Development of IoT-Based Heatstroke Early Symptoms Monitoring System for Students in Malaysia

Nabilah A Rahim[1], Nurmiza Othman[1]*

[1] *Faculty of Electrical and Electronic Engineering*
    Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author: nurmiza@uthm.edu.my
DOI: https://doi.org/10.30880/eeee.2024.05.01.012

Abstract

As climate change intensifies, the risk of heat-related illnesses becomes a growing concern, especially for vulnerable populations like young adults. This system aims to proactively address this issue by providing real-time monitoring of early symptoms associated with heatstroke. The system employs a portable device integrated with physiological sensors to detect crucial indicators such as student body temperature, heart rate, and blood oxygen level. Through a user-friendly interface, administrators can access real-time data. The result shows the students' identification alongside the measurement taken from the sensor. The collected data is processed through a sophisticated algorithm that analyzes patterns indicative of heatstroke risk. The data taken from the prototype is being compared to the conventional measurement data and the result is shown in a line graph shown in the result and discussion part. Using the data that has been collected, the data can be transferred to the authorities such as KKM to analyze further about the student's health condition.

1. Introduction

Climate change has made heat-related ailments, such as heatstroke, a global health concern. Indeed, humans are facing a growing risk of heat-related health issues due to the escalating temperatures and the heightened frequency and severity of heatwaves. This trend is not exempting students, who are also vulnerable to heatstroke cases. As temperatures rise, particularly during heatwaves, students engaging in outdoor activities or spending extended periods outdoors are at increased risk of heatstroke. When the body's mechanism for regulating temperature is unable to keep the body at a normal temperature, heatstroke, a dangerous medical condition, results. Heatstroke is a medical emergency that must be treated right away. Treatment that is delayed may result in major side effects, including harm to key organs like the kidneys, heart, and brain. Symptoms such as muscle cramps and cold, clammy skin may occur, and extreme cases can lead to organ failure, including kidney failure, and even death [1].

The problem statement highlights the challenges faced by students in Malaysia, who attend school for about 6 hours a day and are exposed to hot weather conditions in April and June. Education institute in Malaysia do not provide continuous monitoring devices to keep track of students' condition, and most students do not keep track of their liquid intake. Teachers and friends may not recognize the early symptoms of heatstroke, leading to delayed medical assistance.

Two research studies investigate the correlation between heatstroke and students engaging in outdoor activities. The first, conducted with Guangzhou University students, surveyed 1100 participants involved in activities like marching. Findings showwed 4.2% experiencing syncope due to heat, with most feeling

uncomfortable. Only 20.62% remained symptom-free, suggesting precautions against heat-related illnesses in hot outdoor environments [2]. The second study, led by Oita University's Health Support Centre, found 2.8% of university students experienced heatstroke, with gender differences noted. The research highlights that heatstroke cases are not confined solely to club activities; they also occur during students' daily routines, with home being the second most common location for such incidents. These findings underscore the importance of addressing heatstroke risk factors beyond organized activities [3].

The objective of the development of IoT-based heatstroke early symptoms monitoring system for students in Malaysia is to develop a comprehensive and effective solution for detecting and monitoring early signs of heatstroke among students. This includes the utilization of multiple sensors, such as the MAX30100 and MLX90614, to monitor vital signs including heart rate, blood oxygen level, and body temperature. The system aims to provide real-time monitoring and data recording through a web application, enabling remote access to recorded data for timely intervention. Additionally, the incorporation of RFID technology for user identification and authentication enhances the accuracy and efficiency of data collection.

To address these challenges, the system offers a monitoring device tailored for students in Malaysia to detect early signs of heatstroke. Existing market devices like smartwatches and thermal imaging CCTV are either costly or not designed for this age group [4]. The suggested system integrates multiple sensors and RFID technology to ensure accurate and efficient data collection, along with user identification.

The intended system seeks to improve education institute healthcare by enhancing efficiency and monitoring early signs of heatstroke in students. It specifically targets the lack of dedicated monitoring devices for students, who are especially susceptible to heatstroke due to prolonged exposure to hot weather. The system utilizes various sensors, RFID technology, and real-time monitoring, with remotely accessible recorded data through a web application. This innovative approach positions the system as a promising solution for preventing heat-related illnesses among students in Malaysia.

2. Materials and Methods

Early symptoms of heatstroke can be detected using three parameters: body temperature, heart rate, and blood oxygen saturation levels. Common medical instruments like a thermometer and a Pulse Oximeter can be employed to measure these parameters. Heatstroke may be identified if the body temperature surpasses 37.2 degrees Celsius, the heart rate is 34% higher than normal, and the blood oxygen saturation level falls below 92%.

2.1 Parameter Needed on Heatstroke Detection

2.1.1 Body Temperature

Body temperature is the first parameter that needs to be measured, as the name would imply, to determine whether someone is experiencing the signs of heatstroke. This is due to the elevated danger of heatstroke when a person's body temperature exceeds 40 degrees Celsius. A thermometer can be used to determine the human body's temperature. The normal range for a person's body temperature is between 36.5 and 37.2 degrees Celsius [5].

There are a lot of sensors that can be used to measure human body temperature. Table 1 shows the comparison between available sensors used to measure temperature.

Table 1 *Comparison between available temperature sensor in market*

	LM35	DS18B20	MAX30205	MLX90614
Measured Range	10°C to 150°C	55°C to +125°C	37°C to 39°C	-70°C to +380°C for object temperature
Accuracy	0.5°C ensured accuracy (at 25°C)	±0.5°C accuracy from 10°C to +85°C	0.1°C	0.5°C
Supply Voltage	2.7V to 5.5V DC	3.0 to 5.0 VDC	2.7 to 3.0 VDC	3.0 to 5.0 VDC
Communication Protocol	Basic principle of a diode. Temperature increases alongside with voltage.	Maxim's exclusive 1-Wire bus protocol	I2C protocol	Standard IIC (I2C)

Temperature Resolution	10mV/°C	User-configurable to 9, 10, 11, or 12 bits. Corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively.	16-Bit (0.00390625°C)	0.02°C
Size	2 cm x 1 cm x 1 cm	13 cm x 5 cm x 12 cm	14 x 21 mm	11.5 x 16.5 mm
Physical Contact	Yes	Yes	Yes	No
Application Example	· Thermal protection · Industrial process control · Fire alarms · Power system monitor · CPU thermal management	· Measure liquid temperature · Thermostat controls system · Heating, Ventilation, Air Conditioning (HVAC) systems	· Accurately measures temperature and provide an overtemperature alarm/ interrupt/shutdown output	· Temperature control in printers and copiers · Home appliances with temperature control · Healthcare
Price	RM8.90	RM9.40	RM399.19	RM62.00

Based on Table 1, the most suitable sensor to use is MLX90614 because of its accuracy and it is also affordable compared to MAX30205. The temperature resolution provided by MLX90614 is also quite high, which means the accuracy is reliable [6].

2.1.2 Heart Rate

Heart rate is another sign of heatstroke because those who suffer from it have a higher heart rate than average. The usual range for human's resting heart rate is between 60 to 100 beats per minute(bpm) [7]. Each degree that the ambient temperature rises can cause an increase in heart rate up to 10 beats per minute. An increase in ambient temperature from 22 to 40 degrees Celsius, according to another study, can cause people to consume 35% more oxygen, breathe 35% faster, and have a 34% higher heart rate [8].

MAX30100 is a sensor that can be used to measure heart rate. MAX30100 has a pair of high-intensity LEDs, RED LED and IR LED and both have different wavelengths and a photodetector. RED LED wavelength is 660nm and IR LED has 880nm wavelength. In heart rate reading, RED LED is inactive and only IR LED is used to capture the optical data and determine the heart rate. Mostly, the measured body part is the ear or finger where the skin is not too thick so that both lights can easily penetrate the tissue. Blood is pumped through body parts with each heartbeat thus changing the amount of reflected light and the output waveform. Heart rate reading can be obtained while the photodetector senses the light.

2.1.3 Blood Oxygen Saturation Level

Blood oxygen saturation levels can potentially serve as a warning sign for heatstroke. This is because the human body exerts more effort to provide the brain with oxygen when a heatstroke occurs. The brain's lack of oxygen may lead to fainting [9]. Individuals' normal blood oxygen levels range from 95% to higher [10]. It is recommended that a person take some rest if their oxygen value is below normal.

Human blood oxygen saturation content can be measured using the MAX30100 or MAX30102 sensor. This sensor measured the oxygenated and deoxygenated haemoglobin in the human body system. IR sensor and light-emitting diode are both components of the MAX30100 sensor. Upon inhalation, oxygen traverses to the lungs before entering the bloodstream. A tiny light beam will travel through the finger and be used to determine if the blood is oxygenated or not.

The oxygenated blood is measured by observing the amount of RED and IR light absorbed by human blood. Deoxygenated blood absorbs more RED light meanwhile oxygenated blood absorbs more IR light. The inbuilt pulse sensor on the MAX30100 sensor can be utilized in conjunction with the blood oxygen reading. The MAX30100 will be utilized to monitor the user's pulse and blood oxygen readings.

2.2 Flowchart

The student needs to be registered first in the database before taking any measurement. The registration is done by using an RFID card. There are two sensors that will be used in this work that is MAX30100 and MLX90614. MAX30100 will record students' heart rate and blood oxygen level when the index finger of the student is being placed on the sensor. MLX90614 will record the body temperature of the student. The overall data of the student can be monitored using a website application that has been made. Fig. 1 shows the flowchart of the system operation.
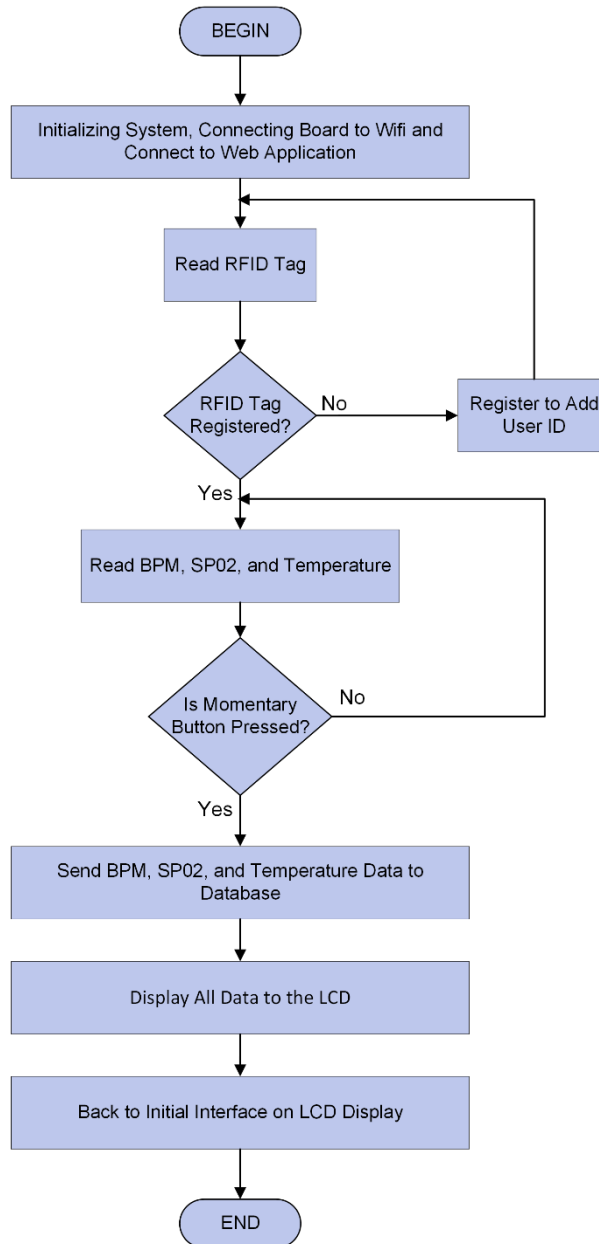
Fig. 1 *Flowchart of the work*

2.3 Block Diagram

This work is divided into three major components: input, process, and output. Fig. 2 shows the block diagram of the system. In this system, input signal from the sensors and the RFID scanner will be sent to the ESP32 board. If the scanned ID is registered, the user needs to stand in front of the sensor for 10 seconds before pressing the momentary button to send the processed data to database. If the scanned ID is not registered, the admin needs to register the card user first then the reading of the user will be taken. The database reading can be monitored by the school admin and people who have access to the web application.
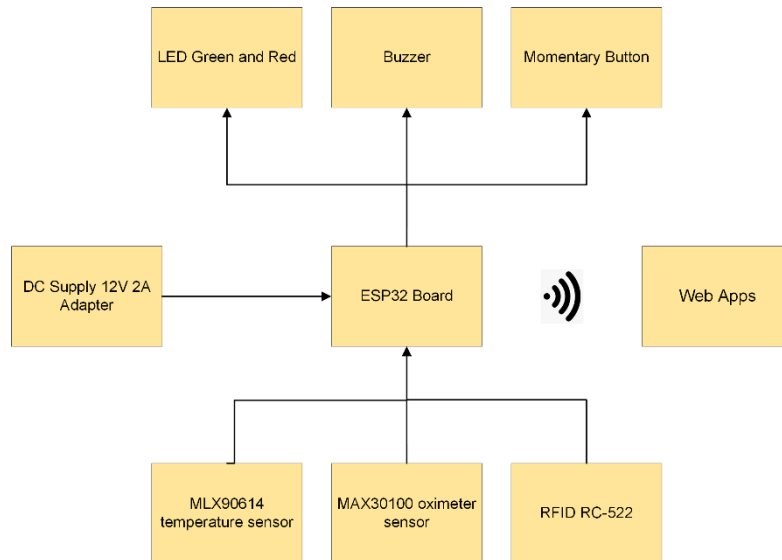
Fig. 2 *System Block Diagram*

2.4 Hardware

The system utilizes the ESP32 microcontroller, which will play a pivotal role in user identification by checking whether the user's ID is already registered in the database. In cases where the user is registered, the ESP32 board will retrieve data from the MAX30100 and MLX90614 sensors and transmit the gathered information to the database through a Wi-Fi connection [11]. On the other hand, if the user is not yet registered, the administrator must register the user before any measurements can be taken. The ESP32 board will function as the central hub for receiving and transmitting data. The connection between the ESP32 board and other components is illustrated in Fig. 3. The LCD display will provide instructions for actions such as touching the identification card or taking measurements.
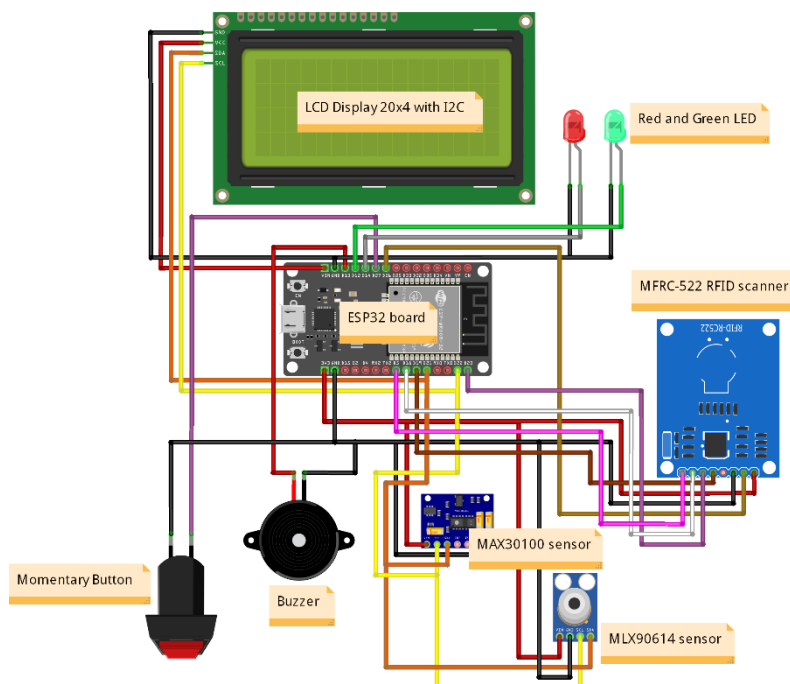

Fig. 3 *Full circuit diagram*

2.5 Software

Two software components are integral to this work; MySQL for database management and the XAMPP application for locally testing the website before its deployment. The MySQL database is designed to store crucial information such as students' names, unique identification for sensor readings, heart rate, blood oxygen level data from MAX30100, and body temperature data from MLX90614.

For monitoring and accessing the stored data, a website application has been developed using PHP files. This application facilitates the transfer of data from MySQL to the website, enabling users to view it on both laptops and mobile phones. The admin utilizes the website application to register students. Anyone with access can use the application to analyze the health data collected from students, determining their well-being. Fig. 4 illustrates the interface for the MySQL database, while Fig. 5 showcases the interface for the created website application.
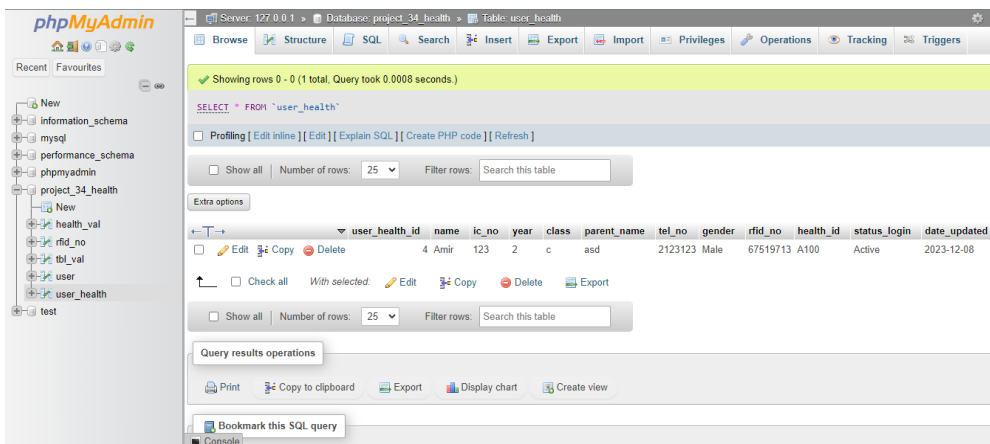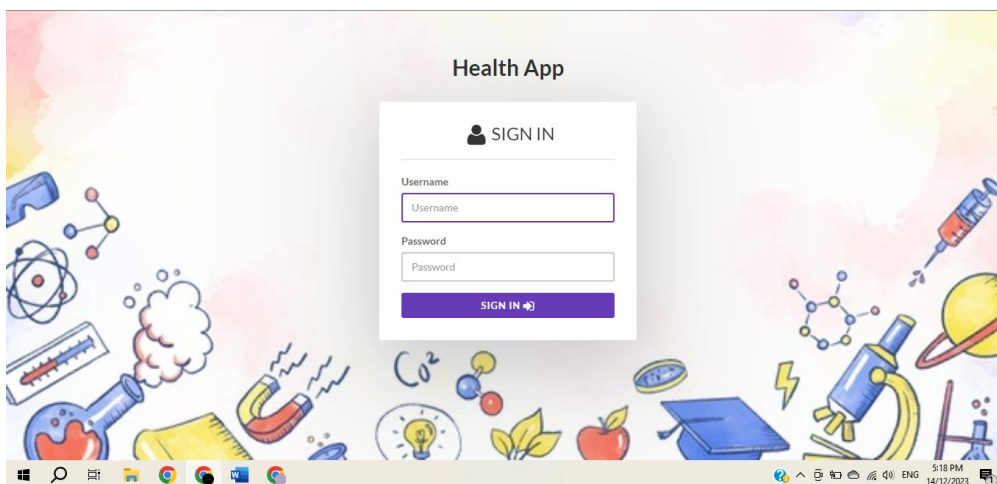

Fig. 4 *MySQL database interface*

Fig. 5 *Website application login interface*

3. Results and Discussion

The research findings are derived from an in-depth exploration of the functioning of sensors employed in the system. The initial segment will delve into the methodology of how the system identifies an RFID card and assesses its registration status. Additionally, the capture and display of data from the sensors on the 20x4 LCD display will be thoroughly examined.

The subsequent section will focus on the database and website components, where comprehensive data recording and analysis take place. The administrator can monitor early symptoms of heatstroke through the website application, enhancing the system's capability to provide crucial insights into the health status of individuals.

3.1 Hardware Development

The system will start up and ask the user to touch the RFID card to the reader. Fig. 6 shows the initial display of the LCD when the system is started up. If the user has been registered in the system, the LCD Display will say the user has been registered and display the text for the user measurement part. If the user is not registered, the LCD Display will say the user is not registered and will ask for the admin to register the user in the website application. Fig. 7 will display the LCD interface, distinguishing between registered users and unregistered users.
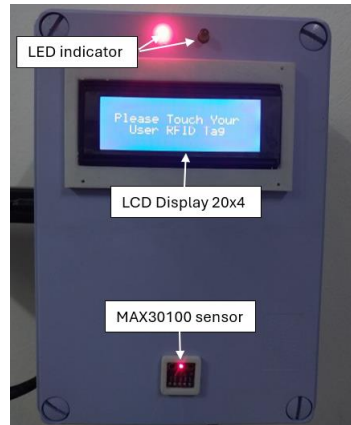
Fig. 6 *Initial LCD Display*

(a)   **(b)**

Fig. 7 *LCD Display for user status (a) Registered user (b) Unregistered User*

If the user is registered, the system will ask the user to place their hand to designated areas in the hardware prototype. To obtain temperature readings, users are required to position their forehead in proximity to the MLX90614 sensor. For heart rate and blood oxygen level readings, users must place their fingertip on the MAX30100 sensor. To ensure accurate readings, users are advised to stand still for approximately 10 seconds, allowing the sensors adequate time to calibrate before obtaining measurements. Fig. 8 shows the hand and forehead placement for the user for taking measurements.
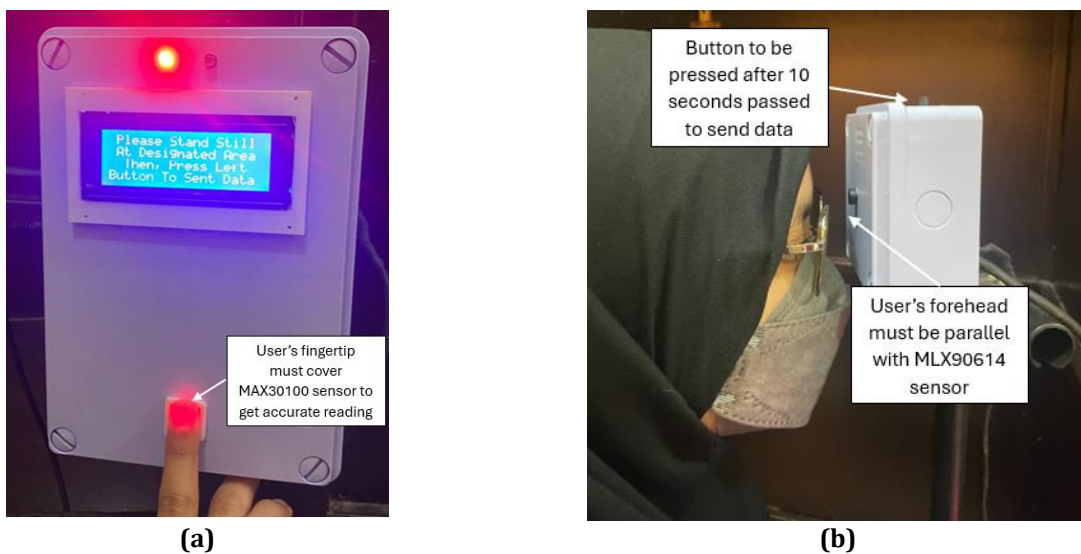

(a)   **(b)**

Fig. 8 *User's hand and forehead placement at the sensor*

3.2 Software Development

Fig. 9 shows the website interface of the administrator. On the left-hand site, there are two tabs that are dashboard and users. Website applications show the interface when to register a new user and the taken measurement of the user. To register a new user, the administrator needs to go to the user's tab and add a new user. Fig. 10 shows the interface to register a new user.
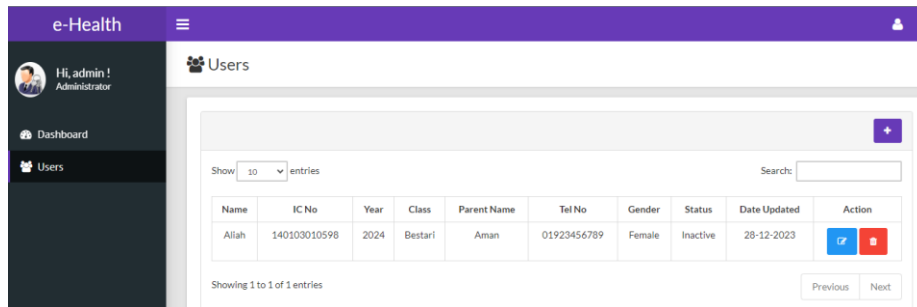

Fig. 9 *Website interface to view existing user*
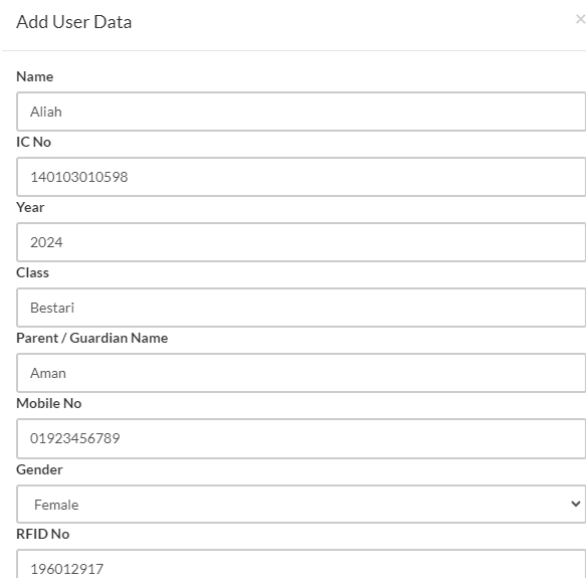

Fig. 10 *Interface to add new user on the database*

The administrator needs to go to dashboard tab to monitor the user condition. Fig. 11 shows the interface of the sensor data measurement taking on the registered user. The name and the sensor value will be displayed together.
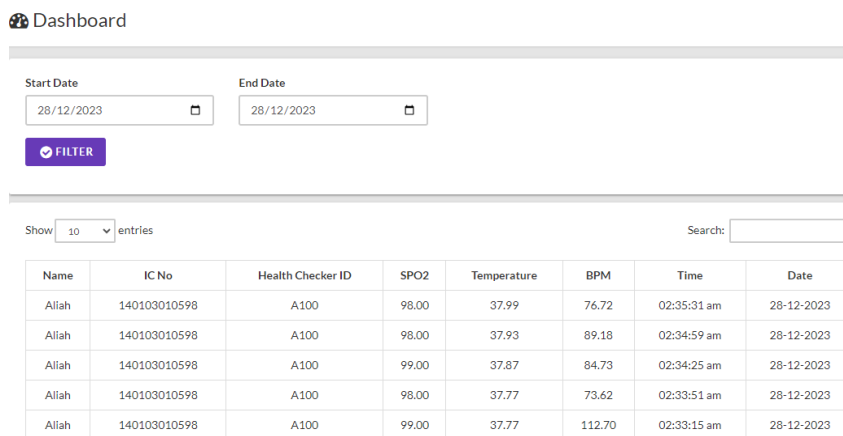

Fig. 11 *User measurement dashboard*

The system undergoes testing on five university students from UTHM to obtain varied readings and ensure its optimal functionality. The measurements are conducted while the individuals are in a resting state and within room temperature conditions. The testing protocol is designed to validate the system's performance under different physiological conditions and ascertain its reliability in a controlled environment.

The user is required to take measurements multiple times, specifically three times, to ensure the reliability of the data. Table 2 showcases the measurements collected from five students, with repeated readings taken at 5-minute intervals. This approach aims to enhance accuracy in comparison to data obtained from conventional instruments.

Table 2 *Compared measurements taken from prototype and conventional instruments.*

No	Gender	Age	Heart rate (bpm)		Blood Oxygen Saturation Level		Temperature (°C)	
			Prototype	Conventional	Prototype	Conventional	Prototype	Conventional
1.	Female	23	89.18	87.00	98	99	37.93	37.90
			76.72	77.00	98	100	37.99	37.80
			84.73	83.00	99	99	37.87	37.50
2.	Male	21	69.82	71.00	99	100	37.37	37.30
			96.59	94.00	99	99	37.63	37.50
			107.13	105.86	99	99	37.95	37.80
3.	Female	21	83.45	88.00	99	99	36.42	36.50
			77.30	79.00	100	99	36.64	37.20
			79.45	81.00	99	99	36.72	36.80
4.	Female	22	80.03	78.00	100	99	35.60	35.50
			71.56	74.00	96	99	36.87	36.10
			82.41	78.00	99	98	37.56	37.10
5.	Male	23	85.35	86.00	100	99	35.45	36.30
			83.70	80.00	99	99	36.14	35.70
			85.76	87.00	98	98	36.34	36.50

The data presented in the table has been simplified into a graph to ensure clear visibility and facilitate a straightforward comparison between the two datasets. Each set of data has been disaggregated into individual figures based on the measured parameters as in Fig. 12.

Each measured parameter exhibits a noticeable distinction between the data obtained from the sensors and the data obtained from the conventional device.

$$Percentage\ error\ (\%) = \frac{project\ data - conventional\ data}{conventional\ data} x100 \qquad (1)$$

The data for each parameter is calculated using the mentioned equation, and the total for each parameter is divided by 15 to determine the average percentage error. The results indicate an average percentage error of 2.6% for heart rate measurements, 0.74% for blood oxygen saturation level measurements, and 0.81% for temperature measurements. The recorded percentage error is considered reasonable as it adheres to electronic component standards since it does not exceed a 5% percentage error.
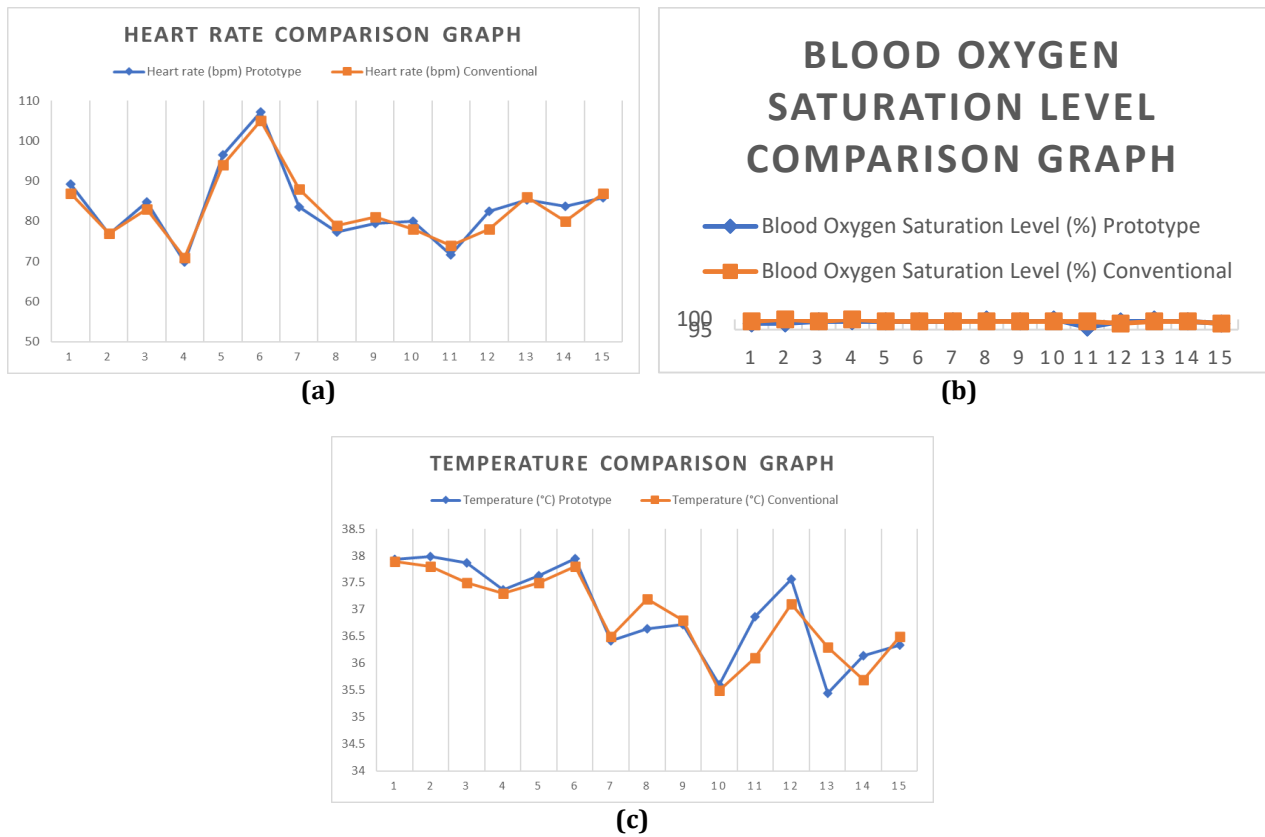
Fig. 12 *Graph data comparison between prototype and available device (a) Heart rate comparison (b) Blood oxygen saturation level (c) Temperature comparison*

4. Conclusion

The purpose of this work is to provide a monitoring system for students about heatstroke symptoms. This system will improve education institute health care and enhance the efficiency of the health care operations. In conclusion, this system can be used to monitor early heatstroke symptoms for students when attending classes. But the monitoring can only be done by an authority that has access to the database.

In accordance with the implementation phase, this work has successfully met its objectives. The achieved results are observable on smart devices, including laptops and smartphones. This accessibility allows for convenient monitoring of the obtained data. Moreover, the system enables the dissemination of results to relevant authorities, facilitating further analysis. This capability is particularly valuable in assessing whether a student is at risk of heatstroke or not. The implementation aligns with its goals by providing a user-friendly interface on smart devices and facilitating the transfer of data for thorough analysis and decision-making by authorities.

Acknowledgement

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

References

[1] Milman, O. (2021, November 25). *Rising heat poses dire risks to small children.* Bernard van Leer Foundation. https://earlychildhoodmatters.online/2021/rising-heat-poses-dire-risks-to-small-children/
[2] Fang, Z., Xu, X., Zhou, X., Deng, S., Wu, H., Liu, J., & Lin, Z. (2019). Investigation into the thermal comfort of

university students conducting outdoor training. *Building and Environment*, 149, 26–38. https://doi.org/10.1016/j.buildenv.2018.12.003

[3] Kudo, Y., Kawano K., Kido Y., Tsutsumi T., Kakuma T., Survey of and measures to prevent heatstroke among university students. *Campus Health,* 57(2), 74-80. https://doi.org/10.57540/campushealth.57.2_74

[4]The World Sixth Sense (2020). How do thermal cameras work? https://www.flir.com/discover/rd-science/how-do-thermal-cameras-work/

[5] Medline Plus (2023, February 2). Body temperature norms: Medlineplus medical encyclopedia. https://medlineplus.gov/ency/article/001982.htm

[6] Microelectronic Integrated Systems, "MLX90614 family Single and Dual Zone Infra Red Thermometer in TO 39" MLX90614 datasheet, Feb 2007 [Revised Feb. 2013]

[7]Hipp, D., & Hashmi, A. (2023, April 20). *Normal heart rate chart by age.* Forbes. https://www.forbes.com/health/healthy-aging/normal-heart-rate-by-age/

[8] Mimish L. (2012). Electrocardiographic findings in heat stroke and exhaustion: A study on Makkah pilgrims. *Journal of the Saudi Heart Association*, 24(1), 35–39. https://doi.org/10.1016/j.jsha.2011.08.003

[9] Arhinful, E. (2021, June 11). *What is heatstroke. Heatstroke: Symptoms, Causes and Treatment.* Allina Health https://www.allinahealth.org/healthysetgo/prevent/heatstroke-symptoms-causes-and-treatment

[10] Department of Health Minnesota. (2022, May 10). Oxygen levels, pulse oximeters, and covid-19. https://www.health.state.mn.us/diseases/coronavirus/pulseoximeter.html

[11] Random Nerd Tutorial (2021, February 21). ESP32 useful Wi-Fi library functions (Arduino IDE). https://randomnerdtutorials.com/esp32-useful-wi-fi-functions-arduino/