):

$$pH\ value = V_{pH} \times m \tag{3}$$

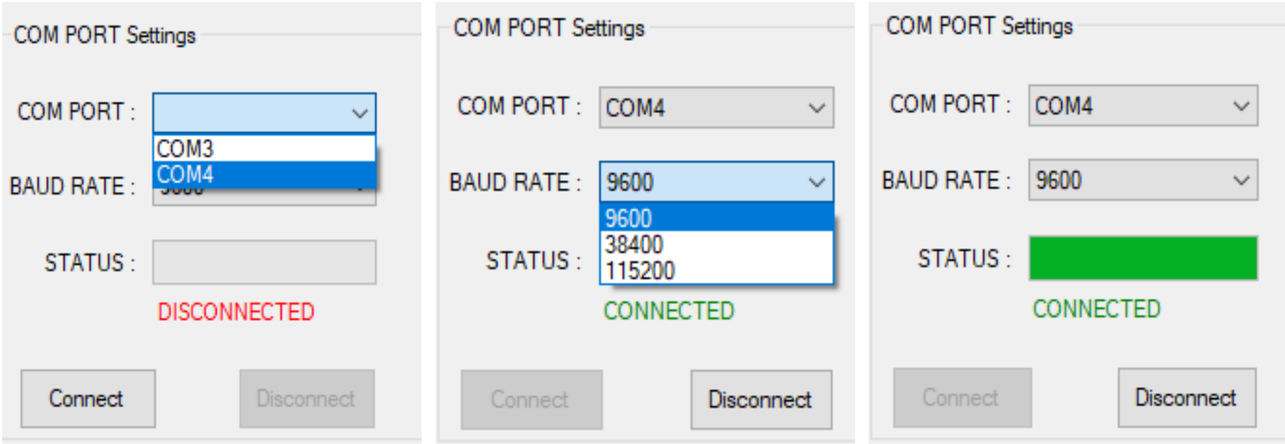
where $pH\ value$ is directly proportional to V_{pH} with a constant of variation, m, is 3.5. All the collected data was then sent to the serial port connected to the computer via a USB cable.

2.3 Software Development for Monitoring System

Three important criteria were used to determine the selection of the software for monitoring, i.e., the capability of setting up communication between the Arduino board and the software, the availability of GUI components provided by the software, and the ability to create setup files for installation on other computers. In this project, the Visual Studio IDE software was selected as it is user-friendly and can be installed using a community license for free.

2.3.1 Serial communication

The serial communication menu as shown in Figure 8, must be included in the monitoring system to set up communication between the Arduino board and the application file. Using the menu, the user can choose the available communication port, the baud rate, and connect and disconnect the connection using the provided button. The status of the connection was also displayed.

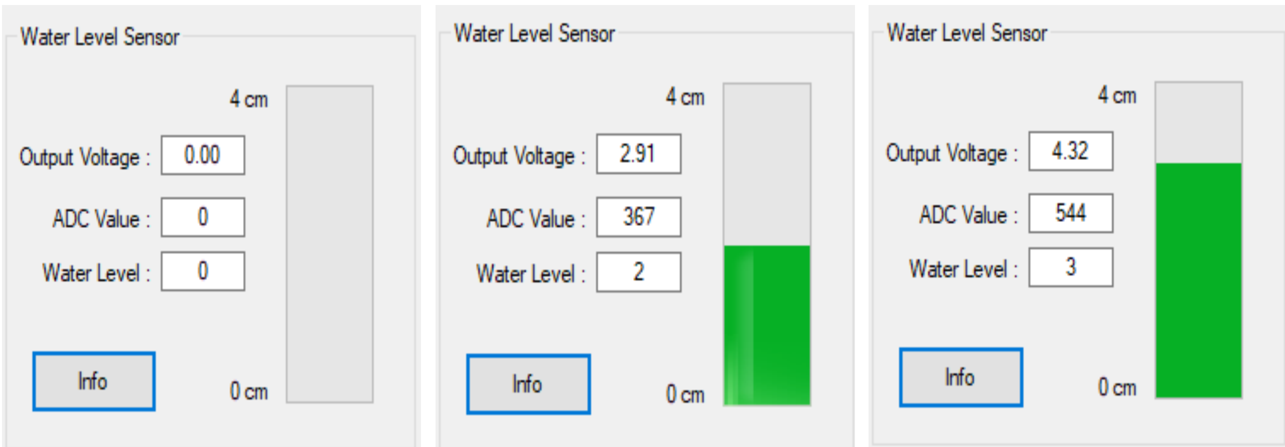


(a) (b) (c)

Fig. 8. Set up communication between Arduino board and monitoring system (a) port selection (b) baud rate selection (c) port is connected

2.3.2 Monitoring menu

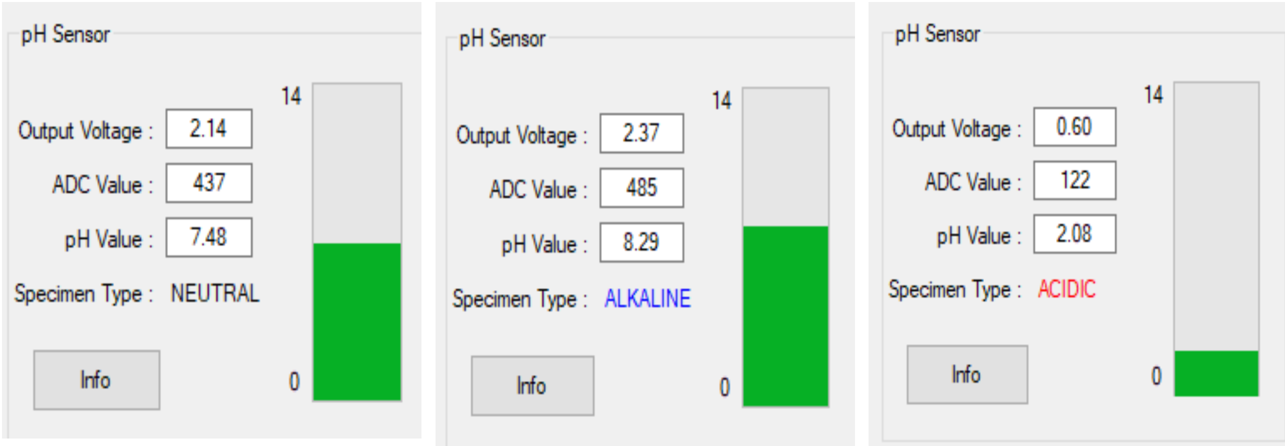
For the water level sensor, five menus were provided as shown in Figure 9: the sensor's output voltage, the corresponding ADC value, and the actual water level value. The vertical progress bar was also used to represent the water level interactively and the info button was provided to help the users know how to connect the sensor to the Arduino board.



(a) (b) (c)

Fig. 9. Water level sensor menu on the monitoring system (a) no water (b) water level at 2 cm (c) water level at 3 cm

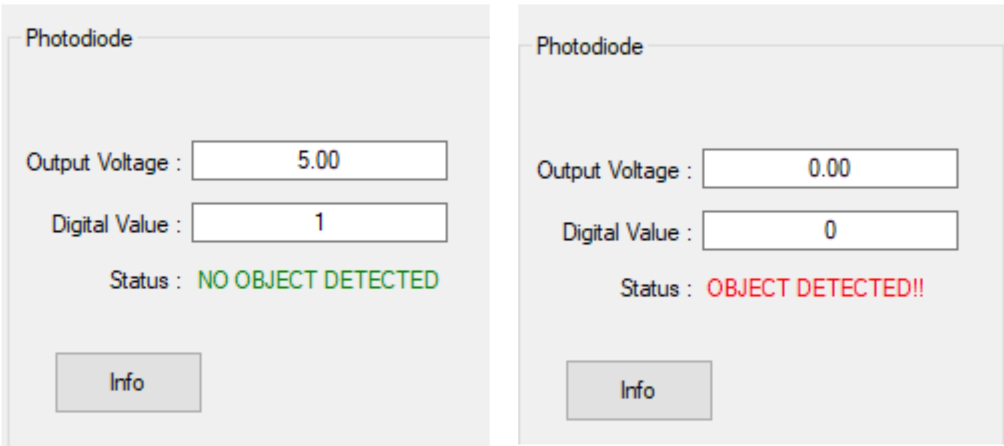
For the pH sensor, six menus were available to be monitored: output voltage, ADC value, the actual pH value, and the status of the measured specimen, either acidic, neutral, or alkaline, as depicted in Figure 10. The vertical progress bar showed the pH value interactively, and the info button was also provided to guide the user on the connection between the pH sensor and the Arduino board.



(a) (b) (c)

Fig. 10. pH sensor menu on the monitoring system for (a) water (b) aqueous solution of sodium bicarbonate (c) vinegar

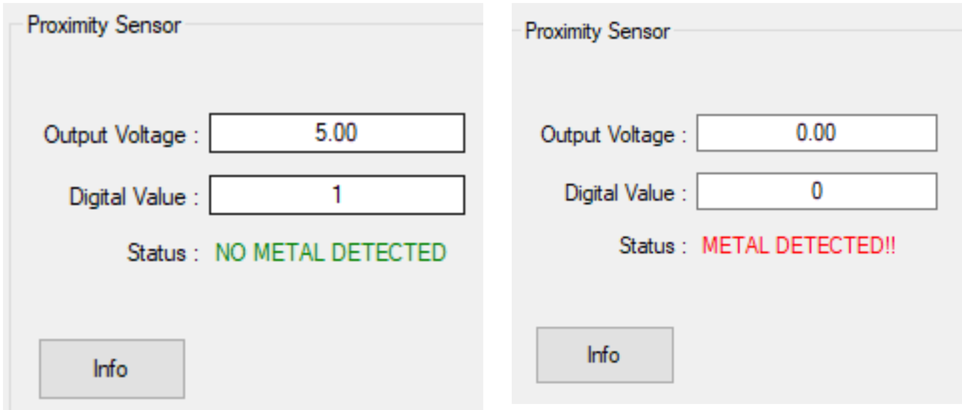
IR sensor module is a digital sensor that only produces either 1 or 0 to indicate whether the object is detected or not. It consists of IR LED to transmit IR light to the object, and reflect light from the object captured by the photodiode. The monitoring menu for the sensor is only four, which are digital values retrieved from the sensor, the corresponding output voltage, the status of whether the sensor detects an object or not, and the info button to show the connection between the IR sensor and the Arduino board as depicted in Figure 11.



(a) (b)

Fig. 11. IR sensor menu on the monitoring system

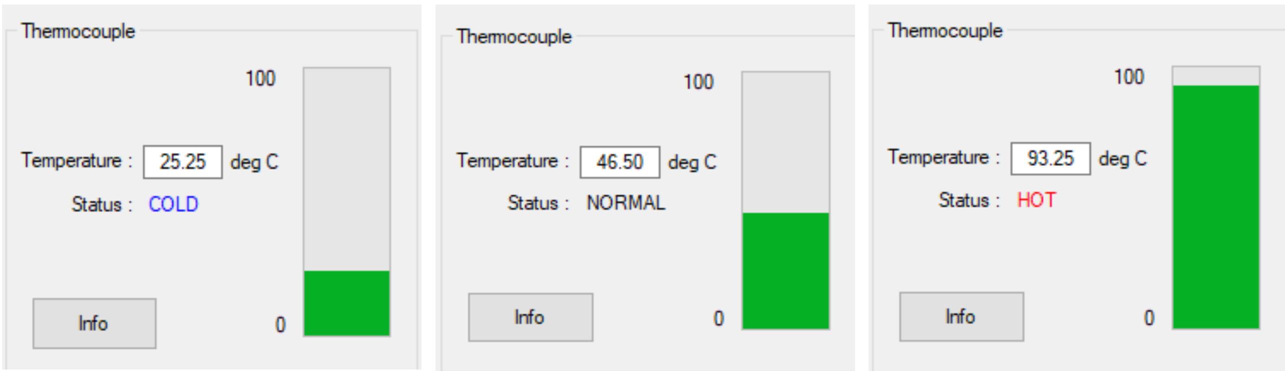
Similar to the IR sensor, the proximity sensor is also a digital sensor, thus the information that can be retrieved from the sensor is either bit 1 or 0. From the data, the corresponding output voltage can also be displayed, and the status of metal detection can be obtained as in Figure 12. The info menu is also provided to display the connection of the sensor.



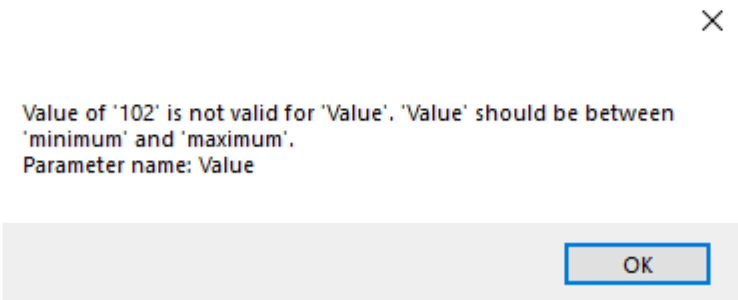
(a) (b)

Fig. 12. Proximity sensor menu on the monitoring system

The temperature value measured from the thermocouple is displayed in text and using the progressive bar as shown in Figure 13. The status menu is added to show that from the measured value, the monitoring system can be used to identify the temperature status, whether cold, normal, or hot. Similarly, the info button guides the user connection between the thermocouple and the Arduino board.



(a) (b) (c)



(d)

Fig. 13. Thermocouple menu on the monitoring system at different conditions (a) cold (b) normal (c) hot (d) greater than 100°C

2.3.3 Create a setup file

The developed monitoring system was tested a few times to make sure all the menus correctly displayed the data sent from the Arduino board by comparing the values shown in the GUI and the monitoring windows on Arduino IDE software before the setup file was created. The setup file could be used to install and run the monitoring system on another computer even if the computer was not installed with the Visual Studio software.

3. Results

This section presents how to use the proposed tool, what happens to each menu when the collected data from the sensors change, and how the user interacts with the menu.

3.1 Serial Communication

For setup serial communication between the Arduino board and the monitoring system application, the COM PORT menu shows all the available ports on the computer as shown in Figure 8. The user needs to choose the correct port from the list. Then, the user also needs to choose the correct baud rate, which is the same rate as in the programming of serial communication on the Arduino board. After choosing the correct port and baud rate, the user presses the connect button to set up the communication. Once the connection is established, the status changes to CONNECTED. To disconnect the communication, the user simply presses the Disconnect button.

3.2 Monitoring Menu

The proposed tool was tested for each sensor to validate the data displayed on the monitoring system. First, the water level sensor was tested by soaking the sensor in a cup of water. Before soaking, the initial value displayed on the monitor was zero, which is correct as shown in Figure 9(a). Then, the sensor slowly dipped into water, and the correct reading was displayed on the monitor as in Figures 9(b) and (c). The corresponding output voltage and ADC value were also correctly displayed following Eq. (1). The water level value was set as an integer to be used in programming the vertical progress bar, so no decimal point was displayed, and the water level increased for every 1 cm. Although the resolution was high, the most important thing to focus on was the change in water level. If the user presses the Info button, Figure 2 will be popped up so the students know how to connect the sensor to the Arduino board.

From Figure 2, it can be seen clearly that the water level sensor used consists of ten lines of bare conducting wires, five power traces, and five sense traces. These traces are interlaced in parallel. These traces are not connected, in other words, it has high resistance and low in terms of conductivity, which does not allow any current to flow from the power trace to the sense trace. When the sensor is dipped into water, the water becomes a bridge between the power and the sense trace, thus reducing the resistivity and increasing conductivity. The higher the water level, the higher the conductivity of the sensor and produce higher voltage.

To test the pH sensor, the sensor was exposed to water with a known range of pH value of around 7, an aqueous solution of Sodium Bicarbonate with a pH of around 8, and vinegar with a pH of around 2. Before getting readings from different specimens, the sensor was washed with water to remove the previous specimen on the sensor. The readings shown on the monitor as in Figure 10 were validated with the data from the internet. When the user presses the Info button, Figure 6 will be shown.

From Figure 6, the pH electrode is composed of two different tubes, a reference, and a measurement tube. Both tubes are filled with a neutral solution, potassium chloride. Inside the tubes are silver/silver chloride (Ag/AgCl) wires. The measurement tube is made of a sensitive glass membrane, with the end of the tube in bulb shape. The bulb glass can be seen clearly at the end of the electrode. Meanwhile, the reference tube is inside the casing. When the glass tube is exposed to the tested solution, Hydrogen ions (H^+) in the solution that is small size in nature can penetrate the membrane glass to be detected by the Ag/AgCl wire. Using Nernst in Eq. (4), the relationship between electrical voltage, U and H^+ concentration can be obtained, where U_0 is the initial voltage, R is the universal gas constant, T is absolute temperature, n is the number of electrons, and F is the Faraday constant.

$$U = U_0 + \frac{RT}{nF} \times \ln{(H^+)} \quad (4)$$

If the tested solution is neutral, the H^+ concentration in the reference and the measurement tubes are the same, thus producing the same electrical voltage, and the potential difference between the wires is zero. Meanwhile, for an acidic solution, the concentration of H^+ is higher, thus producing higher electrical voltage and positive potential difference. In contrast, the alkaline solution has less H^+ and produces low voltage and negative potential difference. The pull-up resistor is used to change the range of voltage produced by the sensor. The pH value can be calculated from Eq. (3).

For the IR sensor, the photodiode is connected in reverse bias, where the p-type material is connected to the negative terminal and the n-type material is connected to the positive terminal power supply. This connection produces a high potential barrier that prevents the flow of current inside the photodiode. Thus, no current flows during no or low intensity of light. When the photon from light strikes the photodiode, the electron-hole pairs are generated, known as the inner photoelectric effect. These carriers are swept from the p-n junction by the built-in electric field of the depletion region. Thus, the holes move towards the anode side and the electrons move towards the cathode side. The movement of carriers produces a photocurrent.

To validate the theoretical concept of the photodiode, a simple experiment was done to expose the IR sensor to any object, both metal and non-metal. The sensor can detect all objects except black objects. For a black object, all lights were absorbed by the object, and the photodiode received no reflected light. Thus, the sensor cannot produce a photocurrent to indicate that the object was detected. For other objects that can reflect the light, the reflected light strikes the photodiode to produce current. From the experiment, the digital value, the corresponding output voltage, and the detection status were displayed correctly as shown in Figure 11. The Info button is used to display Figure 4.

The proximity sensor was used to detect metal. Similar to the IR sensor, only two values were generated by the sensor, either 1 or 0, and the corresponding voltage was either 5V or 0V. It uses the concept of Eddy current. When the proximity sensor is connected to the power supply, the inductor inside it turns to be a magnet, which has a magnetic field. When the magnetic field is passing through a surface, it creates a flux. When there is no movement, the flux is not changing, consequently, no current is induced. However, when there is movement, either close to far from the metal object, the change of flux induced the Eddy current on the surface of the metal due to Lenz's Law. The Eddy current can be induced on non-metal objects. The status of whether the metal was detected or not was validated correctly with a simple experiment by closing the metal or non-metal to the sensor. If the non-metal object was close to the sensor, it gave a value of 1, and 0 when metal was detected. The results obtained were shown in Figure 12. Similarly, the Info button is used to display the circuit connection as shown in Figure 3.

Thermocouples consist of two dissimilar metals, joined together at one end. Using the Seebeck Effect, a conductor generates a voltage when subjected to a temperature gradient. For two different metals with differences in their thermal conductivities, the speed of electrons move varies with different metals at the same temperature. Thus, the voltage is generated between two junctions.

The higher the temperature difference, the higher the voltage. The thermocouple monitoring menu showed the detected temperature value and displayed the hot status for temperatures greater than 50°C, cold if the temperature was lower than 30°C and normal for others. The displayed temperature was validated for cold conditions by comparing it with the air conditioning value. Meanwhile, the sensor was exposed to a heat source, i.e., a lighter, to get normal and hot conditions, and the results were shown in Figure 13. Although the thermocouple can measure higher than 1000°C, for safety reasons, the vertical progress bar set the limit up to 100°C only. Over the limit, the error message popped up as in Figure 13(d). The Info button is used to show Figure 5.

3.3 Overall System Performance

Once the setup file was created, it was tested by installing the file on a computer that did not have the Visual Studio software, and the file was successfully installed. The overall monitoring system of the GUI can be seen in Figure 14.

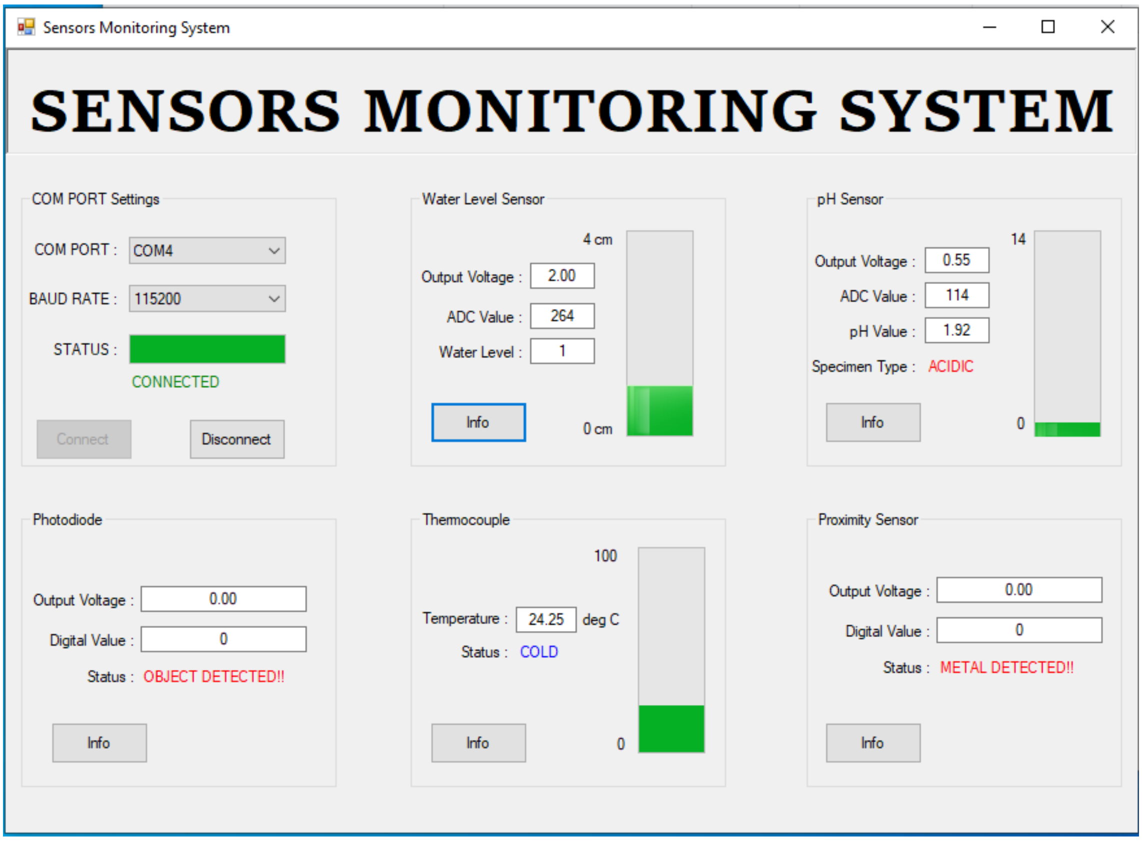


Fig. 14. The overall sensor monitoring system

3.4 Students' Feedbacks

In early 2022, Malaysia was shifting from the pandemic to the endemic phase of COVID-19. Thus, the lecture started with an online class for three weeks before shifting to a hybrid and slowly to a fully physical class. During the online class, the lecturer shared the tool by demonstrating how the sensor was exposed to the measurand using the DroidCam application and at the same time shared the screen with students so they could see both the circuits and the monitoring system as in Figure 15. The same way was used during the hybrid, but the students in the class had the advantage of seeing the demonstration live. Since the tool can be installed on any computer, when the class started physically, the students had the chance to conduct the experiment and see the changes directly on the monitoring system using a computer provided in the lecture hall. However, since the students attended the class physically towards the end of the semester, they had no chance to buy Arduino and sensors and install the software on their laptops.

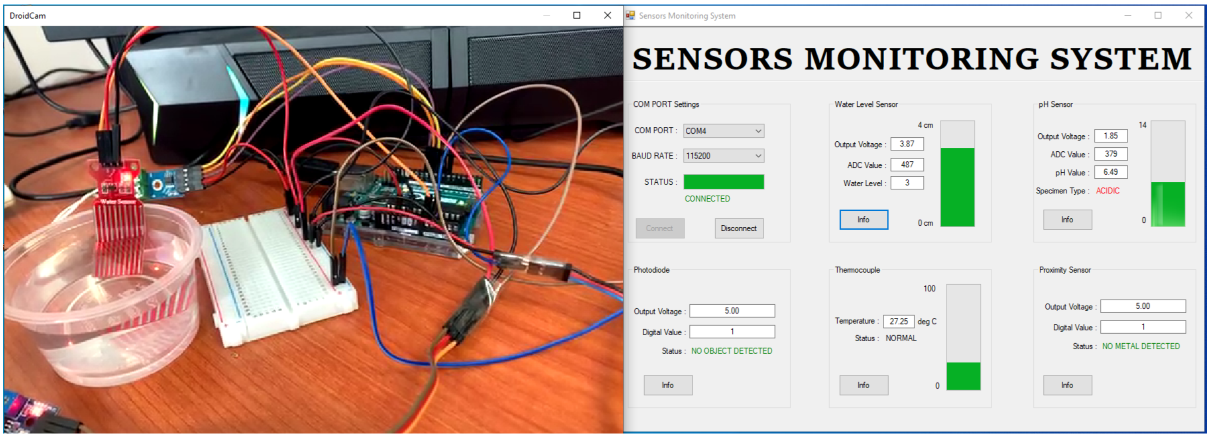
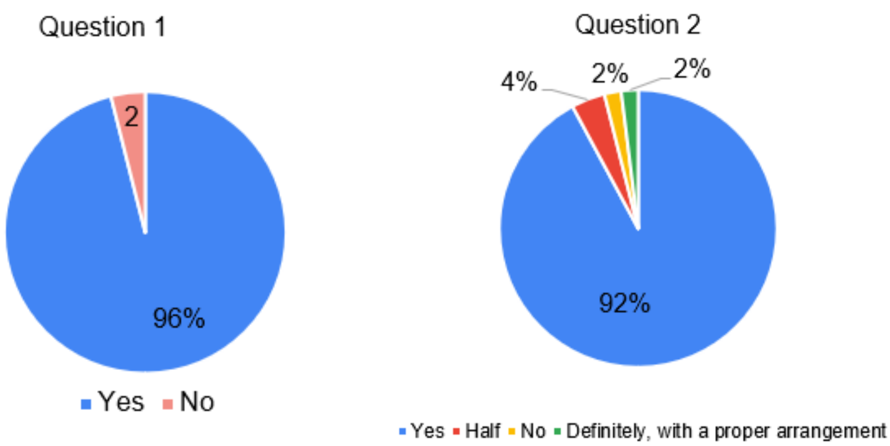


Fig. 15. Demonstrating the proposed tool to students

At the end of the semester, students were given a feedback form to see their opinions on the proposed tool. The feedback can be seen in Figure 16. For Question 1, students were asked if they agree to have a better understanding if the actual sensor shown to them after learning the sensing mechanism. From the feedback, 96% of students agreed to understand better the concepts taught in the class after experiencing the simple experiment. For Question 2, students were asked if they agree to have a better understanding if they are allowed to develop the system shown in the class. A total of 92% agreed to understand better if they had a chance to develop the circuit by themselves.



(a) (b)

Fig. 16. Feedback from students for (a) Question 1 (b) Question 2

Some comments from students were also collected from the feedback as follows:

i. I like that lecturer demonstrated the actual sensor.
ii. Having a demo and doing it together with students
iii. Very fun and learned
iv. Having a demo about the circuit in real
v. Interested in developing the system with a proper arrangement

3.4 Students' Performance

Students' performance was measured based on the final exam questions. The students were asked to select three of five types of sensors to explain their sensing mechanism in an essay form. From the five questions, two questions were related to the sensors used in the interactive tool, which are the IR sensor consisting of the photodiode in question 4 (Q4) and the proximity sensor that used the converting principle of Eddy Current in question 3 (Q3). Meanwhile, three other questions were not used in the proposed interactive tools, which are Question 1 (Q1) – Potentiometer, Question 2 (Q2) – Resistance Temperature Detector (RTD), and Question 5 (Q5) – Fuel cell. The average marks for each question were analysed.

From the average marks obtained for each question in Figure 17, it can be seen that the highest average mark was Q4 followed by Q3, Q2, Q5, and lastly Q1. Both sensors used in the tools had high average marks, indicating that the proposed tool increased the understanding level of students on the theoretical parts of the sensors. Students can better explain for Q4 and Q3 than questions about sensors that are not included in the proposed system.

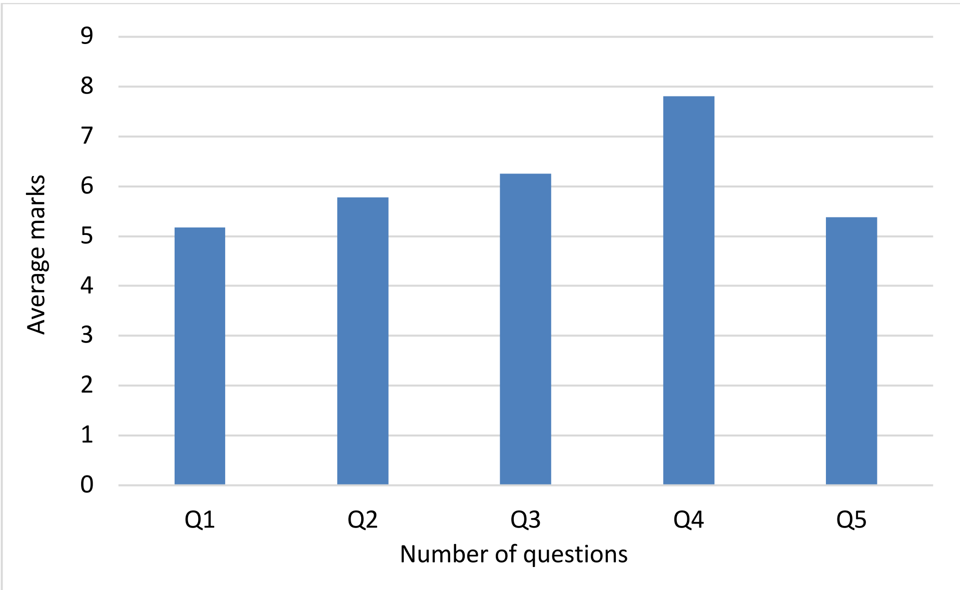


Fig. 17. Average marks for each question

4. Conclusions

The interactive tool to learn the Sensor and Transducer subject was proposed to enhance the understanding of kinaesthetic domain learners. It can be proven from the students' average marks in the final exam. The proposed tool is not only successfully worked, but also can be used as an additional teaching aid via online, hybrid, or physical classes. The positive feedback from students and students' performance also points to a positive trend, in which students participate more in the class and gain a better understanding. For future extend, the tool can also be connected to all types of sensors taught in the class. The GUI concept can also be applied to other subjects such as mathematics and physics to be more interesting to learn.

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References

[1] Patranabi, D. *Sensors and Tranducers*. PHI Learning Pvt. Ltd., 2003.

[2] Sinclair, Ian. *Sensors and transducers*. Elsevier, 2000.

[3] Jurgen, Ronald K. *Sensors and transducers*. No. PT-105. SAE Technical Paper, 2003.

[4] Othman, Norasmah, and Mohd Hasril Amiruddin. "Different perspectives of learning styles from VARK model." *Procedia-Social and Behavioral Sciences* 7 (2010): 652-660. https://doi.org/10.1016/j.sbspro.2010.10.088

[5] Shahzadi, Erum, and Zahoor Ahmad. "A study on academic performance of university students." *Recent Advances in Statistics* 255 (2011): 67.

[6] Kolb, D. A., A. Y. Kolb, and D. A. Kolb. "Research on Validity and Educational Applications." *Experience Based Learning Systems* 5 (2013): 0-233.

[7] Honey, P., and A. Mumford. "The Learning Styles Questionnaire: 40 Item Version Peter Honey Publications Ltd." *Maidenhead, Berkshire, UK* (2006).

[8] Córdova, Felisa M., M. Hernán Díaz, Fernando Cifuentes, Lucio Cañete, and Fredi Palominos. "Identifying problem solving strategies for learning styles in engineering students subjected to intelligence test and EEG monitoring." *Procedia Computer Science* 55 (2015): 18-27. https://doi.org/10.1016/j.procs.2015.07.003

[9] Al Hamdani, Dawood. "Exploring students' learning style at a Gulf University: a contributing factor to effective instruction." *Procedia-Social and Behavioral Sciences* 176 (2015): 124-128. https://doi.org/10.1016/j.sbspro.2015.01.452

[10] McKenna, Lisa, Beverley Copnell, Ashleigh E. Butler, and Rosalind Lau. "Learning style preferences of Australian accelerated postgraduate pre-registration nursing students: A cross-sectional survey." *Nurse education in practice* 28 (2018): 280-284. https://doi.org/10.1016/j.nepr.2017.10.011

[11] Patterson, Darrell A. "Impact of a multimedia laboratory manual: Investigating the influence of student learning styles on laboratory preparation and performance over one semester." *Education for chemical engineers* 6, no. 1 (2011): e10-e30. https://doi.org/10.1016/j.ece.2010.10.001

[12] Wan Muda, Wan Mariam. "International Conference on Teaching and Learning in Higher Education (ICTLHE) Proceedings," in *A Simple Innovation for Teaching and Learning Engineering Subject in Gen Z Era*, 2017, pp. 55–65.

[13] Martins, J., and A. Vianna. "Teaching general concepts about sensors and transfer functions with a voltage divider." *Latinoamerican Journal of Physics Education* 5, no. 4 (2011): 656-666.

[14] Akil, M. "A feasibility study of sensor and transducer trainers as a learning media towards electronics engineering's students." In *Journal of Physics: Conference Series*, vol. 1810, no. 1, p. 012051. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1810/1/012051

[15] Basri, Irma Yulia, Dony Novaliendry, and Intan Maisa Tania. "Design and Development of Inductive Sensor Mini Trainer Based on Arduino." *Jurnal Teknologi Informasi dan Pendidikan* 15, no. 1 (2022): 38-49. https://doi.org/10.24036/jtip.v15i1.561

[16] Sankaran, Sakthivel, M. Pallikonda Rajasekaran, and C. Sivapragasam. "Project-based Learning-A Novel Approach to Teach Biosensors and Transducers Course for Engineering Students." *Journal of Engineering Education Transformations* 34, no. 1 (2020). https://doi.org/10.16920/jeet/2020/v34i1/151945

[17] Wang, Yanru, Shuqin Zheng, Maoyu Zhang, and Bo Li. "Mode Reform of Sensor Courses Teaching in Civil Engineering Based on CDIO Education Concept." *Sensors & Transducers* 173, no. 6 (2014): 297.

[18] Tiernan, Peter. "Enhancing the learning experience of undergraduate technology students with LabVIEW™ software." *Computers & Education* 55, no. 4 (2010): 1579-1588. https://doi.org/10.1016/j.compedu.2010.07.001

[19] Branzila, Marius, Constantin Sarmasanu, Denisa Ciudin, and Diana Lacatusu. "Sensors and transducers laboratory kiosk." In *2018 International Conference and Exposition on Electrical And Power Engineering (EPE)*, pp. 0377-0380. IEEE, 2018. https://doi.org/10.1109/ICEPE.2018.8559812

[20] Trudgen, Mark, and Dominik May. "BYOE: Fabrication, Implementation, and Design of a Remote Lab Setup for a Sensors and Transducers Course." In *2021 ASEE Virtual Annual Conference Content Access*. 2021.

[21] Hariyanto, D., T. Triasih, M. S. Wati, and G. K. Kassymova. "The Design of Sensor and Transducer Learning Media based on Augmented Reality." In *Journal of Physics: Conference Series*, vol. 2111, no. 1, p. 012043. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/2111/1/012043

[22] Organtini, Giovanni. "Arduino as a tool for physics experiments." In *Journal of Physics: Conference Series*, vol. 1076, no. 1, p. 012026. IOP Publishing, 2018. https://doi.org/10.1088/1742-6596/1076/1/012026

[23] Suwondo, Nanang, Hassan K. Juwhari, and Dwi Sulisworo. "Simple Multitasking Sensors-Actuators-Transducers Based on Arduino." (2020).

[24] Ab Wahab, Nurul Ain, and Mohd Agos Salim Nasir. "Graphical User Interface for Solving Non-Linear Equations for Undergraduate Students." *International Journal of Advanced Research in Future Ready Learning and Education* 30, no. 1 (2023): 25-34.

[25] Adam, Asrul, Liew York Leong, Amar Faiz Zainal Abidin, Kamaru Adzha Kadiran, Rozi Rifin, and Saipol Hadi Hasim. "Development of traffic light control system for educational purpose using Motorola 68HC11 microcontroller." *Journal of Advanced Research in Applied Mechanics* 34, no. 1 (2017): 1-9.

[26] Hatmojo, Y. I., and S. M. Azis. "Development Mobile Application Android Based for Sensor and Transducer." In *Journal of Physics: Conference Series*, vol. 2111, no. 1, p. 012010. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/2111/1/012010

[27] Hendeby, Gustaf, Fredrik Gustafsson, and Niklas Wahlström. "Teaching sensor fusion and Kalman filtering using a smartphone." *IFAC Proceedings Volumes* 47, no. 3 (2014): 10586-10591. https://doi.org/10.3182/20140824-6-ZA-1003.00967