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SCHOOL OF COMPUTING AND INFORMATICS

DIABETIC E-PATIENT CARE SYSTEM

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DECLARATION

I hereby declare that this project report is entirely my own work and that it has not been submitted for any other degree at any other university. The work reported and undertaken in this proposal has been executed by me except where explicitly stated otherwise in the text.

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ABSTRACT

Diabetes as one of the Chronic Illness that requires extra effort in its monitoring and management to avoid the glycemic fluctuations through a patient centric medication, that requires close monitoring of the patient physical exercise, insulin intakes and eating habits. The treatments offered for type one diabetic aims to keep patients' blood glucose levels as normal as possible and to prevent health problems developing later in their life. This requires the patients to be followed by a doctor for life but most of them are culprits of inadequate patient follow up as reported by Beran report of implementing national diabetes programs in sub-Saharan Africa. Researchers and developers have created Diabetes applications that already are flooded in the free application stores but basically most of them do offer local data logging with exclusive additional features at high cost. Most of these applications are meant for users targeted in the developed world context. Through the study, a logging application on an Android Smartphone was designed and developed for Children with Type One diabetes for a developing world context to help them in diabetes self-management. Questionnaire survey was done with nine respondents that was used to represent the population on pilot. A modified version of the Summary of Diabetes Self-Care Activities was used to investigate the changes related to the diabetes self-management and the user satisfaction. The survey results for the user satisfaction showed that 81.7% of subjects had positive changes on their clinical course of diabetes self-management after using the application 87.2% of the users were satisfied with the User Interface, Application Structure and supported functionalities of the application. Furthermore, 96.7% of the users stated that the application was efficient in use on logging the data. This study showed that improvement in diabetes self-management activities is greater when user satisfaction is high. In addition, the study showed a positive effect on diabetes self-management and high level of user satisfaction both which plays a big role for improvement on the patients Quality of Life.

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DEDICATION

I hereby dedicate this project to my lovely daughter Jaelyn Wanja. Also to my lovely family for their constant moral support and prayers all through and dedication towards my academics.

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LIST OF ABBREVIATIONS

Diabetes Online Community (DOC)

Diabetic Ketoacidosis (DKA).

Kenyatta National Hospital (KNH)

Self-Monitoring of Blood Glucose (SMBG)

General Practitioners (GPs)

Information and Communications Technology (ICT)

American Diabetes Association (ADA)

Information Technology (IT)

International Diabetes Federation (IDF)

Glycated Haemoglobin (Hba1c)

World Health Organization (WHO)

Open Handset Alliance (OHA)

Graphical User Interface (GUI)

Structured Query Language (SQL)

Operating System (OS)

Short Message Service (SMS)

Food and Drug Administration (FDA)

Random-Access Memory (RAM)

Software Development Kit (SDK)

Gigahertz (Ghz)

Gigabyte (GB)

Extensible Markup Language (XML)

Java Archive (Jar)

Application Programming Interface (API)

Integrated Development Environment (IDE)

Statistical Software Packages (SPSS)

Standard Deviation (SD)

Summary of Diabetes Self-Care Activities (SDSCA)

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CHAPTER 1: INTRODUCTION

1.0 Background information

ICTs are rapidly evolving as an efficacious implement for making information widespread and available online to all communities enabling them to participate in the erudition network across the globe. With the available technology, people are going mobile with every aspect of their life mostly predetermined with the help of Mobile based applications.

Human interaction and concentration on the device screen is what developers are going for so as to pass information and provide personalized mobile based services.

Diabetes also called hyperglycemia is a problem with ones' body that causes blood glucose levels to elevate higher than mundane. According to American diabetes association, diabetes is a chronic disease that have no remedy (American Diabetes Association (ADA), 2005). Diabetes as a chronic illness requires the patient to be vigilant on monitoring and managing their glycemic fluctuations by taking medication, diet, and exercise. These patients on most cases experience challenges in incorporating the various self-care and monitoring components into their daily lives. Patients monitoring their glucose levels daily, also known as self-testing, is an essential part of managing diabetes. This helps to provide relevant information to the patient doctor to enable evidence based care and diagnosis which is vital for early detection of insulin resistance. With increasing prevalence of diabetic risk factors and lack of awareness have been the most critical obstacles to overcoming diabetes in Kenya as discussed in detail by Mcferran (Mcferran L, 2008).

Because diabetes can be a confounding and frightening disease, but with the availability of internet connectivity using the computers or mobile devices, many of these patients have turned to the diabetes online community (DOC) for support. According to Yeager, the DOC is a loose collection of websites, online communities, and bloggers dedicated to sharing information and experiences about living with diabetes and its treatment (Yeager, 2015). Depending on an individual's needs and intrigues, one can find a place in the DOC that addresses their concerns.

Having various limitations - including the fact that healthcare providers lack the time to provide continuous education, the high cost of evidence based lifestyle interventions, challenges in arranging patients' access to healthcare providers - are barriers that complicates provision of the diabetes interventions that are necessary for patients to improve their Quality of Life. Emergence of mobile technology have seen rise in the development of diabetes self-management applications that run on both features phones and smartphones allowing the users to enjoy a more accurate and convenient self-monitoring.

Type One diabetes develops when the body produces little or fails to produce insulin. The patient thus needs to take insulin injections and to continuously monitor their blood glucose levels by eating healthy diet and having regular blood test. For it to be treated, it requires the person to inject insulin, do physical activity, eat healthy diet, and frequent blood glucose testing.

Type Two diabetes develops when the patients had insulin resistance or the body fails to recognize and utilize it thus making sugar build up in the patient's bloodstream. To keep the blood glucose at mundane levels, the patient's pancreas at first makes extra insulin to compensate for it, but over time its unable to secrete the required quantity to keep the blood glucose. This condition is characterized by altered protein, fat and carbohydrate metabolism secondary to insulin resistance. Type 2 diabetes can, in some cases, initially be controlled by healthy eating habits, managing ones' body weight and increased physical exercises. To avoid the complications of diabetes, the patient needs to control their blood glucose very well to minimize the risk of hyperglycemia. The treatments offered for type 2 diabetic aims to keep patients' blood glucose levels as normal as possible and to control any symptoms as well as to prevent health problems developing later in their life thus requiring to be followed by a doctor for life but most of them are culprits of inadequate patient follow up as reported by Beran on the implementation of national diabetes programs in Sub-Saharan Africa (Beran D, 2006). These type of medication includes regular injections or taking insulin drugs.

Kenya - a developing country in Africa – conventionally experiences high cost and low availability of the insulin with inadequate patient follow-up contribute to poor management of the diabetic patients. Studies have shown that in Africa, acute metabolic complications and infections are the most common cause of death (Azevedo M

AS, 2008). This challenge has resulted to many patients suffering of Diabetic ketoacidosis (DKA) that is indeed accounted for 8% of diabetic admissions. From a study conducted at Kenyatta National Hospital (KNH) found out that 29.8% of the diabetes patients presented at the hospital died within 48hrs while Diabetes Ketoacidosis happened in 8% of the hospitalized patients (PK, et al., 2005). This is concurred by another similar study conducted at KNH that also 30% of diabetes patients died within 48 hours of presentation at the hospital (Diabetes UK, 2012).

Diabetes complications can be reduced by having efficient and effective means of measuring insulin resistance that makes the process more routine. Unfortunately, the methods used currently for measuring insulin resistance are complex and have lot of limitation making them not used more routinely. Similarly, the current IT-based systems for diabetes management have limited interaction with patients to improve self-care (E, et al., 2009).

Therefore, there is a need to identify parameters whose estimation is simple, inexpensive and which can identify insulin resistance and dosage without actually requiring estimation of serum insulin, share this information with the healthcare providers and invoke alerts to the parties to forewarn on dangers and means of control to the extremes and this will immensely avoid diabetes complications.

1.1 Problem Statement

Diabetic self-management requires the patients need to keep track of their blood glucose as well as their daily routines that affect their health but this is characterized with inadequate utilization of guidelines that is reflected by in-efficient and un-effective means of taking and recording the patients diabetic related data (M, et al., 2009). The challenge has been too reported to have also led to most of the diabetic patients be culprits of inadequate patient follow-up as reported by Beran on the implementing national diabetes programs in sub-Saharan Africa (Beran D, 2006). The current IT-based systems for diabetes self-management have shown that they have limited patient interactions to improve self-care (E, et al., 2009). There exists a gap between evidence-based guidance and functionalities of the available diabetes applications in the market and very few offers integrated behavioral self-management which generally have been reported by studies to be used by patients from higher social economic backgrounds thus remaining un explored area in the developing context targeting children with diabetes.

1.2 Goal

The goal is to build a diabetic care system that leverages on Mobile and Data Explosion to Offer Personalized Healthcare for Children with diabetes.

1.3 Specific Objectives

1.3.1 System Development Objectives

i. **System Analysis** – Analyzing the missing gaps that leads to the in-efficient and in-effective diabetic patient follow-up in children.
ii. **System Design** – Design a mobile embedded system.
iii. **System Implementation** – Develop a mobile embedded system for children with type one diabetes to provide diabetes self-management with real time intervention by General Practitioner and child care providers.
iv. **System Test** – Iterative tests and redesign to fit user needs.
v. **System Evaluation** – Evaluation against robust measure to ascertain that it can improve patient Quality of Live.

1.3.2 Project Management Objectives

i. Evaluation of the available mobile diabetic management systems and identifying the opportunities that the system had to fulfill.
ii. Development of a prototype that met the standards advocated for diabetic management by the diabetic governance body.
iii. Prototype testing and evaluation, results and data analysis to verify the expected outcome.
iv. Project documentation all through the life cycle of the research project.

1.4 Research questions

i. How can diabetic type 1 patients' data be made available for data mining and refined analysis to enhance General Practitioners make informed decisions?
ii. Whether implementation of sound algorithms for data processing of data will further enhance the value of these mobile self-management systems to offer more evidence based diagnosis?
iii. Whether and how mobile self-management systems could form part of the diabetic type 1 patients' health care system, and how the system can be used to improve patient Quality of Life?

1.5 Project justification

Diabetes has now become a global health problem threatening the lives of millions of people across the world. According to the report by Diabetes Atlas 5, released on 14th November 2011 by the International Diabetes Federation (IDF), there are currently 366 million people with diabetes globally and this is predicted to increase to 552 million by the year 2030 (Federation, n.d.). Control of type one diabetes is quite challenging as it demands day-to-day management that involves frequent self-monitoring to help in making adjustment on the insulin dosage (Aschner P, 2010). Considering the developing countries, the situation is worsened by lack of access to treatment or even failure to diagnose the condition. Research have shown that most of the clinicians often lack adequate information regarding the patients' logbook which may either be produced in electronic format or the paper-based one. (Stone AA, 2002).

Patients with diabetic type one requires self-monitoring so as to collect blood glucose levels at many time points as possible to enable maintenance of a more constant HbA1c level (M, et al., 2009). Although the benefits of self-monitoring of blood glucose in type one diabetics is still controversial (Davidson MB, 2005), the International Diabetes Federation has argued and do recommend that self-monitoring of individual blood glucose be based on their clinical needs (International Diabetes Federation (IDF), 2009). Reports have shown that from the four million diabetes related deaths annually, 80 % occur from the developing countries (G & N, 2010), demands that diabetes self-management interventions needs to be out in place is a serious issue. Thus reinforcing the previous call (C & J, 2011) for intensified diabetes self-management education and interventions in the developing countries, this can be achieved by having both the healthcare providers and institutions participation. This valid opportunity is broadened with the available resources in the developing countries like mobile phones which can enhance the participations of the patients and healthcare givers to provide tailored follow-up to the patient.

Studies have shown that the use of mobile phones for type 1 diabetic self-management have proven to be effective and efficient in handling their health care in developing world context. A study by Quinn et al revealed that using a smartphone application for diabetes management resulted in a statistically significant improvement in A1C in adults with diabetes type one (CC, et al., 2008). Diabetes patient have found blood glucose monitoring using their smartphones been more efficient but the collected data at most time doesn't automatically reach the health care providers in time to make decisions, this is portrayed by the many mobile applications available in the market.

This can be resolved by having auto-data sync for logged readings. This is an important feature because it allows Health Care Providers to have an accurate snapshot of their patients' glycemic control in real time when they have internet access. A 2010 study found that diabetes management apps capable of seamlessly sharing SMBG data with Health Care Providers are likely to benefit patients in managing their condition. From that study, the Health Care Providers were able to rapidly visualize trends and make adjustments to medication therapy regimens, thereby improving health outcomes (A, et al., 2010). Several other randomized studies have reported on the effectiveness of diabetes management using mobile application interventions which makes it a better approach to reach the affected people in the developing countries (SA, et al., 2011)

1.6 Scope of the study

The scope of this study is to investigate the needs of children with diabetics and diabetic care needed for them, then develop an application on Android platform with functionalities based on that research. The focus is on developing log book functionality that strive to automate data sharing with a General Practitioner who can be able to monitor the patient and provide intervention in real time.

1.7 Limitation and Delimitation

The limitations expected from this study include the sample size of the involved population, time constraints, the phones capabilities and accompanying diabetic tools, patient nature of self-reporting and the data analysis method that will be independent on the available knowledge for interpretation.

The delimitation of this study are the literature reviewed that focuses on Children with type 1 diabetic. The sample size that will be picked for the study will represent the type 1 diabetic patients for the developing country context since the proposed General Practitioner cannot handle all the diabetic patient.

1.8 The Outcomes

i. Development of an android based application that captures, processes and shares child with type one diabetes data with an enhanced clinical decision support which enables the General Practitioner to offer personalized and appropriate evidence based intervention in real-time.

ii. The use system shows patient self-management of diabetic condition improves their Quality of Life in short time.

CHAPTER 2: LITERATURE REVIEW

Diabetes conditions and its complications have affected the todays the society's economic status and indeed have resulted to adverse impact due to the cost of treatment, social costs and loss of working days for the employed (Organization, n.d.). To control this, diabetes care requires appropriate strategy in setting goals for glycaemia, blood pressure and lipid levels, regular monitoring for any diabetes' complications, dietary plans and physical exercise arrangements, appropriate medications, appropriate self-monitoring of blood glucose, and assessment (American Diabetes Association, 2012). A collaborative, multidisciplinary approach that puts together the pharmacists, physician dieticians and nurses is the ideal method for provision of diabetes care in order improve the self-management and to encourage patients' empowerment in control of the condition (American Diabetes Association, 2012).

2.0 Diabetes Care

Diabetes, just like other chronic diseases cannot be cured but can be treated successfully. Taking a patient situation having a high blood glucose level, the action to bring it down to a normal level eases the symptoms thus allowing the patient to feel well again though the still can have some risk of complications in the long term if their blood glucose level remains slightly high even if they have no symptoms in the short term. Persons who have better glucose control have been reported to experience fewer complications compared with those people who have poor control.

In low resource settings the need to have patient-centered diabetes control is often dismissed as a luxury considering the gap in the living condition, enlightenment, culture and other societal differences between the patient and the healthcare providers. Nevertheless, patient centeredness care has been found to improve Quality of Life, increase patient satisfaction, improve adherence to treatment, enhance integration of preventive and promote care, improve the providers' job satisfaction. Patient-centeredness implies a more collaborative approach and holistic understanding of the patients that tries to understand, acknowledges and addresses the differences approaches breaking the barriers in the control management of the condition.

Diabetes self-management seem like a full-time job for many patients, but as with any job, having the proper tools and timely information can enable the whole process be streamlined thus reducing patient frustration. Beyond the individual patient is their family and community context who affects the management directly or indirectly. Family beliefs and customs and degree of social support haves an impact on the ability of an individual within that family and society at large to make lifestyle changes and have means to cope with the condition. With presence of technology, it can be used as a tool to help people having the diabetes condition be able to self-manage themselves at the same time be able to conveniently and effectively share, communicate and be assisted over by the healthcare providers on their recommendation of the most appropriate tool based on the patient context and self-care needs.

2.1 Quality of Life

Personal satisfaction is characterized by WHO as "individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" which is an expansive extending idea influenced impressively by the individual convictions, individual's physical wellbeing, their mental state and level of freedom, people social connections and their relationship to striking components of their surroundings (WHOQOL, 1998). Most of the chronic disease management evaluation do use the Quality of Life outcomes as its measures which are frequently used as a synonym for self-perceived health and is shown to be useful in predicting mortality and morbidity (G & T., 1983). The case study done in western India showed that Quality of Life was significantly impaired in patients with uncontrolled diabetics than controlled diabetics.

Diabetes can have a very great effect to an individual Quality of Life in terms of physical ill health, psychological well-being and socially. This condition requires a much effort on individuals' psychological needs at it had been recoded as one of the chronic disease psychosocial factors pertinent to nearly every aspect of the disease and its treatment (CoxWM, et al., 1996). People with diabetic mellitus require not only drug therapy and blood glucose control, but also a healthy lifestyle and sometimes demanding changes in lifestyle (P, et al., 2009). This situation may have a deep psychological impact on affected individuals and increase their perception of a poor Quality of Life (W & E, 1988). Several studies from developing countries have reported Quality of Life in diabetic management and calls for further refinement on the strategies and approaches (FS & J, 2011).

Advances in the treatment of diabetic have resulted in a longer lifespan and this have been achieved by involving a holistic approach aimed at improving the overall Quality of Life notwithstanding the limitations associated with it (RD, et al., 2004). High Quality of Life had been achieved through adherence of patients on monitoring themselves as advised by their physicians. Daily monitoring of diabetic patient blood glucose level and availing that information to their physician have enabled them be able to help them control and avoid complications.

2.2 Diabetes in Children in the developing world

Type 1 diabetes mellitus is one of the most common endocrine and metabolic conditions in Childhood with studies showing that on annual basis worldwide, there is an overall increase in the incidence of which is around 3% [78000] below the age of 15yrs (Federation., 2011). In the developing countries, approximately 19,000 have been estimated to be affected by type 1 diabetes though there is lack of good data of the disease prevalence (Beran D, 2005). The study also found diabetes patients have several barriers to access to good care that included lack of availability of quality insulin, syringes, and monitoring devices. Diabetes in Children have been partly attributed due to urbanization, abdominal obesity, sedentary lifestyle, behavioral habits, physical inactivity, low intake of fruits and vegetables and lifestyle changes (Dahiru T, 2008). Management of diabetes for children requires multidisciplinary participation and this is not readily available in low resource settings as experienced in the developing countries. In a developing country context like Kenya, General Practitioners (GPs) are the first person who one come across to when seeking medical help. With the low number of General Practitioners that have the imperative information, aptitude, and involvement under the watchful eye of children with diabetes, it turns into a noteworthy test on giving kids right to appreciate and have a splendid future.

One of the challenges Health Practitioners' haves is to be able to diagnose children as they get into adolescence as makes it hard to classify the status of the diabetes resulting to type 2 diabetes that have now emerged as a serious issue for the adolescents in both developed and developing countries. Some of the children do encounter impaired Quality of Life which leads them dropping of school or even cause severe complications on their health status. In most of the developing countries, access to insulin and other supplies to help manage diabetes for type 1 children becomes another hindrance to their self-management. A developing world context always experience few number of physicians who are familiar with childhood diabetes and often these patients do land in the hands of the General Practitioners who some time do lack the relevant skills and setting required to educate them.

To decrease morbidity and mortality from type 1 diabetes in children, timely diagnosis of the disease and its complications, treatment and referrals are required from the General Practitioners. This can be achieved by essentially providing the trend of current patient's diabetes status and enhancing better practice and General Practitioners' awareness for the disease and its complications. The right demeanor towards controlling complications of type 1 diabetes is to get the patient under the suitable treatment umbrella from the General Practitioners who frequently are the first to see these patients.

In a developing world context, due to economic constraints, General Practitioners have to play multiple roles in managing the disease and its complications even in busy and wide practice which requires intervention of ICT to be efficient and effective. In most countries, the pharmaceutical care mandates the General Practitioners to dispense medications as well as expect them have an obligation for improving the patients' quality of life. (C & L, 1990).

2.3 Managing Type 1 Diabetes in Children

The management of a child with type 1 diabetes requires the participation of the family members, tutors for the school going children's and the health professional to monitor the wellbeing of the child. Management of this disease requires the family members be able to prepare appropriate food, offer assistance in blood glucose measuring as well as insulin dosage and help in monitoring early signs of hyperglycemia. Some of these task can be managed by use of diabetes mobile health related apps which are already in market (Alberti, 1998). These solutions have shown major advantages to patients upgrading from the paper logbook to the electronic format that is easily interpretable and be easily shared to diabetes clinicians for review and concerned family members takes care of the situation. With this, the health care providers can be able to respond and share with their patients more easily with automated alerts and controls that helps better in managing patient's condition. The use of automated data entry or manual data entry in a digital format have shown the process being more desirable to the users and led to more data being captured (Tasker AP, 2007).

Available solutions have been helpful in one way or the other and reviews done have shown major limitations with the current state of art in the development of these apps. One of the major concern is that the clinical guidelines emphasize on provision of education to the patients on the diabetes self-management which was found missing in most application and where it was available the information was often generic and not personalized to the individual patient's condition (American Diabetes Association, 2012). Additionally, other than just allowing data entry in a more efficient and satisfactory means, using the mobile devices value added features that supports decision support capabilities in food intake, physical exercises, insulin dosage needs to be implemented to the solutions. Most of the current capabilities are just limited to the general generic insulin dosage that fails to be monitored directly by the General Practitioner who may advice otherwise regarding the patients historically based data. To harness the whole potential in the available smart phones and cloud computing that offers seamless flow of information and analytics capability, better solutions can be developed that haves' inclusion and participation of all the stakeholders involved (Martin C, 2011).

2.4 Review of Diabetes Apps in from the Local Market

Mobile phones with currently implemented technologies directed at the patient, are likely to have the greatest potential use in low resource setting. This is because the digital divide along social economic gradient appears to be less evident with mobile phones than other forms of Information Technologies. This have enabled people even in low resource context be able to secure themselves smart devices with at least $30. Several studies and prototypes as well as some publicly available products and services exists but few of these can actually be classified as self-management tools designed for personalized and patient-oriented use with healthcare practitioner intervention. The local market has a multitude of apps with various blood glucose tracking and sharing features. Some application likecare4life sends educational text messages to users and allows them to set up appointments and share data with their health care providers. There are also apps that focus on diet, such as Go Meals, which enables users to check the nutrient composition of their meals at their conveniences and includes glucose trackers, activity recording, calorie calculator and a restaurant

Many online services are now cropping up as platforms that are attempting to assist diabetes people to make personalized and well informed decision on their condition. Services such as Livongo for Diabetes patient have diabetes management tools that uses technology and user coaching to help them be able to track blood sugar results, count steps, share information, or even to speak with a health care provider. Software companies like Tidepool are developing open-source platform to develop apps that aggregate and manage diabetes data.

To explore the extent to which mobile self-management diabetes systems are addressed in scientific publications, peer-reviewed journals or conference papers were searched for combination of the words "diabetes", "mobile" at health publication portals like Pubmed and ResearchGate. More relevant literature was found by checking the references of the identified relevant papers.

The inclusion criteria included: -

i. The system had at least a function to monitor blood glucose values
ii. Mobile, patient-operated tools for people with diabetes.
iii. Platform tested on at least one patient.
iv. Presence of an evaluation or a description of the system.
v. Solution that had information more than ordinary blood glucose meters.
vi. Diabetes patient based systems including those without functions for management of blood glucose measurements.

Table at the Appendix 1 shows apps and solutions offered for diabetic type two that were evaluated while Appendix 2 shows relevant and publicly available mobile diabetes-specific self-management systems for Diabetes Type 1 & 2. Apps that were evaluated and contained diabetes-related functionalities in function-rich mobile self-management systems are shown on Appendix 3. Among the application that were evaluated are described below in detail:

Pumps 4 Kids - This is an informative application for children that equips them with the general knowledge of the diabetes disease. The application has video tutorials and some of the common problems experienced by young ones who are suffering from diabetes, dietary planning and haves a calculator for calculating carbs during intake.

Type 2 Diabetes in Children Disease - The application gives basic definition, symptoms, causes, risk factors, complications among others that children suffering from diabetes type 2 do experience.

OnTrack – This application offers local storage for data pertaining food, exercise, medication, blood pressure with capability to view the data in graphs.

Logbook - This is a diabetes care application that offers user capability to log in blood sugars, meals, insulin, activity for free on local devices but requires payment for online data sync.

mySugar Junior - An android based application that is gamified and allows kids enter data which is stored locally but requires subscription for premium services.

Kids & Teen Diabetes - This is an information application that equips the kids and teens on detecting early signs for diabetes and prescribes tasks that helps the kid overcome extreme occurrences in blood sugar recordings.

HelpDiabetes - It's a free application that helps kids in calculating carbs intake.

Glucose buddy - This application supports both diabetes type 1 and 2 and allows user be able to log in blood glucose, medicalization, food and A1C records. The application stores data locally and can be easily be visualized by use of graphs.

Diaguard - The application records patients' diabetes data which is stored locally in the device and offers graphical view of the data.

Diabetes Recorder - The application offers offline data recording for diabetes patients with minimal graphical views.

Diabetes+ - The application offers wide variety of data that the user can record and modify on the local device storage with support for graphical data views.

Diabetes tracker - The application offers offline data recording for blood glucose, medicine tracking, doctors appointment, blood pressure, food intake, physical exercises among others.

2.5 The Gaps in Diabetes Self-Management Applications

Patients with Type 1 diabetes got themselves into serious complications that leads to use of extra resources to curb the condition and improve their Quality of Life. This had been attributed by lack of personalized education, poor self-management skills and lack of real time clinical health care provider intervention.

According to Franc s, the available paper tools have shown shortfalls that ranges from error in manual data entry, missing or inadequate data captured to help the Health Practitioners in decision making or have mechanism that supports real-time interaction with patients monitoring their condition (Franc S, 2011). This has resulted to patients with diabetes having complications and requiring them to put more resources in to manage this condition and improve their Quality of Life. In most situation, the patient has poor self-care, lack of personalized health information or real time health care provider intervention to curb the condition.

Many Software Developers and researchers have developed multiple solutions that have flooded in the application stores and online tools. Some of these apps uses automated algorithms to calculate insulin dosage, track patients diet program or track patients' physical activities but very few offer integrated behavioral self-management. With technology advancement, data collected by the patients can be stored both locally in the device and enabling implementation of Auto Sync Technology where data is stored online once the device access internet. This helps in record keeping, be able to draw graphs and charts that are data-enriched reports which can be shared to family members, care givers or the health care professionals in real time. The availability of data both offline and online with data visualization tools helps in formulations of algorithms that can be able to search for patterns and relationships in the data which play a big role in decision making to offer a more personalized self-care. WellDoc System, an example of one of the apps in the market that allows auto upload of blood glucose readings and other information and receives real-time feedback from the health care provider have shown the intervention can reduce the A1c by 1.9% compare to the usual care that indicate a decrease of 0.7% (Chomutare T, 2011). The provision of real time diabetic control had been tried out much in the developed country context, there are major capability which the smartphones can be used to allow secure data sharing, real time intervention and sharing of the appropriate patient centered diabetes information to patients in the developing world which is underexplored.

2.6 Android Platform

Android is an open source platform developed by the Open Handset Alliance (OHA) with the main contributor of the project is Google. In 2008, the first phone running on Android was released with a continuous platform upgrade to the latest version 6.0. The platform is majorly used as phone operating system but have also been running on tables and TVs.

Android platform have a unique mechanism in which every application is handled around a sandbox design in which each application runs on its own Linux process and each process has its own virtual machine as described by Google (Google, n.d.). The applications do have access to only its files but with permission request can access other application piles on rooted devices. Android phones are most available smartphone in the market which makes it the best operating system to work on for a developing context. Android platform being an open source, it gives opportunity to developers to incorporate new cutting edge technologies as seen by the different android device manufacturers. The platform provides the developers with a wide range of libraries and tools that developers can access and build applications with extensive capabilities.

2.6.1 Application Manifest

Android platform enables applications to be built based on standard required structure. The application must have the Manifest file. In this file, all application permissions are declared and also any other permission that the application might be require in order to run. These permissions are asked during installation thus the user haves an informed decision about the application. With the latest platform development, the user can be able to modify the permissions on the application without un-installing it. The manifest file also contains all activities, services, broadcast receivers content providers and list of libraries the application is meant to use. The file also indicates the minimum level the Android API is required

2.6.2 Activities

Activities are files that are designed to do specific tasks by interacting with the application user. Activity haves a lifecycle that can start with its creation until its destroyed. Each activity file in an application contains programming concepts that implements different functionalities which indicates the activity state and its resource management. The lifecycle undergoes being active – the activity is in foreground, paused-activity is still in visible but its partial hidden by a transparent activity or the devices goes on sleep mode, stopped- the activity is completely obscured by another activity, and restored-the application is restored from the previously save state.

2.6.3 Services

Services are part of an android application that aren’t linked up with any given activity. Services can continue running even when the application activities are destroyed. They can be started by application or at the device booting. A bound service uses a binder that enables the application to reference to it directly while a hybrid service is started independently and can also connect to an application in order to interact with it.

2.6.4 Intents

Intents are used for linking application activities, services, broadcasts receivers and content providers by communicating the intention to do a given action. Intents are passive data structures that holds abstract description of the intended action to be performed. They can be explicit where it calls a specific android component or implicit where the user is given an option to choose between a list of components that are registered for handling the specific action and that particular data type.

2.6.5 Broadcast receivers

Broadcast receivers are android components that allows one to be able to register for an application or system event. The broadcast receiver would then respond to the broadcast announcement on which it can be displayed using user interface like a status bar or initiate a given service based on the event.

2.6.6 Content Providers

Content providers helps in supplying data from one application to other application on request. This data is then stored using means like databases, files or even over the network. The content providers usually do have well defined APIs to read, insert, update and even delete these data. The data on access can then be used by other application as per the implementation logic on that application.

2.6.7 Services

Android can handle multitasking by creation of Services. A Service is a part of the application that isn't linked to the application life-cycle. It also doesn't run on the GUI-thread and can therefore be active when user is doing something different without stalling the user interface

2.6.8 Databases

Android platform allows the applications to create databases to store information that is used by the application. This information is saved locally and can be accessed using SQLite - open source SQL database - that supports all rational database features. Database created allows tables to be created that do contain rows and columns with given conditions to insert, update and delete data in each cell. To access this data, database queries are written and adapters can also be developed to avoid writing of these queries on each and every time data is accessed.

2.7 Preference of the Android Platform

Android platform is an open source software based on Java development language managed by the Open Handset Alliance that have been the most popular Operating system due to its ubiquity on the range of devices and number of manufacturers that are offering the devices with difference features at different price ranges that matches the context of most users. Among the latest mHealth interventions, smartphones are one of the most promising tools that have a wide use base and easy utility by the community in the developing countries thus making it the most preference tool compared to other platform like iOS, Windows Mobile, black berry OS among others.

An android application requires development in Java though it can be built on cross platform application development tools. The apps take shorter time to be approved in the market store or even one can be able to download from online repository or share the application by use of Bluetooth or Wi-Fi which makes it reach the intended persons more quickly and efficiently. Android development space have existing modules and code subsets that one can use to create similar and functional application more quickly with a vibrant developer community that assists among one another on resolving of bugs and similar challenges that do occur in application development.

2.8 High Level Architecture

Young people with diabetes type one experiences many challenges in achieving their optimal control of their diabetes condition. In most cases, these patients do consider clinic appoint as lacking relevance thus making it in effective support mechanism for the condition. The patients do experience challenges controlling their condition which at worse leads to irreversible complications and is one of the issues that leads to adolescent with type two diabetes. The use of the internet and technology can be harmonized to break these barriers and enable a more effective diabetes self-management particular when the solution are based on use with smartphone which this particular age group are more conversant with.

The proposed Child diabetes care management system architecture is composed of three main components that are being accessed by the users during its functionalities. After data had been collected, these include blood glucose readings, physical activities, insulin dosage, pills intake and blood pressure, these data are entered into the Android Smart phone application. The data is sync to the Azure web service which keeps record of the data. This data is automatically shared with the respected members in the child diabetes management and being visualized with well-designed graphs and charts to enable the concerned party make a feedback or take action that is shared to the appropriate member. The System architecture was a modification of the Mobile Personal Health System designed by Osama E. Sheta (Osama E. Sheta, 2015).

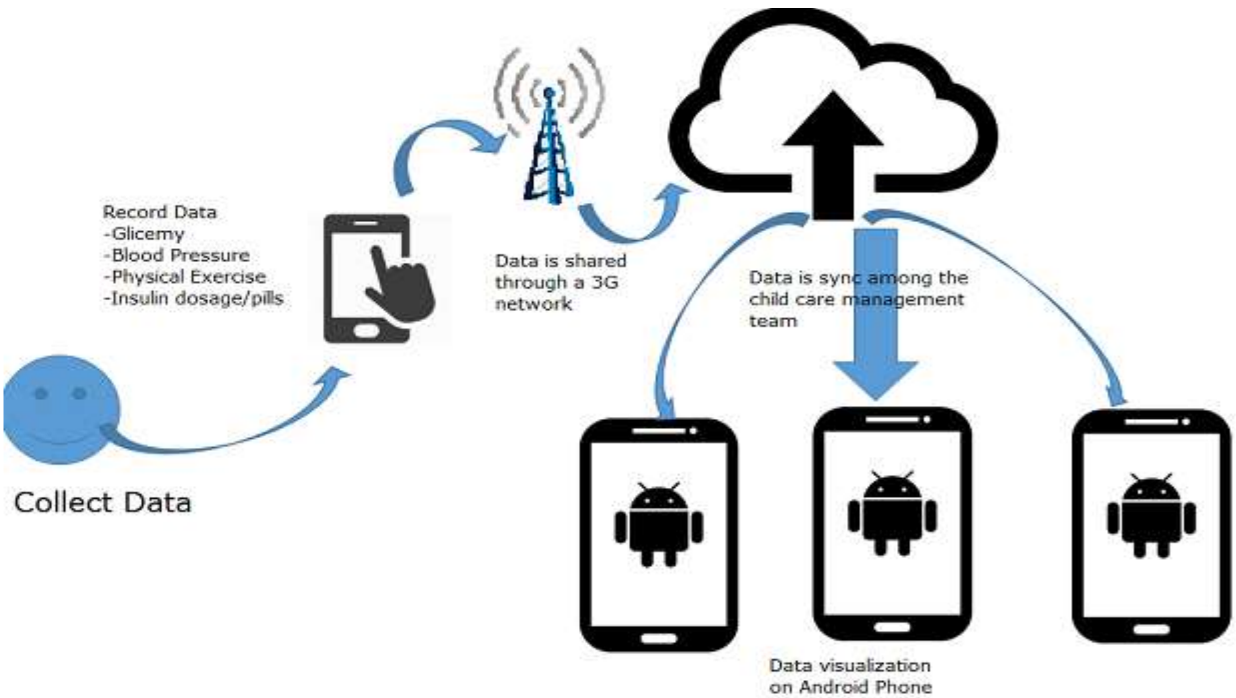

Figure 1: System architecture of the Child Diabetes Care System.

The component involves a user portal that servers for data acquisition and visualization for patients and caregivers, a mobile client that supports data auto Sync and decision support in real time grounded with evidence based clinical guidance and practices and a General Practitioner portal which have patient data viewing functionalities, reports and data analyzing to help the practitioner be able to configure triggers that assist the practitioner to control the parameters and pass relevant personalized information to the patient.

2.8.1 Android Smart phone

Android smart phone with 3G data connection capability is used to gather data, sync the data to the Azure services, process the data and provide data visualization. The end users of the phone can be the child, parent/guardian, Child care giver or the health care practitioner. The devices are used to share data as well as to visualize and issue notifications to the different participants in the child care. With the availability of Wi-Fi Hot spot even in the public places, this can be used as an alternative to data entry using the Access Point and while out of connection to resume to 3G mobile network data usage.

2.8.2 Azure Services

Azure service is provided by Microsoft Azure which is one among other range of cloud services like Analysis and Networking, Computing, Web and Mobile development, Internet of Things among others. Azure services provide secure data storage and accessible on need. The azure services offer data request authentication to different care givers thus accessing what’s necessary for them depending on their privileges.

Blood glucose, blood pressure, physical exercises, insulin intakes and notification data is stored here and shared between the patients and the multiple care providers.

CHAPTER 3: METHODOLOGY

3.0 Introduction

Android platform have seen much focus on progress development of which have enabled the availability of low end smartphone that have enabled high computational powers on these devices at a very affordable price. This have enabled people in the developing countries be able to own a smartphone. Application based on Android OS can now be build running advanced algorithms at the same time supporting real time sharing of information. This power can thus be harnessed to help in diabetes self-management programs thus empowering patients and improving their Quality of Life. Implementation of intuitive and more user friendly applications to be developed running on these devices in order to adopt a long term use by the patients (van der Weegen S, 2013).

The availability of access to Internet services at affordable packages from ISPs such as Mobile Operators in the developing countries have enabled development of customized intervention using Telehealth for diabetes self-management, for instance a study done suggested that 63.6% of parents with children having type one diabetes uses internet to gather information about diabetes and how to curb the situation (Balkhi AM, 2014). According to Jennett, the process includes having the health care professionals' exchanging self-management information in real-time to the patients via data sync, SMS or phone calls thus providing the same care that would be achieved when provided in-person (Jennett PA, 2003).

Diabetes patients requires long-term self-management that can be solved by having more user-friendly solutions. These solutions have shown capability to tailor down insulin dosage to collect blood sugar levels or help to precisely quantify the amount of carbohydrate intake (American Diabetes Association, 2008). When these apps are designed properly, they can dearly help to protect the patient from taking a wrong dosage that may result from calculation errors since insulin has a very narrow therapeutic range (Lamont T, 2010). Handling of children with diabetes becomes more challenging as the patient needs a physician to help in monitoring their HbA1c (Mulvaney SA, 2010) and support them in psychoeducation to empower them and help them overcome negative beliefs of diabetes as reported by Mulvaney et which have shown success in improving glycemic control when done online (Mulvaney SA, 2010).

A collaborative diabetes patient care can be achieved by developing an integrated personal-care system that brings in collaboration of the different stake holders for a child with type one diabetes who includes the child, parents/guardians, family friends, teachers'/care givers and the health practitioners can play a very vital role on the patient self-monitoring and managing diabetes. These tools needs to be more efficient and effective in determining the insulin dosage as well as providing a more personalized management assistance to prevent occurrences of complications.

Mobile application development requires lot of creativity in user design thinking to identify the proposed solution that befits the context of interest. Though there are tools that can be used to help guide the process in designing specific application features there are no set rules that outline how the same user requirements can be translated to specific design features. The methodology used in developing the Child diabetes application is discussed below.

3.1 Storyboards

After user requirement identification and analysis, all the ideas of the Child Diabetes application care were written down in scenario form from which the storyboarding was initiated. The goal was to take the ideas that were generated and sketch an actual User Interface showing how a user would move through the scenarios, this included buttons to click, the information displayed, user expectation from system.

The process started with blank sheet of paper and sticky notes on it. Each sticky note was regarded as one frame in the storyboard. All the scenario was drawn to their depicting User Interface showing the user flow of action on when interacting with the application. After iteration of the different frames to make sure they are logical and coherent, user tasks were identified and discussed below.

3.1.1 Data Entry

The application functionalities were broken down into frames that allowed multiple data entry. These different data sets include, blood glucose, blood pressure, insulin intake, physical exercises, carbohydrates meals take. All the data were to be captured in a given context and time with additional informative data entry was included where necessary. Backdated data was also allowed to be put in situation where the phone could be off during the data collection.

3.1.2 Data Sharing

With every data entry, the data should be made available to all other participating users in the care of the child. The different users included the Child, Parent/Guardian, Caregiver and Health Care providers.

3.1.3 Data Review

Data review allowed the different person be able to add triggers to the data for notification. Data visualization via list-view and charts was facilitated to enhance data summary over given time periods.

3.2 Ethical Issues

The running of this application requires involvement of the General Practitioners, the patient and the caregivers involved. Issues that were considered included the ownership of health data collected. An informed consent from the patient and caregiver together with that of the General Practitioner was agreed on in order of each party to understand the security of their data from the third parties like Microsoft Azure services that was used to provide cloud services, Mobile loopholes that can make the data available to intruders or even sharing of such particular patients' data.

Thorough ethics and governance mechanism on Health Technology are still unclearly documented. A template was drafted and evaluated by the members to enable them feel safe during the course of running the prototype. In September 2013 (FDA, 2013), the FDA released guidance for the developers of mobile medical apps and defined 'mobile medical apps' as those which are intended 'to be used as an accessory to a regulated medical device' or 'to transform a mobile platform into a regulated medical device' and this was last updated on February 2015 (U.S. Food and Drug Administration, 2015). This formed the part and parcel of the standards and guidelines for the solution development.

In Kenya, there are no laid down ethical guidelines regarding the m-Health of which the government should consider enacting legislation that would limit the ability of any agency either by from government or private to access or share personal health information. For the purpose of this study, interventions used were subjected to the same level of security requirement as other forms of electronic technology for health that will involve data encryption and consent agreements from the involved parties.

3.3 Target population

A cross sectional study conducted for people having diabetes in Kenya by the Novartis research team in Nairobi and Mombasa counties by June 2015 pre-released data indicated the registered diabetes care receivers under the Novartis to be more than 1800 patients (Novartis, 2015). Nairobi area was selected as it had 70% of those registered patients, another factor that was considered was the challenge in getting pharmacists who could allow their patients take part and monitor them. The estimated sample size of at most thirty patients was arrived by patients satisfying the inclusion criteria of,

i. Age between infants - 16 years,
ii. Permanent/fluent patients who are attended by a specific General Practitioner,
iii. Agreed to participate in the study.

3.4 Resources

3.4.1 Hardware

i. Computer with at least 2.9 GHz running on a dual core processor with a minimum of 2 GB RAM.
ii. A phone running on Android OS for the participants

3.4.2 Software

i. Eclipse for development of the software.
ii. Windows Azure services for data.
iii. Android SDK
iv. Gent Motion Software

3.5 Diabetes Application Development

With rising number of people having diabetes, there emerges the need to manage this condition in a more efficient, effective and user friendly way. This have resulted to increase in the number of diabetes related mobile solutions that are data driven supporting seamless sharing of the patient data. Most of these application development and maintenance comes at accost have seen the developers target high end smartphone devices of which the users are based in the developed countries. These applications mostly do fall under the native iOS or Android platform and at general do have functionalities like measuring blood sugar levels and recommending the appropriate generic nutrition and medication depending on the patient diabetes type.

In a developing world context market, there is lack of relevant and appropriate health information technologies that are meant for people with low health literacy and scarce resources. On a low resource context, most of these diabetes patients have limited ability to afford high end smartphones like iPhone or Android phones nor their literacy level allow them be able to process and internalize the data collected using these smartphones. Users based on this context do also have barrier in interpretation of basic health information that would enable them make well informed decision in managing their condition. In some cases, these patients even lack know how to across prevention services or control measures in situation when the indicator alerts are extreme.

With the introduction of low end Android Smartphone in the developing context with features that can be utilized used to develop applications that can be used in a more efficient data recording and supporting interpretation of this data for low literacy users with minimal resources and thus had been preferred the choice of Operating System for this case study

3.5.1 Azure Services Configuration

Microsoft Azure for data storage and sharing was preferred since its more agile with minimal back end software integration and relies on the Java Logic Models. Azure services also provide high data security through encryption during transmission and use of user authentication to validate access to data from the storage. Libraries that support the service were freely available in the developers' forum which were also integrated to the application development libraries.

3.5.2 Android Application Programming

The child diabetes care application development started by learning Java and Extensible Markup Language (XML) programming languages used for developing Android Applications. XML is used by Android to create the graphical interface (i.e., the layout), while Java is used to implement the logic behind application functionalities. Android uses a specialized version of XML with its own terms. Java source-files are packaged as Java Archive

(JAR)-files and the interface designs as the xml files. Data binding and object related development hard on skills were acquired during this time.

App development started by identifying the minimum API level 11 and targets the latest android version of API level 23. This means that the application would be supported to run on all the android smartphone based from API level 11 to API level 23. To support this, android-support-v4 libraries were incorporated to the application to enable same application interface between the different API levels and supports backward compatibility. Other libraries that were used during the application development were for Asynchronous background task processing in the phone – volley library, data structuring and visualization libraries – droid Text libraries.

With many available IDE (Integrated Development Environment) in the market supporting android development, Eclipse was the best choice for its efficiency in the user interface and handling of errors during the logic implementation. Eclipse IDE keeps log of the application during development such as warning, informing alerts, errors that links to the source code having the bug.

Genymobile's emulator was downloaded from the open source that support testing development and was used during the debugging process. During debugging of the application, printouts from the application are shown in the debugging-window which are always vital in troubleshooting any issue during the development.

3.6 System Development Method

Prototype methodology is one of the System Development Methods and was used in the system development. Prototyping allows the system development to incorporate building and using a model of the system from the design phase, implementation, testing and system installation. during the initial steps, a model of the system is developed with the system modules, data storage, inputs and outputs as well as the system reports. The methodology helped in modification of the clinical decision support and the system processing and data analytics as well as validations rules used. This also helped to have the users be able to do system test and have the system acceptance tests before launching the platform for patients use and evaluation.

3.7 Implementation

3.7.1 Information Entry

The main functionality of the application will be to log information. Many of the design choices have been around how to serve a large audience where every age and life-style is represented. Logging too much information would make each entry time-consuming and complicated for some users, where else others might want more functionality. All entries were designed to be as general as possible so that the user would decide what works for them. The application supported manual input of these categories: measurements, medicine, physical exercise, meals and feelings. The Entries were also designed only to take a couple of seconds to minutes depending on the user to complete. All entries also had input for notes, where the user can write optional information important to them. When logging medicine, the users can input their own medicines; which will be saved for easy access later through a drop down menu. Meals were also counted as kilo calories (kcal), which is the most relevant information of each meal for diabetics (Mann., 1980). Physical exercise was added as a duration together with intensity and the type of activity done.

3.7.2 Data Presentation

Presentation of data supported list of entries and graphical interfaces. The lists supported all the categories of data and was designed to provide as much relevant information to the user in a way that's easy to understand. Entries were chronically ordered with headings showing dates and each category has its own unique icon. The user would also be able to edit or delete the data by pressing on the entry displayed. Graphing was provided to enable a better way to see how the data-points change over time. Plotting the glucose values shown how many values are too high, too low or in the normal range for a given time period. Setting the range for normal values was facilitated by the General Practitioner on their patient portal.

3.7.3 Data Sharing

All the patient data was shared in real time to the relevant care givers and practitioners. The data would then be visualized in graph formats with features to export it in a format sharable via email to other excluded personnel from the patient handset. The system had automated algorithm as per the prescribed clinical guidance on diabetes care which were configured and tuned by the General Practitioner thus offering personalized care. This helped the system to be able to detect warning from the shared data and assemble a notification and send it to the patient, caregiver alerting them for action.

3.7.4 Data Backup

Microsoft Azure services provided data back-up where the setting configuration and all the patient data were store in the cloud. This storage provided data back-up and seamless data exchange with the different users using multiple devices.

3.7.5 Reminders/Flags

One of the problem with diabetic patients is that patients, especially children, often forget to take their measurements during the day. Therefore, reminders were set to be repeated at particular intervals as recommended by the practitioner. Each reminder would alert the patient by sound and vibration and provides an easy way to open the application through a notification. The care giver would also get a notification so as to be able to do a follow up on the child taking the measurements. Alerts would be triggered on the General Practitioner device on extreme recording thus giving real time intervention.

3.8 Prototype Evaluation

From the storyboarding, application logic was implemented with the user interface design created from a formative usability approach. This made the process to be iterative where try and error are common with problem being identified and diagnosed during the whole process of the application development.

Initial design guidelines were identified from the results of the requirements elicitation and analysis phase the first iteration was developed. The design was also partially influenced by focus group used to do testing who are used to other form of android application for communication. The application was built with an action bar that enabled quick launch to access various application functionalities. The action bar was used as a starting point to guide the design with the expectation that it would iterate and change as the prototyping process moved forward. During this evaluation time, different color codes were selected. Different algorithms were used to trigger errors and warnings during recording of out of rage data and were tuned by the General Practitioner depending on the patients' trend.

CHAPTER 4: ANALYSIS AND DESIGN

4.1 Research Design

This study uses exploratory method since the outcome of the study does not intend to offer final and conclusive solutions to existing on child with diabetes self-management problems. During the study, a triangulated or combined methodological approach to addressing different issues of the research was used to complement each other.

The significance of utilizing triangulated research techniques amid this study is that it is enhanced by the different sources of data and the multidisciplinary character of exploration on health services. This includes taking concern of Patient, Care Givers, General Practitioners and other involved specialist in the patient care. A close relationship was established with health as they are equipped with a range of research skills that facilitated in determining of the best child-care intervention and development of the clinical outcomes of the solution.

4.2 Requirement Elicitation

User requirement gathering was carried out using a qualitative research method so as to understand the Children culture and their needs which had been used to develop the self-management application for the type one diabetes children. To achieve this, focus was emphasized on a User Centered Design and ethnographic research activities to identify the scope of the project. This further helped in gathering literature materials for review, identification of data collection methods, means of obtaining and understanding the ethics required in the run of the project. These task involved doing semi-structured interviews and observations to identify the information of how health practitioners relates with the children who haves type one diabetes, how their parents carry out daily care, how their teachers also play part during school sessions and the children involvement to collect their situations. This was vital to identify the design that would befit all the user in one modified application.

After the user research, the system requirements were plot down and paper prototyping design which was put into evaluation in an iteration manner to keep on refining the application.

4.2.1 Literature Reviews

Several mobile applications and literature materials for type one diabetes apps have shown that the systems that incorporate easy data input, visualization, sharing and real-time interaction have's potential to resolve major challenges in diabetes care. Some of the features also recommended included aspects of motivation for the user to be able to record their blood glucose and other relevant information routinely. With the availability and increased number of smartphone penetration in developing countries, it becomes more realistic in developing an Android Application for the intended users in this context. The materials helped in determining the preliminary design and application functionalities that can be implemented to help and efficient the diabetes self-management process

4.2.2 Interviews

Semi-structured interviews were carried out during the Safaricom Kenya Diabetes for children run which intended to have the anonymity of the participants. With the background knowledge from the literature review and intuitions, it helped in shaping the research interview questions whose main goals was to understand the effective ways of designing the application, data capturing and presentation, sharing of the data and preferred apps functionalities to make the child care more efficient.

4.2.3 Observation

Observation was carried out to understand the interaction between the patient and the physician who had a routine visit which normally do happen after 3month at the Health Provider clinic. This information counted to be valuable in understanding the disease and the impact it had on the patient. Patient consent was asked for before any observation would be made, this was also to accord noninterference with the process undertaken during the visit. During the clinic visit, HbA1C would be taken and much emphasis put on it as it indicates the average blood glucose for the last 3 months. This knowledge helped in adjusting the algorithms used on the application.

General Practitioner would also use the hand written logbook to gather more additional information over that period which included carbohydrate intakes, insulin intakes and the physical activities recorded. Merging this information would equip the physician understand the root cause of the trends in the blood glucose records which would help the physician give recommendations so as to regulate the blood glucose levels. Some of the recommendations includes change in diet intakes, improvement in physical activities and insulin dosages. Though the logbooks used are all slightly different, their layout is almost consistent allowing users to be able to enter their records of blood glucose before and after meals, be able to track carbs taken and the insulin dosage as well as records of physical exercises.

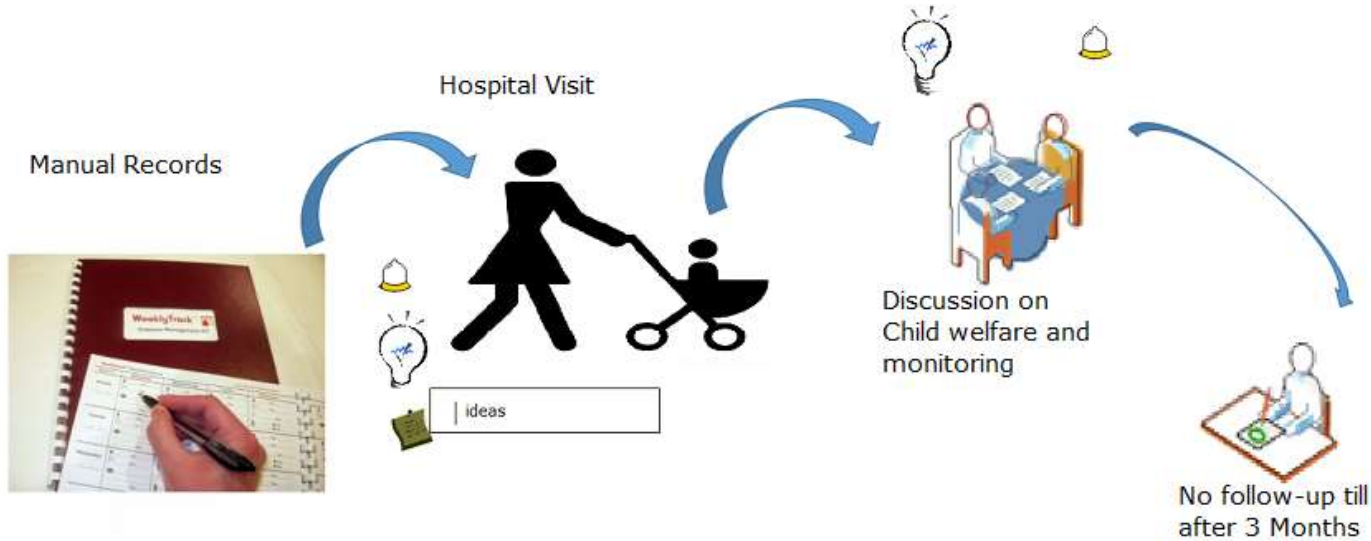

Figure 2: Manual Logbook.

4.3 Requirement Analysis

The process was used to sort out the many ideas and data collected into a more useful requirement to develop the application. An anonymity of the person interviewed was upheld and the requirements were broken down into categories that defined the functionalities that the application required to perform. Sketches were developed and analyzed with the help of participants and thoughts and opinions were added to make the application be more interesting and helpful to the users. Some of the crucial categories were data collection, data tracking and changes; data visualization and decisions pegged on the visualization like charts; data sharing and frequency in sharing, the persons to share the data with and the use of that such kind of data by the user; what would motivate the users –child- be able to input data regularly and routinely.

4.3.1 User Requirements

With the objective of having a solution that would improve the Quality of Life for the patient, improve self-care behavior, being efficient in use and adheres to psychosocial variables a design intervention was developed to make the issues be addressed and formed the main requirements which were identified as the design principles. Data display that is simple and understandable to the young was integrated to the decision support which would prompt alerts as per blood glucose levels. The clinical decision support was meant to detect out of range recordings or consistent out of range recordings and prompt the participants in the child care.

The requirements included: -

Design elements – Color codes that can be associated with reading range. The data should also be summarized and presented in an easier way to understand the values.

Data Visualization – The application should be able to allow the users record physical exercises, emotional feelings and track blood glucose, carbs intake and insulin dosages. Health care providers should be able to make adjustment on the child dosage and give intervention in real time.

Sharing data – All the participants, the child, Child parents, Care giver and other members involved in bringing up the child should be able to receive the vital information during out of range recordings or interventions from the health practitioners so as to do follow up with them.

4.3.2 Building Prototype

From the understanding of the highlighted user requirements, storyboarding was used to identify the task that the child, healthcare practitioners, caregivers and other users would attempt to complete while using the application and what the expected system would be able to respond and accommodate such kind of instructions.

The following task were identified: -

Data Recording – The application should be able to record data in an easy way, fast and be able to display the recorded data which are blood glucose, carbs intake, insulin intake, activities done and individuals feelings.

Data Visualization – Recent and Historical data should be able to be summarized and computed to indicate the trends and prompts when the reading is out of range based on the patient historical data and the clinical decision guidelines.

Data Sharing - The information collected, generated by application or triggered by input triggers per different user roles was formed into efficient easy to share and easy to understand format by all the parties involved.

A prototype was developed upon understanding the above stated expected user interaction with the android application. The application methodology prototyped required iteration of designs with the base design from the identified requirements gathering process.

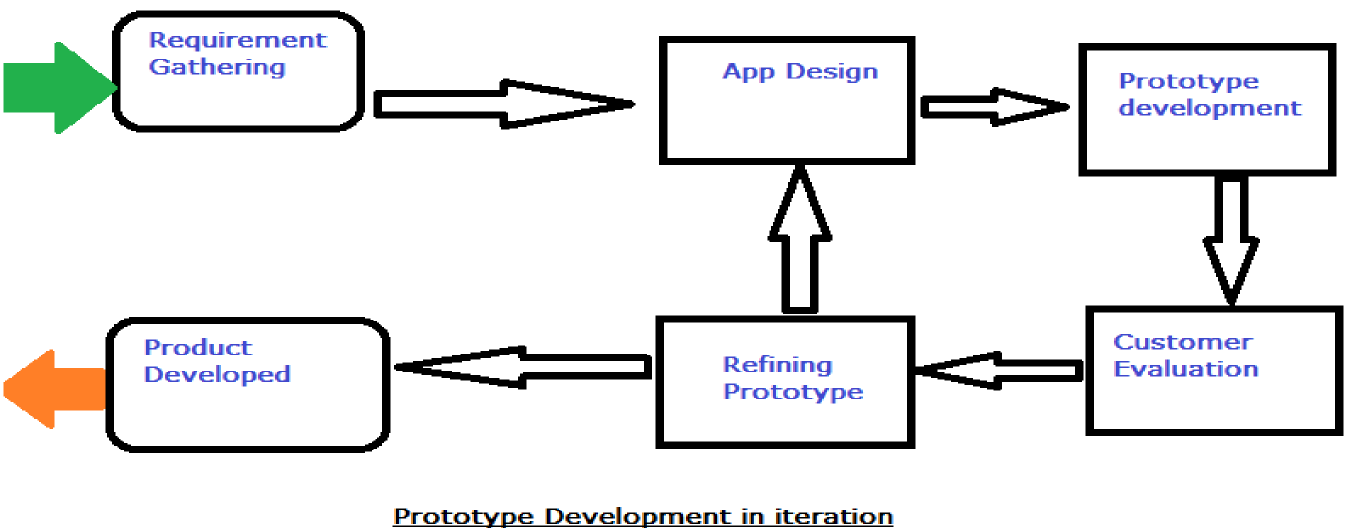

Figure 3: Software Prototyping proposed development methodology.

4.4 System Model and Design

The proposed system would be an integrated Android application that allows the patient be able to record blood glucose values, physical activities, feelings and meal composition. Data is then stored locally in the gadget and allows Auto Sync to an azure server. The application itself would be implemented with functionalities that allows algorithms to run and compute insulin bolus, display data in statistical and charts easy to read

4.4.1 System Design

This process entailed transforming the various structural models into classes, relationship diagrams and interaction diagrams. It also involved defining the hardware and software architecture, components, modules, data and interfaces for the system to satisfy the specified requirements.

System design helped in planning the solution to the problems specified in the requirement document. This process was plays a critical role to produce a high quality software that is easy to test and maintain and allow its evaluation and system evolution be seamless. From this design process, the system components were determined and their interaction to each other defined. This was further broken down to each component modules that were to be used in developing the application. The logic interpretation and flow on each module with the specific data structures, algorithm, data input and output format defined was documented into detail. A design document was drafted which acted as the blue print or plan for the solution, and was used later during implementation, testing and evaluation of the whole system.

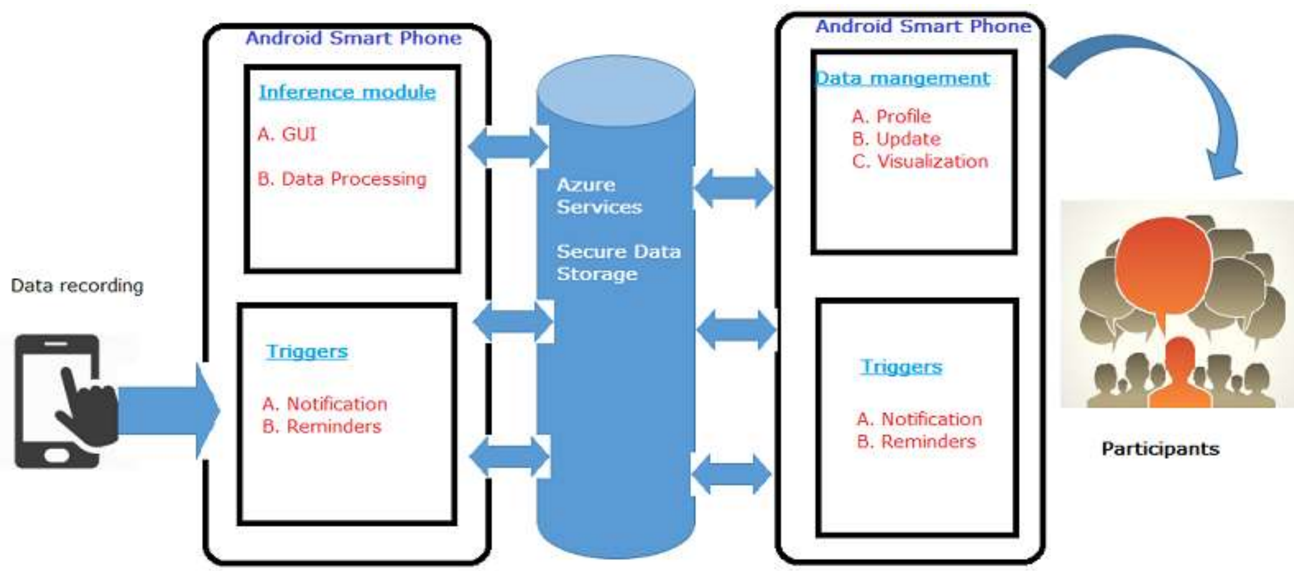

Figure 4: Design for the proposed system.

4.4.2 Use case Diagram

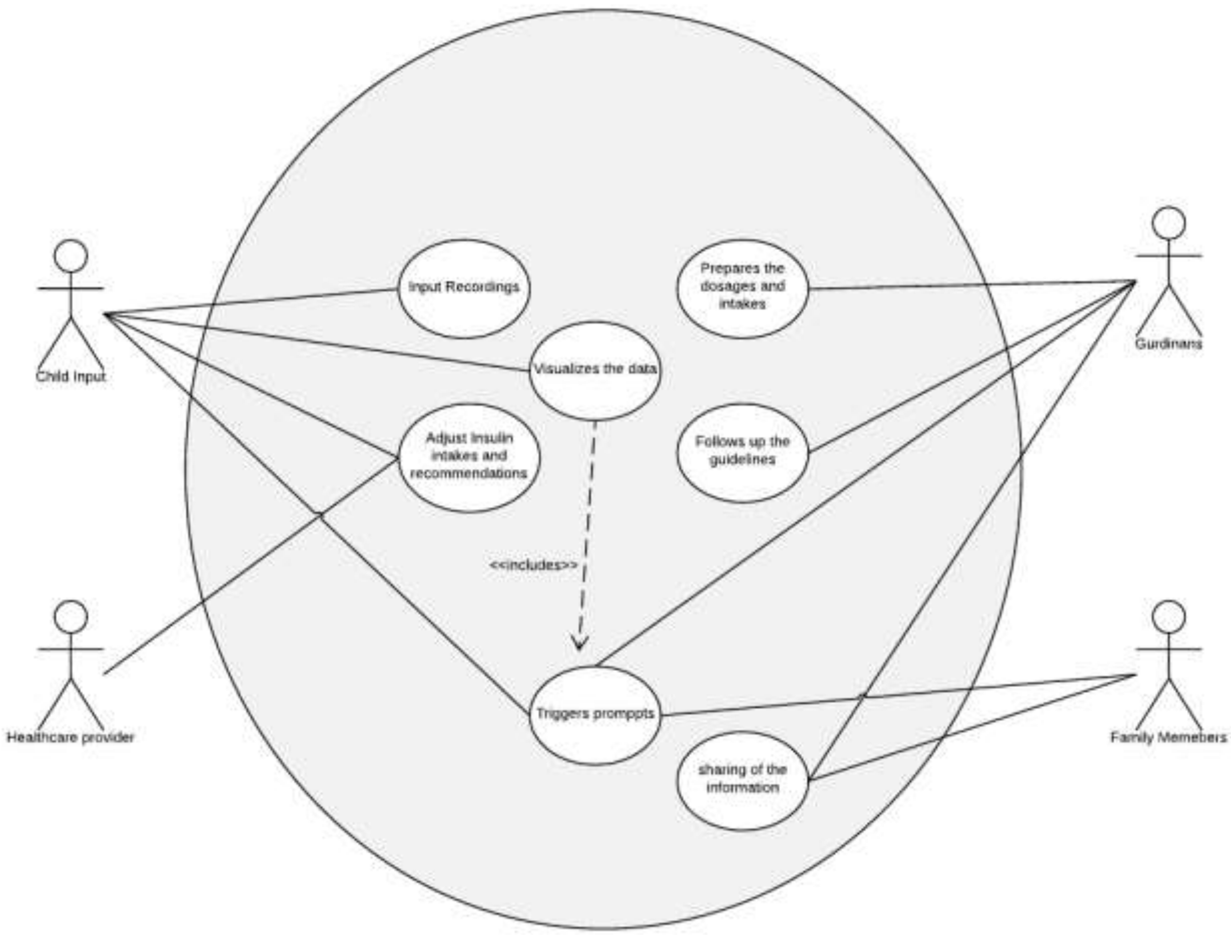

Figure 5: Application use case diagram

4.4.3 State Diagram

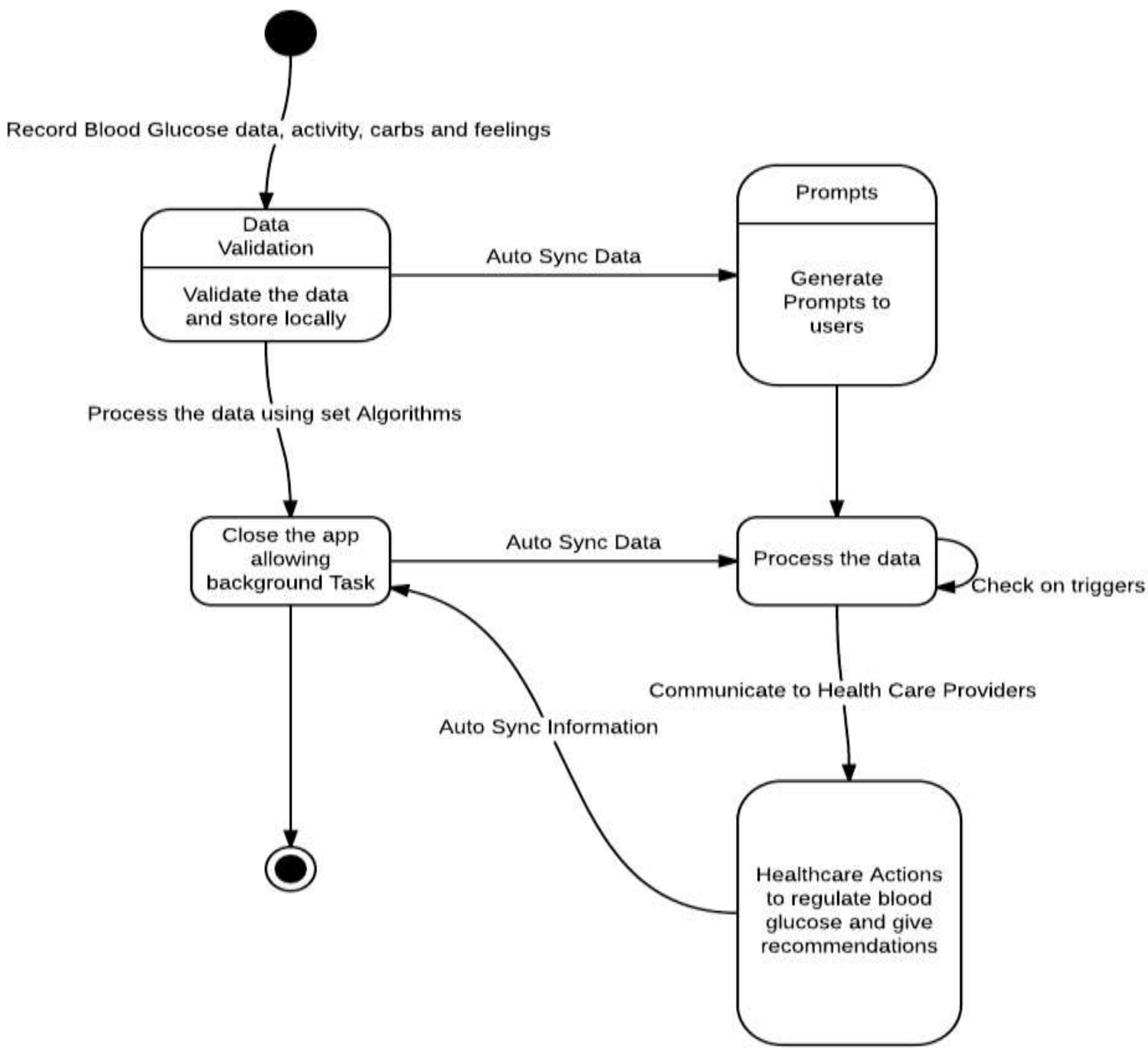

Figure 6: Application state diagram

4.4.4 Application Development

This process involved implementing of the design using the Java and XML language for the Android App and the Azure Services Configuration. Code documenting was done parallel to the programming with unit testing carried out on each and every module. Integration of the modules was further carried out and to connect the components in the application with further integration with the database for data saving and sharing in real time with azure services.

4.4.5 System Testing

To detect the system defects, testing was introduced to uncover the errors starting from unit testing, modules integration testing and finally system testing was carried with documentation on every step. An acceptance test was done with the system users on real-life data. Test report and error report were generated from this task documenting the test cases done and results and action that was undertake to resolve the error reports.

4.5 System Evaluation

Blood glucose levels do vary throughout the day or night with the ideal range considered to be between 80 to 150mg/dl before meals or between 120 to 180mg/dl within two hours after the meal. This helped to create triggers on the blood glucose level change to the extremes. The Subset were grouped into three categories, the infants and toddlers age between 0 and 5, the School-age children between 5 and 12, and young adolescents between age 12 and 16 years. A general range was set between 70to 125mg/dl before meals and 120 to 160mg/dl two hours after the meal.

4.5.1 Scenario A: Infants/Toddlers

These group recommendation is that they should have their blood glucose level ranging between 110 to 220mg/dl otherwise the system should create alerts to notify the parent/guardian/caregiver the quantity of insulin if beyond this. Snack with sugar is hard to intervene with when the blood glucose level is below the margin since eating is not predictable.

4.5.2 Scenario B: School Age Children.

These group one can easily sense and identify the symptoms of low or high blood sugar. More recording was recommended for this group before, during and after physical exercises. The system trigger was set between 70 to 180mg/dl where if the levels are over 180mg/dl, the system alerts the parents of the seriousness of the case and determines child's insulin dosage, otherwise if the level is less than 70, the system alert the parents to gives the child some carbs.

4.5.3 Scenario C: Young Adolescents.

This group of children could be able to identify and sense symptoms related to low blood sugar and be able to follow a meal plan to control their condition. This category of persons was recommended to have a blood glucose range between 70 to 145mg/dl. Range below 70mg/dl would create a trigger to inform the child and the caregivers to do a follow up on the child that they take some carbs to rise the sugar level up. With over 180mg/dl before meals or two hours after meal time, the system creates alerts to inform the care givers the seriousness of the case and determines the insulin dosage to be given.

Blood glucose level recording was highly encouraged for those who were taking insulin dosage at least two to four times in day. More emphasis was placed in having the recording before and after meals as this formed the bases for evaluation of the effectiveness of the insulin dose given. Caregivers were urged to have at least four recording in a day, at pre-breakfast, pre-lunch, pre-supper and pre-bedtime as this information helped to identify how well the rapid-acting insulin is working between the intervals or how well the intermediate insulin taken after the previous instance is working. The pre-bedtime would inform how well the rapid-acting insulin taken at the supper time worked, pre-breakfast reading would show how well the dinner or bedtime intermediate acting insulin worked over the night; the pre-lunch would inform on how the rapid-acting insulin worked or the intermediate-acting insulin taken during the breakfast is working while the pre-supper recording would show how the intermediate-acting insulin taken at breakfast or the rapid-acting insulin taken at lunch is working.

CHAPTER 5: RESULTS AND DISCUSSION

5.0 Introduction

In this study, an Android application, the *Diabetic E-Patient Care System* was developed and designed to enable self-management of diabetes using a smartphone for children. From the application use by the patient, major concern was emphasized on the usefulness of the system in the child diabetes care and to what extent the system improved the diabetes self-management over a smartphone in a developing world context.

5.1 Diabetic E-Patient Care System Application

Diabetic E-Patient Care System application used in this study is a diabetes self-management system that records personal information, blood glucose levels, Blood pressure, Physical Activities, Meal Carbs taken, Insulin dosage and Insulin tabs that the patients utilizes during the self-management program. The application allows easy access to the saved records history through the record sheet and graphs & charts for easier understanding of the data. The data is shared among the caregivers of the child, child device and the General Practitioner portal. The users and their roles in the application are further outlined below.

Users	Roles
Parent	i. Create/Edit Child account ii. Record, View and archive Child Blood glucose, Blood Pressure, Insulin Dosage, Insulin Tabs, Meals Carbs and Physical Activities. iii. Add/Remove a Health Care Practitioner in the child care. iv. Add/Remove a Caregiver in the child care.
General Practitioner	i. Record, View and archive Child Blood glucose, Blood Pressure, Insulin Dosage, Insulin Tabs, Meals Carbs and Physical Activities. ii. Create triggers by configuring each patients' variables and provide real time intervention.

	iii.	Accept/Detach oneself from the child care.
Care Giver	i. ii. iii.	Record, View and archive Child Blood glucose, Blood Pressure, Insulin Dosage, Insulin Tabs, Meals Carbs and Physical Activities. Create Alert notes and provide real time intervention. Accept/Detach oneself from the child care.
Child	i.	Recording and Viewing Child Blood glucose, Blood Pressure, Insulin Dosage, Insulin Tabs, Meals Carbs and Physical Activities.

Table 1: System User Roles.

Sample Screen Shots of the application and the various functionalities is shown on the figure below.

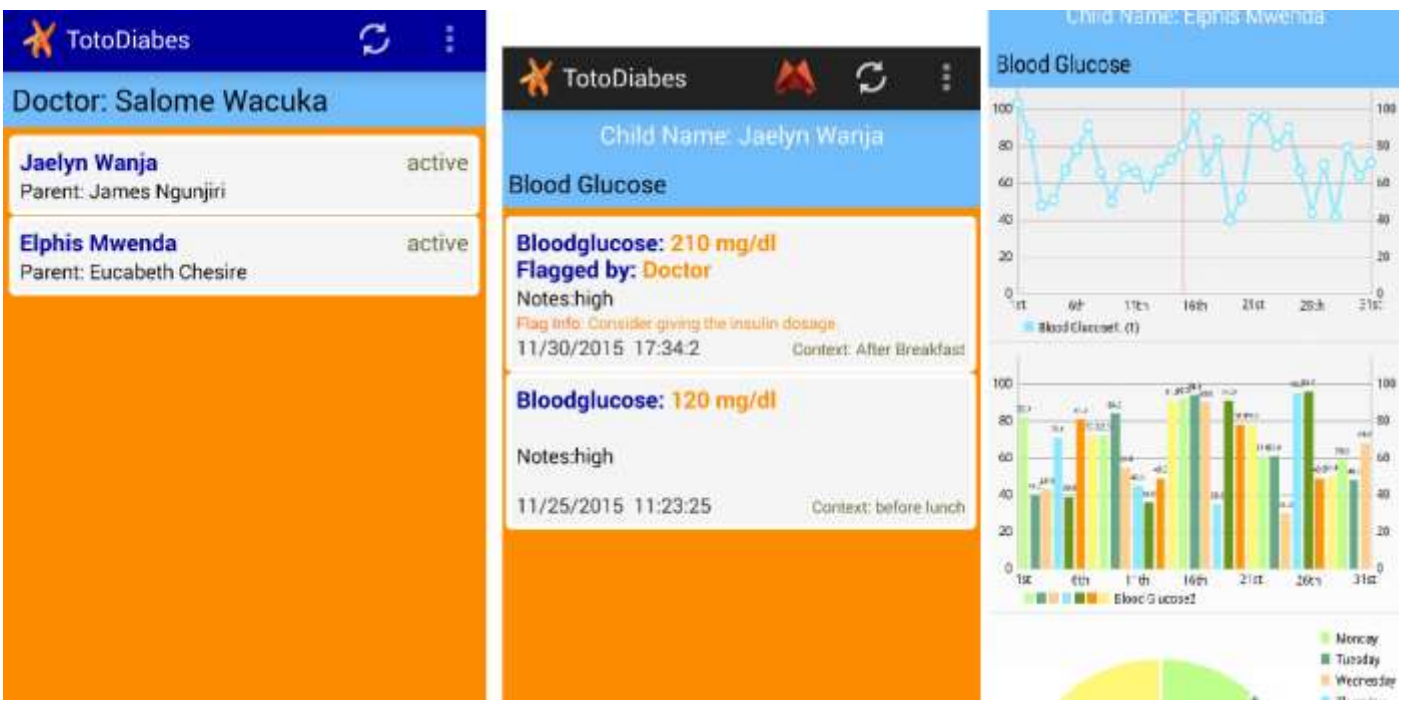

Figure 7: Application Screenshots. A. Doctor Portal where the doctor can select active child accounts and watch their performance. B. Child blood glucose with doctor flag and recommendation. C. Graphical summary of the blood glucose record.

5.2 Application Testing

The system was tested as a whole to determine its overall functionality was achieved. Prospective users of the system were given access to the system to determine if all user requirements were met.

5.2.1 Functional Testing

The application was split up into the required modules; Data recording, Data Processing, Data Visualization and Data Sharing, each performing a very specific function and each module was tested against a set of specific inputs and outputs. In order for the test to fail as required and pass as required, a test project was developed and the project code modified and add exceptions and flags denoting failure or success.

5.2.2 Unit Testing

This was done per function component testing in which given input was tested against resulting output. This was handled per module, submodules and functional units in the whole system. The process involved checking for each functional component, the code syntax errors and that the actual output is consistently the expected output per given set of inputs.

5.2.3 Usability Testing

Once the system was ready, it was availed to the users to gain feedback about the following issues.

Error Handling- The system was able to notify the user once they make errors and direct them and how to recover from those errors like large figures, network error among others.

Efficiency- The time taken to input, process data and issue information was found to be acceptable. This was compared with the manual logbook that patient run parallel with the application.

User interface design- The user interface design analysis was involved for testing on the visibility of instruction and input of data and how thy will be visualized to the users. This helped to capture user interference during the use of the system and how they could cope with the situation.

5.2.4 Test Case

After the application development, various application users were used to undertake the application test during which the following processes were undertaken for the test cases as described on the table below.

TEST CASE: 1 - *Description* : Integration testing of the Input,Output and Alerts.			
Instructions	**Expected Results**	**Actual Results**	**Comments**
i. Launch the application ii. Input the record iii. Validation of the record	Correct fill up on input fields results to positive user toast alert while errror gave warning alerts	All input fields that were mandatory for user fill-up were added triggers to give respective feedbacks.	Test was successful and moderation done.
TEST CASE: 2 - *Description* : System response time			
Start a new application task.	The duration used to download record, process data was adequate with delays showing responses.	Time taken by the system was deemed acceptable.	The system's response time was acceptable.
TEST CASE: 3 - *Description* : Data synchronization			
i. Launch the system ii. Add records	On successful record entry, data is available to all users having the privilege to view it by pressing refresh button.	Time taken to refresh data and display to different users was acceptable.	Data Sharing was successful.
TEST CASE: 4 - *Description* : Userbility and navigation			

1. Launch the system. 2. Navigate to handle different task. 3. Close task and open other tasks. 4. Quit the system	All the task should be able to run independently.	All task was easily navigable to and launched.	Navigation were easy with simple guidance by pressing menu buttons.
TEST CASE: 5 ***Description*** **: Error Handling**			
i. Start the application ii. Add records iii. Make errors in entry.	Errors made in choices supposed to be handled before the user navigates out of the activity	System responded rightfully to the errors	The system handles errors correctly

Table 2: System Test cases

5.3 Subjects

Subjects included those who were ready to use *Diabetic E-Patient Care System* application and willing to give consent to participate in the research study. A final analysis was performed on data from 11 patients who completed the questionnaire after interaction with the application.

5.4 Ethics statement

This study was carried out with subjects who agreed to participate in the research and who were ready to test run the *Diabetic E-Patient Care System* application. The study subjects were recruited via interviews and the willing participants given access to download the application and installing it onto their devices. The participants would fill the questionnaire forms at the end. Anonymity of the user information was up held since the data collected was private and confidential.

5.5 Method in data collection

A questionnaire on the satisfaction with the *Diabetic E-Patient Care System* application was used in this study consisted of personal information of the subjects and the diabetes management status before and after application use. The study focused on identifying changes reflected on the slightly modified Summary of Diabetes Self-Care Activities (SDSCA) items – medication sub-scale was removed - and the extent the users were satisfied by using the system. SDSCA is the most widely used tool to measure the degree of diabetes self-management, and its usefulness has been verified through various other studies. The reason for this is that, in most of the test-retest done, the subjects seemed to report excellent adherence to the medication items thus it wasn't favorable for our research findings. Subjects who agreed to participate in the survey took part in doing recordings using their own personal devices for glucose measurement. Some of the patients who wanted additional consultation would get direct intervention and relative information pertaining their current recordings from the Health Practitioner.

5.6 Statistical analysis

Statistical software packages SPSS V 22 for windows was utilized for the data analysis in this study with the subjects' attributes and survey results been represented through descriptive statistics and the overall results represented using the mean standard deviation.

The SDSCA scales are based on items that, in a few studies, have been worded, responded, and scored barely in another way from each other. A portion of the varieties in items had been based on the time frame of the study, such as searching on the previous month as opposed to the previous seven days.

In line with Mann-Whitney-Wilcoxon check, two statistics samples are impartial they originate from particular populaces and the examples don't influence each other. With this sort of test, one is able to determine whether or not the populace distributions are indistinguishable without accepting them to take after the typical dispersion which turned into so helpful inside the analysis of the collected data.

The Kruskal-Wallis H test was also used in the analytic. This positioned nonparametric based data that can be utilized to figure out whether there are factually critical contrasts between two or more groups of a free variable on a persistent or ordinal ward variable. This was utilized as an expansion of the Mann-Whitney test to allow the comparison of more than two independent groups.

The Wilcoxon marked rank test was used for the evaluation of SDSCA items prior and then afterward the utilization the use of the Diabetic E-Patient Care System. The Mann-Whitney U test was performed for the correlation of changes in SDSCA among the groups with high delight and the group with low fulfillment with the usage of the Diabetic E-Patient Care System. Also, the Mann-Whitney U test and Kruskal- Wallis test was performed to perceive the distinction inside the delight with the Diabetic E-Patient Care System and the progressions in SDSCA consistent with the demographic characteristics of the subjects.

5.7 Results

5.7.1 Subject Characteristics

Among the 26 patients who were picked and taken through system training and gave consent to use the *Diabetic E-Patient Care System* application, only 42.3% of them completed the prototype test phase and issued back their questionnaire. Each subject used the *Diabetic E-Patient Care System* application through his/her own will. From the Analysis of the questionnaire that was given back by the subjects, 18.18% were infants, 45.55% were school going children while 36.4% of the subjects were young adolescents.

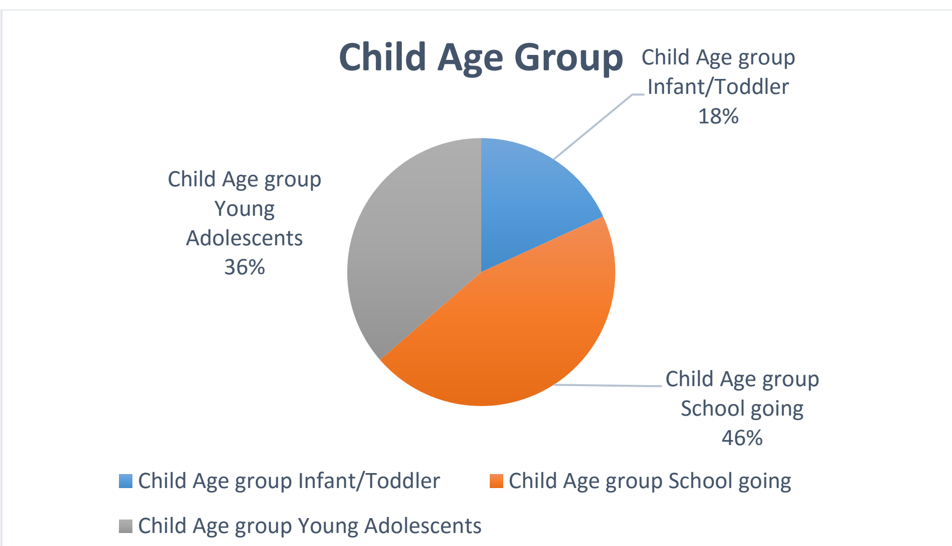

Figure 8: Child grouped by age group distribution

The median age group of the selected subset were children of 6 years with a variance of 13.27± 3.643. 45.5% of the subjects had diabetes for less than year which means they were early adopters of technology on the diabetes care while 27.3% had more than two years controlling the condition using manual logbooks with the remaining 27.3% had the condition between one and two years. 63.6% of these children came from middle income earners while 27% came from rich families and 9% from humble background.

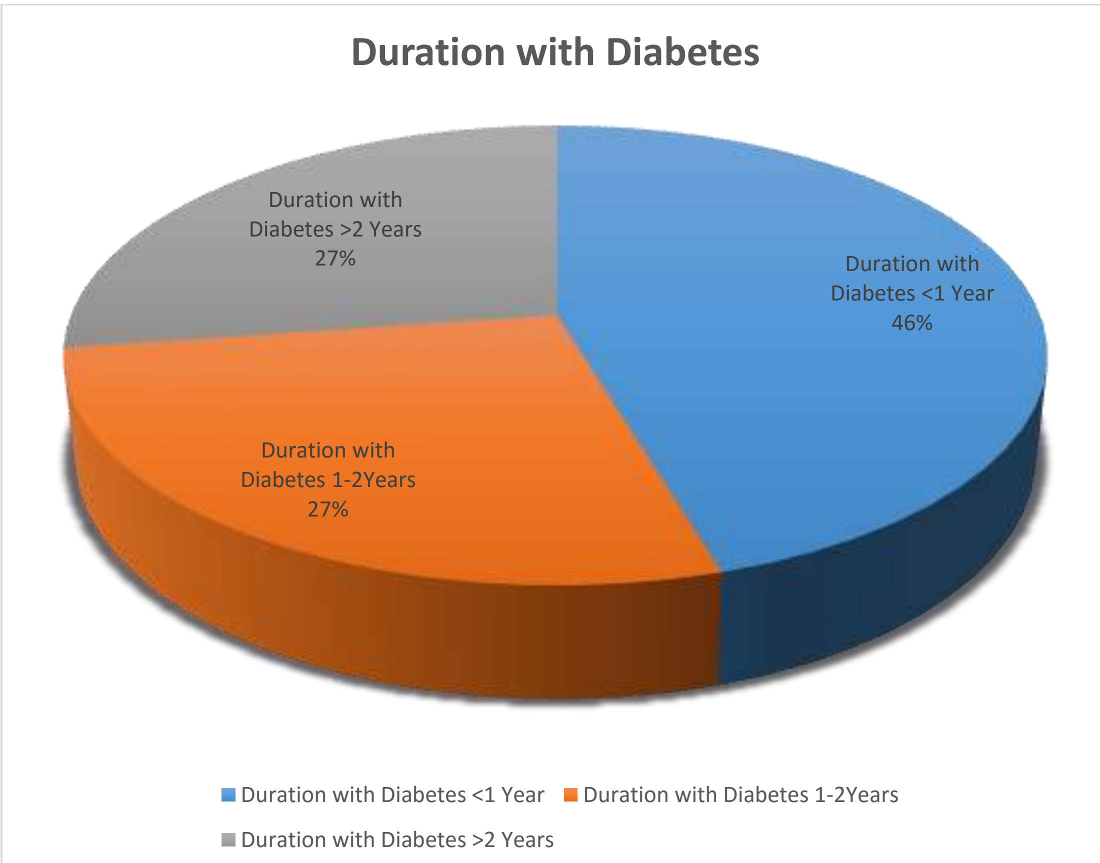

Figure 9: Duration the child had diabetes prior to participation

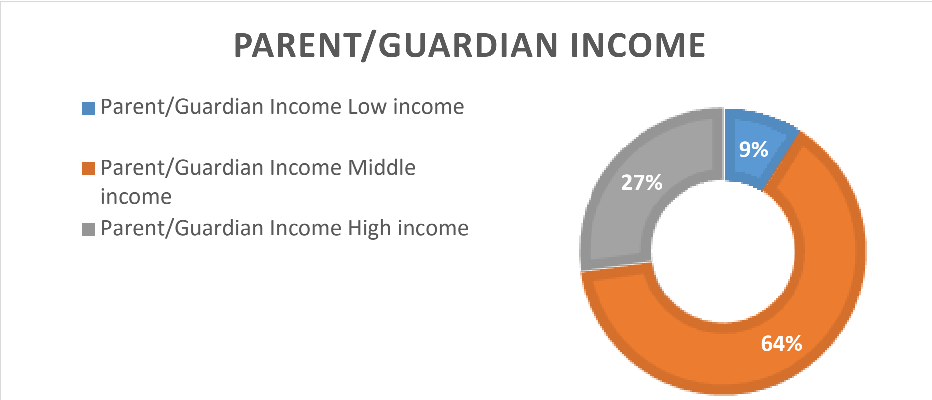

Figure 10: Parent/Guardian income summary

The table below shows the summary of the data:

Item	**Characteristics**	**Value**
Gender	Male	7(63.6%)
	Female	4(36.4%)
Age Variation	In years Variance ±SD	13.27± 3.643
	Median	6 (2-14)
	Mean	6.545
	Population Standard Deviation	3.473
Child Age group	Infant/Toddler	2(18.18%)
	School going	5(45.5%)
	Young Adolescents	4(36.4%)
Duration with Diabetes	<1 Year	5(45.5%)
	1-2Years	3(27.3%)
	>2 Years	3(27.3%)
Parent/Guardian Income	Low income	1(9.1%)
	Middle income	7(63.6%)
	High income	3(27.3%)

Table 3: Demographic characteristics of the study subjects

5.7.2 Subjects Changes in self-management

The Patients records data available for the month before they started using the solution was compared with the data captured during the use of the solution. The Wilcoxon signed test was run on the survey mean ±standard deviation of the number of days the subjects recorded their readings which showed a statistically significant difference with a P=00. There was an increase in patient adherence to take in records as the alert would remain active till a measure is recorded. Recommended regular meals, physical activities and taking insulin dosage was noted to have increased during the course of run of the solution. The frequencies of measuring blood glucose ranges, having ordinary meals, physical exercising, taking normal medication showed can growth during using the application.

Variable	Before, day	After, day	P value
Blood sugar testing	3.60±2.67	5.53±1.78	0.000a
Meal Carbs	4.97±2.05	5.70±1.52	0.000a
Physical Exercise	2.67±2.14	3.78±2.23	0.000a
Medication	4.64±2.83	5.55±2.31	0.000a
Comply with regular lifestyle	3.61±2.15	5.00±1.94	0.000a

Table 4: Values are presented as mean standard deviation.

5.7.3 Subject satisfaction

The questionnaire used during the survey captured the user satisfaction after the use of *Diabetic E-Patient Care System* application for the children diabetes self-care management. The subjects' response for the one who couldn't undertake the filling the forms, their guardian/parents filled for them.

The user survey used Likert Scale multiple questions and Cronbach's alpha was used to measure the internal consistency to determine the scale reliability before and after the use *Diabetic E-Patient Care System* application which showed that it was at least 0.753. The Likert Scale had four point scales from Strongly Agree with a weight of 4, Agree with a weight of 3, Disagree with a weight of 2 and Strongly Disagree with a weight of 1 that were used on the reliability on the SPSS. Each scale used was summed up and the results were categorized relative to the median value of the most general score of all the questions referring to satisfaction. The analysis showed a Cronbach's α of 0.837.

The results showed 81.8% of the subjects were satisfied with the application use from its simple data entry forms, timely alert and real time intervention of the Health Practitioner. 90.91% of the subjects desired to continue using the solution after the study if the doctor would recommend the tool for use. 72.7% of the subjects showed the tool was helpful and easy to use while the 9.1% were grouped to have not fully enjoyed the use of the *Diabetic E-Patient Care System* application. From the use of the application, 54.5% strongly believed that the solution have positive effect on diabetes clinical care with 27.3% disagreeing.

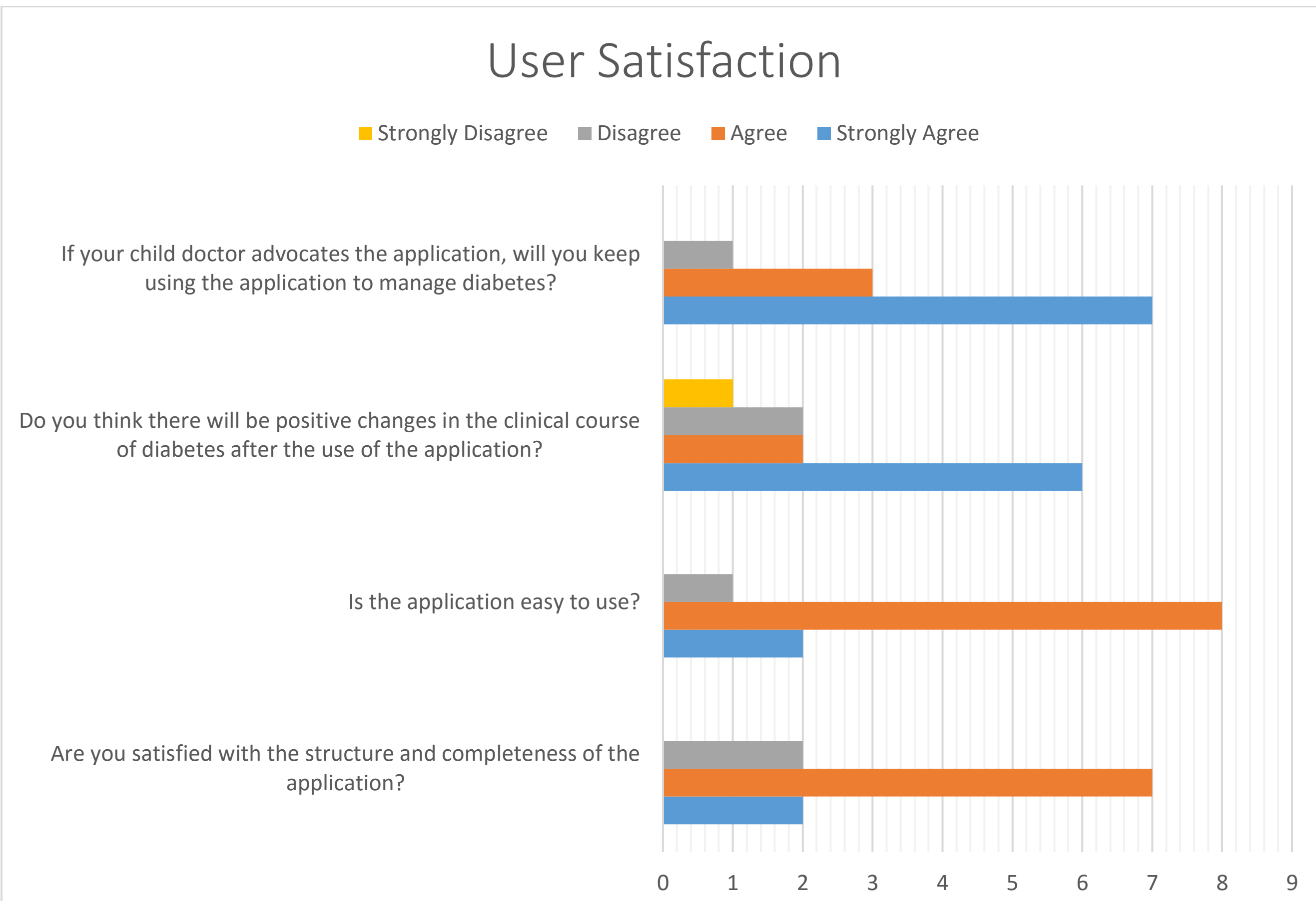

Figure 11: User satisfaction

Subjects satisfaction from the analysis found that age of the subject affected the application user satisfaction with 5.3±0.47 found the application easy to use while 4.35±0.22 who had a lower satisfaction on the application. The other survey items like level of income, duration of the patient had diabetes or the child gender had an impact to the user satisfaction.

	Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
Are you satisfied with the structure and completeness of the application?	2(18.2%)	7(63.8%)	2(18.2%)	0
Is the application easy to use?	2(18.2%)	8(72.7%)	1(9.1%)	0
Do you think there will be positive changes in the clinical course of diabetes after the use of the application?	6(54.5%)	2(18.2%)	2(18.2%)	1(9.1%)
If your child doctor advocates the application, will you keep using the application to manage diabetes?	7(63.6%)	3(27.3%)	1(9.1%)	0

Table 5: Users satisfaction.

5.7.4 Subjects Changes in the SDSCA

Kruskal-Wallis test and Mann-Whitney *U* test were run on the data collected from the subject pertaining the SDSCA items that showed a statistically significant difference of P<0.784. A notable change was identified from the Age group of the child that showed a slight difference of P=0.034 between the School going children and the young adolescent group while other SDSCA items like gender or duration the patient had with diabetes didn't affect the SDSCA of the subject. Subjects with higher user satisfaction compared with users with low satisfaction in using the *Diabetic E-Patient Care System* application showed also a slight difference on how they adhered to recording of their carbs intake (P=0.017), measured their blood glucose (P=0.000) and took insulin at P=0.000.

	Subjects with high Satisfaction	Groups with Low satisfaction	
Variable	**8-Sujects**	**3-Subjects**	**P-Value**
Blood Sugar testing	2.43±2.77	1.19±2.66	0.024a
Meal Carbs	0.85±1.66	0.57±1.17	0.781
Physical Exercise	1.58±2.43	0.43±1.82	0.000a
Medication -Insulin	0.92±2.42	0.89±1.89	0.516

Table 6: Changes in the Summary of Diabetes Self-Care Activities items according to the subjects' satisfaction with the application.

5.8 Discussion

From various other studies, mobile applications running on smartphones have helped patients to monitor their medication and meals for the management of their chronic diseases and also have shown improvement in communication with Health Practitioners as well as the patient's compliance to self-management regular (Bloomgarden Z, 2011). In this study, we demonstrate positive changes in the clinical course of diabetes when using a smartphone application as investigated by a user satisfaction survey and changes in the SDSCA. The survey was conducted with subjects who used the *Diabetic E-Patient Care System*. The application was designed to accommodate all stake holders in the Child with Type One diabetic care and the vital data needed during consultation with doctor for effective diagnosis of the diabetes. In particular, this study showed significant changes in the SDSCA, which is the most frequently used tool for the evaluation of diabetes self-management in Koreans (Toobert DJ, 2000).

Through the evaluation of the paper based log books, comparison with other diabetes application available in the market, *Diabetic E-Patient Care System* application was able to resolve two major handles in child diabetes care:

Overcoming patient data inadequacy in diabetes care - Despite healthcare professionals educate the patients to oversee diabetes checking a wide range of perspectives while the paper-based logbooks just allow one to monitor insulin intake and blood glucose qualities. This reflects the limited time doctors can spend analyzing patient-recorded data; hence, the logbook is limited to the two most relevant parameters to make an assessment during the visits. Parents/Guardian choice of recording other information in the digital application, however, suggests that the daily management of the condition requires a much more fine-grained data collection strategy.

The doctor can be able to make an informed decision having the most crucial data available like meals intake, physical activities, blood pressures in real time.

Enhancement of information sharing - During the diabetes care session, parents/guardian were informed and taken through diabetic care process which is vital in creating awareness to the parents/guardians on how to handle the condition. For effective intervention by the Health Practitioner, a careful analysis of patient data requires healthcare systems to dedicate resources they do not seem to have thus forcing them to use the manual logbook that are evaluated after a period of three months during the regular clinical visits. Moreover, many of these data would not be interpretable by doctors alone without the contextual information that only parents/guardians can provide in which most case is based on their memory and not recorded. This interpretation is supported by the scant attention paid by many users to integrate their blood glucose values with other information in their life's. These data are mostly considered personal and when shared in real time with a Health Practitioner becomes more useful to take decisions autonomously providing a personalized intervention.

This study was only able to confirm positive changes within the short term use of the application by the subjects. With this is in mind, speculating the persistence and compliance of diabetes self-management with the use of a smartphone application as well as the future role of the application in the entire healthcare system is difficult. The system outcome shows well that self-care and monitoring of diabetes is necessary for improving the patient Quality of Life even in the short term. The clinical decision support capabilities used in the system shows that the mobile computing powers can be harnessed to provide more data analytics and efficient the self-care management process. Additionally, long-term studies on the effects of a smartphone-based self-management system are needed also focusing on the use of the application from the Health Practitioners point and evaluate its impact on their role in the self-management for children with diabetes. As the technology advances, the presence of affordable glucose testers for children in a developing world context would open a new horizon for diabetes self-management. In particular, coupling a blood glucose tester with the *Diabetic E-Patient Care System* application would be more likely to be advantageous to the elderly who usually find it difficult to use smartphone applications.

5.8.1 Recommendation

With the consumer uptake of the low end smartphone in the developing world context, it indicates that these patients can be reached increasingly through these advanced m-Health solutions. In any case, completely tackling the abilities of cell phones to convey real time patient doctor intervention, diabetes management control education and secure data sharing among the patients, caregivers and health practitioners remains generally unexplored. Even more compelling is the possibility of positively shaping behaviors, and guiding patients with chronic illnesses towards optimal mental, emotional and physical health and wellbeing.

5.8.2 Future works

The limitations of this study include not analyzing the long-term effects of the use of the application and the selection bias of the subjects. This can be done by having more resources and timelines to implement the application across the country at public facilities. However, this study still has great significance in that the statistically significant positive changes in the clinical course of diabetes which were displayed among users of the widely available application.

5.8.3 Conclusion

Emerging evidence suggests that smartphones induce positive changes on the management of chronic diseases including diabetes. This study shows that the *Diabetic E-Patient Care System* use resulted to a high level of user satisfaction and had a positive effect on diabetes self-management which ultimately improves the patient Quality of Life. In addition, this study demonstrated that improvement in diabetes self-management activities is greater when user satisfaction is high. In the wake of affirming the long haul impacts of the utilization of smartphone applications, one may speculate that smartphone applications could assume a critical part in the administration of diabetes if the application can easily be used by more people and with real time intervention with a Health Practitioner at an affordable price. Although we cannot fully generalize these results without a control group trial for a longer period of time, the findings indicate that the use of these design principles is more promising of having children with diabetes type one have better health care practices to control the condition.

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APPENDIX 1: APPS AND SOLUTIONS OFFERED FOR DIABETIC TYPE TWO.

No	Name of tool and Project year of publication	No of users	Reference
1	Using zigbee and mobile phones for elderly patients. (2009)	17	(H. J Lee et all,2009)
2	Evaluation of a mobile phone tele monitoring system for glycemic control in patients with diabetes (2009)	72	(Istemanian et al, 2009)
3	Mobile communication using a mobile phone with a glucometer (Health Pin) for glucose control – comparison with Internet-based glucose monitoring (2009)	38	(Cho, Lee, Lim, Kwon & Yoon, 2009)
4	Intervention study on the wellDoc's Diabetes Manager system (Mobile phone and web, 2009)	185	(C, Quinn et al, 2009)
5	User-Involved Design of Mobile Self-Help Tools for people with Diabetes (Mobile phone) (2009)	12	(Arsand, Tataea, Ostengen & Harvigsen, 2010)
6	A short message services by cellular phone in type 2 diabetic patients (2008)	25	(Yoon & Kim, 208)
7	WellDoe: Mobile diabetes management (Mobile phone and PC) (2008)	15	(C. C Quinn et al, 2008)
8	Nurse intervention using SMS and Internet (PC) (2008)	18	(S.I Kim & Kim, 2008)
9	The NICHE pilot study (mobile phone and Internet) (2008)	15	(Faradi et al, 2008)
10	Continuous glucose monitoring to change physical activity behavior (SGMS monitor, accelerometers) (2008)	27	(Allen, Fain, Braun & Chipkin, 2008)

11	MAHI (Mobile Access to Health Information) (2008)	25	(Mamykina, Mynatt, David-son & Greenbalt, 2008)
12	Combining digital photography and glucose data (2007)	7	(Smith, Frost, Albayak & Sudhaka, 2007)
13	The prowellness Self-Care System – Information Technology supporting diabetes self-care. (2007)	9	(Halkoaho, Kavilo, & Pietila, 2007)
14	The CenTextNet Study: PDA Use in diabetes Self-Care. (Diabetes Pilot" 42software) (2007)	42	(Forjuoh et al, 2007)
15	Mobile Dietary Management Support Technologies for People with diabetes. (2007)	6	(Arsand, Tufano, Ralston & Hjortdahl, 2008)
16	Usability of a Mobile Self-Help Tool for people with Diabetes: The Easy Health diary (2007)	32	(Arsand, Varmedal & Hatvigsen, 2007)

Appendix 2: RELEVANT AND PUBLICLY AVAILABLE MOBILE DIABETES-SPECIFIC SELF-MANAGEMENT SYSTEMS FOR DIABETES TYPE 1 & 2

No.	Product	Url
1	SugarStast Mobile Edition	www.sugastats.com
2	Diabetes Pilot	www.diabetespilot.com
3	Alive Diabetes Management System	www.alivetee.com/poducts
4	SiDiary	www.sidiary.org
5	HealthEngage	www.healthengage.com
6	GlucoMON	http://mygluco.com
7	SymCare	www.symcare.com
8	Glucose Buddy	http://glucosebuddy.com
9	DiabGo	www.ace-it.com
10	LogbookFX Diabetic Diary	www.mdiabetic.com
11	Glucose-Charter Pro	www.glucose-charter.com
12	GlucoControl 3.0	www.brothersoft.com/glucocontrol-27960.html
13	GlucoTools	httP://glucotools.sourceforge.net
14	UTS Diabetes	http://utracksys.com/software-diabetes
15	smartLAB genie	www.smartlab.org/genie
16	CONFIDANT Diabetes Solution	www.confidantine.com
17	myglucohealth	www.myglucohealth.net
18	GlucoseOne Palm Application	www.glucoseone.com
19	The Polytel System	www.polymapwireless.com
20	OneTouch UltraSmart	www.lifescan.com
21	GlucoPhone	www.healthpia.us
22	OmniPod with Personal Diabetes Manager	www.myomnipod.com
23	DiabetesManger	www.welldoc-communications.com

APPENDIX 3: DIABETES APPS WITH FUNCTION-RICH MOBILE SELF-MANAGEMENT SYSTEMS

Systems/Functions	BGM	Physical Activity	Nutrition	Usability
MDoctor for DM (K. Kim, Han, Lee, Kim & Ahn, 2006) (Prototype)	Yes	Yes	Yes	Full automatic recording of blood-glucose and exercise data.
The diabetic interactive diary (DID) (Rossi et al, 2009) (Prototype)	Yes	Yes	Yes	"Automatic storage of blood glucose measurements", manual physical activity registration.
LogbookFX Diabetic Diary (Mobile diabetic Inc., 2009)	Yes	No	Yes	Wireless Transmission of BG data
SiDiary (Sinovo Ltd, 2009)	Yes	No	Yes	Automatic wireless transmission of BG data to phone and desktop.
DiabetesMananger (WellDoc Inc, 2007)	Yes	No	Yes	Automatic wireless transmission of BG data to healthcare website.
smartLAB genie(HMM Diagnosstics, 2008)	Yes	Yes	Yes	Automatic wireless transmission of BG data to phone or computer.
OneTouch UltraSmart (LifeScan Inc, 2009)	Yes	Yes	Yes	A BGM with options for recording food and exercise data by using predefined choices using its keyboard.

T+ Diabetes (t+ Medical, 2007)	Yes	Yes	Yes	Wirelessly transferred BG Data, but manually initiated. Manual entry of other data.
Personal Assistant (Garcia-Saeza et al, 2009) (Prototype)	Yes	No	Yes	Wirelessly transferred BG Data but manually initiated
Confidant Diabetes solution (Confidant International LLC, 2007)	Yes	No	No	Wirelessly transferred BG data, but manually initiated, to mobile phone and remote server.
Glucose Buddy (MYLEstone Health, 2009)	Yes	Yes	Yes	Manually initiated data transfer from phone to desktop.
Elardo Diabetes Profiler (Mundlein & Koch, 2007)	Yes	Yes	yes	Manual Entry of data, manually initiated data transfer from PDA to desktop.
Personal Glucose Tracker (Future Ware, 2009)	Yes	No	No	Manually initiated data transfer from desktop to phone.
SugarStats Mobile Edition (SugarStats LLC, 2009)	Yes	Yes	Yes	Manual entry data
DiabGo (Ace t&t, 2009)	Yes	Yes	Yes	Manual entry data

APPENDIX 4: QUESTIONNAIRE

INTRODUCTION AND DEFINITIONS

Please read this to have your consent!

Am conducting a survey on a logging application that runs on Android smartphone for Children with type one diabetes to improve diabetes management self-care and improve the patient's Quality of Life. The survey will take at most 5 minutes to complete, additional time to learn and use the application will be added. Any information that you provide will be kept strictly confidential and will not be shown to other people. This is voluntary and you can choose not to answer any or all of the questions if you want; however, I hope that you will participate since your views are important.

1. DEMOGRAPHICS

1.1	What is your gender?	[ ]	Male	[ ]	Female		
1.2	What is your age bracket? (*Tick your age group*)	(< 17 yrs.)	(18-25yrs.)	(26-34 Yrs.)	(35-45Yrs.)	(46-60Yrs.)	(>60Yrs.)
1.3	Give us the age of the child						
1.4	Give us your location of Residence?						
1.5	Give us duration the child had been having diabetes						

1.4	What is the highest level of education you have completed or currently enrolled?	[ ] No schooling completed [ ] Nursery school Primary	[ ] Some high school, no diploma [ ] Tertiary education
1.5	*Are you currently taking care of a Diabetic Patient? If Yes, which is your role*	[ ] Doctor [ ] Parent/Guardian [ ] Care giver	[ ] Child with diabetes [ ] None of the above

1.6	Do you have mobile phone and uses it for Health Care?	[ ]	Yes	[ ]	No
	If Yes, state the smartphone application.				

2. DIABETES APPLICATIONS

2.0	Do you use any diabetes logging tool?	[ ]	Yes	[ ]	No
2.1	If Yes, please name it. How do frequently visit?				
2.2	If "No" on the above, how do you keep record for your/patient blood glucose?	[ ] Web		[ ] Manual Logging	
		Reason for your preferenc			
2.3	After using the Mobile application provided, please fill up below				
	2.3.1	Do you always feel like you Know what to do and where to click?			
	2.3.2	Have you ever done something and got an unexpected result?			

	2.3.3	Did you feel you could trust the mobile application?	
	2.3.4	How quickly could you get what you wanted with this application?	
	2.3.5	Did the application act and feel like other, more familiar applications?	
	2.3.6	Did you find the application efficient to use?	

2. APP NAVIGATION						
	Tick the one that fits your rating.	strongly disagree	disagree	undecided	agree	Strongly agree
2.4.1	Is the interfaces of the application pleasant?	[ ]	[ ]	[ ]	[ ]	[ ]
2.4.2	Is the main navigation easily accessible?	[ ]	[ ]	[ ]	[ ]	[ ]
2.4.3	Are the navigation labels clear and concise?	[ ]	[ ]	[ ]	[ ]	[ ]
2.4.4	Are the links consistent and easy to clicks?	[ ]	[ ]	[ ]	[ ]	[ ]
2.4.5	Are the number of entry fields reasonable?	[ ]	[ ]	[ ]	[ ]	[ ]
2.4.6	Are there some diabetic care fields/content that you think	[ ]	[ ]	[ ]	[ ]	[ ]
	Which field/content can be added?					

3. USER SATISFACTION						
	Tick the one that fits your rating.	strongly disagree	disagree	undecided	agree	Strongly agree
3.1	Are you satisfied with the structure and completeness of the application?	[ ]	[ ]	[ ]	[ ]	[ ]
3.2	Is the application easy to use?	[ ]	[ ]	[ ]	[ ]	[ ]
3.3	Do you think there will be positive changes in the clinical course of diabetes after the use of the application?	[ ]	[ ]	[ ]	[ ]	[ ]
3.4	If your child doctor advocates the application, will you keep using the application to manage diabetes?	[ ]	[ ]	[ ]	[ ]	[ ]

4. APPLICATION INTERACTION AND INFORMATION						
	Tick the one that fits	strongly disagree	disagree	undecided	agree	Strongly agree
4.1	Do the application give error messages that clearly show you how to resolve them?	[ ]	[ ]	[ ]	[ ]	[ ]
4.2	Do the application a recovery easy and quickly with every mistake made?	[ ]	[ ]	[ ]	[ ]	[ ]
4.3	Is it always easy to find the information you need each and every time?	[ ]	[ ]	[ ]	[ ]	[ ]

4.4	In such situation, was the information effective in helping you complete task?	[ ]	[ ]	[ ]	[ ]	[ ]
4.5	Was the organization of such information on the website clear?	[ ]	[ ]	[ ]	[ ]	[ ]

5. APPLICATION EXPERIENCE			
	Tick the one that fits		
5.1	How professional is this diabetic care application?	[ ] Extremely professional [ ] Very professional	[ ] Slightly professional [ ] Not at all professional
5.2	How convenient is the application to use in Health Care for diabetes to use?	[ ] Extremely convenient [ ] Very convenient	[ ] Slightly convenient [ ] Not at all convenient
5.3	How well do you feel that the application understands your diabetic conditions and assistance on dosage?	[ ] Extremely well [ ] Quite well [ ] Moderately well	[ ] Slightly well [ ] Not at all well
5.4	In your own words, what are the things that you like most about the application?		
5.5	In your own words, what are the things that you would most like to be improved on the application?		

Thank You for your Time.

Declaration	
Name (Optional):	Date: _ _ / _ _ / 2015
Sign: ……………………………………..	