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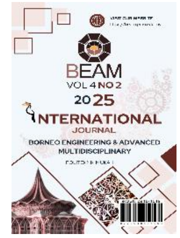

Development of e-Health Education System using IoT and Web-based Application for People Living with Diabetes

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Abstract

Diabetes is a growing concern globally, including in Malaysia, where its prevalence continues to rise, straining healthcare resources and impacting individuals' well-being. The inadequacy of ongoing support and limited consultation time exacerbates poor self-care practices, leading to uncontrolled blood sugar levels and adverse health outcomes. To address these challenges, this project focuses on developing the e-Health Medical Connecting Platform for Diabetes Care, named Medicolink, which integrates web-based resources with hardware, sensor capabilities and IoT technology. Through this innovative approach, the aim is to empower individuals with diabetes by providing them with interactive tools for self-monitoring and data collection. The system employs non-invasive techniques for painless and routine blood glucose monitoring. The system is connected to the body through non-invasive sensors that detect blood glucose level. By gently attaching a finger to the MAX30102 photodetector sensor, blood glucose parameters are detected, with data seamlessly integrated into the Medicolink website. Users can access their health information via both the website and a smartphone application, facilitating real-time monitoring and informed decision-making.

Keywords: - Diabetes Care, e-health, Internet of Things Technology

1. Introduction

Diabetes is a widespread chronic condition that affects a significant number of individuals globally (Pikula et al., 2024). However, many people face challenges in accessing quality diabetes education, which hinders their ability to effectively manage the disease and maintain overall well-being. The emergence of Internet of Things (IoT) technology offers an opportunity to revolutionize healthcare and patient education (Singh & Kaunert, 2024).

The lack of understanding and education among those with diabetes where people don't have a thorough grasp of managing diabetes, which includes the significance of making lifestyle changes, taking medications as prescribed, monitoring blood sugar levels, and spotting issues early (Trani et al., 2024). As a result, they may engage in poor self-care practices, leading to uncontrolled blood sugar levels and negative health outcomes.

On the other hand, Successful education and self-management depend on effective interaction and communication between healthcare professionals and diabetes patients. However, in conventional healthcare settings, the lack of ongoing support and time limits during consultations make it difficult to build trusting patient-provider relationships (Lin et al., 2022). In turn, diabetes education campaigns become less effective. E-health systems can increase communication by enabling people to interact with medical professionals, to manage their diabetes.

2. Literature Review

Prior to beginning the investigation, a literature analysis was conducted to gather data on the technology available by other studies that were already working on the same subject. An IOT based non-invasive glucose monitoring system for diabetic patients has been proposed utilizing wearable infrared skin sensors make-up in the insole (Mustapha, 2022). The pressure-sensing smart insole technology offered distinctive input to the patient. However, the sensors must be put in the insole which make it difficult to be utilized. Invasive blood glucose monitors that require finger piercings are the majority of what are available on the market. This approach is highly accurate yet typically uncomfortable and more likely to cause infections. A portable non-invasive blood glucose monitoring system using near-infrared sensor, was created by (Buda & Addi, 2014). In (Mohi-ud-din, 2017), the inventors suggest a design for a non-invasive, cost-effective glucose monitoring device that makes use of near-infrared spectroscopy. The GSM module attached to this gadget will facilitate wireless data sharing that can be quickly forwarded to the doctor for review.

Pain-free blood glucose monitoring using wearable sensors has been invented by (Siddiqui et al., 2018). The technology uses cutting-edge biosensors that can detect glucose levels in interstitial fluid continually, doing away with the need for uncomfortable finger pricks. An IoT based diabetic patient monitoring system using machine learning and node MCU was proposed in (Rghioui et al., 2021). Results from experiments using Naive Bayes, Support Vector Machine, Random Forest, and Simple CART on diabetic data were gathered with the goals are to assess the effectiveness of the categorization algorithms to employ the most effective method for prediction (Rghioui et al., 2021).

A photodiode sensor was used by (Saputra & Utomo, 2020) to design and construct a noninvasive blood sugar measurement system. The objective is to noninvasively assess blood sugar, including both medical professionals and non-medical personnel. In this investigation, direct blood measurements were made using a photodiode sensor after blood was collected from numerous diabetic patients (Saputra & Utomo, 2020). The NIR sensor-based noninvasive technique provides a painless and practical solution for routine blood glucose monitoring in diabetics with IoT solution has also been utilized in (Abith et al., 2021; Anis & Alias, 2021; Daarani & Kavithamani, 2017 & Luong et al., 2018). It provides a non-invasive approach using an infrared sensor for transmission and receipt of rays from and to the fingertip to continuously monitor the glucose level.

This project is proposed to utilize IoT technology in developing a web-based e-health education system specifically tailored for individuals with diabetes. By integrating IoT into the system, it enables real-time monitoring, data collection, and analysis of crucial health parameters such as the blood glucose levels. This empowers individuals by providing them with valuable insights into their health status, allowing them to proactively manage their condition. The IoT capabilities of the system also enhance the educational aspect, delivering personalized content and recommendations based on individual needs and circumstances. Users will have access to a range of interactive modules on the web-based platform. Furthermore, the integration of IoT enables remote access to healthcare professionals through virtual consultations and remote monitoring, removing geographical barriers and improving convenience.

Through the development of this IoT-based E-health education system, the aim is to address the educational requirements of individuals living with diabetes, empowering them to effectively manage their condition, achieve better health outcomes, and enhance their overall quality of life. Therefore, objectives of this project can be summarized as to develop an e-health education module for people living with diabetes using a web-based platform, and then to design a system that can monitor blood sugar level using sensor and IoT that integrated to the website and mobile phone. Finally, the performance of the measured blood glucose level will be verified.

3. Methodology

The goal of this project is the development of a web-based e-health education system for people living with diabetes.

3.1 E-Health Medical Connecting Platform for Diabetes Care (MedicoLink)

The goal of this project is the development of a web-based e-health education system for people living with diabetes. The website is named e-Health Medical Connecting Platform for Diabetes care (Medicolink). The project aims to develop an interactive and user-friendly system that combines web-based resources with hardware and sensor capabilities. By incorporating these technologies, the goal is to provide individuals with diabetes with innovative tools for self-monitoring and data collection. The ultimate objective is to improve diabetes self-management, empower individuals to make informed decisions about their health, and enhance overall health outcomes for people living with diabetes.

3.2 The Website Module

The website was created to provide a comprehensive web-based platform that integrates diabetic care and management, IoT technology and sensors to support individuals living with diabetes. This user-friendly web application allows diabetic patients and healthcare providers to access real-time glucose data, receive alerts, track historical trends, and set personalized thresholds. Canva is used for the designs of the website and illustrations. Flowchart of the website process is shown in Fig. 1.

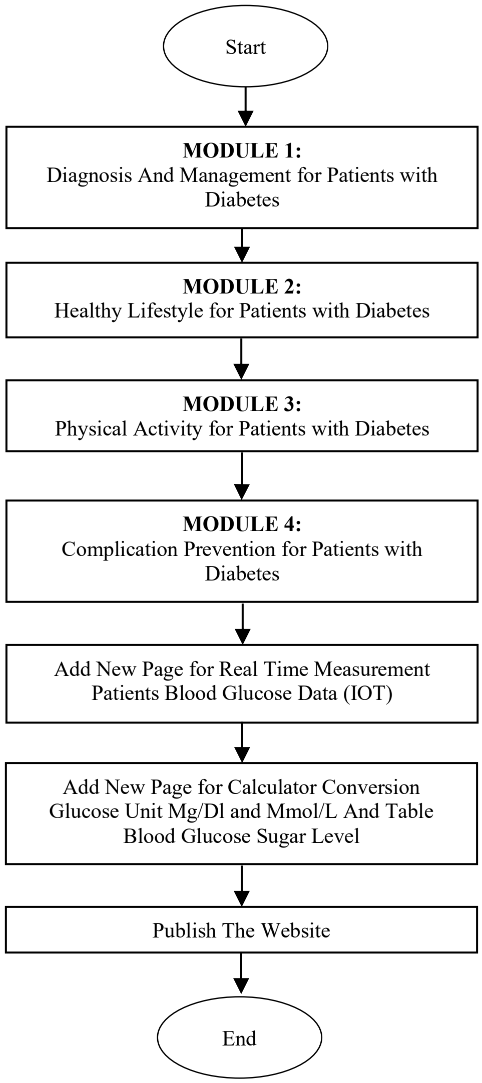

Fig. 1: Flowchart of web-based e-health education system for people living with diabetes

3.3 The Hardware Design

The system architecture for the IoT-based non-invasive glucose monitoring system for diabetic patients consists of several interconnected components. At the core is the non-invasive glucose sensing module, MAX30102 which employs optical or other non-invasive techniques to measure glucose levels. The module is connected to a microcontroller unit (MCU) such as ESP 32, which serves as the central control centre. The MCU processes and analyses the data received from the sensing module and manages the overall system operation.

Wireless connectivity, such as Wi-Fi, Bluetooth, or cellular networks, enables the MCU to connect to the internet. The system leverages cloud-based data storage and analysis, where the glucose data collected by the MCU is securely transmitted and stored. This cloud infrastructure provides scalable computing resources for data analysis, visualization, and long-term storage.

A user-friendly mobile or web application allows diabetic patients and healthcare providers to access real-time glucose data, receive alerts, track historical trends, and set personalized thresholds. The system block diagram for measurements patient's blood glucose can be shown in Fig. 2.

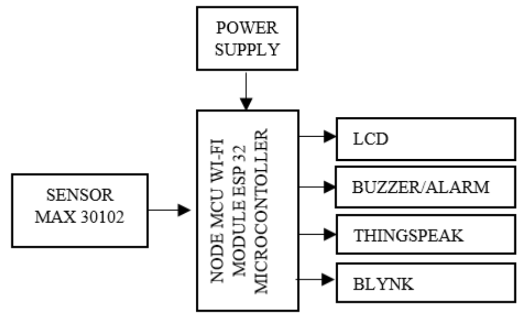

Fig. 2: Block diagram of Non-invasive Glucose Measurement and Monitoring System

For the non-invasive glucose measurement and monitoring system, based on Fig. 3, the overall flowchart displays the whole process of constructing the system, which includes both hardware and software required to operate the monitoring system. For the hardware part, the system is initiated when connection to Wi-Fi is successful. Glucose Monitoring System will be displayed on LCD. The input signal initializes the glucose level through sensor MAX 30102. System will ask user to place finger on measurement site.

Following successful initialization of the input sensor, the input sensor is sent to the microcontroller. After transferring the input data to the microcontroller, it will be calculating and determine the blood glucose level to the LCD as output, which will be shown on the LCD screen as an output display. The data is sent in real-time to the WiFi module and then to the website via Thingspeak (web based) for analysis and display. Real-time updates of the processed and visible data represent the state of the human level will be monitored in the website. Simultaneously, the glucose data value will be sent to Blink (mobile application) through blue-tooth module. The range of blood glucose value can be described in Table 1.

Table 1: Sugar level range

Sugar level (Cut-off)	Indicator
0-70 mg/dL (4 mmol/L)	Low
70-135 mg/dL (7.5 mmol/L)	Normal
>135 mg/dL (>7.5 mmol/dL)	High

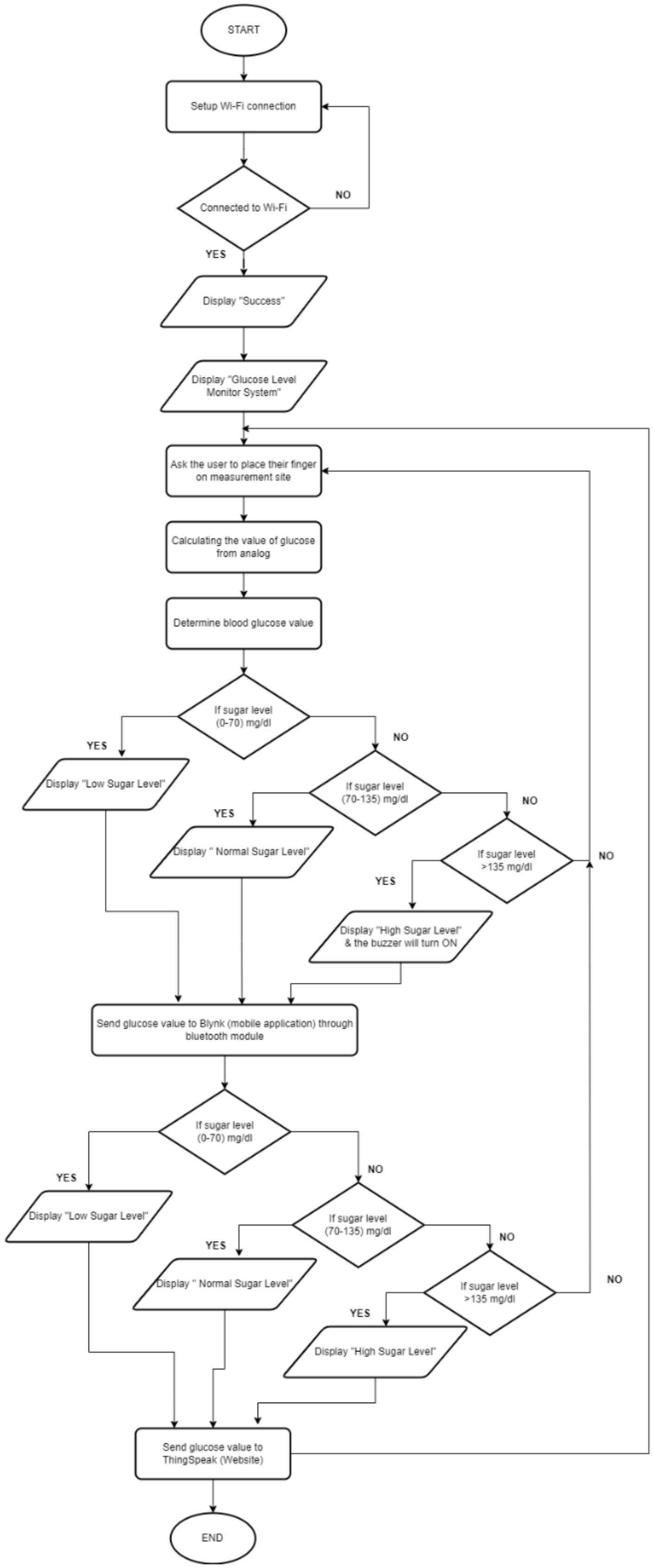

Fig. 3: Overall flowchart of Non-invasive Glucose Measurement and Monitoring System

The schematic circuit was designed by using an open-source program called Fritzing. The schematic circuit is shown on Fig. 4. The ESP32 development board acts as the microprocessor in this system that interfaces with all component input and output. The components include a MAX30102 Pulse Oximeter sensor. The MAX30102 Pulse Oximeter sensor for blood's glucose level detection. It is located on the MAX30102 Pulse Oximeter board in the schematic as the gauge's initialization point. The blood glucose level is sensed when the fingertips are put on the MAX30102 Pulse Oximeter sensor board. The chip receives the collected data. The glucose level is then detected and shown on an LCD screen. Furthermore, this circuit is not only displaying real-time data on the LCD, but also capable of transmitting the data to a server and displaying it via online platforms. Therefore, users may easily monitor their blood glucose levels and make educated decisions regarding their health status.

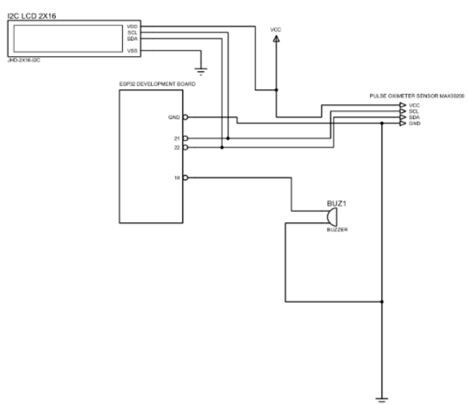

Fig. 4: The architecture of a Non-invasive Glucose Measurement and Monitoring System is shown schematically

3.4 The Software Design

Arduino IDE (Integrated Development Environment) is used to write code using an easy-to-understand language, compile it, and send it to the microcontoroller board. It provides helpful features like libraries and functions that make working with sensors and other electronic components easier. The software is available for Windows, macOS, and Linux, and it is designed to make programming Arduino boards accessible (Docs, 2023).

ThingSpeak is a platform that used to collect and analyze data from the system connected to the internet. It's like a cloud-based service that stores information from sensors or other internet-enabled devices. It can create channels to organize and store the data and then use tools to visualize and understand it. ThingSpeak is often used in applications like monitoring the environment or controlling devices. It's a helpful tool for managing and analyzing data from connected devices (ThingSpeak, 2023). Here, the data output from the hardware system (glucose value) is sent to ThingSpeak for real-time monitoring, visualization, analysis and data storing through the personalized Medicolink website.

Blynk is an IoT platform that allows users to design personalized interfaces using a mobile app. Blynk supports connectivity with different hardware devices, enabling smooth communication with the Blynk Cloud. Real-time monitoring of sensor readings and device status is possible, while remote control capabilities allow users to activate switches remotely. Push notifications keep users informed about data logging and cloud integration features enable data storage and synchronization. Blynk also encourages collaboration through project sharing, facilitating the exchange of ideas within the IoT community (Techexplorations, 2021).

The microcontroller, NodeMCU ESP32, will read all of the data from the input sensors and then transmit it to the user over the Internet of Things (IoT). The process of connecting the NodeMCU ESP32 to the internet in order to interact with the user's mobile Blynk application and Thingspeak platform is depicted in Fig. 5.

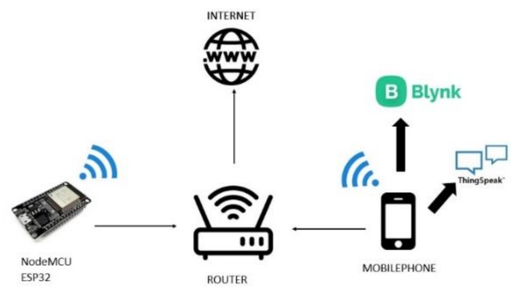

Fig. 5: Internet connection with NodeMCU ESP32

4. Result and Discussion

Based on Fig. 6, it can seamlessly integrate the ESP32 microcontroller with the LCD display, buzzer, and the MAX30102 sensor, creating the non-invasive blood glucose monitoring device. The size of circuit is sized down to fit into the final design casing box shown in Fig.5. Fig. 6 shows the components inside the casing box that are already attached to the casing box. Additionally, the ESP32 can gather the real-time data via a MAX30102 sensor that measures glucose level, linked ThingSpeak (website) and Blink (mobile Apps).

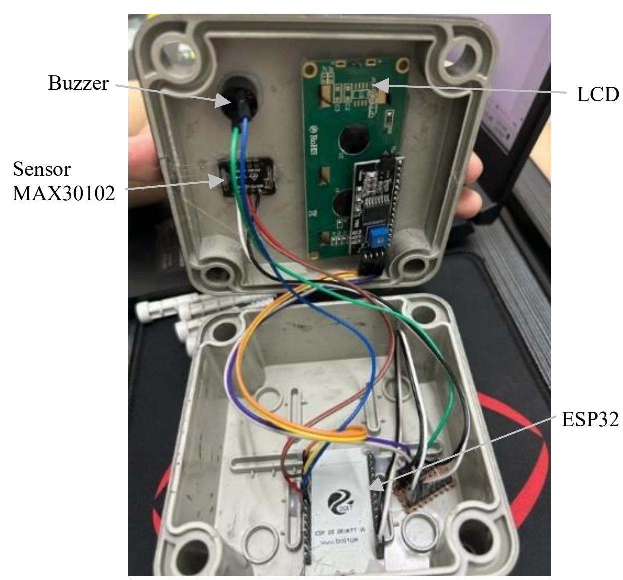

Fig. 6: Components inside the Non-invasive Glucose Measurement System

Fig. 7: Prototype for the Non-invasive Glucose Measurement System

Apart from that, an actual system that can be connected to the global web and used for monitoring, controlling, or communicating is the IoT Module. Blynk serves as the IoT module in this project. Fig. 8 shows the project dashboard on a mobile Apps using Blynk. The Blynk is served to remotely operate hardware, show data from sensors, store and then visualize it. Blynk is utilized to display blood glucose level obtained from the input sensors MAX30102, and the notifications will pop up such as low sugar level, normal sugar level and high sugar level.

Blynk can communicate with what has been programmed in Arduino IDE by using an authentication token that is suited only for one device. Once the Blynk is connected, the value from sensors MAX30102 is collected and immediately displayed. In addition to displaying the value of sensors that are being utilized, this dashboard is equipped with one gauge widgets and chart for blood glucose level.

Users can login into the Blynk apps using the email and password that has been created for this application. Users can easily access the apps and can monitor using their mobile phone. Glucose monitoring is performed non-invasively with this method by simply putting a finger on the sensor and detecting it straight through the skin (Refer Fig. 7).

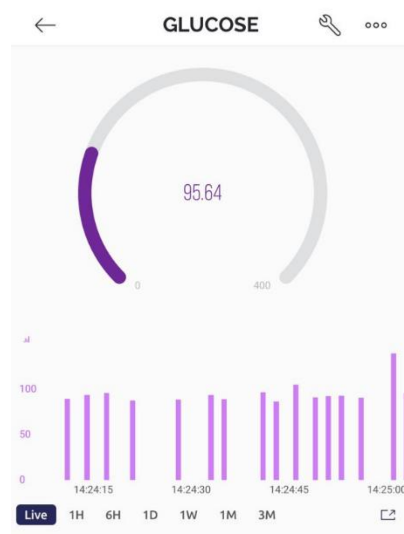

Fig. 8: Successful Development of the IoT for the Non-invasive Glucose Measurement System

4.1 Blynk Notifications

Fig. 9 (a) to (c) shows the demonstration of how the MAX30102 sensor works. When the user put the finger on the sensor board, it will read the blood glucose value. If the sugar level (0-70) mg/dl displays “low sugar level”, next the sugar value (70-135) mg/dl will display “normal sugar level” and if the sugar level value (>135) mg/dl will display “high sugar level”. The notification will pop up and it will be sent to the user. The user may know if their blood glucose level is low, normal or high by having this notification system delivered to their Blynk Application.

(a) (b) (c)

Fig. 9: Notifications are sent on Blynk for (a) low sugar level, (b) normal sugar level and (c) high sugar level

4.2 ThingSpeak Application

Fig.10 shows the chart and numeric to display the blood glucose value via website. ThingSpeak also exports the data that was already measured by using the MAX30102 sensor of blood glucose to Microsoft excel as shown in Fig. 11.

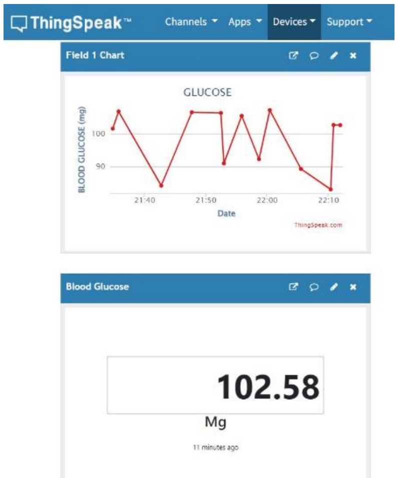

Fig. 10: Data monitoring is sent on ThingSpeak for website

	A	B	C
73	2024-01-07T13:52:27	72	106.2725
74	2024-01-07T13:52:56	73	91.01777
75	2024-01-07T13:55:51	74	105.415
76	2024-01-07T13:58:40	75	92.30032
77	2024-01-07T14:00:26	76	107.1449
78	2024-01-07T14:05:31	77	89.33488
79	2024-01-07T14:10:22	78	83.14945

Fig. 11: Data in Microsoft Excel exported using ThingSpeak

4.3 Website Design and Modules

Fig. 12 show the main page of the website (Home menu) that is created named as MediCoLink. It has four modules, specially focused on people living with diabetes. Details on the many types of diabetes, including warning signs and symptoms, underlying diseases, and risk factors are included. It provides guidance on meal preparation, carbohydrate measurement, and the importance of physical activity and exercise in managing diabetes.

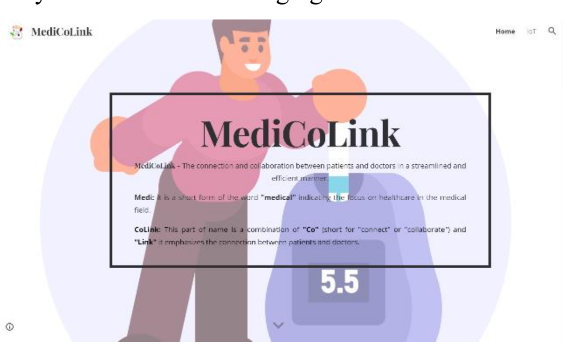

Fig. 12: Main homepage e-Health Medical Connecting Platform for diabetes care www.medicolink.com

Apart from that, the real-time measurement page (IoT Menu) can be accessed next to the Home menu. Fig. 13 shows the page for real-time measurement and IoT sites that connected to ThingSpeak and Blynk.

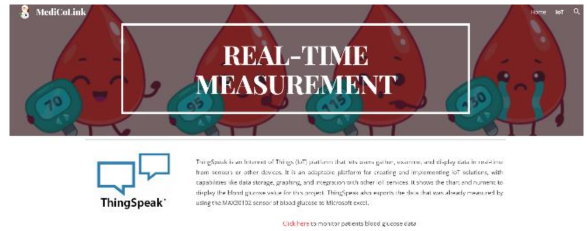

Fig. 13: Page for Real-Time Glucose Measurement (IoT)

Module 1: Diagnosis and Management for Patients with Diabetes. This module highlights the introduction of diabetes, risk factors of type-2 diabetic, symptoms of high blood sugar, diagnostic criteria of diabetes, management and medical treatment of diabetes. Fig. 14 shows example of the illustration in this module.

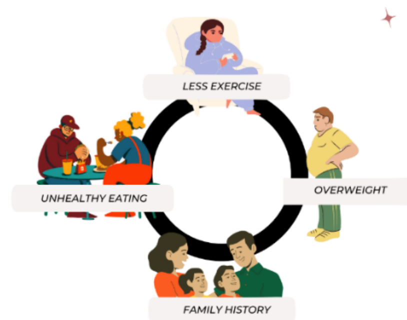

Fig. 14: Risk factors of type-2 diabetes

Module 2: Healthy Lifestyle for Patients with Diabetes. Some of the topics that cover in this module are transtheoretical models of health behavior, tips for healthy lifestyle for patients with diabetes, patient education, professional information, healthy eating, balanced diet for diabetes, glycemic index, and meals during acute illness. Fig. 15 shows stages outline of transtheoretical models of change for patients with diabetes, explained in this module.

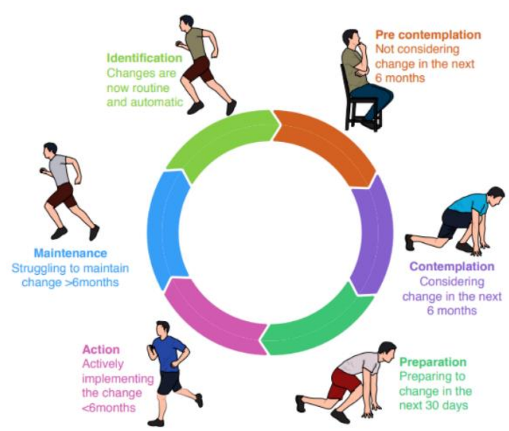

Fig. 15: Transtheoretical model of change illustration in Module 2

Module 3: Physical Activity for Patients with Diabetes. Some of the topics affect physical activities, principles and types of physical activities such as aerobic and muscle strengthening, actions of specific complications and relative contraindications. Fig. 16 shows illustration of the types of physical activities for patients with diabetes.

Fig. 16: Types of physical activity

Module 4: Complication Prevention for Patients with Diabetes. In this module, importance of diabetes management and preventions are explained in detail to educate patients and to avoid complications. Fig. 17 show the illustrations of nerve damage that increases the chance for foot ulcers, infection, gangrene and eventual need for limb amputation.

Fig. 17: Diabetes Foot Care Illustrations in Module 4

Calculator Conversion: Glucose unit conversion calculator and chart are also available via this url link. It gives information about unit conversion of mmol/L and mg/dL.

4.4 Invasive vs Non-invasive Reliability Test

Analysis has been done to compare the readings between the developed prototype and the invasive glucometer (SinoCare ga-3) that is available on the market. This test is tested on 10 non-diabetes individuals. Table 2 compares the glucose readings before a meal and after a meal. The analysis of data provided a thorough examination of glucose concentration measurements, comparing the effectiveness and reliability of both invasive and non-invasive methods in monitoring the blood glucose levels.

Table 2: Comparison of invasive and non-invasive prototype evaluation for measuring glucose concentration

No.	Subject	Glucose concentration mmol/L (Before Meal)		Glucose concentration mmol/L (After Meal)	
		Glucometer	Prototype	Glucometer	Prototype
1.	Person 1	5.5	5.4	6.9	5.8
2.	Person 2	4.9	4.2	7.8	7.0
3.	Person 3	5.8	4.8	7.2	6.0
4.	Person 4	5.4	4.7	6.5	5.7
5.	Person 5	6.1	5.0	8.9	7.5
6.	Person 6	5.0	4.5	7.3	6.2
7.	Person 7	5.9	5.7	6.7	5.5
8.	Person 8	5.6	5.5	7.5	6.9
9.	Person 9	5.2	5.0	6.3	5.8
10.	Person 10	5.3	4.9	8.1	7.7

Fig. 18 and 19 show the graph of glucose measurement before and after meals, respectively. The results show that there is a slightly difference in the glucose measurements by using two different methods with an invasive technique and a non-invasive technique. The proposed non-invasive prototype shows slightly lower value compared to the invasive technique. The difference values obtained from the experiments may differ due to several factors, the measurement of glucose that do not contain other substances such as in the blood. Furthermore, factors from subjects may also tend to affect the glucose measurements because everyone has various skin thickness.

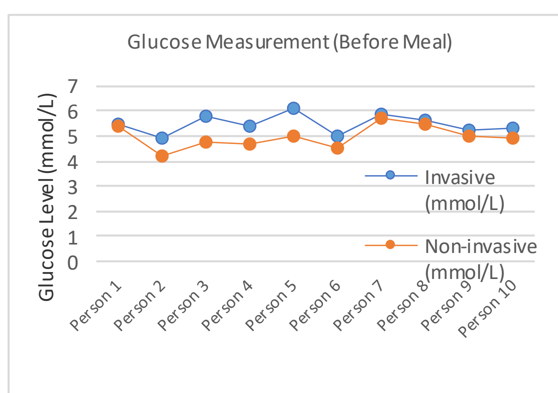

Fig. 18: Results of 10 trial sample readings for glucose measurement (before meal)

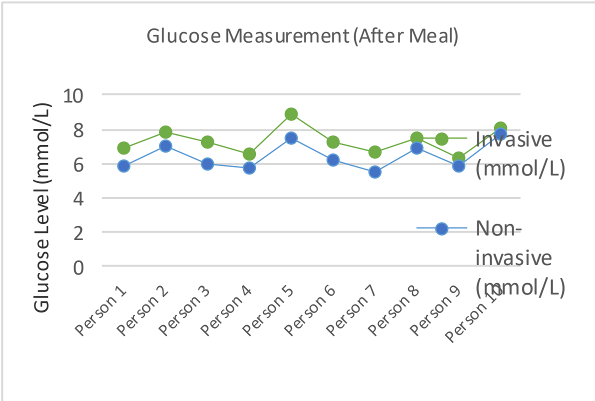

Fig. 19: Results of 10 trial sample readings for glucose measurement (after meal)

The development of a web-based platform that combines real-time monitoring and education module for patient living with diabetes has been developed with integration of the MAX30102 sensor, IoT technology and e-health education system. The system provides teaching tools, such as modules, to help users better understand managing diabetes. The results show that the measurement of the developed prototype has small difference value compared to the invasive glucometer that is already in the market. The developed web-based platform can assist people effectively manage their disease. It has a sizable market value due to the rising prevalence of diabetes and the rising need for remote healthcare solutions.

5. Conclusion and Recommendations

In conclusion, the development of a web-based e-health education system for people living with diabetes offers significant benefits in empowering individuals to manage their condition effectively. By leveraging web-based technologies, such system can provide accessible and interactive educational resources, real-time monitoring capabilities, and personalized support to diabetic patients. The project aims to enhance the knowledge and understanding of diabetes, promote self-care practices, and improve overall health outcomes for individuals living with this chronic condition. The web-based platform can serve as a comprehensive tool for education, self-management, and collaboration between patients and healthcare providers. With the successful development and implementation of this e-health education system, it has the potential to positively impact on the lives of people with diabetes, enabling them to lead healthier and more informed lifestyles. By providing accessibility and monitoring, this e-health education system improves diabetes control while also enabling users to boost their general well-being.

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Author Contributions: The research study was carried out successfully with contributions from all authors.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abith, V., Deepika, M., Gurumoorthy, M., Devi, V. K., & Nithya, R. (2021). Non-Invasive Glucose Estimation Based On Infrared Using Finger Plethysmograph. *International Research Journal of Modernization in Engineering Technology and Science*, *3*(8), 14–19.

Anis, S. N. S., & Alias, R. (2021). A portable non-invasive blood glucose monitoring device with IoT. *Evolution in Electrical and Electronic Engineering*, *2*(1), 36-44.

Buda, R. A., & Addi, M. M. (2014). A Portable Non-Invasive Glucose Monitoring Device. *2014 IEEE Conference on Biomedical Engineering and Sciences (IECBES)*, 964–969.

Daarani, P., & Kavithamani, A. (2017). Blood Glucose Level Monitoring By Noninvasive method using near infrared sensor. *International Journal of Latest Trends in Engineering and Technology*, 141–147.

Docs. (2023). Arduino Integrated Development Environment (IDE) v1. *Docs*. Retrieved February 2, 2024 from https://docs.arduino.cc/software/ide-v1/tutorials/arduino-ide-v1-basics.

Lin, K., Zhang, W., He, F., & Shen, J. (2022). Evaluation of the clinical efficacy of the treatment of overweight and obesity in type 2 diabetes mellitus by the telemedicine management system based on the Internet of Things technology. *Computational Intelligence and Neuroscience*, *2022*(1), 8149515.

Luong, D. T., Huy, N. X., Hung, D. V., Ha, N. T., & Thuan, N. D. (2018). Research and Design a Non-Invasive Blood Glucose Measuring Module. *American Journal of Biomedical Sciences*, *10*(3), 149–156.

Mohi-ud-din, Q. (2017). GSM based Needleless Blood Glucose Monitoring System. *Journal of Bioengineering & Biomedical Science*, *7*(3), 7–10.

Mustapha, B. (2022). IOT Based Non-Invasive Glucose Monitoring System for Diabetic Patient. *Politeknik & Kolej Komuniti Journal of Engineering and Technology*, *7*(1), 20–35.

Pikula, A., Gulati, M., Bonnet, J. P., Ibrahim, S., Chamoun, S., Freeman, A. M., & Reddy, K. (2024). Promise of lifestyle medicine for heart disease, diabetes mellitus, and cerebrovascular diseases. *Mayo Clinic*

Proceedings: Innovations, Quality & Outcomes, *8*(2), 151-165.

Rghioui, A., Naja, A., Mauri, J. L., & Oumnad, A. (2021). An IoT based diabetic patient monitoring system using machine learning and node MCU. In *Journal of Physics: Conference Series* (Vol. 1743, No. 1, p. 012035). IOP Publishing.

Saputra, F. A. D., & Utomo, B. (2020). Development of Measuring Device for Non-Invasive Blood Sugar Levels Using Photodiode Sensor. *Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics*, *2*(2), 74–79.

Siddiqui, S. A., Zhang, Y., Lioret, J., Song, H., & Obradovic, Z. (2018). Pain-free Blood Glucose Monitoring Using Wearable Sensors: Recent Advancements and Future Prospects. *IEEE Reviews in Biomedical Engineering*, *11*, 21–35.

Singh, B., & Kaunert, C. (2024). Integration of Cutting-Edge Technologies such as Internet of Things (IoT) and 5G in Health Monitoring Systems: A Comprehensive Legal Analysis and Futuristic Outcomes. *GLS Law Journal*, *6*(1), 13–20.

Techexplorations. (2021). What Is Blynk? A Quick Review. *Techexplorations*. Retrieved April 25, 2024 from https://techexplorations.com/guides/blynk/1-what-is-blynk/.

ThingSpeak. (2023). About ThingSpeak. *ThingSpeak*. Retrieved April 25, 2024 from https://thingspeak.com/.

Trani, M. R., Bilocura, I., Bersabal, S., Panilagao, R. K., Toledo, B. R., Garrido, E., ... & Ghisi, G. L. D. M. (2024). Effects of a comprehensive structured patient education intervention on disease-related knowledge and behaviour change among people living with type 2 diabetes in the Philippines. *Frontiers in Rehabilitation Sciences*, *5*, 1374850.