

ONLINE SELF-LEARNING SYSTEM FOR PREDIABETES PATIENTS



A Thesis Submitted in Partial Fulfillment of the Requirements  
for the Degree of Master of Engineering in Electrical Engineering

Department of Electrical Engineering

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ระบบเรียนรู้ด้วยตนเองแบบออนไลน์สำหรับผู้ป่วยที่มีภาวะก่อนเบาหวาน



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ปีการศึกษา 2565  
ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

Thesis Title                                    ONLINE SELF-LEARNING SYSTEM FOR PREDIABETES  
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By    Mr. Ye Moe Myint  
Field of Study                                    Electrical Engineering  
Thesis Advisor                                   Associate Professor LUNCHAKORN WUTTISITTIKULKIJ,  
Ph.D.

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Accepted by the FACULTY OF ENGINEERING, Chulalongkorn University in  
Partial Fulfillment of the Requirement for the Master of Engineering

..... Dean of the FACULTY OF  
ENGINEERING  
(Professor SUPOT TEACHAVORASINSKUN, Ph.D.)

THESIS COMMITTEE

..... Chairman  
(Assistant Professor PASU KAEWPLUNG, Ph.D.)

..... Thesis Advisor  
(Associate Professor LUNCHAKORN WUTTISITTIKULKIJ,  
Ph.D.)

..... Examiner  
(Associate Professor CHAIYACHET SAIVICHIT, Ph.D.)

..... External Examiner  
(Dr. Pisit Vanichchanunt)

ยี โม่ มิน : ระบบเรียนรู้ด้วยตนเองแบบออนไลน์สำหรับผู้ป่วยที่มีภาวะก่อนเบาหวาน.  
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 หลัก : รศ. ดร.ลัญจกร วุฒิสทิธิกุลกิจ

วิทยานิพนธ์นี้พัฒนาแอปพลิเคชันเว็บที่ผสมรวมศูนย์การเรียนรู้แบบสามมิติและเกมการเรียนรู้เพื่อรองรับสนับสนุนการตรวจติดตาม การจัดการ และการดูแลรักษา ผู้ป่วยที่มีความเสี่ยงต่อภาวะก่อนเบาหวาน โดยมีแผนออกกำลังกาย และการควบคุมอาหาร แอปพลิเคชันนี้ใช้เทคโนโลยีเว็บที่ทันสมัย การจำลองสามมิติ และหลักการสร้างเกมเพื่อสร้างประสบการณ์การเรียนรู้ที่น่าสนใจและมีประสิทธิภาพ การออกแบบให้ความสำคัญกับผู้ใช้ส่วนบุคคลทำให้มั่นใจว่าสามารถใช้งานได้ง่าย และผลการทดสอบให้ผลลัพธ์เชิงบวก กล่าวคือ เพิ่มความรู้ แรงจูงใจ และความมีส่วนร่วมในการเรียนรู้ งานวิจัยนี้มีส่วนช่วยในการสนับสนุนการแก้ไขปัญหาด้านสุขภาพได้ โดยเสริมสร้างให้ผู้ป่วยมีการตัดสินใจที่เหมาะสม และประพฤติปฏิบัติตนที่เป็นผลดีต่อสุขภาพ ทิศทางในอนาคตสามารถขยายแอปพลิเคชัน ปรับปรุงส่วนประสานผู้ใช้ และการประเมินผลในระยะยาวเพื่อดูผลสัมฤทธิ์ที่มีต่อการจัดการโรคเบาหวาน



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 ปีการศึกษา 2565

ลายมือชื่อนิสิต .....

ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

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Ye Moe Myint : ONLINE SELF-LEARNING SYSTEM FOR PREDIABETES PATIENTS. Advisor: Assoc. Prof. LUNCHAKORN WUTTISITTIKULKIJ, Ph.D.

This thesis implements a web-based application that combines a 3D learning center and educational game to facilitate the monitoring, management, and treatment of patients with prediabetes mellitus, by providing exercise plans and controlled diets. The application utilizes advanced web technologies, 3D modeling, and gamification principles to create an engaging learning experience. User-centered design ensures usability, and testing demonstrates positive outcomes, including increased knowledge, motivation, and engagement. This research contributes to digital health interventions by empowering prediabetes patients with informed decision-making and healthy habits. Future directions include expanding the application, refining the user interface, and evaluating long-term impact on prediabetes management.

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CHULALONGKORN UNIVERSITY

Field of Study: Electrical Engineering

Student's Signature .....

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Advisor's Signature .....

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## Chapter 1

### Introduction

In 2014, diabetes affected 8.5% of adults aged 18 and older globally. Diabetes directly caused 1.6 million deaths in 2016, while high blood glucose was responsible for an additional 2.2 million deaths in 2012[1-4]. There are two main types of diabetes: Type 1 and Type 2. Type 1 diabetes, previously known as insulin-dependent, juvenile, or childhood-onset diabetes, is characterized by inadequate insulin production and requires daily insulin administration. The cause of Type 1 diabetes is currently unknown and cannot be prevented with current knowledge[5]. Type 2 diabetes, formerly referred to as non-insulin-dependent or adult-onset diabetes, occurs due to the body's ineffective use of insulin. Type 2 diabetes accounts for the majority of diabetes cases worldwide and is primarily associated with excess body weight and physical inactivity[1, 5-8].

According to the World Health Organization (WHO), adopting a healthy lifestyle is crucial in preventing type 2 diabetes and its complications. This includes achieving and maintaining a healthy body weight, engaging in regular physical activity of at least 30 minutes per day, following a healthy diet that avoids excessive sugar and saturated fat intake, and abstaining from tobacco use, as smoking increases the risk of diabetes and cardiovascular diseases[1, 8, 9]. The treatment of diabetes involves dietary adjustments, physical activity, blood glucose control, and managing other known risk factors that can harm blood vessels[8-12].

WHO literature review reveals a continuous rise in the incidence of diabetes mellitus worldwide, affecting both developed and developing countries. An increasing number of people in these countries are leading sedentary lifestyles. While there is evidence that diabetes complications can be prevented, many individuals with diabetes lack the necessary knowledge and skills to effectively manage their condition using available technology and adopt healthier lifestyles. Changing habits and lifestyles require deliberate effort, and individuals with diabetes bear the ultimate responsibility for their care and treatment, utilizing available technological

systems. These systems include meal recommendation tools, activity monitoring and tracking devices, medication reminder systems, and interactive chatbots to address questions related to their condition.

This thesis focuses on the design and development of an online website system that encompasses various aspects of diabetes management. It places emphasis on creating modules for personalized health assistance, such as meal recommendations, activity reporting and monitoring, web-based diabetes education, and medication reminders. The research also highlights the development of a 3D educational platform that provides answers to common questions from individuals living with diabetes. This platform allows doctors to gather data on patient behavior and symptoms and intervene when patients fail to follow their regimens or experience worsening of their condition. The diabetes management system aims to determine patients' nutritional requirements, recommend appropriate meals, remind patients to take medications on time, identify factors that influence blood sugar levels, and educate patients on these factors. Additionally, the system encourages patients to engage in regular exercise, track their activities, and keep doctors updated on their condition.

### **1.1 Motivation**

For four kinds of diabetes, namely type 1, type 2, prediabetes, and gestational diabetes, proper examination of patient's condition over time, proper diet, stress management, well-planned exercise routine, and regular health care are needed to help to prevent and minimize the exposure to a long-term problem[4]. There are many applications in the market for managing type 1 diabetes, but people seem not so aware of the possible danger of prediabetes and type 2 diabetes. In the case of type 2 diabetes, an efficient online healthcare system is essential to help to reverse their diabetes. When we say efficient online healthcare system, it may lead to a question of why online? The reasons why the diabetes patients need an efficient online healthcare system are that the COVID-19 outbreak make the diabetes patients in a lot of physical restrictions such as lock down, social distancing and the patients

difficult to be in touch with the medical professionals to monitor, manage patients' daily activities and follow-up on patients' medical conditions.

So, our efficient online healthcare platform permits regular healthcare to prediabetes patients using the responsive Internet website. Diabetes patients need a suitable exercise routine for treatment. Nowadays, it's difficult to workout outside because there are still COVID-19 infections and outdoor activities are not suitable for the patients. So, we will provide exercises videos which are suitable for prediabetes.

Finally, Responsive website including the advanced data visualization for glucose level, exercise routine and processing functionalities enable optimized diabetes treatment through computational tools for real-time personalized dietary and exercise schedules, thereby allowing medical specialists to assess the health status of patients. We will build a responsive web application for diabetes patients using the FARM (FastAPI[13], ReactJS[14], and MongoDB[15]) stack. FARM stack uses FastAPI[13] as backend, ReactJS[14] as frontend, and MongoDB[15] as Database. This thesis will discuss details on how to build a website for diabetes patients using FARM stack. In addition, a 3D website has been developed to serve as a self-learning platform for people who are interested in prediabetes and type 2 diabetes.

## 1.2 Objectives

To design and implement a platform to support the monitoring, management, and treatment of patients with prediabetes mellitus, by providing exercise plans and controlled diets. The proposed platform allows patients to report their daily exercise and diet through the Internet using mobile devices or PCs/laptops through our developed application, while the physician can monitor the progress, intelligently process the data, and determine proper exercise and diet plans to individual patient. This platform is expected to serve as a useful tool in reversing diabetes, so that patients are no longer dependent on regular insulin injections and can return to live their normal life.



### 1.3 Scope of the thesis

This thesis implements a 2D and 3D web-based platform for monitoring and management of patients with prediabetes where blood glucose of the patients, their diets and planned exercises are collected daily. Required knowledge of prediabetes and Type 2 diabetes, suitable daily diet, exercise and various kinds of knowledge and activities to reverse the prediabetes which can transform into type 2 diabetes.



## Chapter 2

### Background and Literature Review

In this chapter, the theory and background pertaining to the thesis topic will be explored. The discussion begins by providing an overview of diabetes and the elements involved in self-management of the condition. Subsequently, the medical treatment of diabetes will be outlined, along with an examination of the associated health concerns. Furthermore, the chapter will delve into the concepts of eHealth and welfare technology, elucidating their definitions and significance. Additionally, the available mobile health applications designed to support the self-management of diabetes will be described.

#### 2.1 What is Diabetes?

Diabetes is a condition that hinders the body's ability to convert glucose into energy. It can occur due to the absence of insulin secretion from the pancreas, reduced insulin production, or impaired insulin effectiveness. Any of these factors can contribute to the development of diabetes. Symptoms of diabetes manifest when elevated glucose levels in the bloodstream cause glucose to also accumulate in the urine, resulting in increased urination, thirst, and dehydration. Other symptoms include fatigue, weight loss, tiredness, and susceptibility to infections. Managing diabetes revolves around maintaining optimal blood glucose levels, and self-care along with regular monitoring of glucose levels are crucial for effective diabetes management[9].

The prevalence of diabetes is increasing worldwide, with approximately 400,000 diagnosed individuals in Finland alone. The majority, about 80-90 percent, suffer from type 2 diabetes, while the other common form is type 1 diabetes[9].

##### 2.1.1 Diabetes type 1

Type 1 diabetes is characterized by an autoimmune reaction that damages the beta-cells in the pancreas, resulting in insufficient insulin production. Eventually, the pancreas ceases to produce any insulin at all, leading to the

onset of diabetes symptoms and a reliance on externally administered insulin. The development of type 1 diabetes is influenced by both genetic factors and environmental causes, such as viral infections[10]. Many individuals diagnosed with type 1 diabetes often experience ketoacidosis, a condition where the body lacks insulin and cannot utilize glucose for energy, despite elevated glucose levels in the body. Instead, the body resorts to using adipose tissue, leading to the accumulation of ketoacids and subsequent acidosis when blood pH drops below 7.35. Symptoms of ketoacidosis include abdominal pain, nausea, increased urine production, and thirst. Without treatment, dehydration, decreased blood pressure, elevated heart rate, the smell of acetone on the breath, and abnormal breathing may occur. In severe cases, ketoacidosis can be fatal[10].

The treatment approach for type 1 diabetes focuses on normalizing blood glucose levels to reduce long-term complications, increase life expectancy, and enhance quality of life. Insulin therapy is essential for managing the disease and can be administered through multiple daily injections or an insulin pump. Monitoring blood glucose levels throughout the day is also necessary, which can be achieved by measuring glucose levels from the fingertip or using continuous glucose monitoring devices. The goal is to identify the most suitable treatment approach for each individual with type 1 diabetes[11].

### 2.1.2 Diabetes type 2

The diagnosis of type 2 diabetes is often influenced, at least in part, by hereditary factors. This condition typically develops gradually over an extended period. Individuals with type 2 diabetes may not exhibit symptoms initially, but as the disease progresses, symptoms may include increased thirst, frequent urination, fatigue, slow wound healing, and recurring infections. Insulin production in the pancreas gradually diminishes in this condition, reaching a point where the amount of insulin secreted is insufficient to maintain desirable blood glucose levels. Insulin resistance, characterized by the body's reduced ability to effectively utilize insulin, is another characteristic of type 2 diabetes. The presence of excess adipose tissue in

the body is closely associated with the development of insulin resistance. While the body initially compensates by increasing insulin secretion to regulate glucose levels, as the disease advances, insulin production often slows down, leading to hyperglycemia and the onset of symptoms[9].

Treatment primarily involves implementing lifestyle changes, such as adopting a healthy diet, losing weight, and engaging in regular exercise. The goal is to maintain a stable and acceptable blood glucose level, which enhances quality of life and supports life expectancy comparable to the corresponding age group. Long-term HbA1c levels should be kept below 53 mmol/l. Oral diabetes medications like Metformin, which affects liver glucose production, can be used to help regulate blood glucose levels. If the combination of Metformin and lifestyle modifications is insufficient, other oral diabetes medications may be added to the treatment regimen. If adequate control is still not achieved, insulin therapy can also be considered as an additional treatment option[11].

### 2.1.3 Gestational diabetes

Gestational diabetes refers to the occurrence of elevated blood glucose levels during pregnancy and is diagnosed using a glucose tolerance test. In Finland, all expectant mothers undergo screening for gestational diabetes between weeks 24-28 of pregnancy. However, if a mother is at a higher risk of developing gestational diabetes due to factors such as being overweight or having a family history of type 2 diabetes, the glucose tolerance test may be conducted earlier, between weeks 12-16, and repeated between weeks 24-28. The glucose tolerance test involves fasting for 12 hours, followed by measuring the fasting blood glucose level. Then, the individual consumes a drink containing 75 grams of glucose, and blood glucose levels are measured after one hour and two hours. If any of the measurements exceed the predetermined thresholds, gestational diabetes is diagnosed. In this test, blood glucose levels are assessed using blood samples drawn from a vein rather than a fingertip measurement.

During pregnancy, the additional weight and hormonal changes caused by the placenta can increase insulin resistance, necessitating higher levels of insulin to

maintain acceptable blood glucose levels. The treatment for gestational diabetes typically involves nutritional therapy, and in some cases, oral medications or insulin treatment may be necessary. The specific treatment approach is determined on a case-by-case basis. After giving birth, blood glucose levels generally return to normal. However, approximately one-third of mothers who become pregnant again may experience a recurrence of gestational diabetes. Additionally, gestational diabetes increases the risk of developing type 2 diabetes. Therefore, early prevention and patient education are crucial. The glucose tolerance test is repeated after childbirth, with an earlier test performed if the expectant mother required insulin during pregnancy, or a test conducted one year after birth if lifestyle management was sufficient[12].

## **2.2 The psychological dimensions of diabetes**

According to Jon Haug, a psychology specialist, there are specific psychological challenges associated with diabetes that require careful consideration and appropriate treatment to enhance the individual's overall quality of life[16]. Haug explains that calculating insulin dosages can be highly complex, and it becomes even more complicated when emotional factors influence glucose levels and insulin requirements. In his article, Haug highlights the prevalence of eating disorders among individuals with diabetes, particularly noting that young girls with diabetes are at a higher risk, being 3-4 times more likely to develop an eating disorder compared to girls without diabetes. These individuals may intentionally administer insufficient insulin as a means of promoting weight loss. However, this behavior can lead to severe consequences such as kidney failure and vision loss[16]. Haug emphasizes that the fear of complications can be detrimental, causing anxiety and fear in individuals with diabetes. He also points out that doctor appointments often allocate insufficient time to address the psychological well-being of patients[16].

## **2.3 mHealth**

The Global Observatory for eHealth (GOe) of the World Health Organization (WHO) defines mHealth as supporting public health practices and medical issues with the usage of mobile devices[17]. mHealth applications can function as instruments. to encourage enhance treatment, behavior change, and promote strict adherence to

schedules by personalizing goals and tasks, notifications, and incorporating gamification elements. These applications can assist in overcoming memory lapses and provide educational resources. By offering disease and treatment-related education, they can be valuable in facilitating communication between patients and healthcare providers during shared decision-making processes[18].

In the article "What is the clinical value of mHealth for patients?", mHealth applications are categorized into four groups as follows[18]:

- Supporting clinical decision-making and diagnosis.
- Improving clinical outcomes by enhancing patient adherence and compliance with established treatment pathways through behavior change.
- Acting as individual digital health solution.
- Chiefly delivering diabetes-related education.

The authors anticipate that mHealth technologies can serve as tools for patients to manage their own health, integrated into digital care plans created by their healthcare providers[18]. Many individuals rely on digital devices to monitor the symptoms when they suspect an illness. However, the accuracy may be vary depending on the urgency of the situation and the specific symptoms being assessed, such as those affecting the knees and hands. Emergency cases generally yield higher accuracy compared to non-emergency cases, and the use of symptom checker applications may lead to an increase in unnecessary non-emergency consultations[18].

Behavior change-focused applications have demonstrated improvements in glycemic control for individuals with diabetes, optimal weight loss, and long-term treatment adherence for chronic illnesses. Functionalities such as reminders, customizable medication regimes, and activity logs have received positive feedback[18]. Applications functioning as digital therapeutics support self-management in treatments such as cognitive-behavioral therapy, with features like mood and symptom tracking. While these applications can enhance self-management, they currently do not replace face-to-face therapy[18].

Educational applications can provide patients with a better understanding of their disease, leading to improved decision-making and communication with healthcare providers. Patients can express their concerns more effectively and feel empowered in their relationships with healthcare providers. In diabetes management, self-management strategies are crucial for improving quality of life through maintaining normal blood sugar levels. Mobile applications are increasingly popular among individuals with diabetes for managing their condition, and mHealth technology has the potential to enhance their quality of life[19]. This is particularly evident in type 2 diabetes, although results for type 1 diabetes are more varied. Factors such as age and intervention duration have been linked to the effectiveness of mHealth self-management tools. Wang et al. explain that there is a significant improvement in HbA1c levels in adults but not in the youth group they analyzed. Moreover, interventions lasting longer than six months resulted in a significant decrease in HbA1c levels, whereas shorter interventions did not produce the same effect. The study concludes that longer intervention durations yield better glycemic control[19]. Conway et al. conducted a study examining user preferences regarding mHealth applications for diabetes[20]. The majority of participants expressed the view that patient education would be beneficial, despite this feature being sparsely implemented. Furthermore, younger individuals exhibited greater enthusiasm for integrating social media into these applications compared to older users. The study also highlighted the potential of mHealth applications in facilitating web-based interventions and enhancing accessibility, with many users preferring them for diabetes management. However, factors such as age, gender, and diabetes type influenced individuals' preferences for using mHealth applications. Notably, women over 56 years of age were significantly less inclined to prefer diabetes management applications. It is crucial to avoid excluding specific sub-groups within the population. The study concluded by emphasizing the vast potential of mHealth systems to empower patients, expand choices, improve outcomes, and offer services in a different and sustainable manner[20].

## 2.4 Existing Works

Examining existing solutions and their reception provides valuable insights into the effectiveness of different functionalities. The Play Store was explored to review ratings and rankings of various diabetes applications, ranging from simple manual glucose input options to more complex ones that include features such as Bluetooth connectivity, food tracking, bolus calculation, and activity monitoring. Among the applications downloaded and tested were, mySugr, diasend, and Diabetes:M. The ratings, reviews, and main functionalities were gathered from the PlayStore.

### 2.4.1 mySugr

Rating: 4.7

- Negative reviews: Users expressed the need to upgrade to the premium version for proper testing, desired compatibility with activity trackers, found the sounds annoying, and considered the monster theme childish.
- Positive reviews: Users appreciated the organized interface and ease of tracking food, and found the bolus calculator to be very useful.
- Main functionalities: Allows logging of medications, carbohydrates, activity, moods, emotions, and more. Provides estimated HbA1c and glucose trends. Features a bolus calculator and the ability to generate shareable reports.
- Limitations: Certain features require a premium account.
- Unique functionalities: Offers feedback based on trends, tracks mood and emotions, and includes achievements and a bolus calculator.

### 2.4.2 Diabetes:M

- Rating: 4.5
- Negative reviews: Criticisms included the lack of a Norwegian language option and the failure to save login data if the phone runs out of battery.
- Positive reviews: Users found the app reliable and precise.
- Main functionalities: Enables report generation for sharing, displays trends, food intake, and activity logs, and supports automatic input.
- Limitations: Many useful features require a premium account, and users cannot choose their own safe glucose levels.



- Unique functionalities: Includes a bolus advisor and a comprehensive food database for logging meals.

#### 2.4.3 diasend

- Rating: 2.8
- Negative reviews: Users expressed dissatisfaction with the absence of an option to upload CSV files.
- Positive reviews: Not applicable.
- Main functionalities: Allows data sharing with a clinic, features trend graphs, supports automatic input from compatible glucose devices, and allows users to set their own safe glucose levels.
- Limitations: Lacks documentation, making it somewhat challenging to use.
- Unique functionalities: Not specified.

Based on the reviewed applications, no single application encompasses all the functionalities desired by people with Type 1 Diabetes Mellitus (T1DM) according to the literature review or as indicated by Play Store reviewers. Nevertheless, valuable understandings were acquired concerning specific functionalities that could be integrated and assessed. Features like a bolus calculator and estimated HbA1c were positively received. The significance of user-friendliness was also emphasized, with stability, navigation, and language identified as aspects requiring enhancement. It is noteworthy that there is currently no existing application capable of preventing or reversing prediabetes, a condition that may progress to Type 2 diabetes.

## Chapter 3

### Methodology

#### 3.1: Web development

For web development, this thesis will use Visual Studio Code[21] for implementation and installation. The installation and implementation will be demonstrated in the Visual Studio code's terminal and PowerShell. The main components of this thesis's web development include React[14], FastAPI[13], MongoDB[15], and Firebase[22].

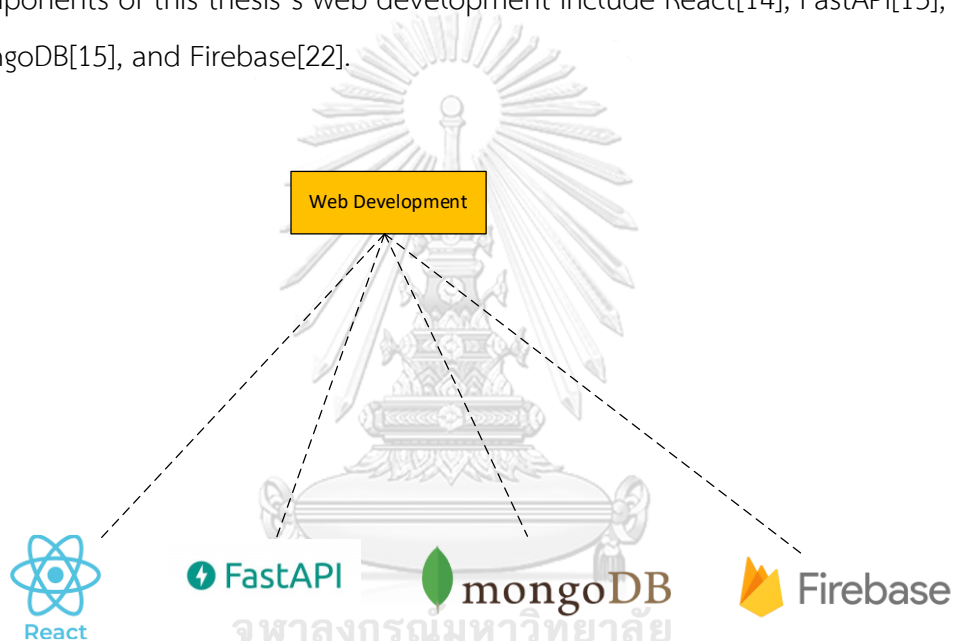


Figure 1: Main components of the thesis's web development

##### 3.1.1 Frontend (ReactJS)

This sub-section will demonstrate details about setting up the environment for ReactJS[14] development. This will include installing NodeJS[23] and ReactJS.

###### 3.1.1.1: NodeJS

Before we start installing ReactJS, we need to install NodeJS[23].

NodeJS can be downloaded from [23].

###### 3.1.1.2: ReactJS

After we finish installing and setting up NodeJS, we can start implementing ReactJS. First, we will create the react app using 'npm

create-react-app frontend' where npx stands for node package execute, create-react-app creates a single page web page and frontend is the folder name where files and folders related to react will be kept. Installation steps of reactJS app can be seen in Figure 2.

```
PS D:\React\ThesisInstallation> npx create-react-app frontend
```

```
PROBLEMS OUTPUT TERMINAL DEBUG CONSOLE
PS D:\React\ThesisInstallation> npx create-react-app frontend
npx: installed 67 in 5.858s

Creating a new React app in D:\React\ThesisInstallation\frontend.

Installing packages. This might take a couple of minutes.
Installing react, react-dom, and react-scripts with cra-template...
```

```
Directory: D:\React\ThesisInstallation\frontend

Mode                LastWriteTime         Length Name
----                -
d-----           2/21/2022   1:47 PM             node_modules
d-----           2/21/2022   1:46 PM             public
d-----           2/21/2022   1:46 PM             src
-a-----          10/26/1985   3:15 PM             310 .gitignore
-a-----           2/21/2022   1:47 PM        504132 package-lock.json
-a-----           2/21/2022   1:47 PM             811 package.json
-a-----          10/26/1985   3:15 PM             3359 README.md

PS D:\React\ThesisInstallation\frontend>
```

Figure 2: ReactJS installation

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CHULALONGKORN UNIVERSITY

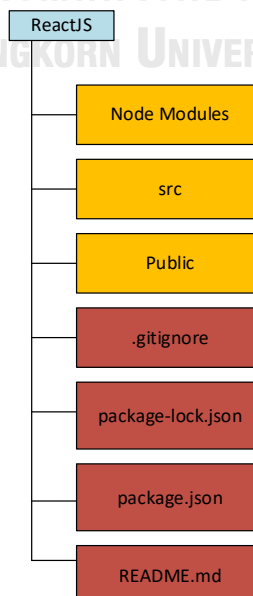


Figure 3: Structures of ReactJS Application

The structures of the ReactJS app can be seen in Figure 3. The first folder is the “Node modules” folder where all dependencies and sub-dependencies defined by the “package.json” file exist. The folder name “src” includes the main javascript component of the react, App.js, and CSS. In “public”, there is an “index.html” file inside which App.js is executed. In addition to it, we usually store the photo or the file that we will need to make public or show to the user in the “public” folder. The file “.gitignore” is the file by the git to differentiate the files whether to be updated or ignored while pushing the code to GitHub. The file “package-lock.json” includes an identical dependency tree installed in the “node modules” folder. “package-lock.json” gives the developers the chance to work in a team and create a local app with the same dependency version. Required dependencies and scripts are in the “package.json” file. The “README.md” file gives instructions for developers to explore the react app.

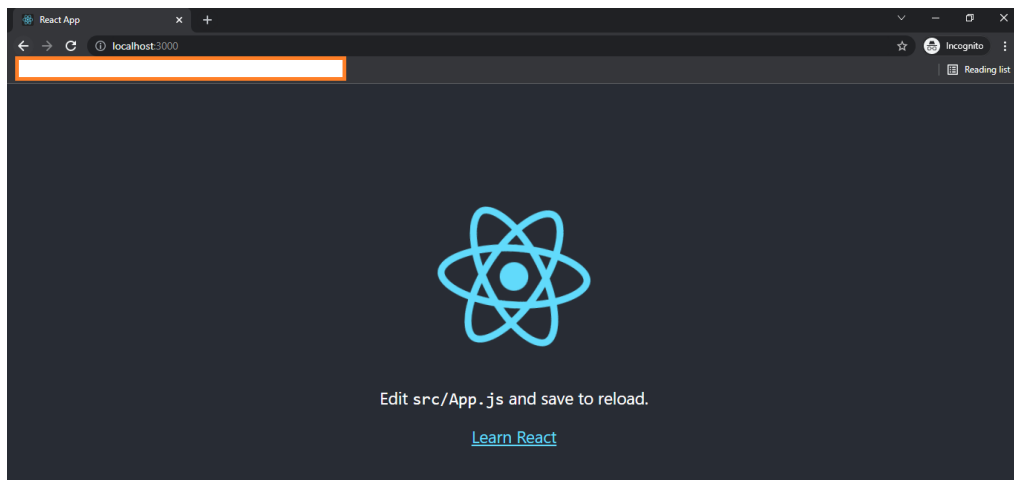
After we’ve finished the installation of ReactJS, we can start the react app. We can start the app by using the command – npm start as shown in Figure 4 (a). After we executed the npm start command, the starting process can be seen in Figure 4 (b) and we can access the single-page website by localhost on port 3000 as shown in Figure 4 (c).

```
PS D:\React\ThesisInstallation> cd .\frontend\  
PS D:\React\ThesisInstallation\frontend> npm start
```

(a)

```
PROBLEMS OUTPUT TERMINAL DEBUG CONSOLE  
modules by path ./src/ 18.1 KiB  
modules by path ./src/*.css 8.82 KiB  
./src/index.css 2.72 KiB [built] [code generated]  
./node_modules/css-loader/dist/cjs.js??ruleSet[1].rules[1].oneOf[5].use[1]!./node_modules/postcss-loader/dist/cjs.js??ruleSet[1].rules[1].oneOf[5].use[2]!./node_modules/source-map-loader/dist/cjs.js!./src/index.css 1.37 KiB [built] [code generated]  
./src/App.css 2.72 KiB [built] [code generated]  
./node_modules/css-loader/dist/cjs.js??ruleSet[1].rules[1].oneOf[5].use[1]!./node_modules/postcss-loader/dist/cjs.js??ruleSet[1].rules[1].oneOf[5].use[2]!./node_modules/source-map-loader/dist/cjs.js!./src/App.css 2 KiB [built] [code generated]  
modules by path ./src/*.js 5.68 KiB  
./src/index.js 1.79 KiB [built] [code generated]  
./src/App.js 2.5 KiB [built] [code generated]  
./src/reportWebVitals.js 1.39 KiB [built] [code generated]  
./src/logo.svg 3.61 KiB [built] [code generated]  
webpack 5.69.1 compiled successfully in 14670 ms
```

(b)



(c)

Figure 4: Starting ReactJS App (a) "npm start" (b) Starting ReactJS App (c) Accessing ReactJS app after starting.

We developed our frontend pages into two web page types as shown in Figure 5. The first type is the web page type where the user or patient will need to be authenticated and the second type is the web page where you don't need to be authenticated. For the publicly available pages, we share information about Prediabetes and Type 2 Diabetes, food, exercise, stress management, and about the website. But for private pages, users need to log in with their username and password because the diet, exercise, and blood sugar data will depend on each diabetes patient.

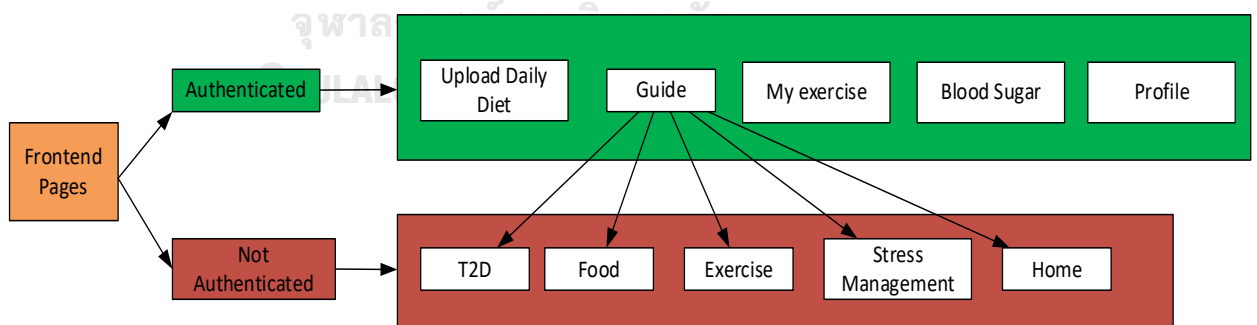


Figure 5: Functions of Frontend (ReactJS)

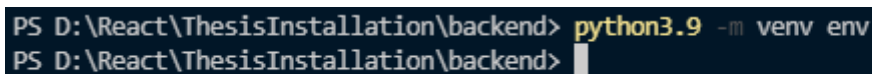
### 3.1.2 Backend (FastAPI)

We will use FastAPI[13] as the backend. FastAPI is a high-performance, modern web framework for building Application Program Interfaces with Python version 3.6+.

FastAPI has a user-friendly GUI for testing the APIs. The key features of FastAPI are extreme performance, quick and easy to code, fewer bugs or errors, support of clear and simple documentation, and being standards-based. The requirement of FastAPI installation is Python 3.6[24] or above and pip[25]. Before we start the installation of FastAPI, the computer or host we will implement FastAPI is already installed with Python 3.9. We will not demonstrate how to install Python in this thesis. We will install FastAPI from visual studio code.

To install FastAPI, we will create a folder called the backend. Inside the backend folder, we will create a new environment for our project using the command “python3.9 -m venv env” as shown in Figure 6(a). We can see the new environment in “env” folder as in Figure 6(b). We will activate the environment in ‘env/scripts/’ with the script name “activate.bat” as seen in Figure 6(c). After activating the environment, we will install FastAPI and uvicorn by using “pip install fastapi” and pip install "uvicorn[standard]”.

After installation is finished, we can start the FastAPI by using the command “python3.9 -m uvicorn main:app --reload”. We put simple hello world output in the main.py file as shown. A simple hello world code and starting FastAPI is demonstrated in Fig. 3.7. One of the benefits in using FastAPI is that FastAPI provides an interactive API documentation provided by Swagger UI [35]. As shown in Figure 8, we can access the API and get the “hello world” output by executing “get” method in the API.



```
PS D:\React\ThesisInstallation\backend> python3.9 -m venv env
PS D:\React\ThesisInstallation\backend> |
```

(a)



```
PS D:\React\ThesisInstallation\backend> ls
```

```
Directory: D:\React\ThesisInstallation\backend
```

Mode	LastWriteTime	Length	Name
d-----	2/22/2022 10:51 PM		env

(b)

```
PS D:\React\ThesisInstallation\backend\env\Scripts> .\activate.bat
```

(c)

Figure 6: Installing FastAPI (a) Starting FastAPI, (b) Environment folder named “env”, and (c) Activating environment

```
PS D:\React\ThesisInstallation\backend\env> python3.9 -m uvicorn main:app --reload
INFO: Will watch for changes in these directories: ['D:\\React\\ThesisInstallation\\backend\\env']
INFO: Uvicorn running on http://127.0.0.1:8000 (Press CTRL+C to quit)
INFO: Started reloader process [22816] using statreload
INFO: Started server process [23516]
INFO: Waiting for application startup.
INFO: Application startup complete.
INFO: 127.0.0.1:51074 - "GET /docs HTTP/1.1" 200 OK
INFO: 127.0.0.1:51074 - "GET /openapi.json HTTP/1.1" 200 OK
WARNING: StatReload detected file change in 'main.py'. Reloading...
```

(a)

```
main.py x
React > ThesisInstallation > backend > env > main.py > root
1 from fastapi import FastAPI
2
3
4 app = FastAPI()
5
6 @app.get("/")
7 async def root():
8     return {"message": "Hello World"}
```

(b)

Figure 7: Starting FastAPI (a) Command to start FastAPI and (b) Simple “Hello World” program

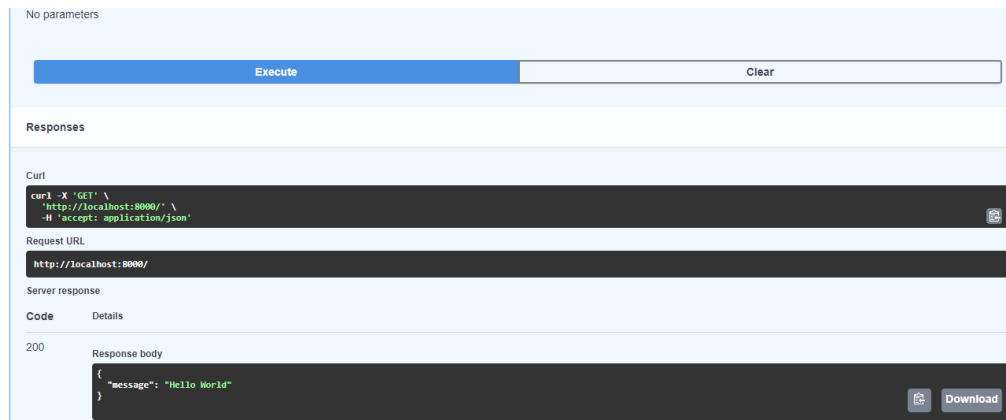
FastAPI 0.1.0 GA33

/openapi.json

default

GET / Root

(a)



(b)

Figure 8: FastAPI Interactive API Docs (a) FastAPI GUI, and (b) Executing simple “Get”

The main functions of backend – FastAPI in our website platform are authentication, creating an API for CRUD (create, read, update, and delete), connecting between the database and react js-frontend, and defining the data structure of the website. As our website is intended for multiple users or patients, we will have different username and password. To be able to handle username and password or authentication, we will implement it in FastAPI. Next, we will define the database (MongoDB)’s database structure in FastAPI. For example, we define username to be the string data type, user’s age to be the integer data type, etc. We also define APIs for ReactJS(frontend) to create, read, update, and delete the data from MongoDB (database).

Figure 9 shows the APIs created by our FastAPI backend. They are register, login, create\_bloodsugar, get\_bloodsugar, create\_myexercise, get\_myexercise, and update\_myexercise. Register API is used when the new user registers to the website. The API ‘/register’ is used to register for new user in the frontend. The API ‘/login’ is used to login to the website with username and password in the way that check whether the username and password typed by the user is matched or not. ‘/api/create\_bloodsugar/username’ API is used to put the blood sugar data with the username to MongoDB database. ‘/api/get\_bloodsugar/username’ serves as an API between frontend and database to load the blood sugar data from MongoDB. ‘/api/create\_myexercise/username’ is used to create the exercise data such as minute of the exercise, intensity, and the date with the username in database by the frontend. ‘/api/get\_myexercise/username’ is used to retrieve the data from MongoDB



by frontend. ‘/api/update\_myexercise/username/exercise/intensity/ date/done’ is used to update the exercise data by the frontend to the database.

default	
GET	/ Read Root
POST	/register Create User
POST	/login Login
POST	/api/create_bloodsugar/{username} Post Bloodsugar
GET	/api/get_bloodsugar/{username} Get Bloodsugar
POST	/api/create_myexercise/{username} Post Myexercise
GET	/api/get_myexercise/{username} Get Myexercise
PUT	/api/update_myexercise/{username}/{exercise}/{intensity}/{date}/{done} Update Myexercise

Figure 9: APIs for the website platform

### 3.1.3 Database (MongoDB)

This thesis will use MongoDB[15] as the main database. In this section, we will explain how to install MongoDB. First, we can sign-in in[15] to create a database. After sign-in and setting up an account, the cluster will be created as shown in Figure 10. Figure 11 shows the cluster after creating. To be able to connect from our FastAPI (backend), we have to define an access list. To be able to access from our backend, we can put the ip address of backend or every IP address (for experimental purpose only) to be accessed as shown in Figure 12. The URL to connect the FastAPI (backend) and the database (MongoDB) can be seen in Figure 13.

VERSION	REGION	CLUSTER TIER	TYPE	BACKUPS	LINKED REALM APP	ATLAS SEARCH
5.0.6	AWS / Singapore (ap-southeast-1)	M0 Sandbox (General)	Replica Set - 3 nodes	Inactive	None Linked	Create Index

Figure 10: Creating MongoDB cluster.

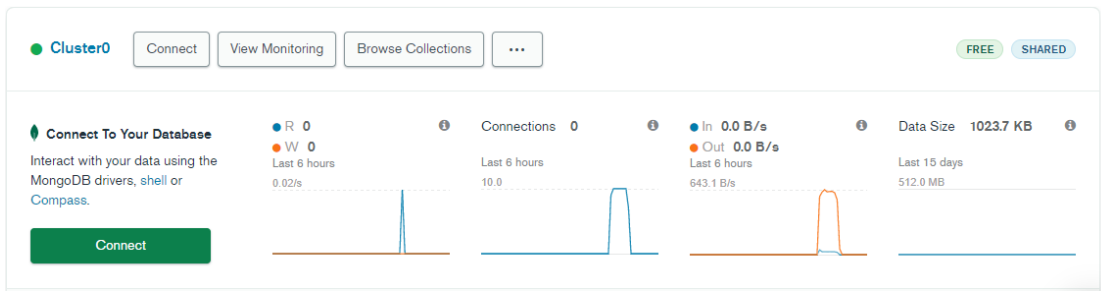


Figure 11: MongoDB Database Cluster

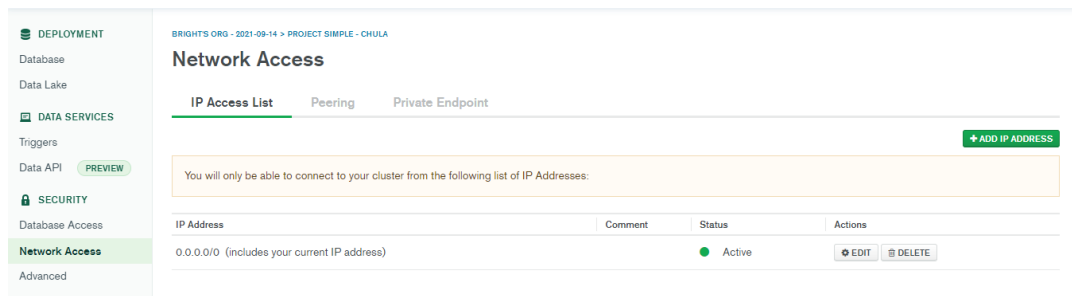


Figure 12: Defining IP Access List

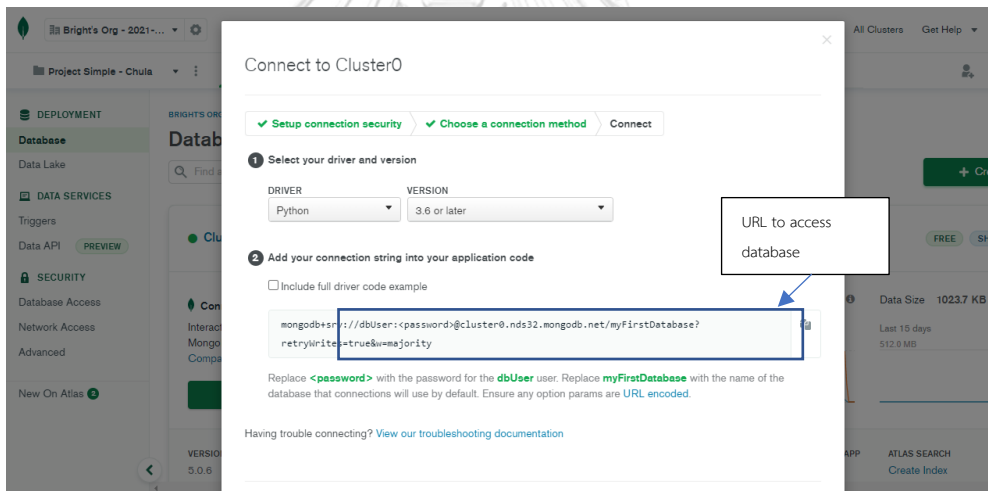


Figure 13: URL to connect with Backend.

The main function of MongoDB is to store the data of the website platform such as username, name, age, etc. Figure 14(a) shows the example data of the user information when the user is registered. We can see that username, real name, surname, dob, gender, email and password are defined as string and weight, and height are defined as integer. Figure 14(b) shows how the blood sugar data or glucose level is kept in the database. There is username, meal type, time, date, and blood sugar data in glucose data. Figure 14(c)

shows how the exercise data is stored. Exercise data includes minutes, intensity, and date.

```

>
_id: ObjectId("61b57c79b7ad683f27e082c9")
username: "testtest"
real_name: "test"
surname: "test"
dob: "2021-12-01"
gender: "female"
weight: 1
height: 1
tel: "1"
email: "test@example.com"
password: "$2b$12$0yFcJ.u7sksmWdNew1UKP.ERS0SEb9muyF9gzx3032Qp2uHF0Mwa"
confirmpassword: null

```

(a)

```

_id: ObjectId("616520c2ab752deaa6f4b7ca")
username: "bright"
mealtype: "Before breakfast"
time: "13:44"
date: "2021-10-12"
bloodsugar: 110

_id: ObjectId("616549a292fcd81325a59423")
username: "bright"
mealtype: "Before breakfast"
time: "15:39"
date: "2021-10-12"
bloodsugar: 100

```

(b)

QUERY RESULTS 1-4 OF 4

```

_id: ObjectId("620e0645ac28aa448b8e774b")
minute: "30"
intensity: "moderate"
date: "2022-02-17"

_id: ObjectId("620e06b4ac28aa448b8e774c")
minute: "20"
intensity: "light"
date: "2022-02-15"

```

(c)

Figure 14: MongoDB database datastore (a) user information, (b) blood sugar data, and (c) exercise data

### 3.1.4 Image Database (Firebase)

Firebase[22] is a Google platform for developing web and mobile applications. This thesis uses firebase to store the image from the user. This section will discuss starting and implementing firebase. After we've logged in to the firebase in[22], we can press "Add Project" to start a project as shown in Figure 15. After we've started a project, we will name our project as shown in Figure 16(a). Next, we can choose whether to enable Google analytics. In step 3, we can choose the default firebase account to finish creating the project. After we've finished creating the project, we can see the firebase console. The steps of creating a firebase can be seen in the following.

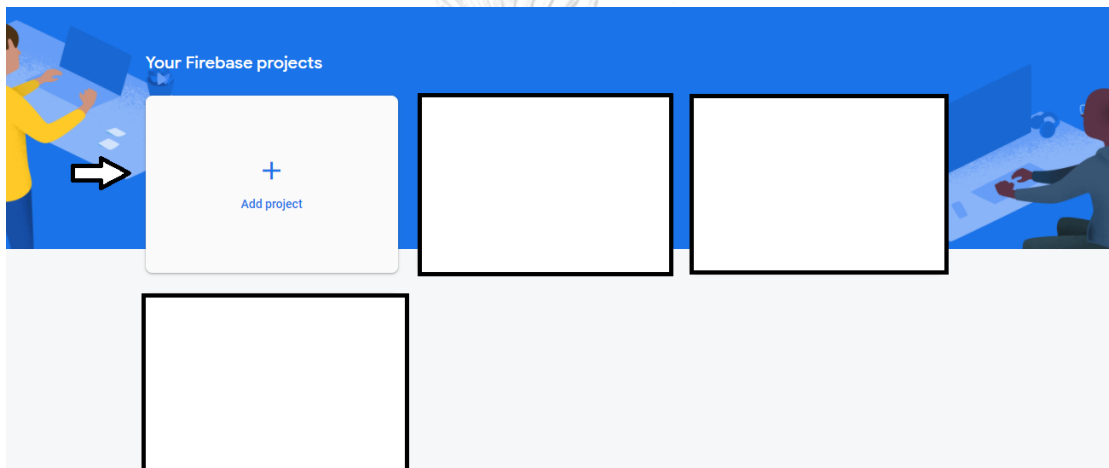
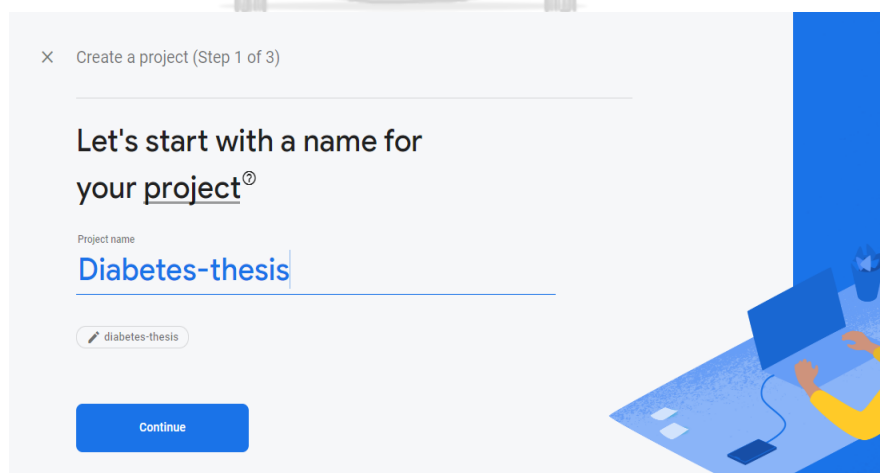
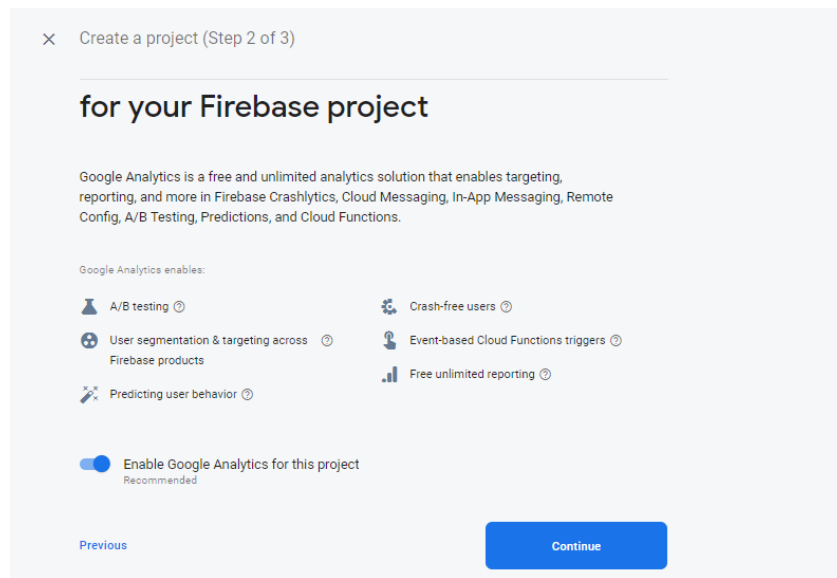


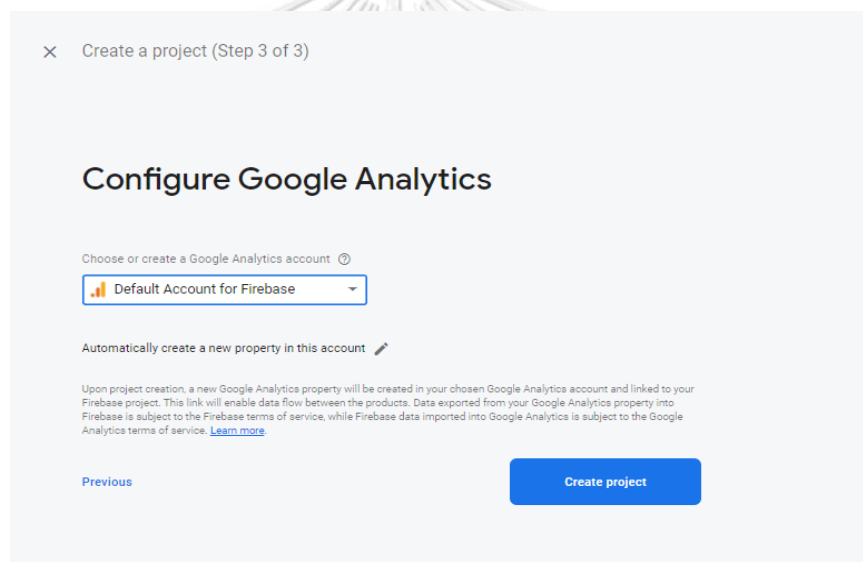
Figure 15: Firebase "Add Project"



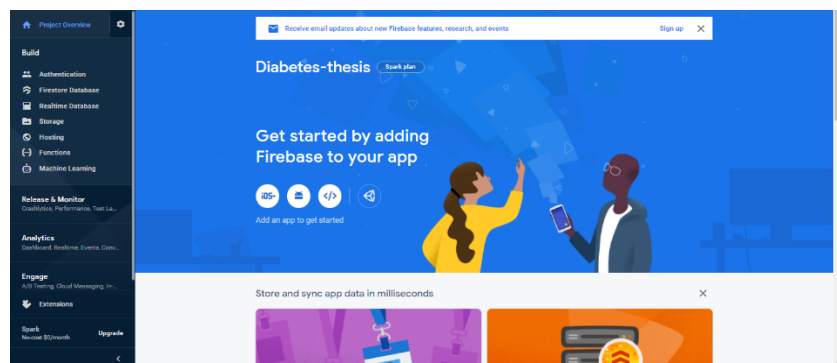
(a)



(b)



(c)



(d)

Figure 16: Firebase setup (a) Naming the Project, (b) Enable Google Analytics, (c) Choosing Google Analytics account, and (d) Completing firebase set-up

The reason we are using firebase for storing images is that the complexity of configuration for storing image is lower in firebase than MongoDB. In addition, we don't need to use FastAPI (backend) API to connect with ReactJS and firebase. Firebase provides backend service as well. As shown in Figure 17, the username with the name, date, mealtype, and avatar (image URL) are stored in the firebase's firestore database. The actual images are stored in firebase's storage as shown in Figure 18.

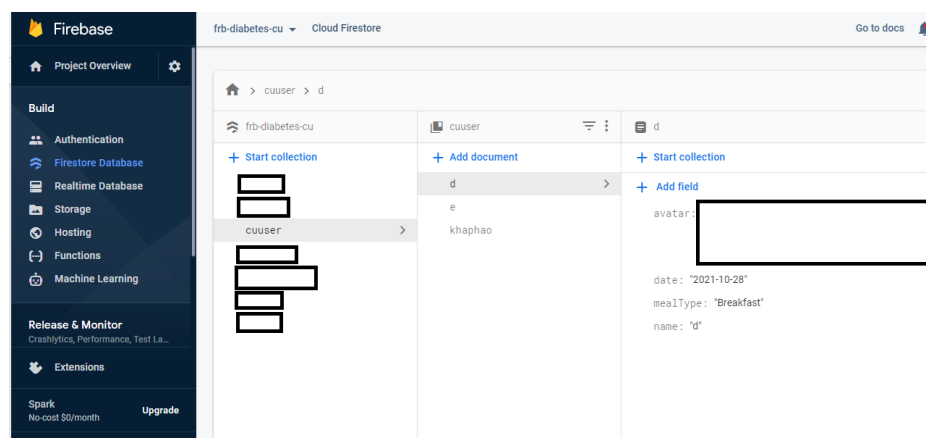


Figure 17: Firebase's firestore database

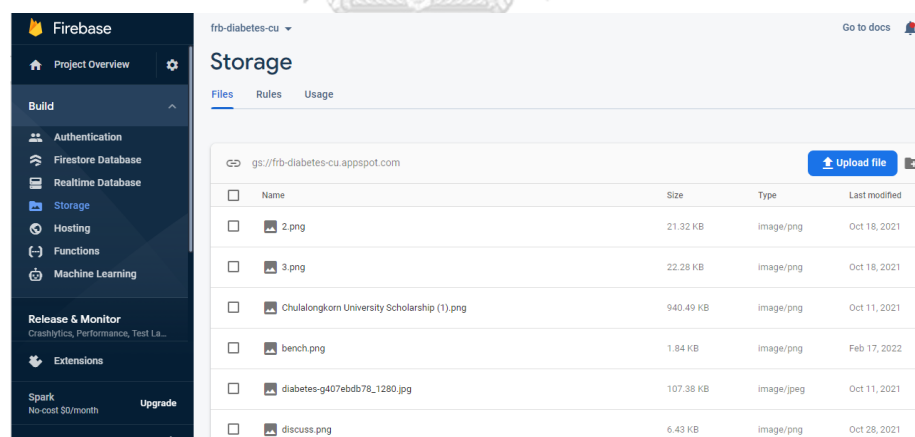


Figure 18: Firebase's storage

## 3.2 3D Web Application Development

### 3.2.1 Blender[26]

In recent years, alongside the successful implementation of films and other projects, the capabilities of the Blender program in the realm of 3D design have witnessed significant growth. Blender, as a robust technological instrument, aids 3D designers by

offering them complete freedom of action. The official and public regulation of Blender prioritizes stimulating user-designers, enabling them to unleash their full potential and become co-authors in Blender's development. This dynamic fosters the potential for a mutually prosperous relationship between the open-source Blender system and designers. The selection of Blender stems not only from its free license but also from the following advantages provided to users:

- Blender is released under the GNU General Public License (GPL), ensuring it is free software.
- Users have the option to reprogram the software positively and distribute it in new forms.
- Blender is compatible with various operating systems, including Windows, Linux, Mac, and FreeBSD.
- Users receive responsive support and maintenance, and they can actively contribute through comments and suggestions.
- New versions of Blender are released relatively quickly, allowing for swift integration of added innovations into design practices.
- Blender utilizes the Python programming language.

Blender will serve as a valuable tool for the creation and design of objects to be employed within the scenes of the learning center's 3D web application. The 3D objects created using Blender will be imported into the Unity editor software for integration into the 3D learning center's scene.

### 3.2.2 Unity[27]

Unity, a multi-platform game engine, is commercially available and is used for 2d and 3D video games production accompanied by visualizations and non-game interactive simulations. Moreover, Unity is one of the popular engines for games that is easily accessible, and in the current epoch is communal amid the developers due to its ease, flexibility, efficiency, and power consumption. Multiple tools have been featured in the Unity Editor that permits rapid iteration and editing in the cycles of development comprised of smart previews

play mode in real-time. Furthermore, Unity is offered on Mac, Linux, and Windows. It contains an artist-friendly range of tools for immersive designing and game worlds, in addition to a strong developer tools suite for implementing high-performance gameplay and game logic. Moreover, Unity supports 3D and 2D development with functionalities and features for the specific needs that are further focused on categories.

The Unity software will be employed as the primary tool for constructing and designing immersive scenes within the 3D web-based learning platform dedicated to diabetes education. Upon the completion of crafting the 3D scenes for the system, it became imperative to securely host said scenes within the cloud infrastructure, enabling seamless accessibility and utilization for end-users. Required static files for web deployment can be exported by Unity by exporting the scenes as WebGL platform.

### 3.2.3 Hosting 3D Application[22]

For hosting the 3D application, Firebase will be served as the database for storing 3D and as web hosting. To host 3D app on Firebase, firstly we need to create a project in Firebase. Firebase project can be created as shown in Figure 19. After creating the project, we will have to register our application in the project as shown in the following figure.

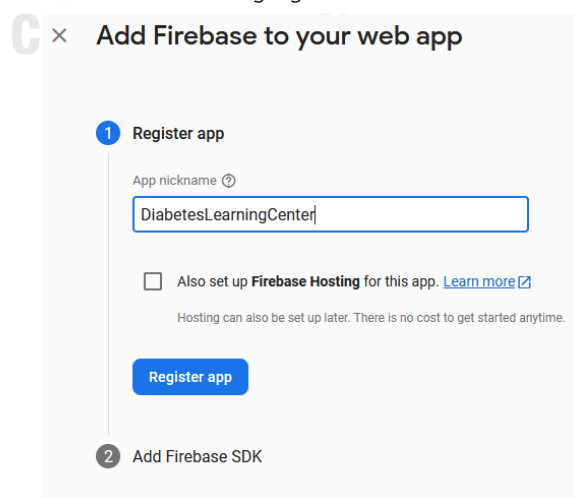


Figure 19: Registering Application in Firebase



And then we need to install the required module bundler such as webpack or rollup by running the following command.

```
C:\Users\Public\DiabetesLearningCenter>npm install firebase|
```

Figure 20: Installing required module bundler for Firebase

To host the 3D website with Firebase Hosting, Firebase CLI is required.

```
C:\Users\Public\DiabetesLearningCenter>npm install -g firebase-tools |
```

Figure 21: Installing Firebase CLI

After that 3D application can be deployed by navigate to or create a root directory for 3D web application. In the root folder, run the following command to sign in to Google.

```
C:\Users\Public\DiabetesLearningCenter>firebase login
```

Figure 22: Logging into Google

Initiate the project by running the following command.

```
C:\Users\Public\DiabetesLearningCenter>firebase init
```

Figure 23: Initiate project in Firebase

Now is ready to deploy the web application. Before that, all static files exported by Unity software must be put in web application's deploy directory ("the default is public"). Then the following command is used to deploy the application.

```
C:\Users\Public\DiabetesLearningCenter>firebase deploy --only hosting:diablearningcenter
```

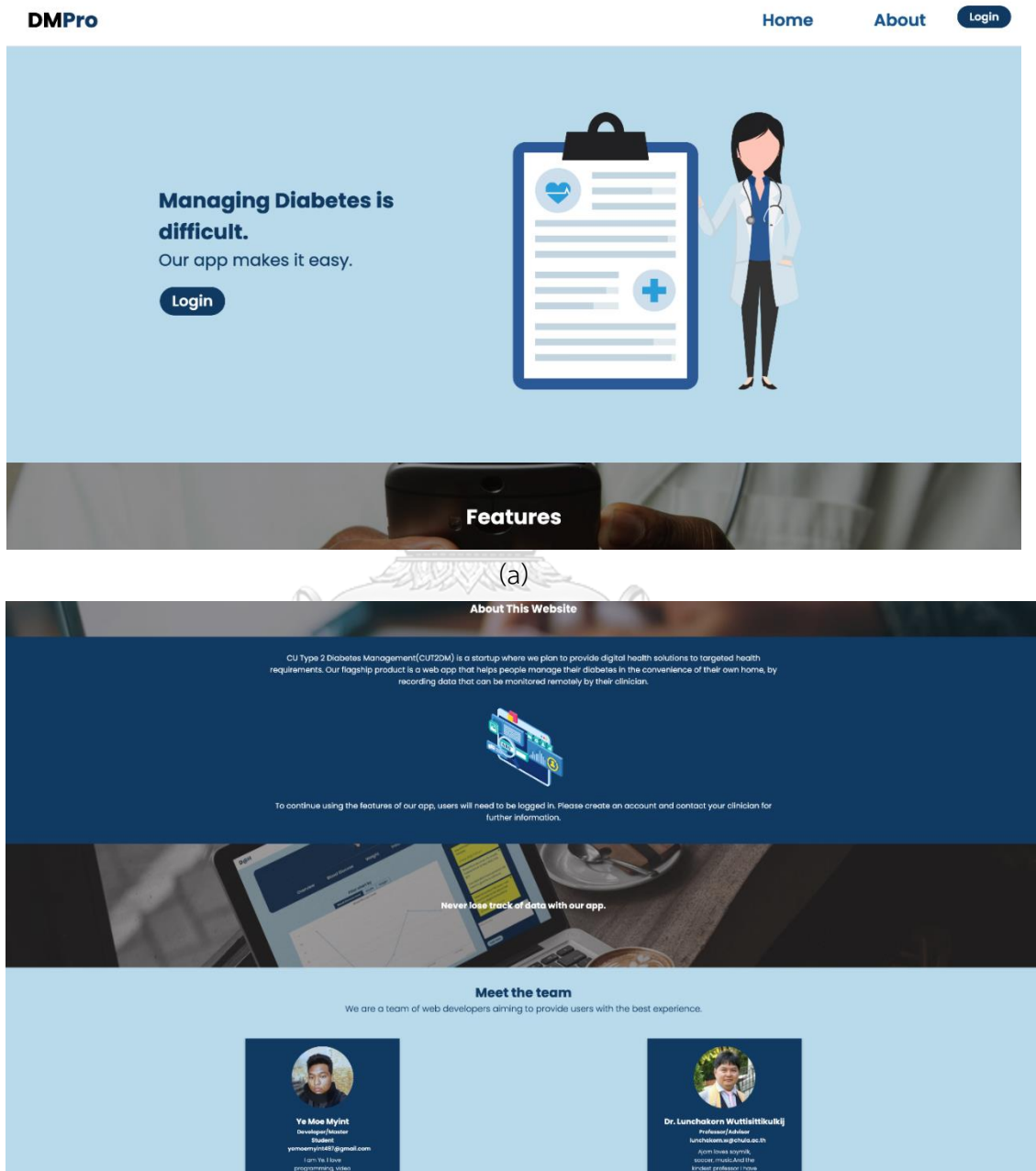
Figure 24: Deploying web application

## Chapter 4

### Online 2D and 3D self-learning system for prediabetes patients

#### 4.1 2D web application system

The landing page of the frontend can be seen in Figure 25. The landing page provides the user or patient with the general idea and objective of platform.



(b)

Figure 25: Landing page (a) Main page and (b) Website Page

#### 4.1.1 Glucose (Blood Sugar) Measuring

The functionality that is first presented on the main page is the Glucose measuring section Figure 26(a). This page allows users to register the time, level of glucose as well as ticking of medications. The idea is that medications can be adjusted and personalized in settings to show the appropriate medication. Using the arrows next to the current date, the user can browse through different days to see the exact time and the glucose level measurement appearing in the list below the "blood sugar measurements for today" text. The user saves the data by tapping the check mark and the registered reading and time is added to the list below.

1. Choose the meal type

2. Select the time you

3. Put your blood sugar level

Blood Sugar Input

Meal Type: Before Breakfast

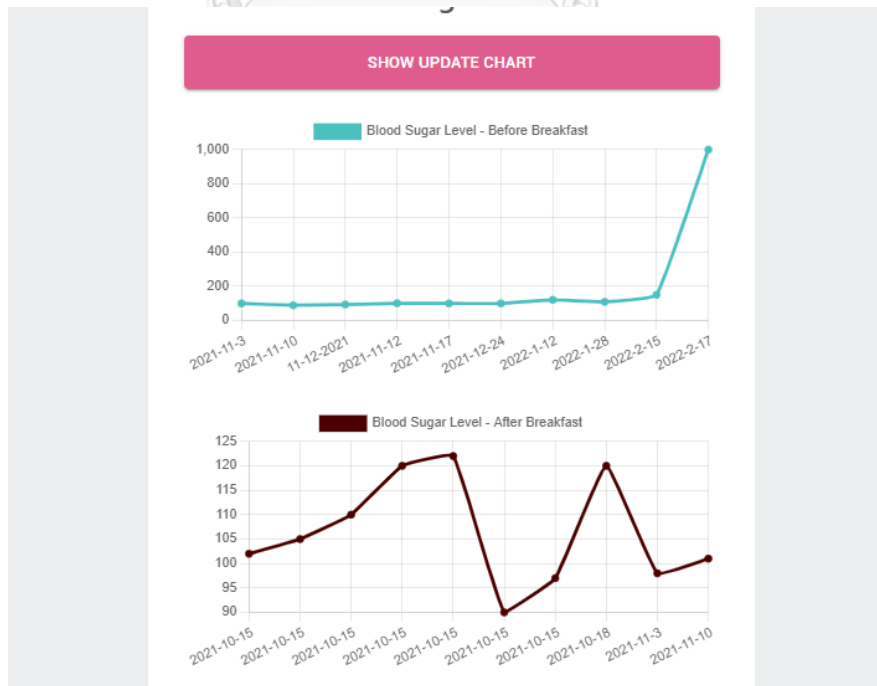
Select Time: 10:58 PM

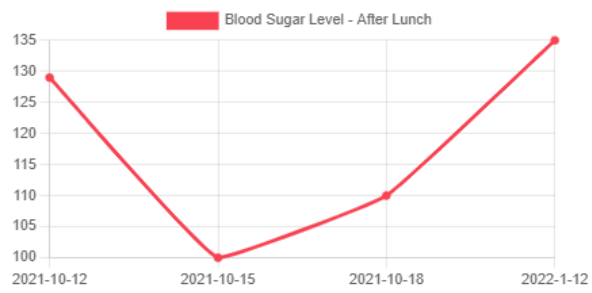
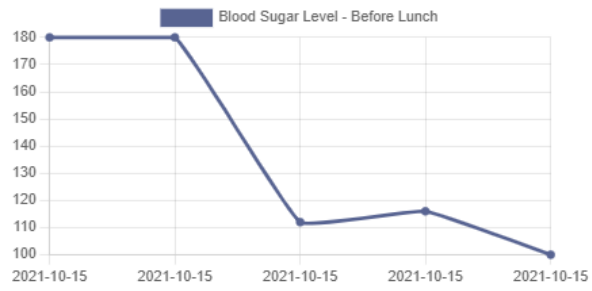
Enter Your Blood Sugar Level: 110 mg/dL

SUBMIT

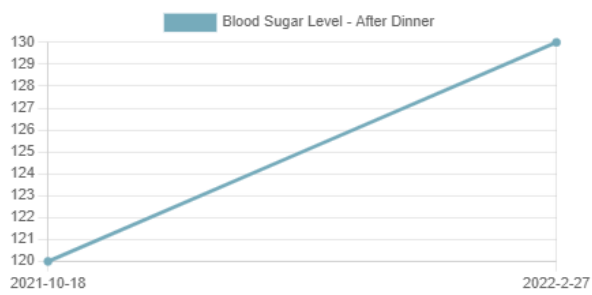
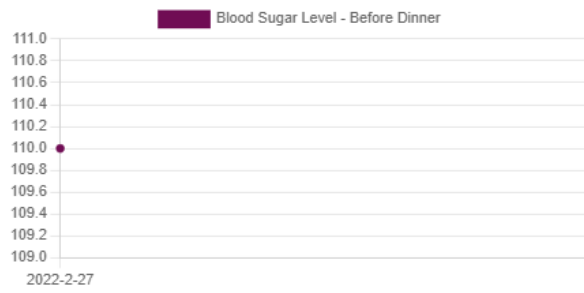
Blood Sugar Record

(a)

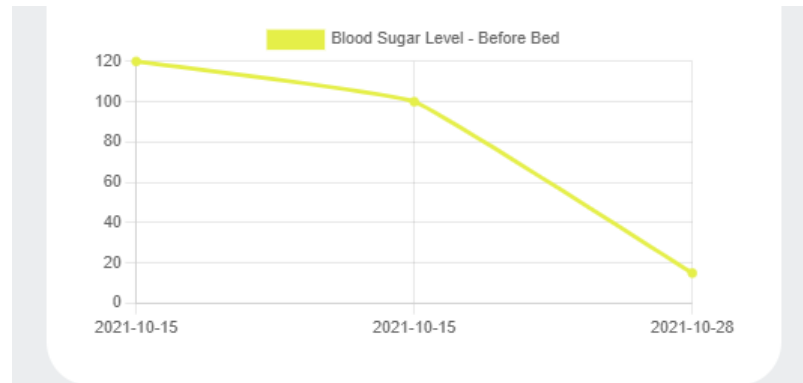




(c)



(d)



(e)

Figure 26: Glucose (Blood Sugar) Measurement Data

#### 4.1.2 Diabetes Information

The Diabetes info page (Figure 27) provides the user with general information about

topics related to diabetes giving them an easier way of learning about this topic. They can search for specific topics and filter their results. Each topic is presented with a short text and a "read more" option. After tapping on a topic, such as insulin the user is taken to the page giving information about what insulin is and how it works. Using pictures and tables the information becomes easier to understand. At the bottom of the page there is an explanation of words that might be unknown to the users as well as some useful links that can be a resource if they want to read more about the topic.

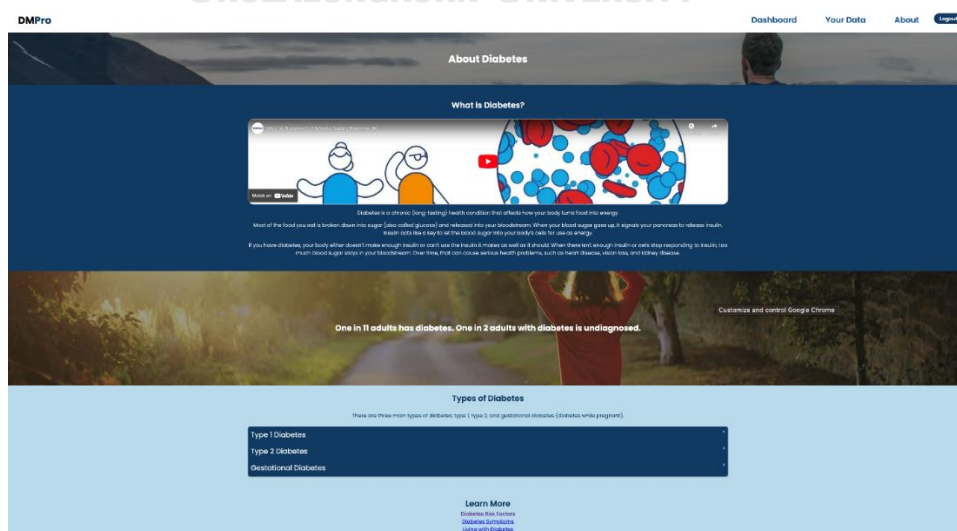


Figure 27: Diabetes Information Section

#### 4.1.3 Diet

After the user has logged in, the user can access authenticated or private frontend. The first page is the daily diet where the patients can post what they eat in a day as shown in Figure 28(a). The steps to upload the picture of food are as follows:

1. Choose the meal type from Breakfast, lunch, dinner, or other.
2. Choose the picture to upload.
3. Put the name of the food.
4. Press “SUBMIT” button to upload photo as shown in Figure 28(a).

The user can check food photo uploaded by pressing the “Show/Update Album” and there is a photo album where the user can see all photos uploaded as shown in Figure 28(b).

The next front-end page is the blood sugar page where the user can put your daily blood sugar level on each day as shown in Figure 5.22. The steps to record daily blood sugar are shown in Figure 28(a).

Diabetes Reversal Project | Upload Daily Diet | Blood Sugar | My Exercise | Guide | Profile | Log Out

### Upload Food

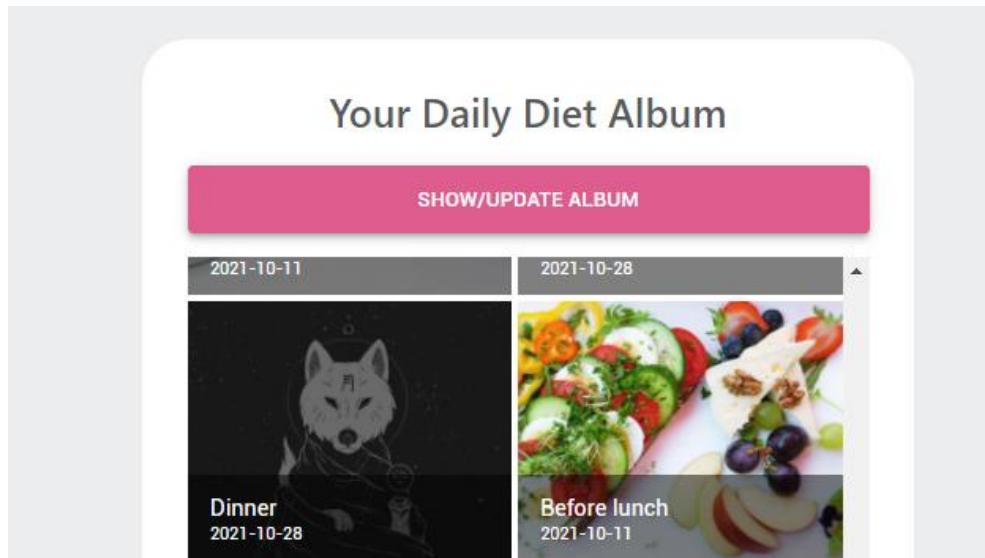
Meal Type: Breakfast

CHOOSE PICTURE | Joke Moo

SUBMIT

1. Choose the meal type
2. Choose the picture to upload
3. Put the name of the photo
4. Press submit to upload

(a)



(b)

Figure 28: Diet and Setting Section Page

#### 4.1.4 Exercise

The last pages are “About Exercise” and “Exercise”. Exercise plays a crucial role in managing diabetes effectively. It can help improve insulin sensitivity, lower blood sugar levels, manage weight, reduce cardiovascular risk factors, and enhance overall well-being. Some information on exercise for diabetes is shown in a section as below in Figure 29.

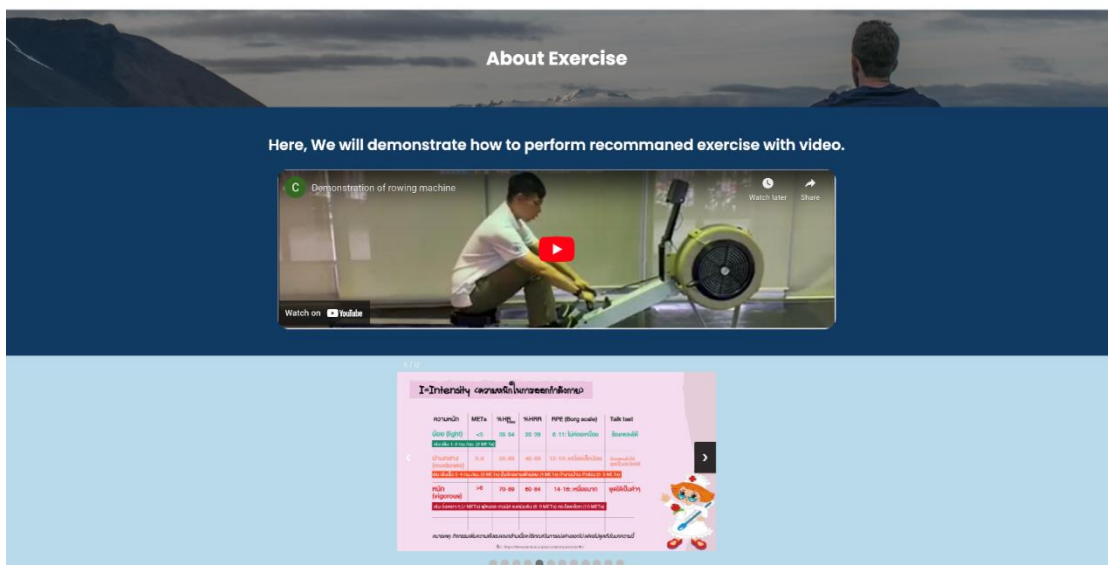
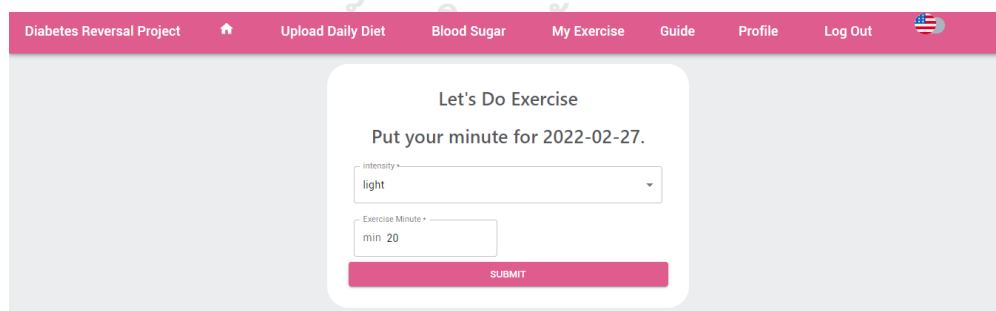


Figure 29: Exercises with video and slide explanation on how to do

Exercise where patients do exercises and can record their exercise minutes and intensity to the database by using the API called '/api/create\_myexercise/ username' as shown in Figure 30(a). The steps to put your exercise data are shown in Figure 30(a). The steps are as below:

Put your exercise minutes in the minute box.

1. Press "Submit" to upload your data.
2. The user cannot modify the date, so the user must put your exercise data daily. And to update the data, just put the new data and press submit. It will be automatically updated.
3. The website shows the exercise minute done by the patients daily for one week with intensity as shown in Figure 30(c), each week for five weeks as shown in Figure 30(c) , and each week's score for five weeks Figure 30(b). We score the patients in seven ways – 5 scores in green color if the patients do exercise for 150 minutes in a week, 4 scores in dark green with 120 minutes exercise done, 3 score in pink with 90 minutes exercise done, 2 scores in orange with 60 minutes, 1 score in gray with 30 minutes and 0 scores in red if no exercise minute or less than 30 minutes.



Diabetes Reversal Project [Home](#) [Upload Daily Diet](#) [Blood Sugar](#) [My Exercise](#) [Guide](#) [Profile](#) [Log Out](#)

**Let's Do Exercise**  
Put your minute for 2022-02-27.

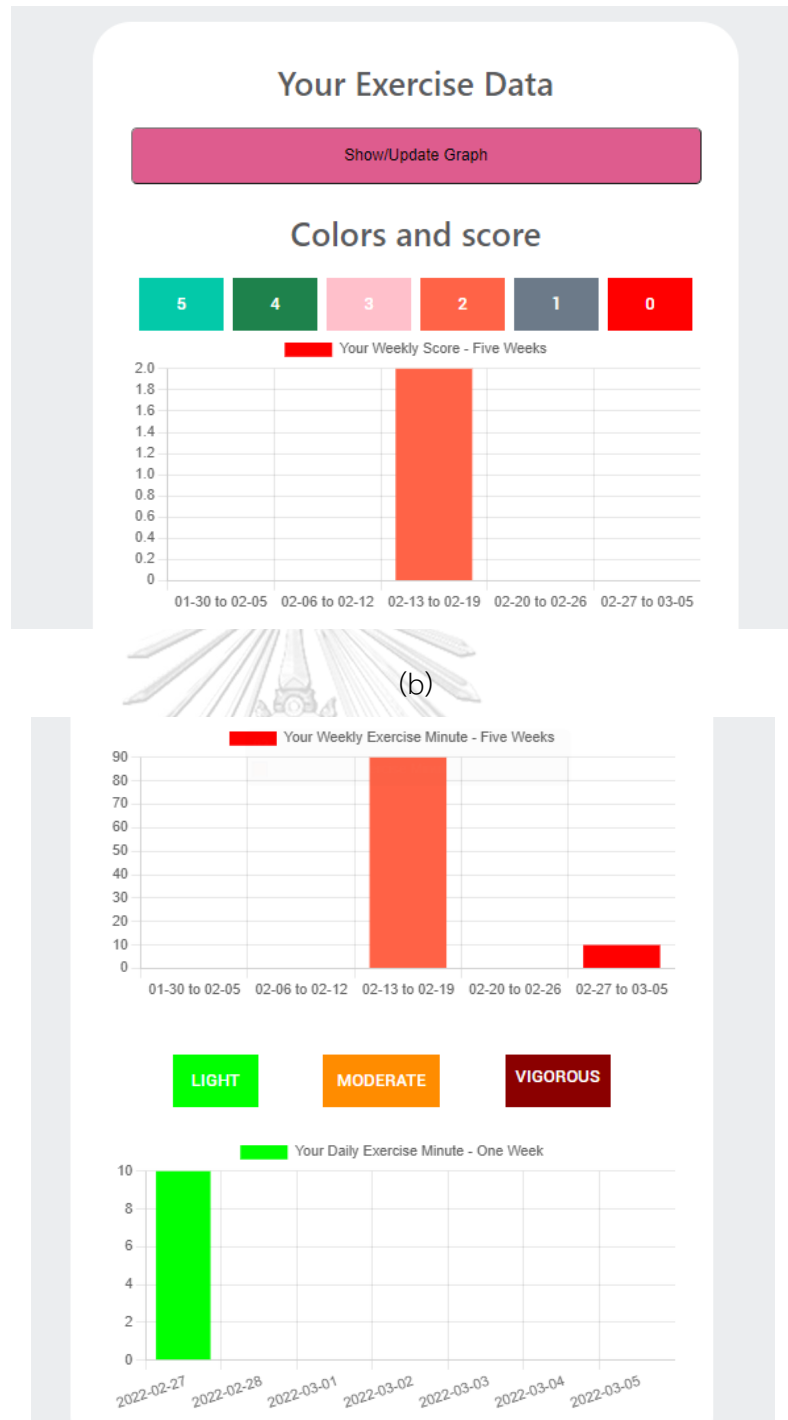
intensity  
light

Exercise Minute  
min 20

SUBMIT

(a)





(c)

Figure 30: Exercise Data

#### 4.1.5 Stress Management Information

Stress management is crucial for individuals with diabetes because stress can have a significant impact on blood glucose levels. When a person is stressed,

the body releases stress hormones like cortisol and adrenaline, which can cause blood sugar levels to rise. Additionally, stress can also make it more challenging to manage diabetes effectively by affecting self-care behaviors such as healthy eating, exercise, and medication adherence. Here are some stress management techniques that can help individuals with diabetes. Explaining about Stress Management for diabetes with visualized colorful slides are provided as in following figure.

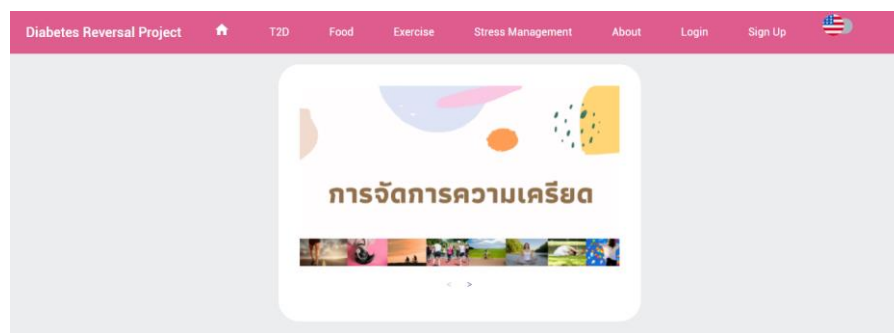


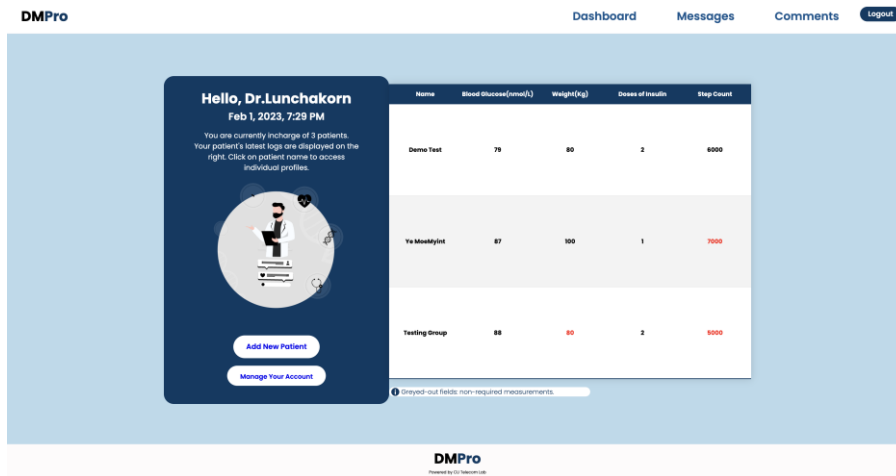
Figure 31: Stress Management Information

#### 4.1.6 Interactions between patients and doctors

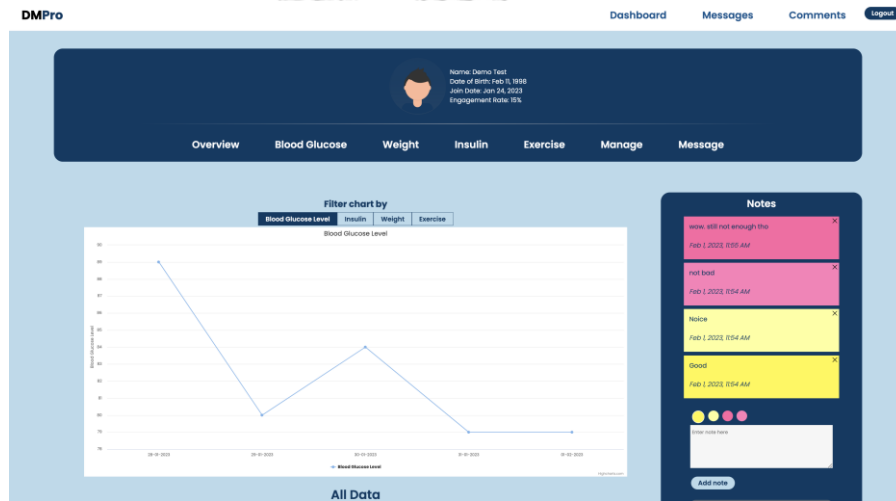
Doctors and patients can communicate with each other directly via the platform.

##### 4.2.6.1 Doctor's Account Functions

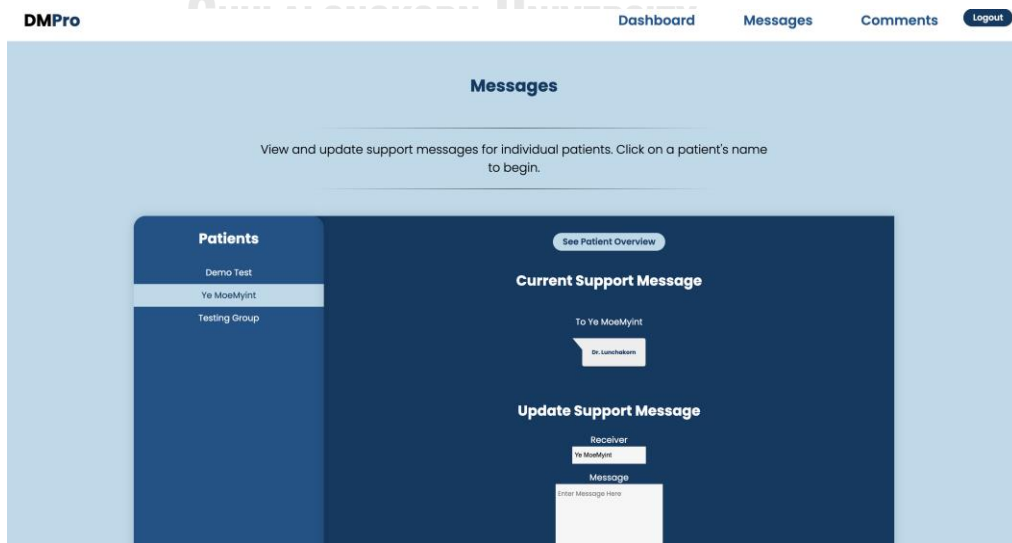
Doctors can access their patient's information from the doctor's dashboard as show in Figure 32(a) and Figure 32(b). Doctors can also comment on notes to the patient's progress. Whenever there is anything doctors would like to know, they can contact the patient through the message box as shown in Figure 32(c). Doctors also have the authority to create the new patient profile for their patients in Figure 32(d).



(a)



(b)



(c)

**DMPPro**      **Dashboard**      **Messages**      **Comments**      **Logout**

### Create New Patient

**Enter Patient Details**

First Name      Last Name  
     

Screen Name      Date Of Birth  
     

Text Bio

Email Address      Password  
     

**Enter Patient Required Measurements**

Blood Glucose Level

Weight

(d)

Figure 32: Doctor Account Functions (a) Doctor Dashboard, (b) Patient Information from doctor's view, (c) Doctor Sending message to patients, (d) Doctor can create new patient

#### 4.1.6.2 Patient's Account Function

Patients can see their progress and information from the patient dashboard Figure 33(a) and (b). They can also see the comments of the doctor on their progress. There is a leaderboard for completing daily tasks to motivate the patient for their daily self-management of diabetes. Patients can communicate with doctor through the message box if there is any advice they need from the doctor.

**DMPPro**      **Dashboard**      **Your Data**      **About**      **Logout**

### Dashboard

**Reminders**

Hi Day, Demo. Today you need to:

- Enter your blood glucose level
- Enter your weight
- Enter step-count
- Enter your insulin doses

**Record measurements**

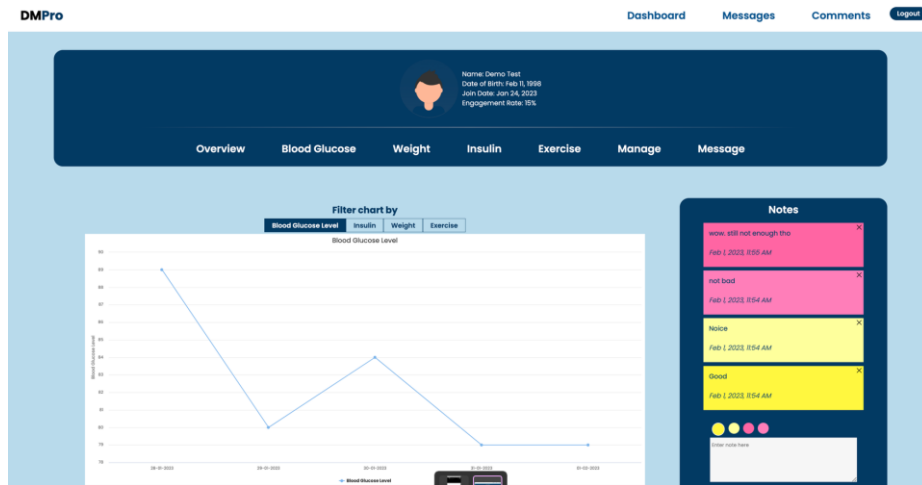
**Messages**

Please clear the schedule of tomorrow afternoon 2:00 PM for an appointment.  
 - Dr. Lunchakorn

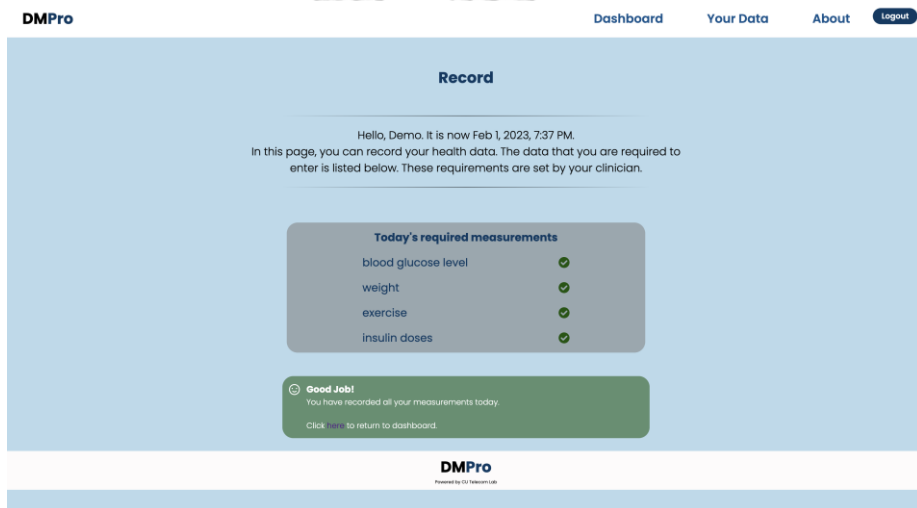
**Leaderboard**

Position	Name	Engagement Rate
1	Ye	100%
2	Demo	85%
3	Ye	-100%
4	test	-100%

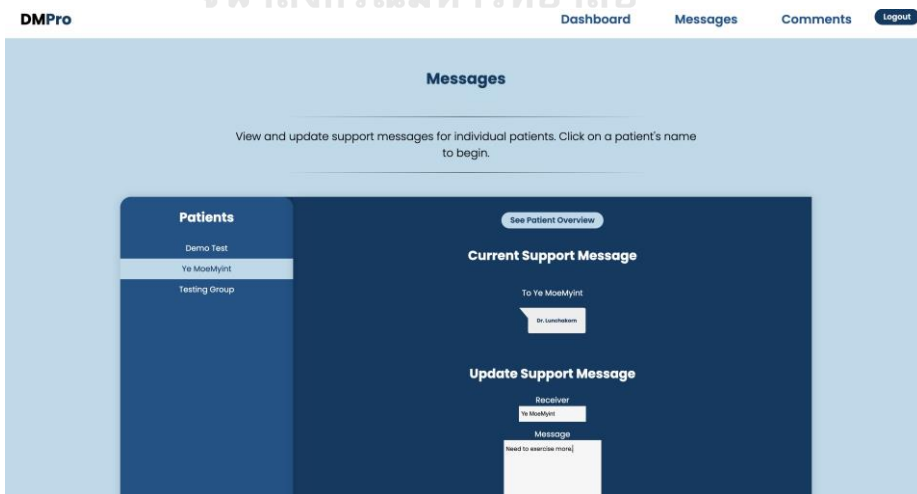
(a)



(b)



(c)



(d)

Figure 33: Patient Account Functions (a) Patient Dashboard, (b) Patient Progress Board Completion Check, (c) Patient Record, (d) Patient Message Box to Doctor

#### 4.2 3D Diabetes Web-Based Learning Center

The 3D diabetes learning center will be offering the information which is in 2D web application but with more visual attractiveness.

The user can go around the 3D web application and learn about diabetes and related information which are also available in 2D web platform. However, in 3D web app, the information will be displayed visually and there will also be voice casting for the information just by clicking on the information board.

When the user enters the 3D web application, user will start from the entrance of diabetes learning center as shown in *Figure 34*.

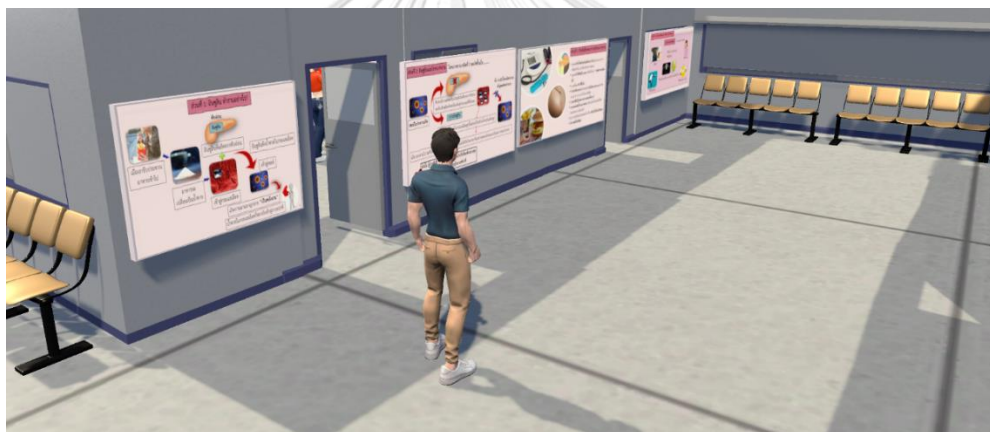


*Figure 34: Starting point of 3D diabetes Learning Center*

There is information boarding in hallway which are about prediabetes and type 2 diabetes. Player or user and can go near them to see the information or click on the information board to listing the casting about information on the board.



(a)



(b)



(c)

Figure 35: (a), (b),(c) Information boards in the hallway



There are also special information rooms like diet, exercise, and prediabetes rooms in which more related information is displayed.



Figure 36: Diet information room



Figure 37: Exercise information room



Figure 38: Prediabetes information room



Subsequent to visiting the learning center, users will have the opportunity to engage in an enjoyable and educational game aimed at assessing their acquired knowledge pertaining to diabetes-specific dietary practices. The game is designed to foster the retention of information and cultivate enhanced self-awareness regarding prediabetes.

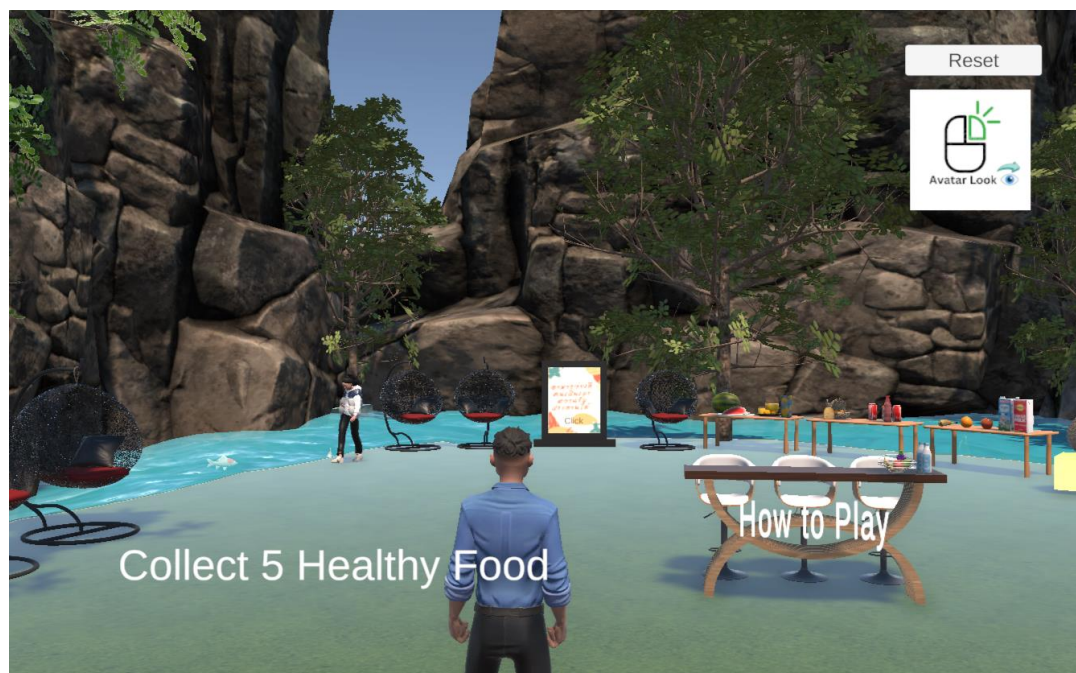


Figure 39: Starting point of the Educational Game for Prediabetes

In the game, the players have to choose 5 healthy foods for prediabetes patients given on the table as shown in figure and put them into the bracket. When they successfully put the right 5 types of foods in the bracket, they will play the game. When the player go near the reception table which is also labeled as “How to Play” and click on the table, they will see the instructions for the game as in Figure 40 .

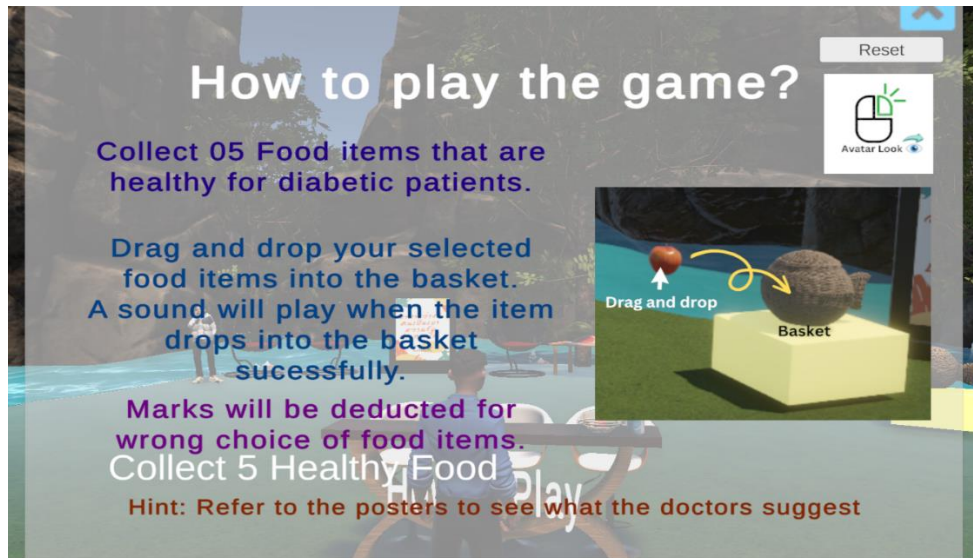


Figure 40: Instructions for the game

As described in the instructions, the player can get the hint from the diet information suggested by doctors at info boards which are right beside the food table.



(a)



(b)

Figure 41: Diet information board

When the player go to the information board like in Figure 41(a) and click on it, they will see the information about the diet as shown in Figure 41(b).

As shown in Figure 42, variety of foods are put on the food table to be chosen by the player. At the right side of the table, there is a little basket to put the healthy food which can be seen in Figure 43.





Figure 42: Table with variety of food

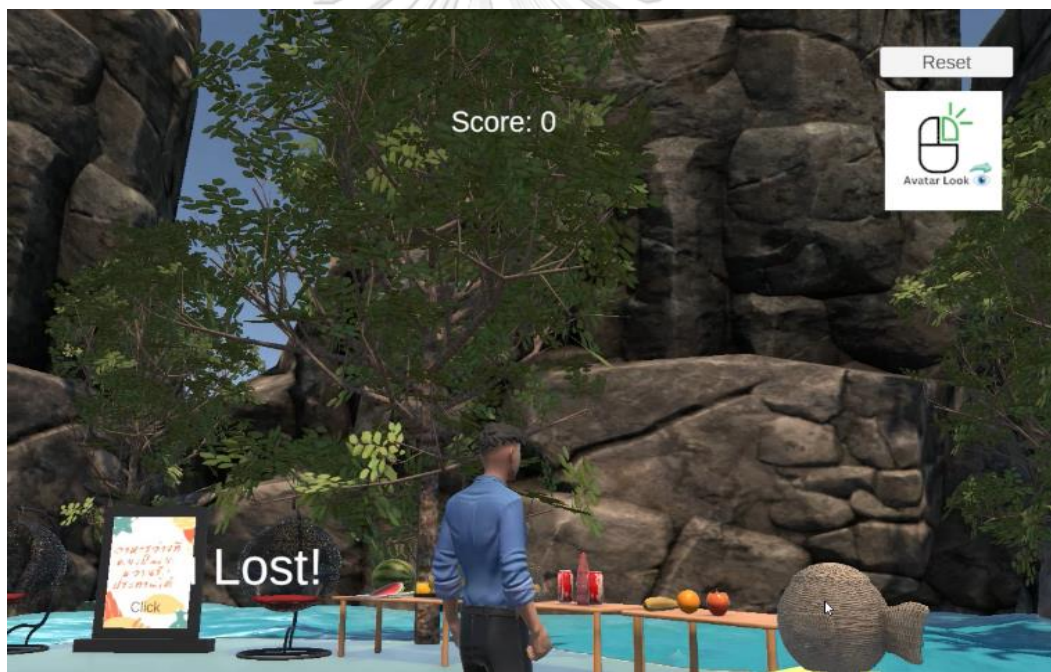


Figure 43: Food basket to put the food

Whenever the player puts the right food for the diet, they get one point. When they get a total of 5 points, they win the game. But if they put one wrong food, they total score will be zero and have to start over the game. They could check the diet information from the board if they needed the hint and start the game again.



(a)



(b)

Figure 44: Game scores

## Chapter 5

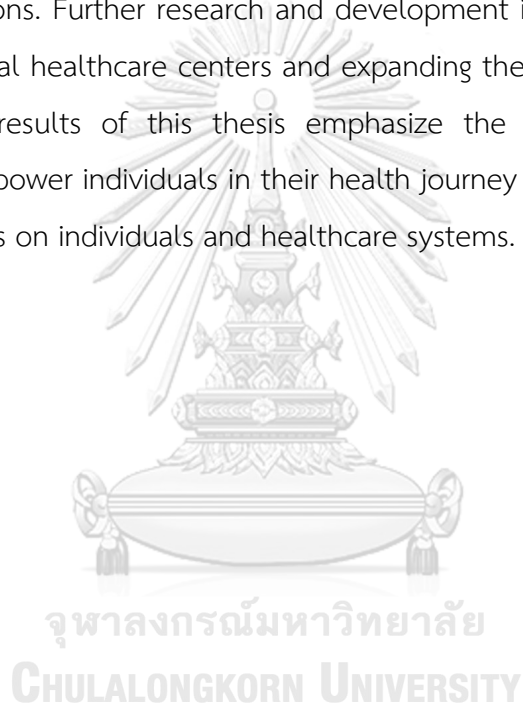
### Conclusion

In this thesis, we explored the implementation and effectiveness of a virtual educational learning system specifically designed for pre-diabetes patients. The primary aim of the virtual healthcare center was to provide accessible, convenient, and personalized healthcare services to individuals at risk of developing type 2 diabetes.

The integration of a web-based application, a 3D learning center, and a 3D online game focused on selecting healthy food for individuals with pre-diabetes brings numerous benefits to their daily lives. Firstly, the web-based application serves as a centralized platform, offering a wide range of educational resources, including articles, videos, and interactive modules. Users can access comprehensive information about nutritional guidelines, meal planning, and the impact of different food choices on pre-diabetes management. This knowledge empowers individuals to make informed decisions about their dietary habits, leading to healthier daily food choices. And also, they can record their progress like glucose level, exercise hours, insulin injection which will be reviewed by the doctors and can get instructions and advice. Additionally, the 3D learning center provides a dynamic and immersive environment where individuals can engage in virtual scenarios, simulations, and interactive lessons specifically designed to enhance their understanding of various information of pre-diabetes. By actively participating in these learning experiences, individuals acquire practical skills, such as identifying physical activities, nutritious options, and mindful eating, which they can apply in their daily lives. Furthermore, the 3D online game component adds an element of entertainment and engagement to the learning process. Through gamified challenges, players can reinforce their knowledge and skills while having fun. The game provides a safe space for experimentation and decision-making without the fear of real-life consequences, allowing individuals to practice and refine their healthy food selection abilities. Overall, the integration of a web-based application, a 3D learning center, and a 3D

online game offers a comprehensive approach to promoting healthy dietary habits for pre-diabetes individuals, improving their daily lives by providing extensive educational resources, practical skill development, and an enjoyable learning experience.

In conclusion, the virtual learning system implemented in this study demonstrates its potential as an effective and patient-centered approach to support pre-diabetes patients. The convenience, accessibility, and personalized care offered by virtual platforms make them a valuable tool in the prevention and management of chronic conditions. Further research and development in this field can contribute to optimizing virtual healthcare centers and expanding their reach to benefit a larger population. The results of this thesis emphasize the importance of leveraging technology to empower individuals in their health journey and ultimately reduce the burden of diabetes on individuals and healthcare systems.





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จุฬาลงกรณ์มหาวิทยาลัย  
**CHULALONGKORN UNIVERSITY**

## VITA

NAME YE MOE MYINT

DATE OF BIRTH 14 August 1996

PLACE OF BIRTH MYANMAR

INSTITUTIONS ATTENDED University of Information Technology (UIT), Myanmar

HOME ADDRESS No. 56, Sa Ya Pha Tat Su (4), Kabar Aye Pagoda Road,  
Yankin, Yangon, Myanmar

