INTEROPERABILITY MODEL FOR E-HEALTH SYSTEMS IN HETEROGENEOUS ENVIRONMENTS: A CASE STUDY OF THE UNIVERSITY OF ZAMBIA HEALTH SERVICES

By

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DECLARATION

I, the undersigned, declare that this work has not previously been submitted in candidature for any degree. The dissertation is the result of my own work and investigations, except where otherwise stated. Other sources are acknowledged by given explicit references. A complete list of references is appended.

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APPROVAL

This dissertation of **Kingford Mutinta Haakalaki** has been approved as fulfilling the requirements or partial fulfilment of the requirements fro the award of the Master of Science in Computer Science by the University of Zambia.

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ABSTRACT

Electronic Health Records (EHR) Systems have over the recent years become an integral part of any effective Health Care System. Volumes of data is kept in heterogeneous systems and although continued health care highly depends on knowledge acquired from medical history captured at various points, this information is usually not readily available. The University of Zambia's (UNZA) Electronic Health Records (EHR) System does not interoperate with administrative systems. This study proposes a model to improve the efficiency of healthcare at UNZA Clinic by introducing an EHR system that applies interoperability with the University's Human Resource and Student Information Systems at as less a cost a possible.

The study was guided by two objectives: (1) A baseline study was conducted to evaluate the performance of the currently implemented modules of the Electronic System at UNZA Clinic to address the first objective. 200 questionnaires were distributed during clinic visits with 150 of them being used to collect data from within University community. Of these, 50 were given to members of staff that benefit from the health services, 75 to students and 50 to the healthcare providers. The remaining 25 questionnaires were shared amongst staff dependents and the community outside the University. Our results suggest that there is need to improve the performance of the current system. (2) A model has been proposed to address the second objective for the design of a prototype with interoperability.

In achieving interoperability in an eHealth Records System we proposed a Service Oriented Architecture using Web Services. To this effect, a model has been developed that incorporates mechanisms to help improve efficiency in a health records system and successfully implemented interoperability with a non-health related system.

Keywords—*interoperability, electronic health records, Web Services, HL7 Standards*

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Thank you.

Kingford Mutinta Haakalaki

DEDICATION

I dedicate all the works to my wife, Sandra Miyanda C. Haakalaki, and my children Danielle, Michelle and Nicole Haakalaki.

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ABBREVIATIONS

EMR	Electronic Medical Record
EHR	Electronic Health Record
eHealth	Electronic Health
mHealth	Mobile Health
SNOMED	Systematized Nomenclature of Medicine
SNOMED -CT	Systematized Nomenclature of Medicine -Clinical Terms
HL7	Health Level 7
MoH	Ministry of Health
UNICEF	United Nations International Children's Emergency Fund
CHAI	Clinton Health Access Initiative
ZPCT II	Zambia Prevention, Care and Treatment
RIM	Reference Information Model
SOA	Service Oriented Architecture
ISO/IEC	International Standards Organization
QR	Quick Response
GRN	Goods Received Note
API	Application Programming Interface
SIS	Student Information System
OOP	Object Oriented Programming
UPC	Universal Product Code
POS	Point of Sale
IDE	Integrated Development Environment
UML	Unified Modelling Language
SOC	System On Chip
NOOBS	New Out Of Box Software
MVC	Model View Controller
SMS	Short Messaging System
HTTP	Hypertext Transfer Protocol
GSM	Global System for Mobile Communications
GPRS	General Packet Radio Service
OOP	Object Oriented Programming
FIFO	First In First Out

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1 Introduction

This chapter introduces this research study. The chapter is sectioned as follows; background to the study to the research, Statement of the problem, the aim of the study, Research Objectives, Research Questions, Significance of the study, organization of the thesis and lastly the summary of the chapter.

1.2 Background

Information Communication Technologies (ICTs) have over the years become an integral part of many a business today. ICTs are now more commonly referred to as the backbone of businesses in our world today regardless of the field. There are different technologies at our disposal that support various business processes ranging from wearable devices, Mobile Apps, Web Application, Web 2.0 Tools, the Internet of Things (IoT) and Pervasive Computing. In health, we have seen an increase in Electronic Health (eHealth) and Mobile Health (mHealth) applications over the years and many more technologies that have changed the way healthcare is given. In health, it is important to use computational systems as aids in providing useful information to health professionals at various level for decision making processes [1].

With the vast number of systems and technologies being used to gather patient history, records, information and analysis, the major challenge in this field is interoperability. Health Care organizations tend to generate and keep large volumes of data every single day [1]. The data is usually of different types, shapes and nature and is kept in various databases when there is a system, on papers and in various books that are opened on a monthly basis or regular basis depending on the volumes of clients. Shared amongst stakeholders, this data would contribute to effective and informed health care, Continued Health Care, Personalized Medicine and reduce on data redundancy [2].

1.3 Statement of the problem

The University of Zambia (UNZA) Health Services Unit currently has a system that does not fully cater for the complete workflow of its services. Some of the modules that are currently being used have bugs and shortcomings needing to be optimized and because of this the system fails to cater for all vital processes of the Unit. Some essential modules such as pharmacy and billing are not yet developed. The Unit also keeps data in various departments in a non-interoperable manner and this data is gradually lost and may not make meaningful historical data towards continued health care over time.

There is a manual method of registering patients, monitoring stock movement and billing that is used without any linkage between the current Electronic Health Information Management System (EHIMS) and other UNZA system like Human Resource, Accounting and Student Information Systems which already keep data for over 90% of the unit's clientele. This makes the verification process longer and difficult to prove that a patient is really a member of staff, a spouse to a member of staff, legal dependent of a member of staff or even a registered student. Finally, the clinic spends a lot of time producing their stock management reports due to the fact that they manually record all their stock on various papers and books. Tracking of this inventory has proved to be less productive as it takes them a lot of time to do their stock taking and balancing of the figures. This inventory management problem has affected especially the stores and pharmacy departments on the clinic that handles receiving and dispensing of various items used at the clinic.

1.4 Motivation and significance of the thesis

Electronic Health Records are a drive to better healthcare from healthcare providers. Integrating systems, automating the capture, management and analysis of the large volumes of data that are generated greatly improves business processes. The motivation of this study is to use low cost materials and methods to achieve the stated factors that can improve operations and efficiency in healthcare in developing countries such as Zambia.

1.5 Aim of the study

To develop a model for the UNZA EHIMS optimization and structural interoperability with other systems such as the Human Resource, Accounting and Student Information Systems.

1.6 Research objectives

1. To evaluate the performance of the currently implemented modules of the EHIMS at UNZA Health Services Unit
2. To design a model for the optimization of the current EHIMS in order to achieve structural interoperability with the University's Human Resource, Student Information Systems and develop a prototype.

1.7 Research questions

1. What are the major challenges and short comings of the currently implemented modules of the EHIMS at UNZA Health Services Unit?
2. How can we develop a model and prototype that will optimize performance at the UNZA Clinic using structural interoperability with other UNZA systems such as the Human Resource, Student Information Systems?

1.8 Research contributions

This research was focused on improving healthcare services through interoperability and automation of routine tasks in the day to day operations of a healthcare service provider. The study was conducted using a case study of The University of Zambia Clinic. The major contribution was the baseline study and building of the prototype to meet the Clinic user requirements for an eHealth system.

1.9 Organization of the thesis

This research is divided into five chapters:

Chapter 1 is the introduction to the research and it gives the overview of the research, the aim, significance and research objectives. It concludes with a summary of the chapter.

Chapter 2 is a discussion on various literature that was reviewed around the subject area of electronic health systems and technologies used for such systems.

Chapter 3 details the methodologies that were used in the research study. The main methods that were adopted in this research were baseline study, observations, interviews, design and development of a prototype

Chapter 4 outlines the research findings of the baseline study and the system design and implementation.

Chapter 5 presents the discussion and conclusion

1.10 Summary

This chapter introduced the research work by discussing in brief the area and context in which this research is being conducted. Further, the background, aim, significance and scope of the work has been identified and outlined in this chapter. Lastly, objectives of the research, research questions and significance of the research have all been outlined.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter will focus on discussing the application of Information Communication Technology (ICT) in health, also known as Health Information Technology (HIT). Various technologies will be revealed in the context of interoperability. The chapter focuses on the literature that have at least been written over 6 to 8 years on the subject matter and academic databases were used to find this literature. It covers, Electronic Health Systems, Interoperability, Standards in interoperability in health systems, inventory management, coding technologies such as QR and Barcoding, Microcontrollers and a review of some related works. The chapter concludes with a summary of the chapter.

2.2 Electronic health management information systems

Electronic Health Management Information Systems (EHMIS) are systems that cover a wide area of health services. The final deliverable in this area is quality healthcare. They also provide continued health care as patient history can be accessed easily. As compared to keeping these volumes of generated information on patients in books and paper, Health Management Information Systems provide a wider variety of features to improve healthcare delivery. These features include mechanisms for keeping information on medical practitioners, pharmacy drug movements, laboratory results, clinical investigations and patient history. Much advancement in usage of ICTs has been seen in the health sector. It covers wider areas of healthcare such as [1] the Electronic Medical Record, Biometrics, Telemedicine, and Biological Signal Processing. Electronic Health Management Information Systems are commonly defined as systems that promote the integration of processes and technologies that support fundamental information operations, management and availability for the improvement of healthcare [1].

The benefits of Electronic well-implemented Health Management Information Systems are seen in the healthcare efficiency and effectiveness [11]. For instance, in a healthcare facility that offers services to a large clientele, fetching a patient's record

can be time consuming. The agony continues as the financial controllers have to sum up all the accumulated bills for each patient by the time the patient is about to leave the healthcare facility. This also adds to the time spent by the patient waiting for their bills. With EHMIS, all information is centrally kept and is accessible in a single quick search on the system for as long as medical practitioners keep updating the patient's record at every point of contact with the patient. A good EHMIS is one that supports efficiency in planning, initiating, organizing and controlling operations of all hospital subsystems and thereby creating synergistic organization in the processes. Commonly these EHMIS are also closely supported and integrated with Electronic Medical Records and Electronic Health Records that provide various information datasets to health practitioners [11].

2.3 Electronic medical records

The Electronic medical records (EMR) is a simplified way of managing patient information, increase productivity and lower cost associated with medical information management [12]. Organizations providing healthcare that have embarked on implementing EMRs have in the near future witnessed competitive advantage in their sector [12]. Unlike the Electronic Health Record Systems, EMRs typically contain patient medical history, diagnoses and treatment by particular physicians, nurses, specialists, dentists, surgeons or clinic. The introduction of EMRs in health care brings about a number of benefits to both healthcare givers and the recipients of the healthcare and these include efficiency in patient handling, billing of services, queuing management in institutions of health that attend to many patients in a day. In addition to that, physicians have information at their disposal on time, though this is made possible only if the other technical matters of a typical EMR such as interoperability are considered [12].

The downside of EMRs would be the initial costs of the equipment and gadgets that would be used in the providing healthcare. Such gadgets as mart phones, tablets with proper wireless connectivity and special application programs designed for purpose of education and healthcare delivery, security, wall-mounted computers may pose as a high cost for the public healthcare institutions especially as is in the case of the Zambian context. This infrastructure, however, is vital in an environment where

EMRs are properly setup. Lastly, EMRs require that both the hardware and the software that is developed for the environment meets ergonomic standards as these are vital when dealing with intuitive human-computer interaction. Of course the major benefits of EMRs over paper-based systems would be better tracking of information overtime, timely reminders for screening and check-ups and improved patient care [12].

2.4 Electronic health records

On the other hand, Electronic Health Records (EHRs) Systems are medical systems that aim at improving efficiency in health care by documenting patient visits to the healthcare facilities, laboratory results, allergies and authorized users in the domain have access to parts of this information for them to be able to give their necessary care to the patient [13]. Some of the typical benefits of EHRs are that up-to-date information of the patient is shared in a real-time manner, there are tools for decision making in EHRs and they contain a complete medical history of the patient including radiology images, allergies, bio data and lab results [14]. The major differences between EMRs and EHRs can be seen in the sense that EHRs are developed with the ability to be able to share patient information with authorized users even outside the organization for as long as they have authorization to view the information. Another great feature of the EHR is that it can be extended to where a patient moves with their medical information from one specialist, lab or pharmacies to another.

EHRs reduce by far the amount of duplication that is found in manual and paper systems because they provide mechanisms of sharing patient information not only between departments within the same clinic, hospital or healthcare facility but even across health institutions. In healthcare, the more complete the information the better the diagnosis, so EHRs are expected to make healthcare more effective and less costly. Therefore, a useful and meaningful EHR system is there to make professionals practice evidence-based knowledge management and make decisions [14]. Both EMRs and EHRs provide for confidentiality as the record of the patient is shared by specialists and the patient gets to know about their conditions when being counselled by a medical expert at the end of their visit to the healthcare provider.

According to [20], there are various applications of ehealth and these include;

- Electronic Medical Record (EMR): These refer to the electronic record that stores health-related information for an individual. The information is created, managed and accessed by authorised administrative and or healthcare personnel within a single health facility
- Electronic Health Record (EHR): Referring to a comprehensive lifelong record of an individual's health information generated through one or more encounters in more than one healthcare facility
- Personal Health Record: Referring to an electronic record of an individual's health information generated through one or more visits in another of different healthcare service providers
- Computerised Provider order entry (CPOE): This refers to applications that support electronic ordering of drugs, laboratory results and other medical tests by physicians and clinicians
- Electronic Prescription: An application used for prescribing and dispensing medications between the physicians and the pharmacy
- mHealth: Applications that take advantage of mobile, Bluetooth and Wireless technologies on mobile devices such as phones and tablet PCs
- Telemedicine: These are applications in eHealth that are used to deliver services where distance is a critical factor. The diagnosis and treatment is done by health professionals that may be far away from the patient.

2.5 Challenges of e-health systems

Health Management Information Systems that are successfully developed and implemented bring a lot of benefits to a health institution. Notably, efficiency, patient wait time and accuracy are all improved thereby speeding up productivity. However, there are a number of challenges that the technology brings up that [11] discusses in their findings. Such challenges as ineffective designs in the Health Information Systems, loss of data that may be caused by different system or non-system errors, slow system speeds either caused by user computers or network infrastructure if the system is web-based, inadequate equipment to gather and manage patient information and lack of internet. These may be considered the most frequently met challenges

including phobia or uncertainty of the usage of computer systems to perform such works in the health environment.

In the survey conducted by [15], the findings indicate that amongst many challenges such as capacity of clinicians and other administrative staff in using computer based systems, the main challenges are security and interoperability. Other concerns were the fear of data loss, uncertainty of clinicians on the security and availability, human errors, complexity and user friendliness of the system.

2.6 Interoperability

Interoperability is defined as the ability for two or more systems to be able to exchange information and having the ability to use the data exchanged without losing its meaning [16]. Interoperability is not only a technology implemented in systems but it may also be implemented amongst components that need to exchange data. Interoperability being a complex and broad subject may be viewed from a number of perspectives notably being; (1) "The ability of two or more systems or elements to exchange information and be able to use the exchanged information", (2) "capability of units of equipment to work efficiently together to provide useful functionality", (3) "heterogeneous equipment working together via common standards" [17] [18]. ISO/IEC2382:2015(en) under Information Technology –Vocabulary, defines interoperability as the capability of two or more functional units to prepare and process data cooperatively [31]. Further, interoperability is defined as the capability to communicate, execute programs, even transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristic of those units as they transfer the data. Interoperability in health is the engine that drives timely access to necessary information about a patient. This makes systems cost effective by reducing the recapture of the same information on a patient and provides for information that is available for evidence based medicine or even personalized healthcare [20][86].

However, Interoperability, like in many sectors, is still a major challenge health [2]. There are many stand-alone systems that keep various large volumes of data and each application normally has its own way of interpreting data, therefore the need of

standards in achieving meaningful interoperability. The major reason for linking EHIMS systems in this manner is motivated by being able to provide accurate, consistent and useful patient historical information towards decision making for health professionals. According to Ministry of Health (MoE) in Zambia, there are many eHealth solutions that have been introduced and implemented in many healthcare providing organisations but these are not in any way bringing efficiency by means of being interoperable thereby making interoperability a matter of concern in health systems [19]. Studies have been conducted to point out the challenges and means of achieving interoperability in heterogeneous systems. Such themes as privacy especially in health records systems are always of top priority. In addition, for a while the focus has been on interoperability within the health related domains but it is important to note that health systems now need to link to other non-medical systems that are needed for various inputs [2][3].

[4] E-health refers to the application of Internet and other ICT related technologies in healthcare in order to improve access, efficiency, effectiveness and the quality of the clinical and business processes provided by healthcare organisations to its patients, practitioners and consumers of those services. In achieving interoperability in health related environments, [5] proposes that interoperability in health systems is in three levels namely; Foundational, Structural and Semantic.

According to [16], attaining interoperability requires resolutions at various distinct levels. Interoperability has four levels namely: technical, syntactic, semantic and organizational levels [16]. This literature review will focus on describing all the three levels of health information technology interoperability identified by [21] which are grouped as Foundational, Structural and Semantic levels.

2.6.1 Foundational Interoperability

This level of interoperability in health focuses on allowing data exchange from one information technology system to be received by another. It does not require the ability for the system receiving the information to interpret the data for its use. Foundational interoperability is also known as Technical Interoperability and is achieved amongst communications-electronic systems or items of communications-

electronics equipment when information is exchanged directly. This type of interoperability is mainly based on communication protocols that will make this communication amongst similar or heterogeneous systems communicate [23].

2.6.2 Structural Interoperability

Structural interoperability is an intermediate level and it defines the structure or format of data exchange [21][24]. This level deals with aspects of message format standards. To be able to achieve this level, there must be uniform movement of data from one system to another that such the clinical or operational interpretation, meaning and purpose of the data is maintained and unaltered. This level also defines the syntax of data exchange and ensures that the data exchange between the systems can be interpreted a data field level.

2.6.3 Semantic Interoperability

This is the highest level of health systems interoperability and it provides for systems to exchange patient information and be able to use the information that has been exchanged. This level uses both the structuring of the data and codification of the data including some kind of vocabulary that can be used across the systems. This means that the meaning of terms from one system to the other must remain consistent. At this level, patient financial data, history, patient summary information is shared amongst caregivers and other authorised users. This level of interoperability is used across disparate electronic health records (EHR) systems, medical devices etc [2][24].

2.7 Standards in Health Information Technology

The purpose of health technology standards in Health Information Technology is to facilitate one of the identified five main areas. These areas being interoperability, safety/security, quality/reliability, efficiency/effectiveness and communication. Amongst the five areas of health information technology, arguably the most important of them in the subject of interoperability. Interoperability is defined as the ability of systems or software components to pass and share messages that will be understood by the sharing parties and interpret it correctly for use [40]. There are a number of standards that have been developed to be able to achieve this and some of them

include ISO 9000, ISO 9001, ISO 18308, Extensible Mark-up Language (XML), Web services, Health Level Seven (HL7), Digital Imagining and Communication in Medicine (DICOM), Systematized Nomenclature of Medicine (SNOMED), Systematized Nomenclature of Medicine – Clinical Terms (SNOMED-CT) which are a health specific protocol. There are commonly adopted models and standards of achieving healthcare interoperability such as Health Level Seven (HL7) standard; Terminology related as implemented by Systematized Nomenclature of Medicine – Clinical Terminology (SNOMED-CT); Clinical information and patient records (openEHR and HL7 Clinical Document Architecture CDA); and images (Digital Imaging and Communications in Medicine DICOM) [22]. Table 1 below summarizes some of the most commonly used standards used in interoperability of health systems:

Table 1 Standards for interoperability (adopted from [33])

TYPE OF STANDARD	EXAMPLE STANDARDS	SDO CREATING THE STANDARD
General standards	XML, TCP/IP, 802.11, Web services, security, wireless, GPS	W3C, IETF, IEEE, OMG, HL7
Data components	Reference Information Model (RIM), data elements, data types, terminology, templates, clinical statements, clinical document architecture	HL7, CEN, ISO, openEHR, IHTSDO, LOINC, RxNorm, UMLS, WHO
Data interchange	Structured and free-form documents, images	HL7, ASTM, DICOM, IEEE 1073, NCPDP, X12N, CEN, ISO
Knowledge representation	Guidelines and protocols, decision support algorithms	HL7, ASTM
Electronic health record (EHR)	Functional requirements, EHR models, Continuity of Care Record (CCR), patient summary record, personal health record	HL7, ASTM, openEHR, CEN
Application level support	Identifiers, resource registries, disease registries, tool sets, conformance requirements, implementation manuals	HIPAA, HL7, ASTM, ISO, CEN

2.7.1 Health Level Seven – HL7

HL7 (Health level Seven) is an organization that provides the standards used in healthcare systems for the execution, management and integration of patient clinical data in order to achieve interoperability in health information systems. HL7 Version 3 which is a Reference Information Model (RIM) forms the foundation for all information modelling within the HL7 [27]. This model in [27] uses fundamental techniques of the object-oriented modelling to identify the life cycle of the events that HL7 messages will carry and consists of 4 primary subject areas, 35 classes, 181 attributes, 9 associations and 28 generalizations. HL7 is normally used alongside Web Services which are purely catalysts in the process of interoperability. Web Services are used in implementing and integrating the Service Oriented Architecture (SOA).

Development of EHRs requires that the most recently models and frameworks are used and referenced. The use of HL7 CDA (Clinical Document Architecture) which is an XML-based standard can be used for document structures and semantics. This model is used for documents such as hospital discharge, clinical history, transfers and referrals [32]. The use of XML in this model makes it easier to integrate with other interoperability frameworks such as SNOMED for clinical terms.

2.7.2 Service Oriented Architecture

Service-Oriented Architecture (SOA) makes it possible to link external and internal healthcare systems by nature of its model and design. It utilizes web service standards such as Extensible Markup Language (XML), which will be discussed further later in this review, for its data encoding, Simple Object Access Protocol (SOAP) for defining its message envelopes and Web Services Description Language (WSDL) for its service description. The four enabling technologies are what make up this SOA framework [35].

Amongst these many standards that have been in existence as frameworks for eHealth systems, most of the challenges for an environment like a developing country may arise from the cost of implementation. This review is focused on discovering what standard(s) can be used in a low-end economy such as that of our country Zambia.

With this constraint in mind, four methods of achieving the interoperability have been selected to be reviewed further and possibly be tested as the possible solutions and these are: HL7, Web services, XML and JSON.

2.8 Model View Controller Design Pattern

The Model View Controller (MVC) architecture is a software design pattern that helps the developer to separate code into three layers namely; the view which is the Presentation layer, the Model which is the Data layer and holds the business rules that govern the operations to be done on the data, then lastly the controller which is layer that handles the requests to and from the user [79]. There are many frameworks today that implement the MVC architecture such as struts and spring in java, code igniter, laravel and cakephp for PHP, ASP.Net and many others.

In all the various frameworks, the underlying principle of the MVC is basically the same. A brief detail is given for each aspect of the MV below;

2.8.1 Models

The model could be said to be the principal part of the application program. It handles the application logic layer. In this layer, all the business logic is defined and followed as the application is in operation. One model is responsible for only one table in the database. It is important also to note that the model knows how to interface with another of data sources and the rest of the application does not need to know what kind of data source the model is interacting with [79][80]. Lastly, research has shown that one model may be able to provide data to many views and that reduces repetition in the application there by making MVC applications easily readable and neatly written [80].

2.8.2 Views

The view the User Interface that the user will interact with. It usually gets the data rendered to it via an action that is in a controller. Normally, MVC architecture supports a number of different views that the application can render such as HTML, JSON, XML, PDF etc [79][80].

2.8.3 Controllers

The Controller translates the user's interactions with the view [80] through the actions that are found in the controller. It controls the UI data displaying and updates the model object state according to the users input [79]. In the process of interacting with the application, the user will use the controller as an entry point in the application, through the controller will access an action which will render the required view to the user or interact with a model. As part of the response to the request, various options are available including downloading a file or rendering another view.

Figure 1 below shows the relationship amongst the three components of the MVC architecture:

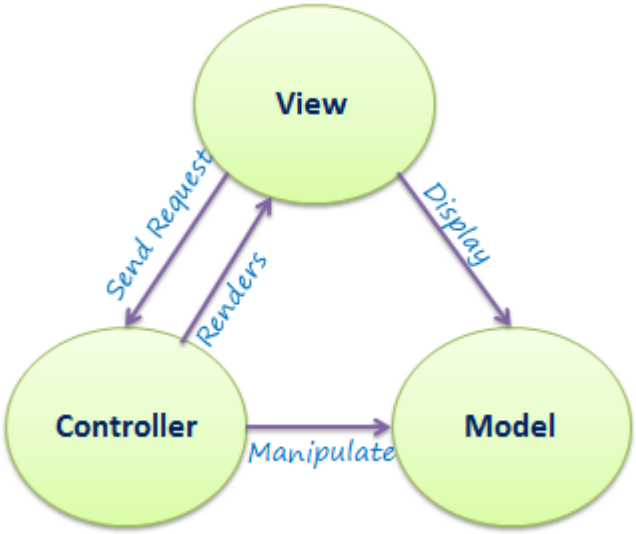


Figure 1 Relationship of MVC

2.9 Enabling Technologies for eHealth Systems

In order to achieve useful information that can be provided to health experts whilst achieving quality and efficiency in health care provision, health information systems need to fulfil a number of items on their checklists. These include; quality, interoperability standards, security, scalability, reliability and timeliness in data processing [1]. This review includes some of the commonly used technologies that in their nature add value to the development of health care systems.

2.9.1 Extensible Mark-up Language – XML

Extensible Mark-up Language (XML) is a self-descriptive language that was designed to store and transport data. It defines how information should be put and wrapped in what are known as tags though it does not really specify how the information should be transported, received and stored or displayed [28]. XML is considered more flexible as a developer is able to define their own data types since the tags are not used in any standard format but defined by the owner of the document, hence its extensibleness.

XML stores data in plain text format and easily integrates with other tools to standardize how to get, change, add or delete XML elements. With XSLT, XML documents can be transformed into HTML and rendered in a more human readable manner. The use of XML in health has grown in the last years. More and more applications because XML easily allows the standardization of formats and definitions for exchanging and developing EHRs. XML is still amongst the preferred standards of data exchange methods between inter-enterprise applications on the internet. Exchanged information is distributed in XML format and uses document type definition (DTD) to specify the data structures and grammar that allow different systems to know each other [28] [29].

2.9.2 JavaScript Object Notation – JSON

JavaScript Object Notation (JSON) is a syntax for storing and exchanging of data. JSON is text and any JavaScript object can be converted into JSON and sent to a server and vice-versa without worrying about any parsing or translation. Like XML, JSON notation can be ready and integrated with any programming language. the downside of using XML is that it needs to be parsed before being used at both the client and server sides and that's where JSON is becoming a more popular alternative to XML. This parsing may actually be time and memory consuming. JSON is, however, a light-weight key-value style data exchanging format. According to [30], JSON is becoming more and more of an obvious choice over XML for web services

2.9.3 Web Services

Web Services refer to loosely coupled, reusable software components that semantically encapsulate discrete functionality and are distributed and programmatically accessible over the internet standards and protocols. Unlike websites, web services are not designed with human interaction in mind hence they do not even include a user interface. They operate rather at application level, there by being called by software and executed by software.

Web services are normally distributed over standard internet protocols. This is to say that the actually do use standard exiting infrastructure such as File Transfer Protocol (FTP), Extensible Markup Language (XML), Simple Mail Transfer Protocol (SMTP) and Hypertext Transfer Protocol (HTTP) even as they need to conform to the standards and procedures of the Internet. Technically, they are layered similar in nature to that of the internet. Figure 2 below depicts the relationship in the structure of web service which is similar to the structure of the internet.

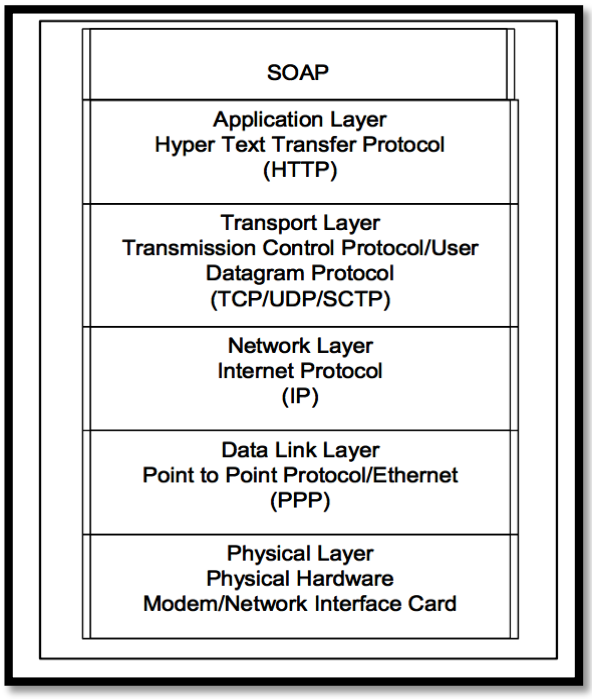


Figure 2 The Structure of a Web Service [36]

Web services also provide a standard way of sharing information between heterogeneous systems. This is because of the standards that are used. The following are the main features of the web service namely: SOAP for standardizing the message

structure, XML for encoding the data that needs to be shared between or amongst software components, Web Service Description Language (WSDL) which is used to describe the Application Programing Interface (API) and how to use the service and finally Universal Description Discovery Integration (UDDI) used to register a service so that it is discoverable by others. Figure 3 shows components of a Web Service.

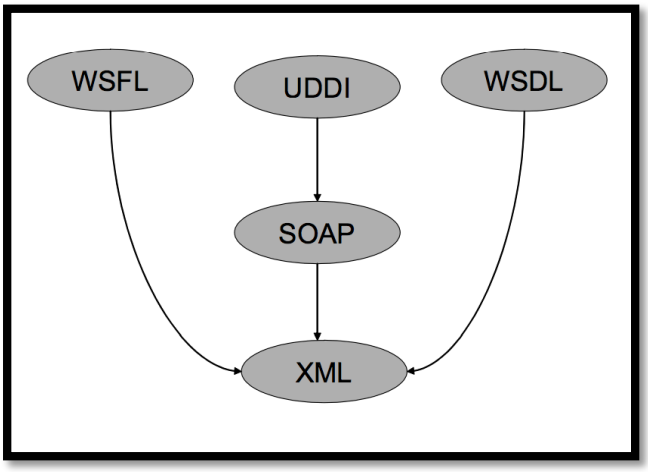


Figure 3 Components of a Web Service [36]

Using the SOAP protocol, a web service is invoked on a computer by sending a message. The SOAP message contains information needed to perform the interaction. There are generally two types of Web Services i.e. SOAP Web Services and REST Web Services.

2.9.4 Simple Object Access Protocol Web Services

Simple Object Access Protocol (SOAP) based web service architecture define three entities i.e. Service provider, Registry and Service Requester. [37] The service provider is the service, the network addressable entity accepting and executing request from the consumer. The service consumer would be an application or software component that requires a service. Figure 4 below depicts the structure of a typical SOAP message which is generally in XML format

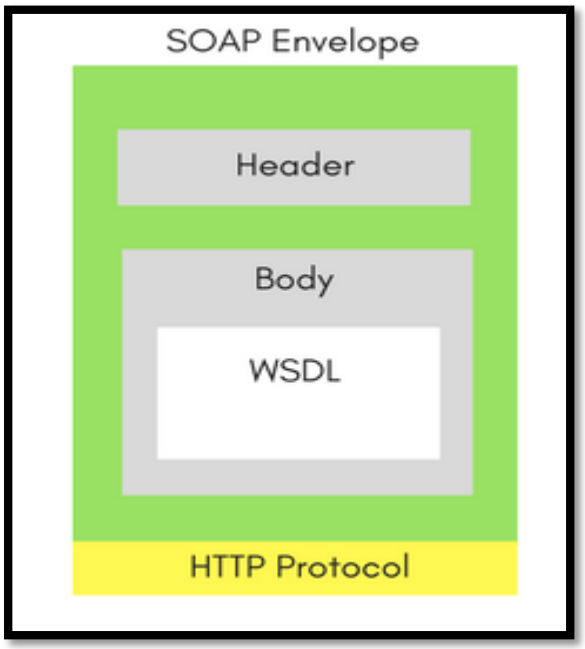


Figure 4 Structure of SOAP message [37]

2.9.5 Representational State Transfer Web Services

Representational State Transfer (REST) has a client-server architecture where a client sends a request to the sever then the server processes the request ad returns the response to the client. When using RESTFUL web services, a resource is something that is identified by a Uniform Resource Identifier (URI) [36]. The REST language is based on the use of nouns and verbs, therefore, REST is strongly typed than SOAP. This is to imply that, REST does not require message formats such as envelope and header which is a requirement in SOAP. Because of the design pattern of REST web services, they are seen to be lightweight and simple to implement [36]. Restful Web Services implement HTTP methods that are commonly by web application developers such as GET, POST, PUT, and DELETE to do operations such as retrieve, create, update and delete. When compared in terms of performance and ease of use and implementation, REST is preferred to SOAP due to the outcome of the end-to-end delays and network load tests that were conducted in a study that was conducted by [36]. Figure 5 below is an example from of a restful architecture

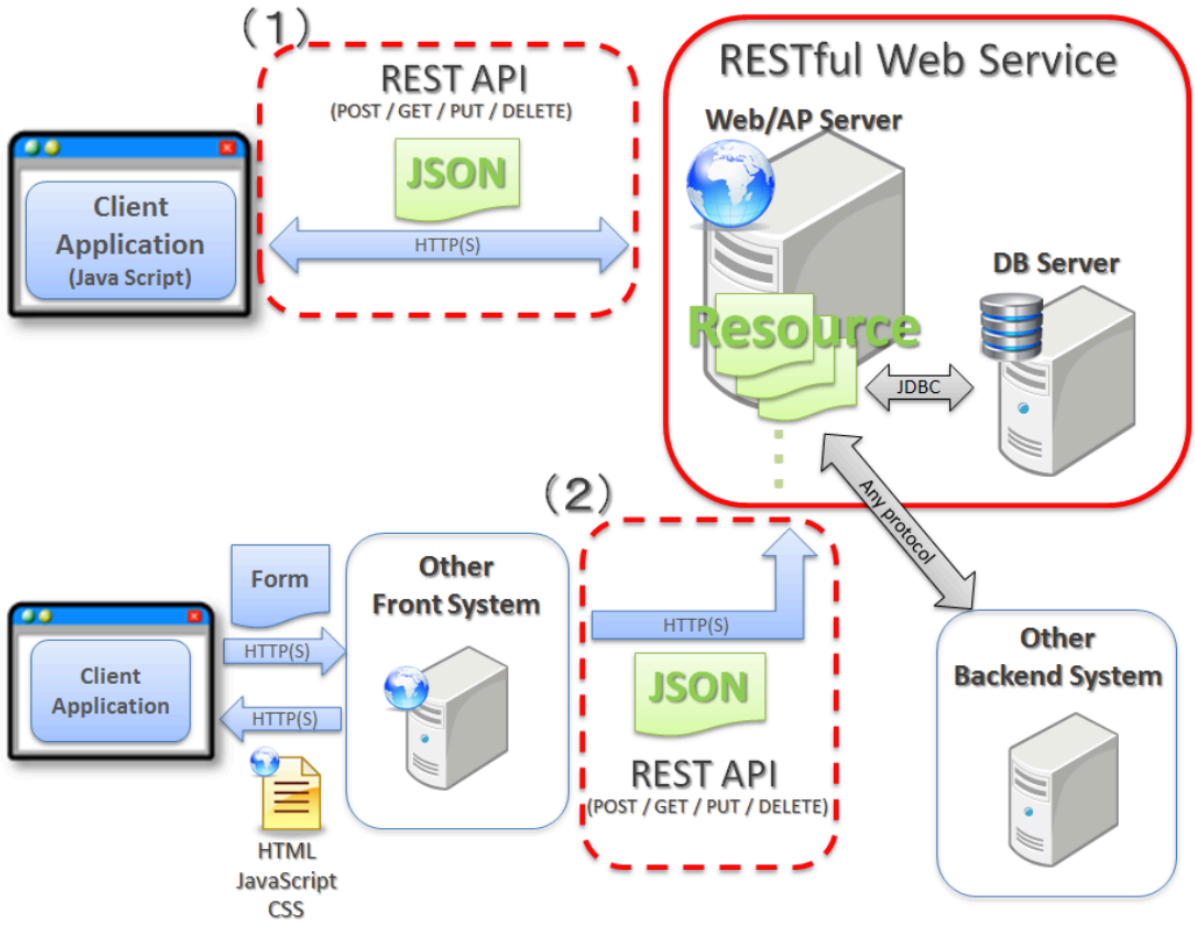


Figure 5 Architectures showing Restful Web Service [39]

2.9.6 Barcode technology

Barcodes are a good technology for labelling tags on a product so that people can easily identify content the content of the product. There are two types of barcodes namely, One-Dimension(1D) and Two-Dimension (2D) [48]. the major difference between the two being that 1D barcodes keep information in a straight set of lines and have to be scanned horizontally in one direction whereas 2D barcodes keep data in a matrix of vertical and horizontal dimensions and can be scanned from a wide range of angles. There are a variety of 1D and 2D barcodes that have evolved over time with the idea of advancing the ease of scanning and reading the information stored and how much data can be stored. Figure 6 shows examples of some of the barcodes variations that are available.

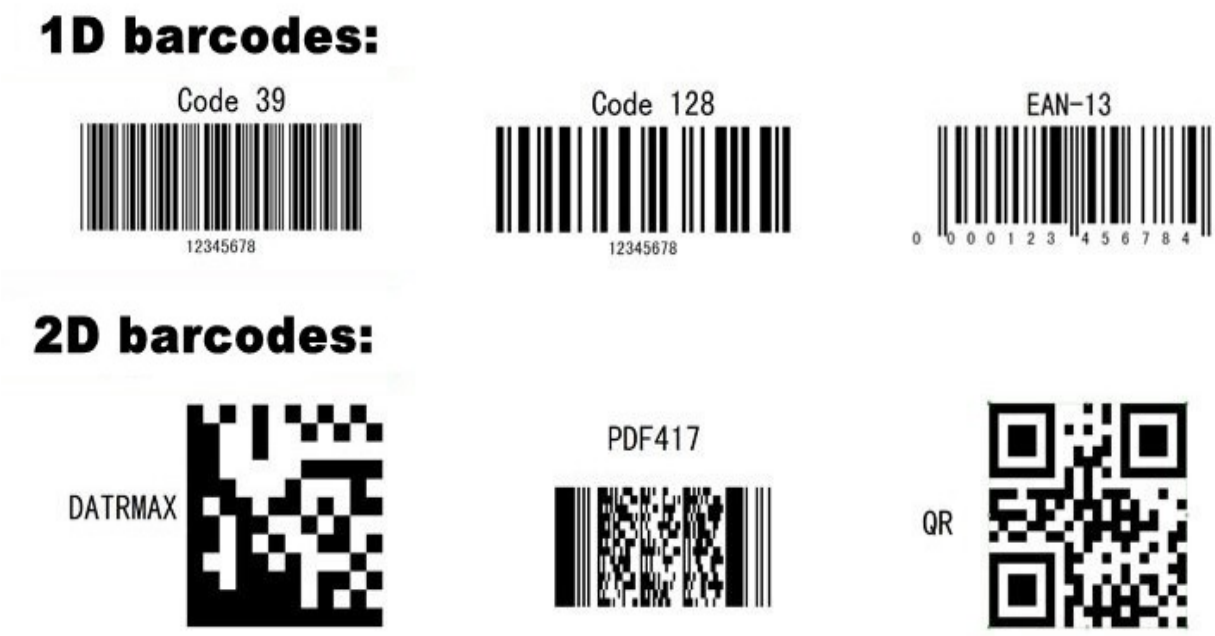


Figure 6 Example of 1D and 2D Barcodes

In this literature review, we further discuss 2D type of barcodes for their advanced features, easy of use and security. Quick Response is a technology that helps to link the physical world to the electronic resources like mobile devices. The technology is used to store small amounts of data as a two-dimensional barcode. Information such as web addresses or identification can be kept in a QR code and this information can be accessed by a device that supports a QR code reader. The advent of QR code readers on smart phones has made it easy to scan the information easily using one's mobile phone. The code can be read through an app on the phone that takes advantage of the phone's camera [45][50]. The use of the smartphone to access this information that is kept on a QR code introduces to business processes a concept of Just in Time (JIT) [45] [46].

Unlike the globally used Universal Product Code (UPC) which is one dimension, QR Codes store information in a two-way dimension. Various kinds of data can be encoded into the QR code such as audio information, email, app stores, URL information, contact details and any other text [50][51][52]. Their use in industry spans multiple business environments such as manufacturing, libraries, healthcare education to reduce on errors in stock management and inventory control [51][52][53]. Among some of the advantages of QR codes [46] are that they are free

and can be created using libraries provided for in many programming languages. They also provide for quick access to information using the embedded code, easy to read using scanners and smart phones. The demerits if QR codes could range from unfamiliarity, the dependency on internet and the need for the scanning device [47][48][49]. The structure of a QR code is depicted by figure 7 below:

Figure 7 QR Code structure

The parts of a QR code are explained below as stated by [50]

- Position Pattern: These are usually the three big squares found on the QR Code. These are used for detecting the position, size and angle of the QR Code.
- Alignment Pattern: This is a pattern that is used for correcting any distortions on the QR Code.
- Timing Pattern: this pattern consists white and black modules arranged and placed between usually two patterns. It is used to determine the central coordinate of each cell of the QR Code.
- Quiet Zone: This is a margin space that makes detection of the QR Code easier from its surrounding.
- Data Error and Correction Keys: This is the area of the QR Code that has the actual stored data usually encoded in binary.

Lastly, the advantage of a UPC is that due to it's simplicity, it can be used directly as a keyboard input to a computer system and it is internationally recognized by the same

product. UPC barcodes are used to label and scanner consumer goods normally as seen at point of sale (POS). The UPC codes are also known globally, meaning that you do not have to re-code if the barcode is already on the product [56].

The application of both QR and Barcode technology cuts across many business models. The technology has been used on Point of Sales, in libraries, places, events, advertising, food processing etc.

2.9.7 RFID Technology

Radio-frequency Identification (RFID) is a technology that uses electro-magnetic fields to identify and track objects that are known by itself. This technology uses the RFID readers and tags to communicate and identify objects. There are both passive and active tags that are used with this technology. The active tags collect and contain in them some energy from a nearby RFID reader where as the passive ones have a local battery source of power and may operate at a longer distance from its reader [62].

RFID technology has been used in various implementations such as warehouses, in automobiles, assembly plants and medicine. RFIDs can also be used in libraries, shops, attached to clothes, in people and in livestock animals to track them. Due to the kind of data that they may carry, they are subjected to the ISO/IEC 18000 standard which describes RFID technologies and frequency ranges [62][63]. Figure 10 below is a diagram on how the RFID technology basically works;

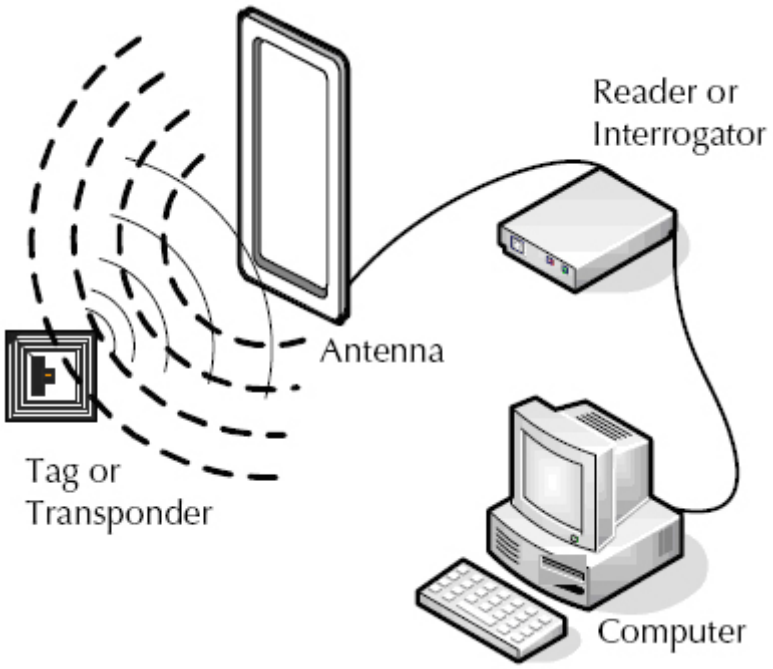


Figure 8 RFID Technology

To be able to read information, RFID technology as a two-way radio transmitter-receiver called an Interrogator. This interrogator emits and receives signals using an antenna that it has. On the other side, the tag has memory where it stores the needed information. After the communication has taken place, the interrogator then sends the information to a computer program that will be listening to the interrogator's signals [63].

2.9.8 Near Field Communication

Near Field Communication(NFC) is a contactless data transfer technology that allows users to hold devices that are NFC ready at close proximity and then the devices can access content, services and transmit data. The proximity is usually at about 10cm between the devices. The short-range wireless communication allows for a data exchange rate up to about 424 kilobytes per second [75][76]. [77] NFC technology is also available in form of use of NFC tags. These NFC tags can store some information in it with a unique identification number assigned to it. This feature of NFC tag can be used in many real time applications. Mobile devices that are NFC enabled must be able to support reader/writer mode, peer-2-peer mode and card emulation mode simultaneously [79]. Mobile devices that are NFC enabled must be able to support reader/writer mode, peer-2-peer mode and card emulation mode simultaneously.

Applications of NFC range from shopping services where customers carrying their coupons or gift cards electronically whilst the balance is kept in the cloud. The use of smart phones is heavily relied upon to pay and view the balance a customer has. Electronic ticketing is another application of NFC where the phone is used as a ticket. NFC can also be used in mobile financial services and in electronic health records [75].

Based on a study conducted by [78], a comprehensive comparison of QR codes and NFC and its tags were analysed. Table 2 below shows some of the highlights that they brought out:

Table 2 A comparison of QR Code and NFC [78]

functionality	NFC tags	QR Code
Appearance	 Integrated into objects and posters without distracting from visual design	 A harsh appearance, but are eye catching and self-evident from a user perspective.
Environmental requirements	can be used in dark, dirty, and busy environments in which QR codes could be difficult to read	require a direct line of sight for scanning, but can be read from a distance.
Hardware requirements	users must have an NFC-enabled device in order to read an NFC tag	QR codes require cameras
Software requirements	The software ecosystem for NFC is still evolving.	a barcode scanner application
Data storage	Store up to 1Mb.	Store up to 100 bytes
Data exchange	two-way interactivity	only provide a one-way, one-time data dump
Accessibility	a smoother user interaction, in that a user simply taps their device to a tagged object. So, it is ideal for access of visually impaired as well as users with limited use of fine motor skills	visual cues and require the user to first see the code and then photograph it

2.10 Microcontrollers

A microcontroller is a small computer that sits on a single integrated circuit. It contains one or more processor cores, some memory and programmable input/output (I/O) peripherals [58]. Microcontrollers are designed to handle embedded applications or ubiquitous computing which has come back on the technology market as a basic drive for the internet of things (IoT). Since microcontrollers are small enough to be embedded in other devices, they are commonly used to build automation devices and devices so that they can be controlled by the microcomputer. They find their application in multiple industries and applications such as home use, building automation, manufacturing, health, robotics, security, smart energy, office machinery

such as scanners, communication, Automated Teller Machines (ATM) to least a few. When they where first introduced on the market, microcontrollers used to be programmed in assembly language but today, they have become easier to program as they programmed in high level languages C/C++.

2.10.1 Raspberry PI

A Raspberry PI is a small general purpose computer that is used in today's IoT and many other applications. The PI is also a fully blown low-cost computer which is directly connected to the internet. The PI is able to display content such as videos even in high definition. By default, the Pi runs Raspbian which is a Debian Linux Operating System, as an OS of preference, thereby there is no need to buy an OS. This makes the raspberry pi a very cheap computer where we can write and upload applications to it and automate many business processes [66][67]. Since the raspberry pi is not a microcontroller nor a microprocessor but a single board computer, which has System On Chip architecture with multicore processor ROM and I/O Peripherals inside it, the raspberry pi gives us the capability to connect a keyboard, mouse and display such as a monitor and we can begin to write and programs or instructions from it.

Though a number of programming languages have come up with platforms that can be run on the Pi, the number one language for the Raspberry Pi seems to be python which is a widely used, general purpose, text-based language. The figures 8 and 9 below show an example of the raspberry pi 3.

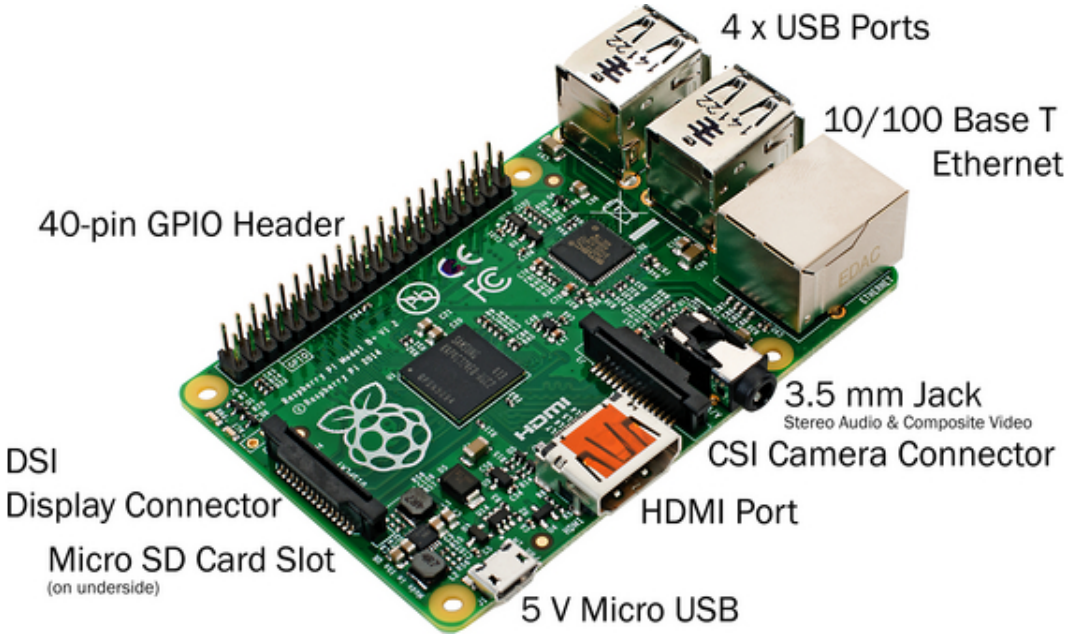


Figure 9 Labelled Raspberry Pi 3

Figure 10 Raspberry Pi 3

To get going on the Raspberry Pi, it requires a few things to be put in place. You need and SD Card that comes preinstalled with NOOBS. NOOBS is New Out Of Box Software which is an installation manager for operating systems. The cards are best bought with NOOBS already preinstalled to provide for quick setup. You also need a

display and connectivity cables as the Pi hardware already includes an HDMI port in it, USB mouse and keyboard and power supply. These requirements are enough to have you started on the raspberry pi.

2.10.2 Application of Raspberry PI

Applications of architectures such as the Raspberry Pi go beyond the imagination of the developer. As a tool for Internet of Things (IoT), it can be implemented in any scenario where computer processing can be required [70]. The PI can be used in a wide range of implementations such as a webserver since it uses very little power. The PI has been implemented in various environments including IoT biometrics, creating refreshable braille displays [67] [69]. Taking advantage of its design nature i.e. size and connectivity, the Pi can be deployed in environments where it can run for very long periods and monitor environmental conditions such as in monitoring the environment and uploading the data collected to a webserver [71][72].

Other uses include home automation is one of the tasks that are becoming very popular in the modern world today. Studies suggest that to effectively introduce home automation, the raspberry pi is one of the key devices that can make this process a success [73] [74]. The devices can be loaded with various applications that can deliver educational material in various disciplines such as engineering, science, mathematics to name a few. In their research, [74] gives examples of this implementation in the schools of Uganda. More applications of the technology are given by [75] including managing medical diagnosis machinery, home alarm systems, temperature sensing, webcam surveillance and siren management, learning tools in developing countries using raspberry pi.

2.10.3 Arduino microcontroller

An Arduino is an open-source prototyping environment. The platform provides various development circuit boards, some of which utilize Atmel's low-power CMOS 8-bit microcontrollers [58][60]. These microcontrollers provide an integrated development environment (IDE) that is capable of running on all major operating systems and has support for C/C++ languages. Being open-source, there is also a large online community that stimulates engagement in development and enables rapid

prototyping and debugging of programs [65]. Apart from this, there is a wide range of available sensors, such as temperature, sound, fire etc. and devices that have been manufactured to easily integrate with the different types of Arduinos [58]. The Arduino has basically power supply port that can be used with a 9V battery or it can get power from a computer using its provided USB cable.

It also provides for serial port connectivity and has a circuit board that manages its basic circuit. Arduinos come with different modules such as Ethernet, Motor driver, Wireless shields. These modules have specialized functionalities that extend the functionality of the Arduino board [65][69]. Figures 11 and 12 below show the Arduino UNO

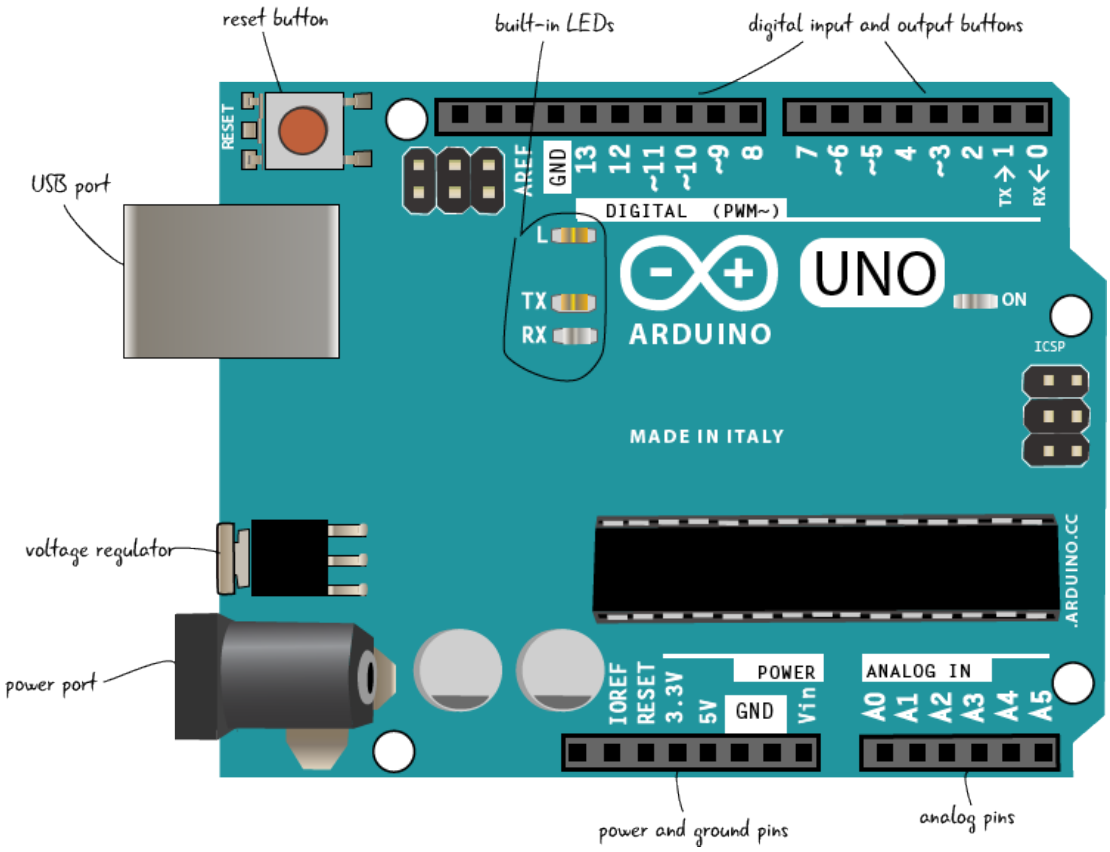


Figure 11 Labelled Arduino

Figure 12 Arduino UNO

They are various types of Arduino boards that are available at our disposal to build machinery on. Other boards come with in-build modules such as the BT which comes with an in-build Bluetooth module as an example [65]. These built in modules also come as separate modules which can be attached to the board and when they are separate they are known as shields e.g. Ethernet, Wireless and Motor etc. Some of the commonly used boards available are depicted by [65] as shown in table 3 below:

Table 3 Types of Arduino Boards adopted from [65]

Arduino Type	Microcontroller	Clock Speed
Arduino Uno	ATmega328	16 MHz with auto-reset
Arduino Duemilanove / ATmega328	ATmega328	16 MHz with auto-reset
Arduino Nano	ATmega328	16 MHz with auto-reset
Arduino Mega 2560 or Mega ADK	ATmega2560	16 MHz with auto-reset
Arduino Leonardo	ATmega32u4	16 MHz with auto-reset
Arduino Mini w/ ATmega328	ATmega328	16 MHz with auto-reset
Arduino Ethernet	Equivalent to Arduino UNO with an Ethernet shield	
Arduino Fio.	ATmega328	8 MHz with auto-reset
Arduino BT w/ ATmega328	ATmega328	16 MHz with auto-reset
LilyPad Arduino w/ ATmega328	ATmega328	8 MHz (3.3V) with auto-reset
Arduino Pro or Pro Mini	ATmega328	16 MHz with auto-reset
Arduino NG	ATmega8	16 MHz with auto-reset

To be able to write programs and upload the instructions in the Arduino memory and have them executed and make the Arduino perform the desired actions, the Arduino Integrated Development Environment (IDE) is used to write these instructions. Figure 13 below is an example of an Arduino sketch with code that has been written in C/C++ in the Arduino IDE.

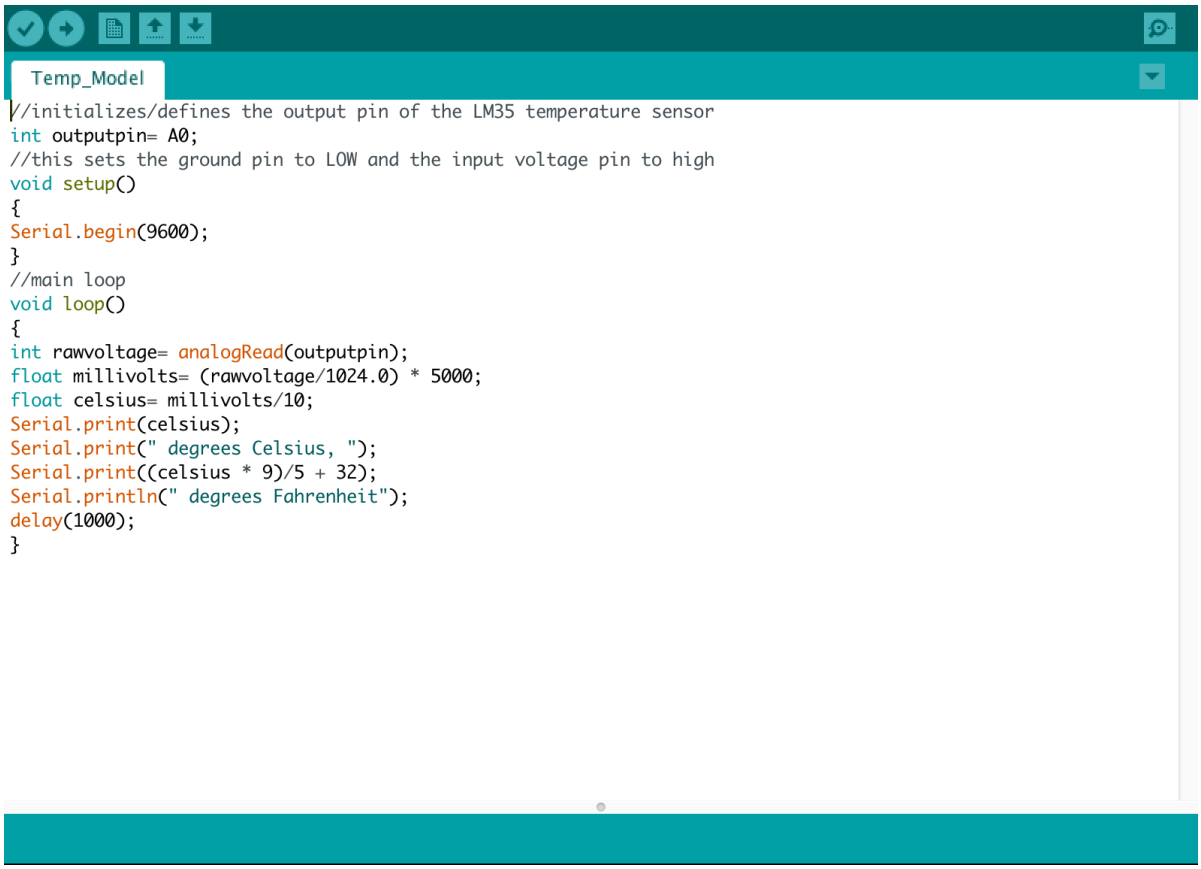


Figure 13 Arduino IDE

[65] The programs usually have two main routines i.e. the setup and the loop. The setup routine is where all the initialization of all inputs and outputs is done from. The loop routine is where the repetitive instructions are written. The IDE also supports the use of comments using the C style of commenting out code.

2.10.4 Applications of Arduino

The portability, cost and power of Arduinos are an attracting factor to their application in various fields. An Arduino is cheap enough to be bought at a price of about $35 and yet powerful enough to be able to control a wide range of devices using the software

that is loaded on it. Arduinos have been applied in monitoring of entrance into a building together with Radio Frequency Identity (RFID) [59]. Arduino based Bluetooth controlled robot was developed that is remote controlled using an android phone and can perform some tasks [61].

2.10.5 Arduino Satellite

Another of the many examples of the application of Arduinos is the ArduSat. ArduSat is an open source nanosatellite completely based on Arduino to create a stage for space discoveries. ArduSat is fitted in with numerous sensors such as temperature, pressure, cameras, GPS, spectrometer, and magnetometer and other sensors. ArduSat can be used for photography from space, making a spectrograph of the sun, detecting high energy radiation, compiling temperature readings and observing meteors [65]. An example of the ArduSat is shown in Figure 14 below:

Figure 14 ArduSat adopted from [65]

The ArduSat is build with complexity to be able to lift itself into space with a lot of slave Arduinos, sensors and cameras each performing specialized tasks in space exploration. The extensive Arduino sensor suite on board gives students the opportunity to create their own satellite experiments and collect real-world space data

using the Arduino open-source prototyping platform. Detailed complex aspects of the ArduStat are labeled below in Figure 15;

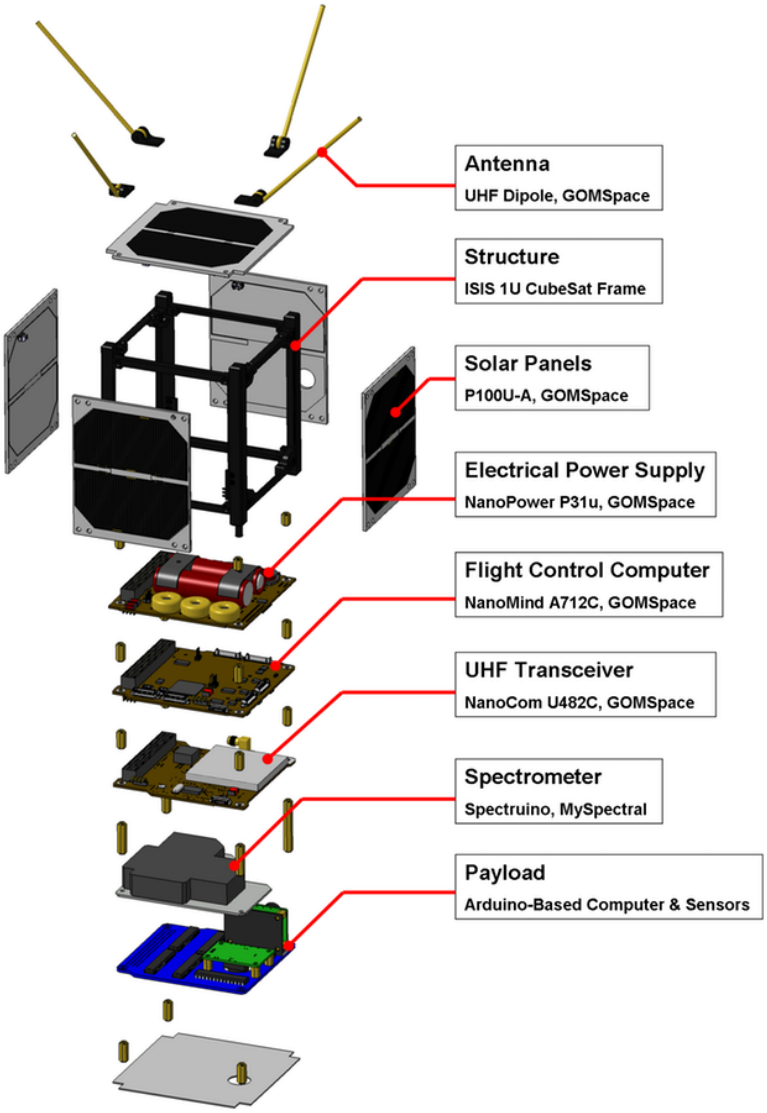


Figure 15 Components of ArduSat Adopted from [65]

2.10.6 Lilypad Arduino

Lilypad is a wearable device which is just like Google's wearable device. This device was built in the context of building interactive electronic textiles or what is dimed e-textiles [65]. The lilypad, as shown in figure 16, is built to be attached into normal day to day fabric and it let's you embed lights, sounds, sensors as part of cloth accessories.

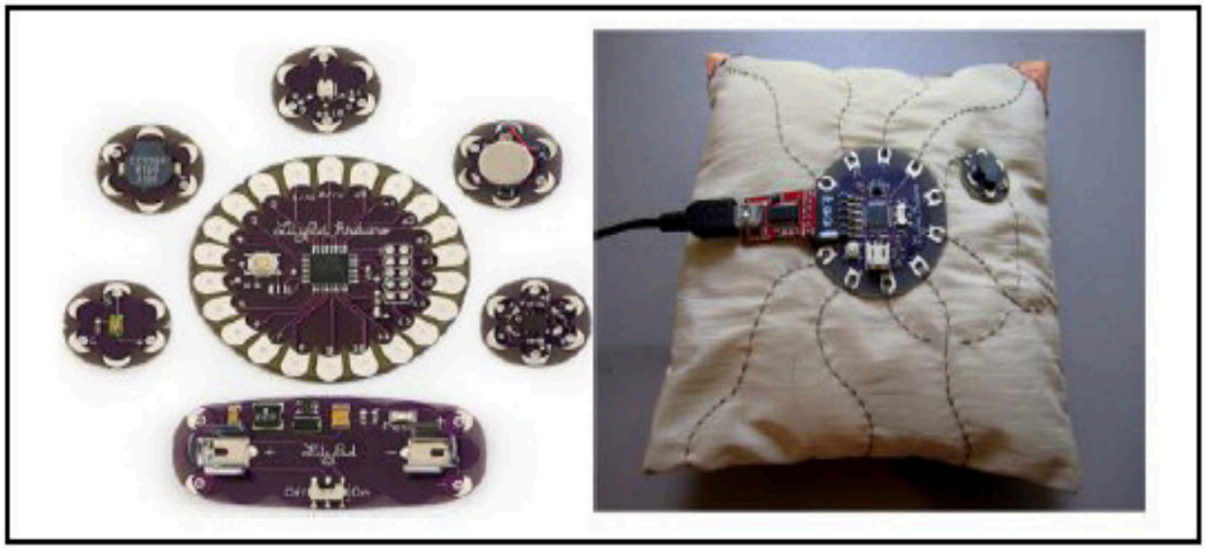


Figure 16 lilypad

2.11 Arduino Shields

An Arduino shield is a modular circuit board that is connected to the Arduino either directly or through a breadboard to extend the functionality of the Arduino. Shields are usually specialized in the way the work, specifically providing specialized functionality. Shields are boards that can be plugged on top of the Arduino PCB extending its capabilities [90]. The different shields follow the same philosophy as the original toolkit: they are easy to mount, and cheap to produce. Examples of shields would include to list a few wifi shield, Ethernet shield, gsm-gprs shield etc. In this literature review, we will discuss shields that post data from the Arduino to another platform.

2.11.1 Gsm-Gprs Arduino Shield

GSM stands for Global System for Mobile Communications and is the global standard for mobile communications. GPRS stands for General Packet Radio Service. GPRS is a mobile service on the 2G and 3G cellular communication. Working with Arduinos and other microcontrollers, one easy to setup and commonly used GSM shield is the SIM900. It works on frequency 900/1800MHz [84] [85]. It has a selectable interfacing voltage, which allows connecting 5V and 3.3V microcontroller directly without any

level conversion chips. The baud rate is configurable from 9600- 115200 through AT commands. The GSM/GPRS module has an internal TCP/IP stack to enable it to connect with the internet via GPRS and even be able to send data and receive data through both POST and GET requests of the Hypertext Transfer Protocol (http). It is also suitable for Short Messaging System (SMS) [87]. The modem can operate at both TTL 3.3V and 5V logic level hence making it suitable for controllers like 3.3V or 5V and power the module with supply range. Figure 17 is an example of the GSM-GPRS shield:

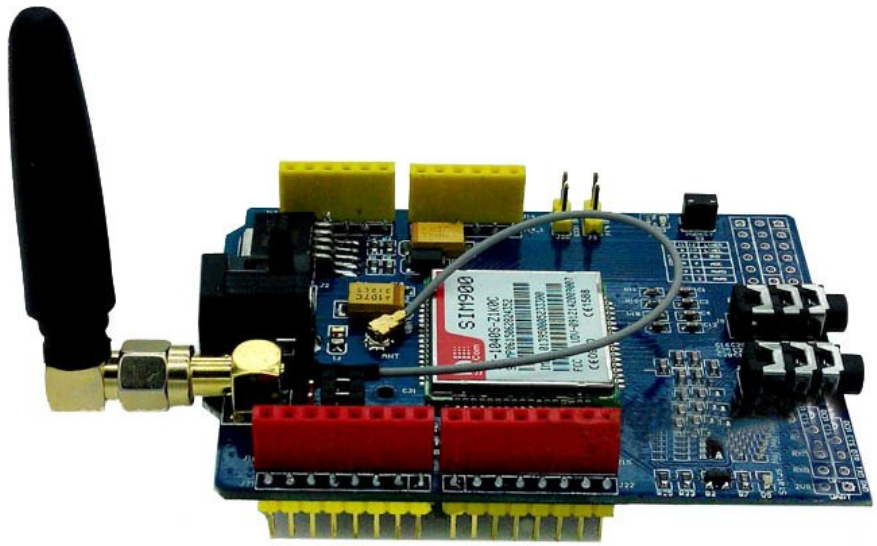


Figure 17 GSM-GPRS Arduino Shield

2.11.2 Ethernet Shield

The Ethernet shield allows an Arduino board to connect to the internet. It is based on the Wiznet W5100 Ethernet chip which provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. There is an Ethernet library that is readily available to developers that would want to write sketches which connect to the internet using the shield. The Ethernet shield has a standard RJ-45 connection, with an integrated line transformer and Power over Ethernet enabled [91] [93].

There is an onboard micro-SD card slot, which can be used to store files for serving over the network. This on-board microSD card reader is also accessible through the SD Library which can be imported and used in the sketch. Figure 18 below shows as example of the Ethernet shield [91].

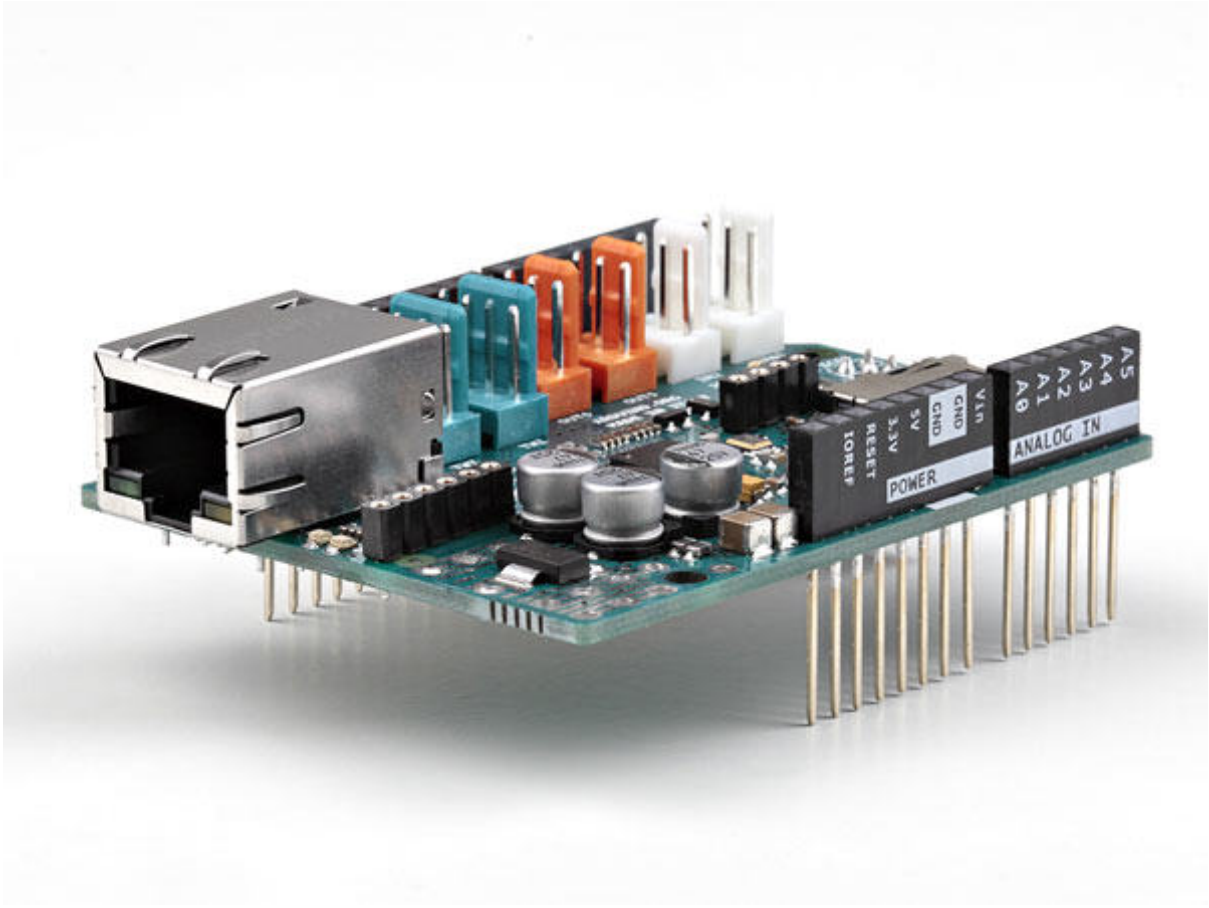


Figure 18 Ethernet Shield[91]

2.11.3 Wifi Shield

The Arduino WiFi Shield is a modular circuit that allows an Arduino board to connect to the internet using the 802.11 wireless specification (WiFi). It provides a network (IP) stack capable of both TCP and UDP. It also has a WIFI library that is imported and used in the sketches. Like the Ethernet shield, it has an onboard micro-SD card slot, which can be used to store files for serving over the network [92][65]. It is compatible with the Arduino Uno and Mega. The onboard microSD card reader found on this shield equally can be accessible through the SD Library which can be imported into the sketch [93]. Figure 19 below shows the the WIFI module:

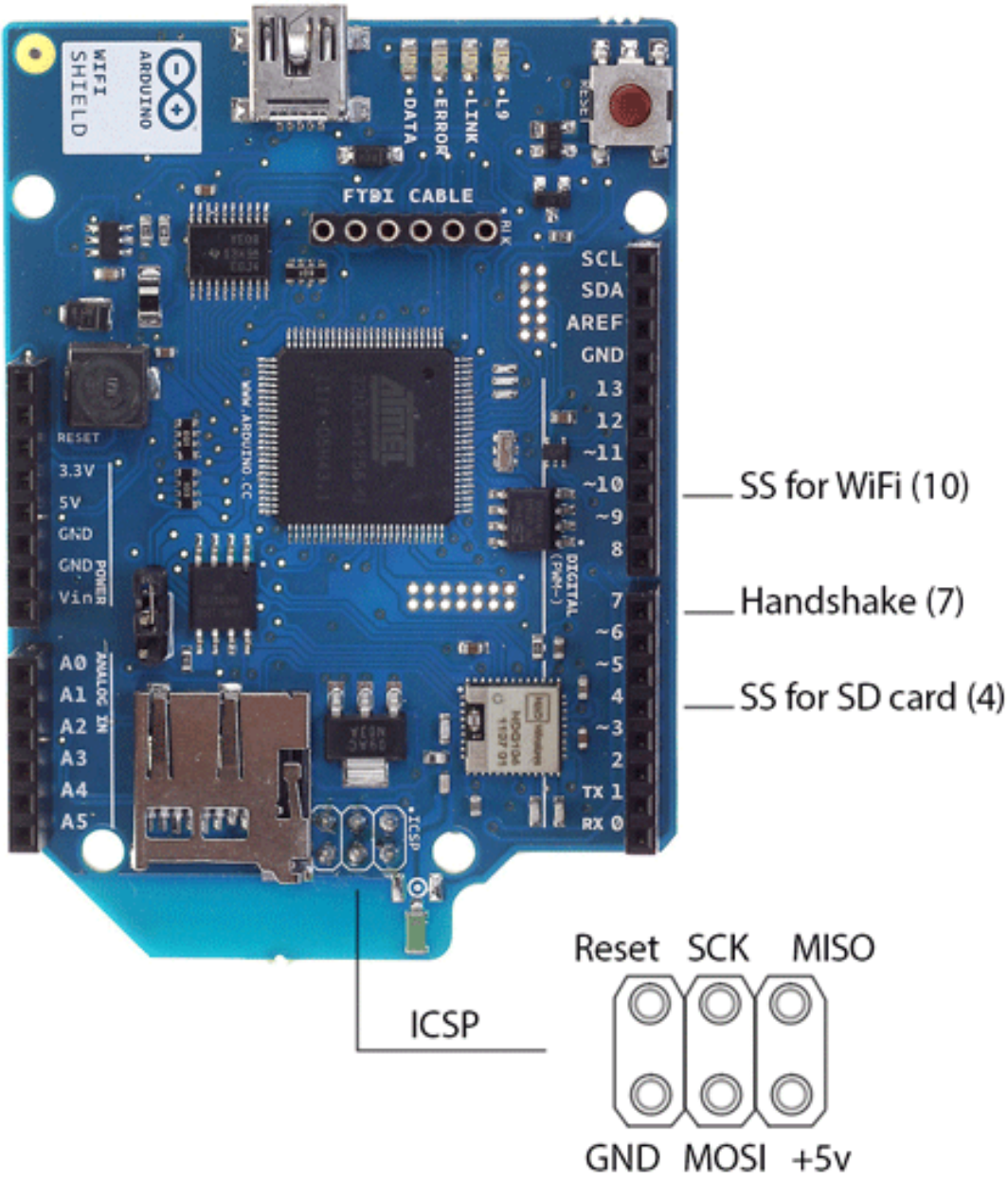


Figure 19 Arduino WIFI Shield [92]

Connected and integrated to sensors and other shields, the WIFI can be used to monitor temperature and humidity and sending the readings from the sensors to a web application or mobile application via wireless connectivity. In their research [94], the shield was used the shield along side monitoring environment changes in the home such as door status, video monitoring and fire or smoke detection. The shield has no sensors but can be used to transfer data from remote sensing environments.

2.12 Temperature Sensors

Temperature sensors are among the most commonly used sensors. All types of equipment use temperature sensors, ranging from computers, cars, kitchen appliances, air conditioners, and (of course) home thermostats. The five most common types of temperature sensors include: Thermistor, Thermocouple, RTDs (resistive temperature detectors), Digital thermometer Integrated Circuits (ICs), Analog thermometer ICs [82].

Table 4 below shows a comparison between the different temperature sensors discussed. However, keep in mind that this information should be received as a generalization. The table is intended primarily for those who lack extensive experience with and/or knowledge of temperature sensors

Table 4 Comparison of Temperature Sensors

Sensor Type	Typical Temperature Range (°C)	Accuracy (+/- °C)	Pros	Cons	Applications
Thermistor	• Within ~50°C of a given center temperature • Common range: -40° to 125°	1	• Low cost • Durable • Small size	• Nonlinear output • Slow response time	• Ambient temperature measurements
Thermocouple	-200° to 1450°	2	• High resolution • Small size • High temperature range	• Calibration is highly recommended • Two temperature readings are required: hot junction and cold juntion.	• Industrial use
RTD	-260° to 850°	1	• Linear output • Accurate	• Expensive • Fragile: are often housed in protective probes.	• Industrial use
Analog IC	-40° to 125° (TMP36)	2	• Simple to interface with • Easy to use • Linear output	• More expensive than thermistors. • Limited temperature range.	• Domestic thermostat • Digital thermometer
Digital IC	-55° to 125° (DS18B20)	0.5	• Simple to use with microcontrollers • Accurate • Linear output	• Requries a microcontroller, or something similar. • More expensive than thermistors. • Limited temperature range.	• Domestic thermostat • Digital thermometer • Consumer electronics

2.12.1 TMP 36 and LM 35 TEMPERATURE SENSORS

Both the LM35 and TMP 36 are analog output temperature sensors that produce a linear output voltage in relation to the detected temperature. The sensors circuitry is sealed and therefore are not subjected to oxidation and other processes. With LM-35,

temperature can be measured more accurately than with a Thermistor [88]. It also contains low self heating and does not cause more than 0.1-degree Celsius temperature rise in still air. The LM-35 has three pins - VCC (Pin 1), Out (Pin 2) and Ground (Pin 3). The VCC and Ground pin are connected to VCC and ground respectively. The LM-35 can be supplied a voltage between 4V and 20V, so a 5V supply is used on it same which is powering the Arduino board.

The out pin of the LM-35 is connected to A1 pin of the Arduino since the output from the LM-35 is analog in nature. The value read is converted to Fahrenheit using the standard formulas [88][89]. LM35 three has three pins and their use is indicated in Figure 20 below:

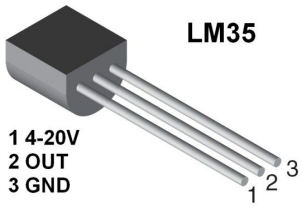


Figure 20. LM 35 temperature sensor

The application of the LM 35 ranges from being used in measuring environmental changes to being used as a thermal shutdown for a circuit and for checking battery temperature. The TMP 36 in terms of the structure and the wiring to an Arduino board is not so much of a difference as it is also an analog sensor [89]. Figure 20 below shows an example of the TMP36 sensor.

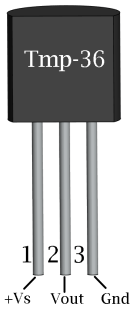


Figure 21 TMP 36 temperature sensor

Since the output voltage of LM35/ TMP36 is connected to ADC channel (A1), the ADC converts the analog readings into digital values according to the following formula: ADC value = Sample* 1024 / Reference Voltage. To convert the voltage to temperature, we use the basic equation, equation 1 below :

$$Temp\ in\ °C = [(Vout\ in\ mV) - 500] / 10$$

Equation 1 Calculation for temperature

2.13 Research Gaps

In this literature review, our main articles that were used for this study were read for possible gaps and work areas that would form the basis for this study. Table 5 highlights the major journal articles that we revealed and found gaps:

Table 5 (Gaps found in Literature)

No	Year	Authors	Title	Findings	Gaps
1	2013	Sandra V.B. Jardim	The Electronic Health Record and its Contribution to Healthcare Information Systems Interoperability	Despite being a challenge to implement interoperability, it is necessary for better healthcare	No technologies discussed on how to achieve interoperability in health care systems which the evaluates
2	2017	N. A. Mohamadali, N. F. A. Aziz	The Technology Factors as Barriers for Sustainable Health Information Systems (HIS) – A Review	Technological issues need to be resolved for HIMS to be used effectively for care delivery	No suggestions on technical barriers in achieving interoperability Does not consider developing countries setup where technologies are expensive.
3	2017	C. Mata, A. Oliver, A. Lalande, P. Walker, J. Marti,	*On the Use of XML in Medical Imaging Web-Based Applications*	The use of XML in health systems will continue due to the advantages that XML has over its alternatives such as JSON and YAML	The paper addresses medical solutions but limits itself to just Image Processing for Medical Systems
5	2017	K. Afsari, C. Eastman, D. Castro-Lacouture	*JavaScript Object Notation (JSON) data serialization for IFC schema in web-based BIM data exchange*	JSON has evolved into the desired choice for data exchange over the traditional XML	Though discusses strongly on usage of JSON over XML related web services, it does not apply itself to health related solutions

2.14 Related works

There are various eHealth solutions that have been developed for the Zambian market and beyond. Below is a review of some of the implemented systems including SmartCare and Project Mwana to mention but a few:

2.14.1 SmartCare

SmartCare is said to be Zambia's National EHR system which supports clinical care and continuity of healthcare by providing confidential portable health records [25]. it was developed in Zambia by USAID team to be a nationally scalable system designed specifically for low resources and disconnected settings. SmartCare is a portable EHR built as a .NET desktop application developed in C# with SQLServer for it's database [19]. It has other components that come along side its operations such as smart cards as shown in figure 22, printers, smart card readers and data transfer flash drives.

Figure 22 Smart Care

The smartcard is mainly where the information of the patient is stored from one facility to the other, hence, the patient gets to move with an encrypted version of their records. With the introduction of SmartCare, there has been, in the facilities where it has been implemented, better records management and storage as there is no physical storage space required [25].

Though SmartCare in Zambia has been declared the national EHR, it comes with its own challenges. The system is not web-based and is not centralized. Normally, the upgrades of the application have to be done on-site. It also suffers the known challenge of connectivity in our health facilities. The cost of maintaining the hardware of this EHR may also be high and data is transferred from the rural health facilities by flash drives. Other than that, SmartCare at the time of conducting this research was only used for managing and tracking patients on Antiretroviral treatment.

2.14.2 Project Mwana

Project Mwana is an mHealth (Mobile Health) health solution that was developed to address Early Infant Diagnosis (EID) of HIV and post-natal care. The application has been deployed in two countries in Southern Africa namely Zambia and Malawi. In Zambia, the project has been implemented by Ministry of Health (MoH), UNICEF and CHAI with the help of Zambia Prevention, Care and Treatment (ZPCT II) [95].

The mobile application is built on RapidSMS which is an open source framework and is meant to be government owned and operated [95]. A number of health facilities are already using the solution in Zambia. The current workflow is that the health facility gets the sample details and transmits them via SMS to the lab. Once the results are ready and out, the system alerts the clinic workers at the facility which would eventually be able to deliver them to the mothers. Only authenticated and authorised clinic workers can send a request to the server and retrieve the records. Some of the notable challenges currently faced by the system are; failure to accurately identify the number of children currently infected, health facilities cannot tell whether the mothers actually get to receive their results and the process of delivering the samples to the lab is long.

2.14.3 openEHR

OpenEHR is a virtual community that focuses on interoperability and computability of patients' data and uses a methodology that is similar to a standard for interoperability in health systems called Health Level 7 (HL7) [27]. This is done by mapping clinic data onto the model. It is an Open-Source application that includes in its framework an Electronic Health Record, EHR extract, demographics, Data structures, Data type and Integration

information. The system was developed as a product of research and riding on earlier platforms such as Synapses and the Good European Health Record (GEHR). It is currently developing reference implementations in programming languages such as .NET and Java [34]. OpenEHR implements a two-level modelling approach i.e. the reference model and the archetype where aggregation constraints are applied. Figure 23 below shows the structural architecture of openEHR:

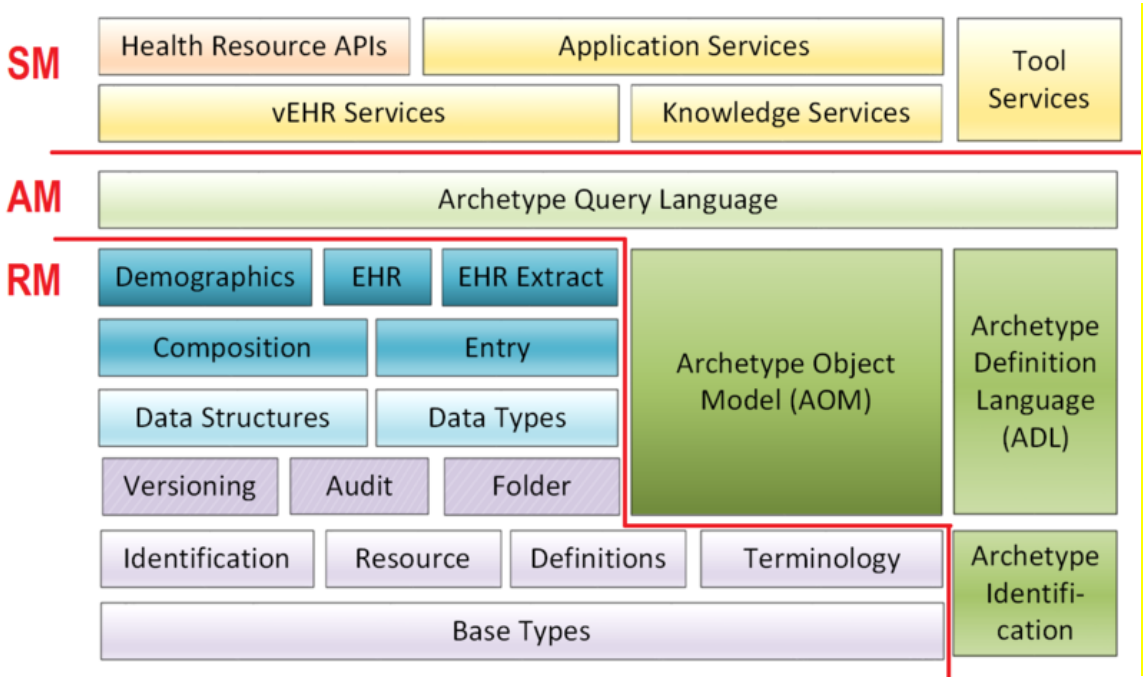


Figure 23: Architecture of openEHR (adopted from wikipedia)

The challenges at The University of Zambia's Health Unit are no different from the challenges that are met by many health institutions in managing patient records especially where there is a partial implementation of an eHealth system or a complete manual system. There is not enough equipment to implement a typical Electronic Health Management Information System (EHMIS), Electronic Health Record (EHR) and or Electronic Medical Record (EMR). This is due to the fact that the devices and technology needed for keeping certain records such as scans and image information may not be possible to buy for every health practitioner. There idea is to look for effective standards and models of interoperability amongst health systems and non-health related systems yet maintaining a cost effective approach to mitigate the challenges that a developing country like Zambia would face with implementing high end solutions. This research work was conducted to find the cheapest

possible way to implement a system that can help in improving the efficiency of the Unit in healthcare giving and improve patient wait time and service delivery.

2.15 Summary

This chapter was based on a review of various literature that has been published on healthcare systems, technologies used in healthcare and interoperability. The chapter looked at challenges in healthcare and technology and related works in the subject area and gives a brief reflection of the gaps that were identified in the literature that was revealed in line with the problem domain of this research. Lastly, the chapter reviews some related systems that have been developed and implemented for eHealth.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter is based on the methodologies that have been adopted to carry out this research. The chapter discusses in depth how the objectives that were earlier introduced in this document have been addressed. The chapter is composed of the following aspects; Sampling and data collection, analysis of the currently used documents, baseline study, proposed workflow, proposed model, proposed concept and finally use case and use case documentation.

3.2 Baseline study, sampling and data collection

To address objective 1, a baseline study was conducted and targeted at the users of the current system and main stakeholders of the UNZA Health Services Unit. Purposive Sampling was used for the identified Key Respondents who in this case were the Health Care Providers and Random Sampling was used for the Students, Staff, Community respondents. Academic databases and filtered by subject relevance to health and Physical Sciences and Engineering, Life Sciences and Health Sciences. To address objective 2, a review of existing models of interoperability will be conducted and finally, Agile Methodologies will be used for the design of the prototype

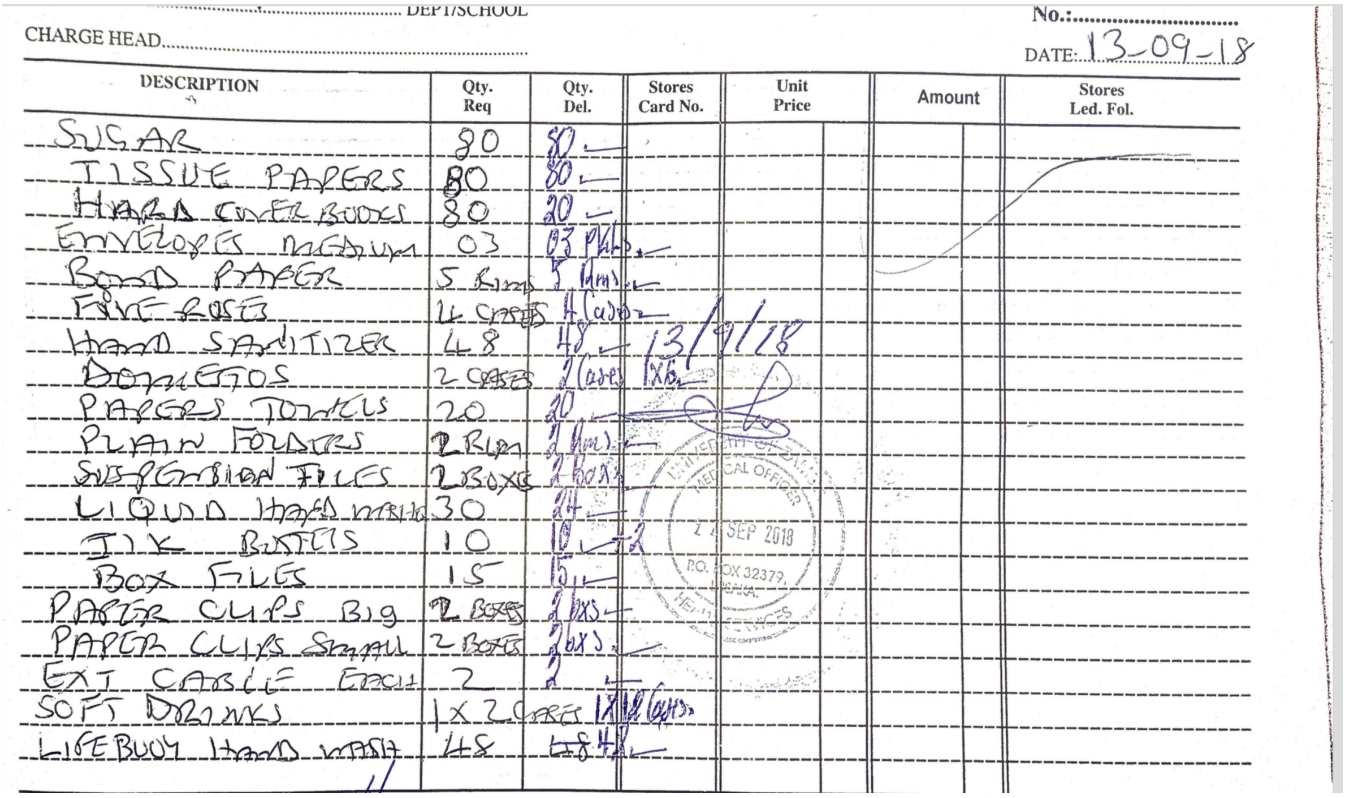
3.3 Document analysis

In this research, part of the objectives was to assess the current working system. In our analysis, we considered the documents that are used to capture patient bio-data, recording of the diagnosis of the patient, documents used to request for a lab test and also those used in the pharmacy and stores department.

The following documents are samples that are used on daily transactions and were considered for analysis i.e. Stores Request, Transfer Note, Stores Card and the Goods Received Note (GRN).

3.3.1 Stores Request Form

This form is used by the requesting office or department. The requesting officer indicates the items and quantities that they are in need of and sends this to the stores department. Figure 24 below shows a sample of the stores request form;



DEPT/SCHOOL

CHARGE HEAD.....

No.:.....

DATE: 13-09-18

DESCRIPTION	Qty. Req	Qty. Del.	Stores Card No.	Unit Price	Amount	Stores Led. Fol.
SUGAR	80	80				
TISSUE PAPERS	80	80				
HARD COVER BOOKS	80	20				
ENVELOPES MEDIUM	03	03 PKTS				
BOND PAPER	5 Rims	5 (rims)				
FIVE ROSES	4 CASES	4 (cases)				
HAND SANITIZER	48	48				
DOMESTOS	2 CASES	2 (cases) 1X6				
PAPERS TOWELS	20	20				
PLAIN FOLDERS	2 Rim	2 (rim)				
SUSPENSION FILES	2 BOXES	2 BOXES				
LIQUID HAND WASH	30	24				
INK BOTTLES	10	10				
BOX FILES	15	15				
PAPER CLIPS BIG	2 BOXES	2 BOXES				
PAPER CLIPS SMALL	2 BOXES	2 BOXES				
EXT CABLE EACH	2	2				
SOFT DRINKS	1X2 CRATES	1X12 CRATES				
LIFEBUOY HAND WASH	48	48				

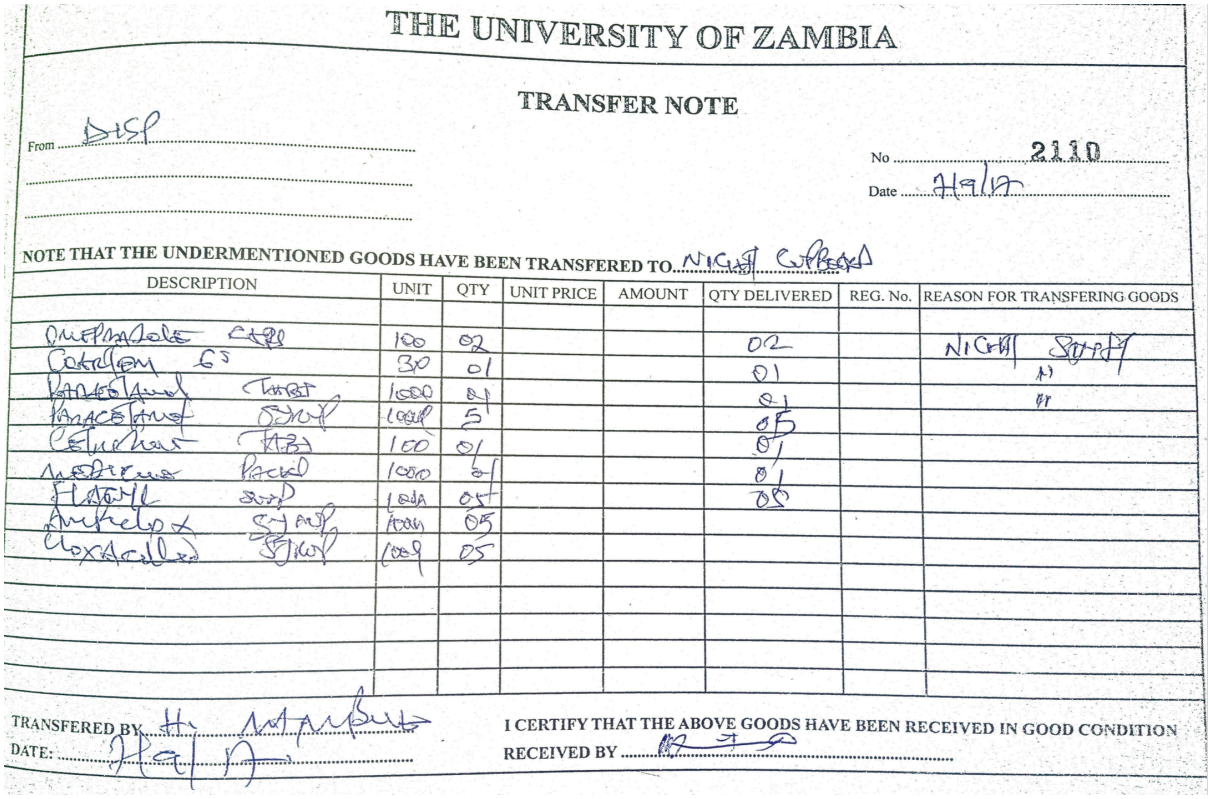
13/9/18

Figure 24 (Stores Request Form)

3.3.2 Transfer Note Form

The Transfer note form is used by the pharmacy and the stores office to transfer stock to a requesting department. Upon this receiving a stores request form, stores have to counter-check on their stock inventory to check if they have the right quantities of the requested items in stock. On the transfer form, the stores officer will re-capture all the items requested along side their initial quantities.

After which stores will indicate per item, how much can be released as per their stock levels. This stock movement requires authorization from the Medical Officer. Figure 25 below is an example of the form;



THE UNIVERSITY OF ZAMBIA

TRANSFER NOTE

From DISP

No 2110

Date 7/9/17

NOTE THAT THE UNDERMENTIONED GOODS HAVE BEEN TRANSFERED TO NICU CUPBOARD

DESCRIPTION	UNIT	QTY	UNIT PRICE	AMOUNT	QTY DELIVERED	REG. No.	REASON FOR TRANSFERING GOODS
Ceftriaxone	100	02			02		NICU Supply
Ceftriaxone 6s	30	01			01		
Paracetamol Tablet	1000	01			01		
Paracetamol Syrup	100ml	5			05		
Ceftriaxone Vials	100	01			01		
Metronidazole Packet	1000	01			01		
Flagyl Syrup	100ml	05			05		
Amphotox Syrup	100ml	05					
Cloxacillin Syrup	100g	05					

TRANSFERED BY H. Mwamulima

DATE: 7/9/17

I CERTIFY THAT THE ABOVE GOODS HAVE BEEN RECEIVED IN GOOD CONDITION

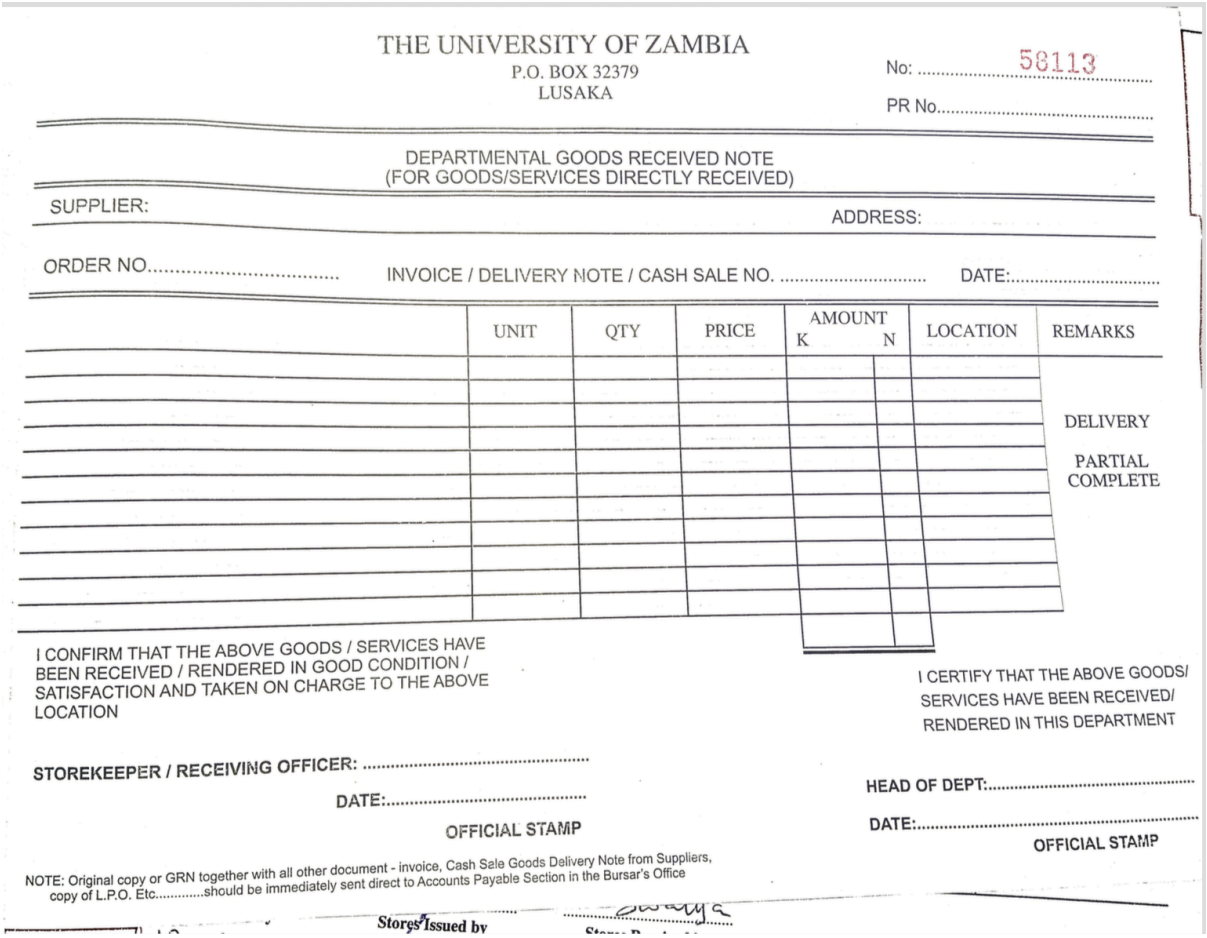
RECEIVED BY

Figure 25 (Transfer Note Form)

3.3.3 Goods Received Note

The Goods Received Note (GRN) is the internal proof of goods received to process and match against the suppliers' invoice or purchase order. It is generated as an internal organizational document after inspecting the delivered stock by the supplier.

The form is filled in by the stores officers after their have done an inspection. This form also needs approval from the Medical Officer. Figure 26 below is an example of the form;



THE UNIVERSITY OF ZAMBIA
P.O. BOX 32379
LUSAKA

No: 58113
PR No.....

DEPARTMENTAL GOODS RECEIVED NOTE
(FOR GOODS/SERVICES DIRECTLY RECEIVED)

SUPPLIER: ADDRESS:

ORDER NO..... INVOICE / DELIVERY NOTE / CASH SALE NO. ..... DATE:.....

	UNIT	QTY	PRICE	AMOUNT K	AMOUNT N	LOCATION	REMARKS
							DELIVERY
							PARTIAL
							COMPLETE

I CONFIRM THAT THE ABOVE GOODS / SERVICES HAVE BEEN RECEIVED / RENDERED IN GOOD CONDITION / SATISFACTION AND TAKEN ON CHARGE TO THE ABOVE LOCATION

I CERTIFY THAT THE ABOVE GOODS/ SERVICES HAVE BEEN RECEIVED/ RENDERED IN THIS DEPARTMENT

STOREKEEPER / RECEIVING OFFICER: .....
DATE:.....
OFFICIAL STAMP

HEAD OF DEPT:.....
DATE:.....
OFFICIAL STAMP

NOTE: Original copy or GRN together with all other document - invoice, Cash Sale Goods Delivery Note from Suppliers, copy of L.P.O. Etc.....should be immediately sent direct to Accounts Payable Section in the Bursar's Office

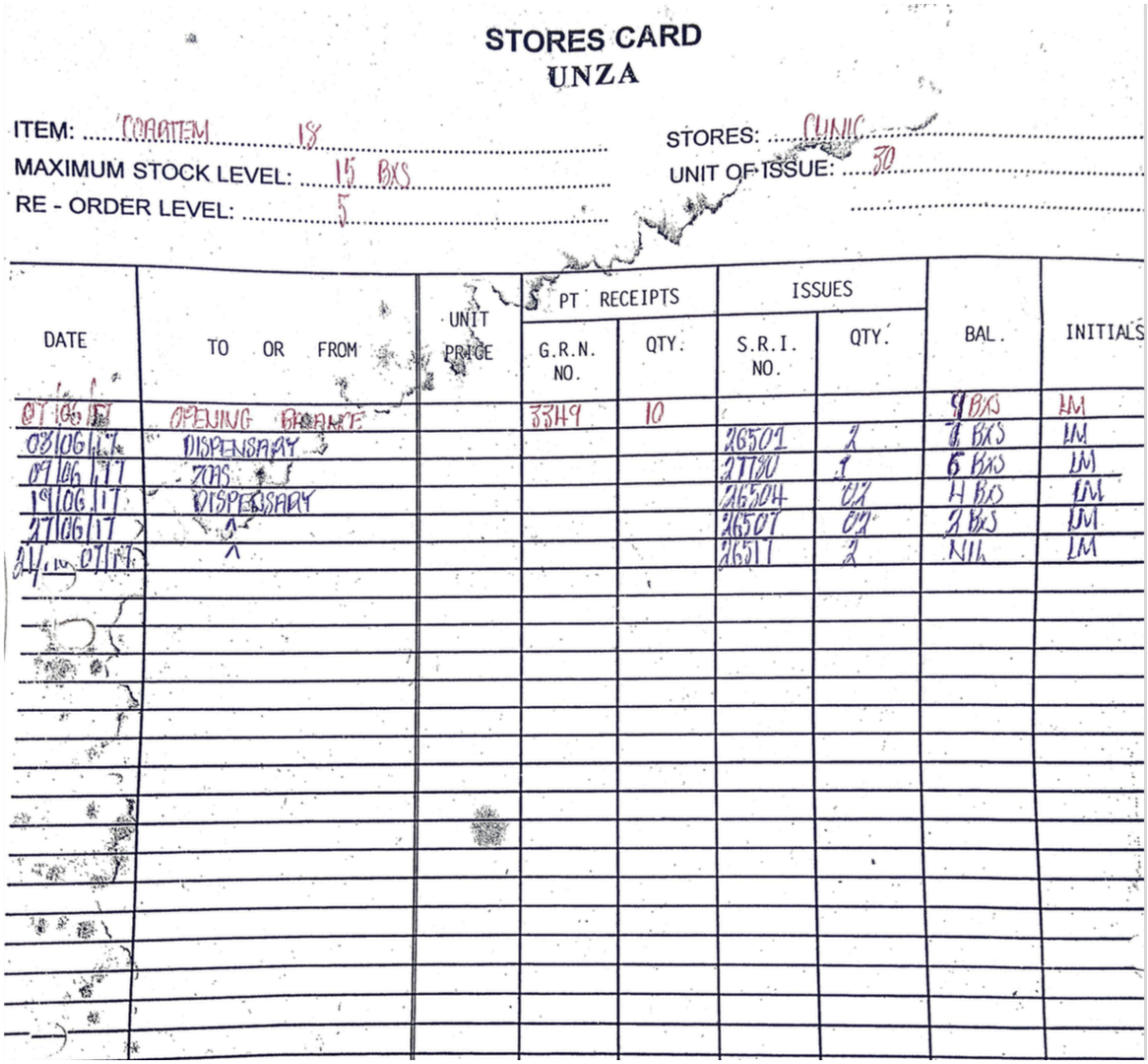
Stores Issued by

Figure 26 (Goods Received Note)

GRN's play a key part in the accounts payable process by confirming that items have been received as expected, in accordance with the original order, and that the items can therefore be invoiced by supplier and subsequently paid for. However, manually processing paperwork such as GRNs can take a large amount of staff time in data entry and distribution to various departments. Paper copies of notes can be misplaced, supplier payments delayed and stock control systems out of date.

3.3.4 Stores Card

The stores card also referred to as a Bin Card is another document that is used by stores at UNZA Clinic. This document, in terms of inventory management, is used per drug or artifact. It is on this document that the actual quantities of the artifact are initially recorded including the re-order levels. From the initial stock level, the quantities are reduced based on the requests that are coming through to stores. This is the main document that is used in tracking stock movement.



STORES CARD

UNZA

ITEM: COARTEM 18

MAXIMUM STOCK LEVEL: 15 BXS

RE - ORDER LEVEL: 5

STORES: CLINIC

UNIT OF ISSUE: 30

DATE	TO OR FROM	UNIT PRICE	PT RECEIPTS		ISSUES		BAL.	INITIALS
			G.R.N. NO.	QTY.	S.R.I. NO.	QTY.		
01/06/17	OPENING BALANCE		3349	10			9 BXS	LM
03/06/17	DISPENSARY				26501	2	7 BXS	LM
07/06/17	ZOAS				27130	1	6 BXS	LM
19/06/17	DISPENSARY				26504	02	4 BXS	LM
27/06/17					26507	02	2 BXS	LM
24/06/17					26511	2	NIL	LM

Figure 27 (Stores Card)

Figure 27 above is an example of a filled in stores card. Using a Stores Card is very time consuming and it is even worse when it is time for reporting as the officers has to tally the items per artifact and per stores card. The time for report generation is therefore significantly delayed. Another problem that arises from manually using a stores card is that the officer may never get to know what quantities have been left in stores until when thy are looking for those items. Therefore, the levels of stock-level alertness are not effective especially if the stores department is as busy as that of a healthcare facility.

3.4 Performance Matrix of Current System

During the interviews and observation, we performed a system evaluation per module of the currently used system. Table 6 below is a list of items that were considered in the evaluation process. Due to the nature of the environment, the main users of the system could only be

interviewed in a limited period of time at the time of the evaluation as they were attending to patients. In the table below, various system functionalities were tested and evaluated. A pass was assigned to functionality that worked as expected and produced desired results whereas a fail meant that the functionality did not meet the user requirement.

Table 6 Current EHR System Evaluation

	Module	Functionality	Result of Test
1	Registry Clerk	• Create users • List active users • Reset password • Register patient • Queue patient • Medicals	Pass Fail Pass Pass Partial Pass [not picking schools] Pass Pass
2	Admin	• Audit Trail • Normalization • Add look up data	Fail Fail Fail
3	Clinician	• Register patient • Search patient • Medicals • Change password • Post to lab • Post to pharmacy	Pass Pass Pass Pass Pass Pass Fail
4	Laboratory	• Change password • Medicals • Post to clinicians	Pass Pass Fail
5	Pharmacy	• Change password • Post to clinicians • Dispense medication • Manage inventory	Pass Fail Fail Fail
6	Secretary	• Change password • Print medical fitness certificate	Pass Pass

Based on the evaluation that was conducted, we gathered requirements on what was required to bridge the gap in the electronic health record system at the clinic.

3.5 Data Analysis

To analyze the data that was collected through the administered questionnaires and interview, we used the statistical packaged called IBM SPSS to perform quantitative analysis and produce various charts and tables. The analysis considered both descriptive and quantitative analysis.

3.6 Current Business Process

The current business process at the clinic is depicted in figure 28. The patient first visits the registry to be identified as a first time patient or returning patient with a record card. The patient is further isolated to be identified as either being student staff or Non-UNZA patients, member of staff who is on scheme with the clinic or not, staff dependent or not. patients that are coming for the first time to the clinic need a record card created for them by the registry clerks.

If a patient has been to the clinic before, then the registry clerks looks through a number of record cards based on the clinic number that was assigned to the patient on the last visit. If the record book for the patient's previous record card can be traced, it is retrieved and used or else a new record card is created. Once the record card is found, the registry clerks has to manually check which clinician has less patients on their queue outside the consulting room. The registry staff then has to divide the number of record cards across the available clinicians.

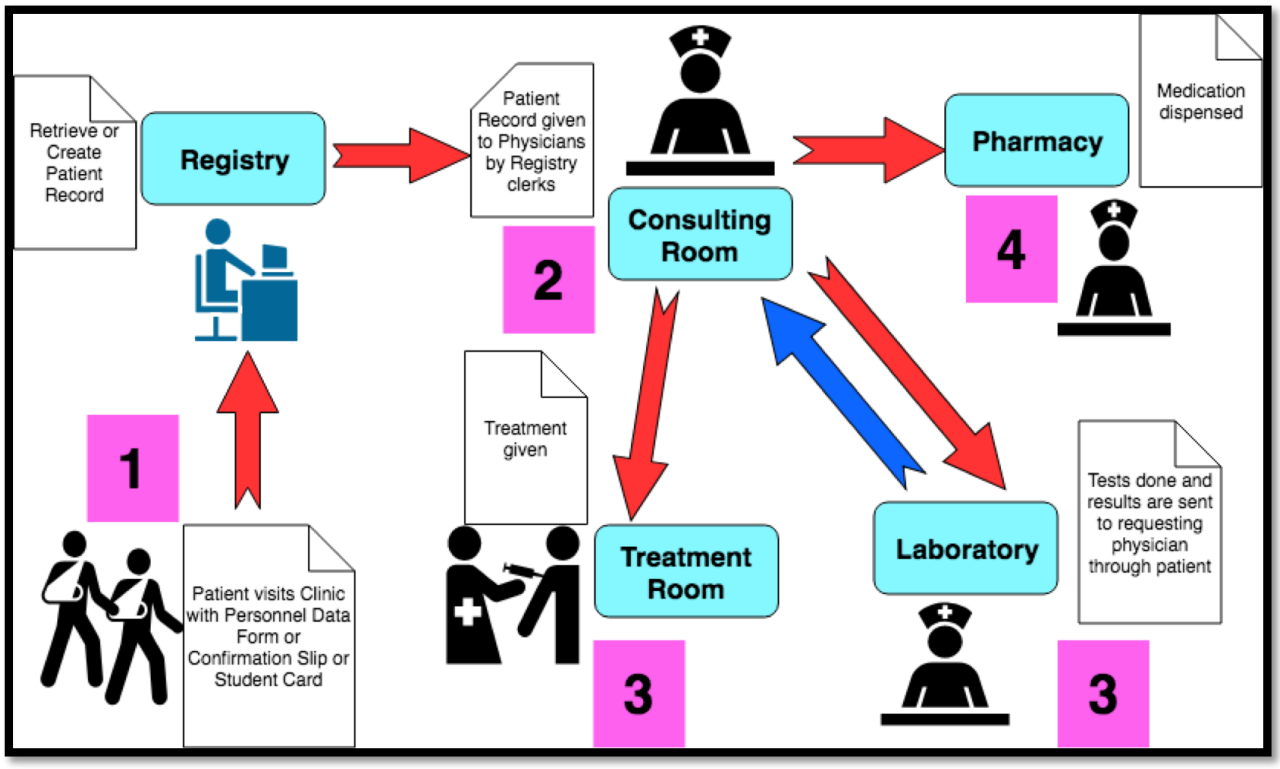


Figure 28 –Current Business Process

At the time of this research, we also observed that currently the clinic is running four different systems for the running of the clinic namely; SAGE for accounting purposes, a locally developed EHR system built in PHP running on MySQL Database and PHP 4. The application was developed using a procedural approach rather than using Object Oriented Programming (OOP) concepts making it difficult to reuse code and maintain it. Lastly, a proprietary Pharmacy Ordering System was used for ordering of drugs from medical stores.

3.7 Proposed Model

This proposed model incorporates a number of modules that will constitute the EHR. These modules include the registration, diagnosis and treatment, laboratory, pharmacy and inventory modules. The model is also designed to interoperate with the Student Information System (SIS) using an API that queries the SIS. Figure 29 shows the proposed model for the registration process. Figure 30 shows the proposed model for the pharmacy model and figure 31 shows the configuration of the sensor module.

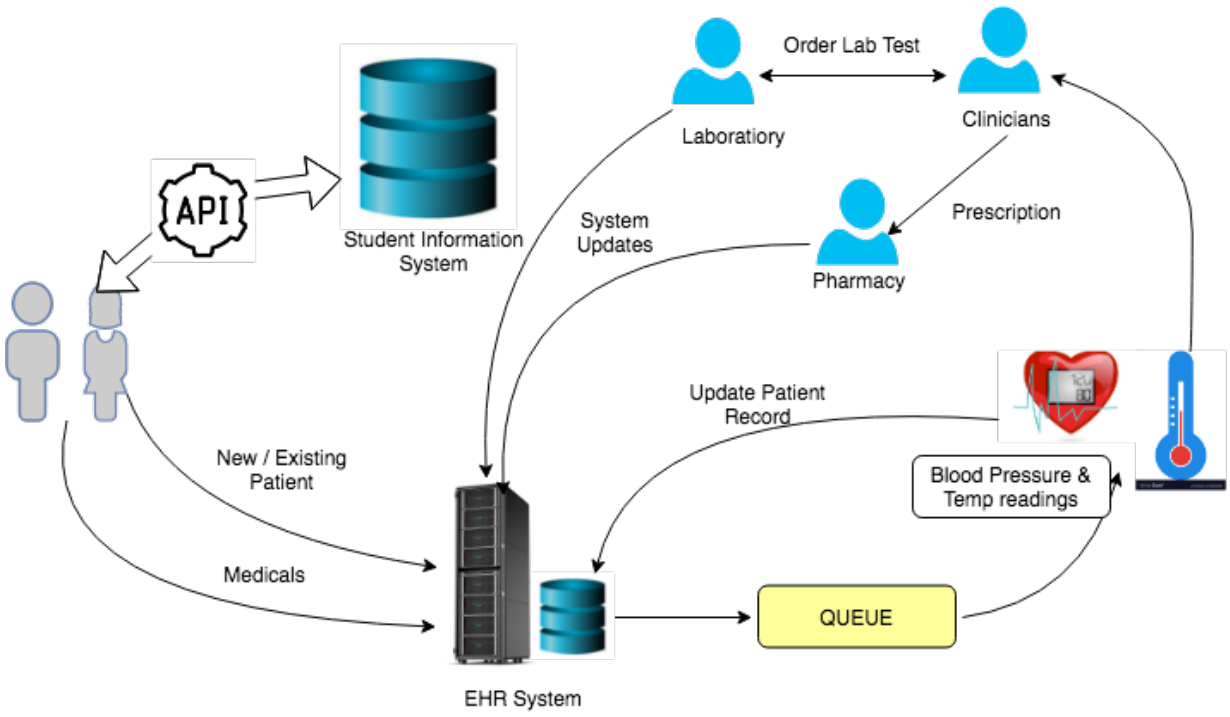


Figure 29 Proposed Registration Model

The work flow of the proposed model is that at the beginning, a patient needs to be identified as to whether they are a student or non. In this model, the SIS will be modified to include an API that will be used to provide the data when queried by an API on the EHR model and if no record is found we proceed to capture details of patient. If a record is found on the SIS, then we populate the interface with the details of the bio data as provided by the SIS and their registration status. If the patient is not a student, we capture the records manually into the system and the patient is either queued for vitals. At the checkpoint for vitals, the nurses will determine if the case needs further queueing or needs immediate attention and this is also recorded in the system. The patient is then seen by the clinicians who either will place a lab test or prescription to be given to the patient depending on the diagnosis.

As a part of the proposed EHR system, we propose a pharmacy sub-module which will incorporate QR and Barcode technology for the purpose of inventory management. This is proposed to increase the efficiency of stock taking and reduce on the human errors that are introduced by manually updating the stock records. It will also increase accuracy in terms of dispensing drugs.

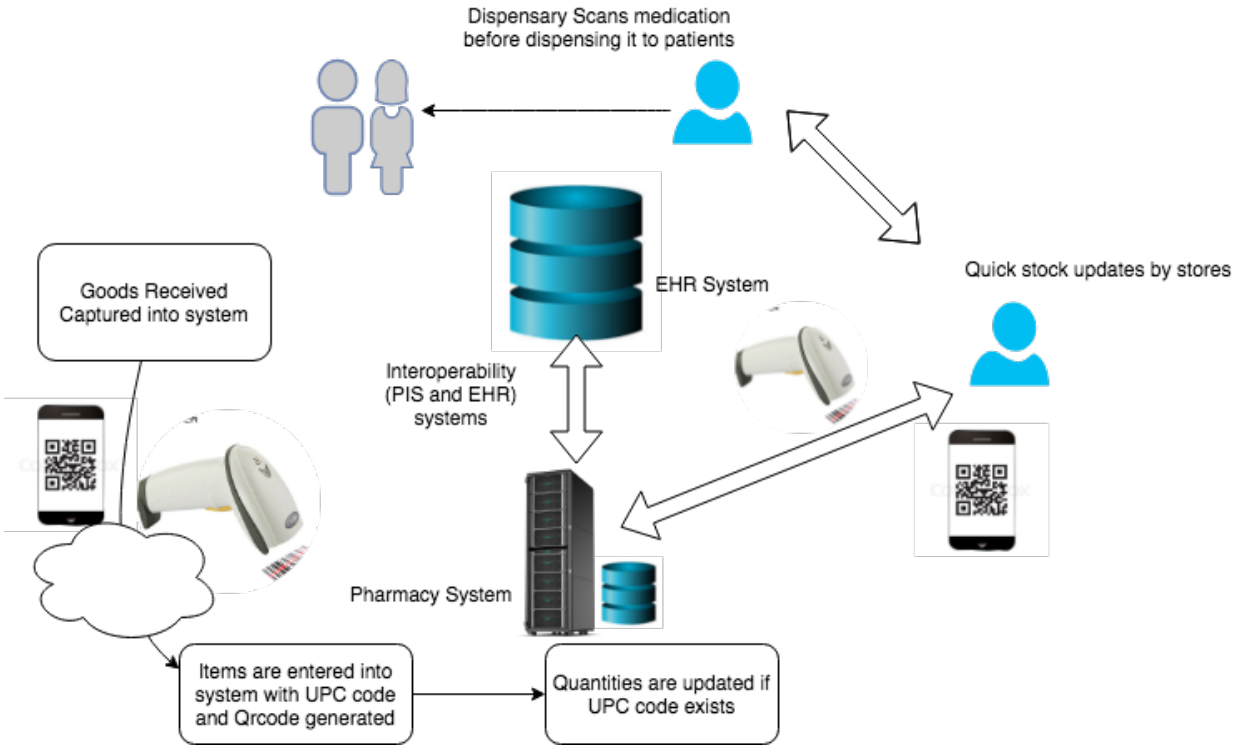


Figure 30 Proposed Pharmacy Model

This module will be used starting from the point of receiving the stock that is will be used at the clinic. The clinic has a stores department that is in-charge of ordering new stock and managing the stock movement. The module will provide for the generation of QR codes which will be printed and put on the boxes and bottles. This will be done in order to keep information about the product. The module will also have an option of using the already tagged barcode for the stock that especially will not need pre-packaging.

Both the QR codes and Barcodes will be used to identify the stock and its movement. A barcode scanner will be used for those packages that have internationally recognized UPC barcodes. This will ensure that we do not need to generate barcodes for these again. For the items that will be pre-packaged, we will tag them with the QR codes. The QR Codes will be scanned using an android device i.e. a phone or tablet which will be used on the same network as a way to be able to easily access the record identified on the system and to perform the necessary operation on it. An android device will be used because the QR code scanning application is free on android and ready to use.

Finally, the registration module will have an automated mechanism of reading temperature at the vitals checkpoint. To do this, we propose the use of an Arduino based temperature sensing that will measure the temperature of the patient for about a minute and beep once it has taken the last reading at the 60th second. This reading will then be sent into the the system and updated on the patient's record.

To achieve this task, we propose the use of an Arduino UNO Microcontroller, a buzzer, an LED, an LM35 Temperature Sensor, Breadboard, GSM shield, 1K Ohm Resistor and a Transistor. The components are connected as shown in Figure 31 below:

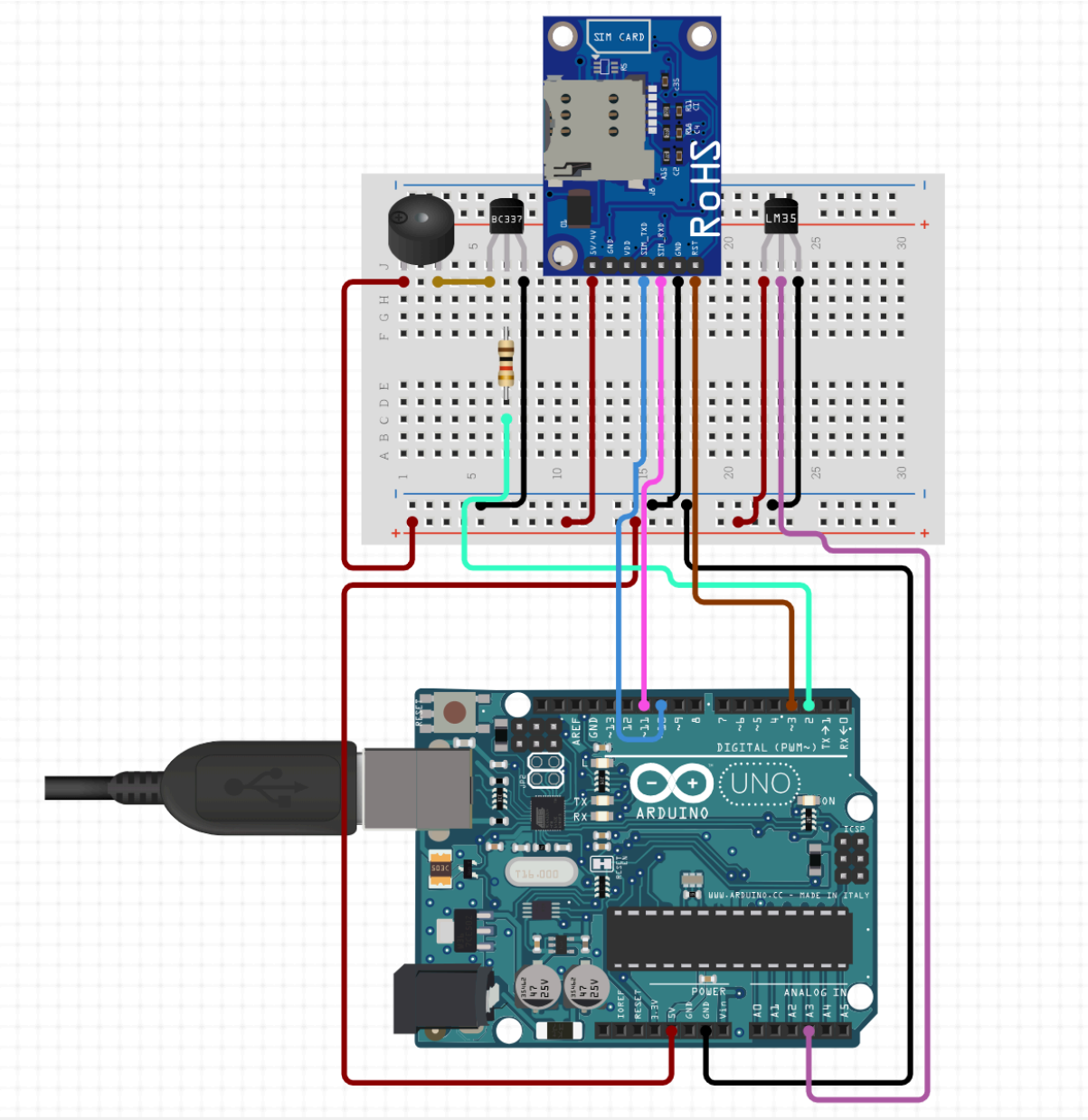


Figure 31 Temperature Sensing Model

The input from this sensor is in millivolts which is read by the Arduino. Since we need to convert this reading to its temperature reading equivalent, we used the following formula to convert;

$$Temp\ in\ °C = [(Vout\ in\ mV) - 500] / 10$$

Equation 2 Calculation for temperature

3.8 System Requirements

Software systems requirements are often classified as either functional or non-functional. In determining what kind of system needs to be built, it is important to define and understand the system requirements, both functional and non-functional. These were gathered partly through the questionnaire that was provided, the interviews that were conducted and some best practice in management information systems development.

3.8.1 Functional Requirements

Functional requirements are statements of service the system should provide. These will usually define how a system should react to particular inputs and how the system will behave in those situations [81]. In some cases, the functional requirements will also provide statements that will indicate what the system should not do.

Table 7 below is a breakdown of the functional and non-functional requirements that were identified. This is a high level view:

Table 7 Functional Requirements

SN	Module	Functionality
1	User Management	• Access to the system must be role based and users must have access to the data by username and password
2	Registration	• Automation of health vitals capturing • Automation of queue management

		• Interoperate with student information system for student records
3	Inventory Management	• Generate and Print bar/QR codes • Item tagging • Automate inventory management • Stock level remainders • Transfer goods between departments
4	Pharmacy	• Read patient queue • Dispense drugs • Automate inventory management
5	Laboratory	• Read patient queue • Automate inventory management • Post lab results
6	Reporting	• Generate reports in Excel and PDF • Customizable reporting

3.8.2 Non-Functional Requirements

Non-functional requirements as the term suggests, are requirements that are not directly concerned with the specific services delivered by the system to its users [81]. They may relate to emergent system properties such as reliability, response time, and store occupancy. Alternatively, they may define constraints on the system implementation such as the capabilities of I/O devices or the data representations used in interfaces with other systems.

Non-functional requirements, such as performance, security, or availability, usually specify or constrain characteristics of the system as a whole. Failing to meet a non-functional requirement can mean that the whole system is unusable and rejected by the users as they are identified closely with how the user perceives the system [81]. Non-functional requirements may affect the overall architecture of a system rather than the individual components. Table 8 below shows the non-functional requirements that were identified:

Table 8 Non-functional Requirements

SN	REQUIREMENT	DESIRED OUTPUT
1	Performance	• Acceptable response time • Attainable Resources required
2	Scalability	• The application must be built in such a way that whenever there will be new requirements to be added to the system, this will easily be achievable. • The application must be open source to make it possible to add new modules
3	Availability	• The application must be online and accessible through out since the clinic runs 24/7
4	Reliability	• The application must be reliable, if an error or failure occurs, there must be a backup or fall back plan
5	Maintainability	• The application must be developed with standardised coding practices to be able to have another developer maintain the code base
6	Data Integrity	• The application must preserve data integrity. The data must be meaningful
7	Usability	• The system must be efficient with less or no errors. Where errors occur, the system must have a way of gracefully handling the errors. • The system must be user friendly and easy to learn and use.
8	Security	• The system must have user access levels so as to maintain data privacy and data protection

3.9 DATABASE MODELING

A database model is a type of data model that determines the logical structure of a database and it fundamentally determines in which manner the data will be stored, organized and manipulated once implemented. There are several models available such as network model, object model and others but the most commonly used is the relational model which shows entities and their structures.

3.9.1 LOGICAL MODELING

The proposed database will contain the following entities and below is the detail of what will constitute each relation.

3.9.1.1 Categories

This relation is a reference table that will store categories for items that are going to be dispensed from stores. Figure 32 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	*None*		AUTO_INCREMENT
2	category	varchar(255)	latin1_swedish_ci		No	*None*		

Figure 32 Categories relation

3.9.1.2 Departments

This relation is a reference table that will store details of all departments that are associated with the UNZA Clinic facility. Figure 33 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	*None*		AUTO_INCREMENT
2	department	varchar(255)	latin1_swedish_ci		No	*None*		

Figure 33 Department relation

3.9.1.3 Drugs

This relation is a reference table that will store details of all drugs that are used at the clinic. Figure 34 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	None		AUTO_INCREMENT
2	drug_name	varchar(255)	latin1_swedish_ci		No	None		
3	drug_type_id	int(11)			Yes	NULL		
4	drug_price	float			No	None		
5	drug_strength	varchar(255)	latin1_swedish_ci		No	None		
6	drug_dosage	varchar(255)	latin1_swedish_ci		No	None		
7	dose_form	varchar(255)	latin1_swedish_ci		No	None		
8	unit	int(11)			No	None		
9	qty	int(11)			No	None		
10	expiry_date	date			No	None		

Figure 34 drugs relation

3.9.1.4 Drug Catalogues

This relation is a reference table that will store details of all drug catalogues where drugs are identified with. Figure 35 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	drug_name	varchar(100)	latin1_swedish_ci		No	None		
2	dose_form	varchar(100)	latin1_swedish_ci		No	None		
3	strength	varchar(50)	latin1_swedish_ci		No	None		
4	unit	varchar(10)	latin1_swedish_ci		No	None		
5	drug_type	varchar(100)	latin1_swedish_ci		No	None		
6	total_quantity	decimal(11,3)			No	None		

Figure 35 drugs catalogue relation

3.9.1.5 Drug Types

This relation is a reference table that will store details of all drug types. Figure 36 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	None		AUTO_INCREMENT
2	drug_type	varchar(255)	latin1_swedish_ci		No	None		
3	category_id	int(11)			Yes	NULL		

Figure 36 drug types relation

3.9.1.6 Goods Receivables

This relation is going to be storing details of all the goods that have been received from the suppliers. Figure 37 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**supplier_id** 🔗	int(11)			Yes	*NULL*		
☐	3	**item_type**	varchar(255)	latin1_swedish_ci		Yes	*NULL*		
☐	4	**item**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	5	**invoice_no**	int(11)			No	*None*		
☐	6	**quantity**	int(11)			No	*None*		
☐	7	**price**	int(11)			No	*None*		
☐	8	**location**	varchar(50)	latin1_swedish_ci		No	*None*		
☐	9	**date**	varchar(50)	latin1_swedish_ci		No	*None*		

Figure 37 Goods received relation

3.9.1.7 Patients

This relation will store all patient records that are created by the application. It will be used for historical data too where a patient visits the clinic again in the future. Figure 38 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	None		AUTO_INCREMENT
2	student_id	varchar(10)	latin1_swedish_ci		No	None		
3	fname	varchar(20)	latin1_swedish_ci		No	None		
4	lname	varchar(20)	latin1_swedish_ci		No	None		
5	other_names	varchar(50)	latin1_swedish_ci		Yes	NULL		
6	sex	varchar(6)	latin1_swedish_ci		No	None		
7	DOB	date			No	None		
8	patient_type	varchar(30)	latin1_swedish_ci		No	None		
9	residential_address	varchar(300)	latin1_swedish_ci		No	None		
10	kin	varchar(100)	latin1_swedish_ci		Yes	NULL		
11	kin_phone	varchar(20)	latin1_swedish_ci		Yes	NULL		
12	kin_email	varchar(50)	latin1_swedish_ci		Yes	NULL		
13	patient_phone	varchar(20)	latin1_swedish_ci		Yes	NULL		
14	patient_email	varchar(50)	latin1_swedish_ci		Yes	NULL		
15	patient_status	varchar(10)	latin1_swedish_ci		No	alive		
16	nationality	varchar(100)	latin1_swedish_ci		No	Zambian		
17	on_queue	varchar(4)	latin1_swedish_ci		No	no		
18	date	date			No	None		
19	kin_address	varchar(200)	latin1_swedish_ci		No	None		
20	kin_relationship	varchar(200)	latin1_swedish_ci		No	None		
21	emergency_contact_name	varchar(100)	latin1_swedish_ci		No	None		
22	emergency_contact_number	varchar(20)	latin1_swedish_ci		No	None		

Figure 38 Patients relation

3.9.1.8 Prescriptions

This relation is in charge of storing and queueing all treatment prescriptions that are assigned to the patient. Figure 39 shows the relation:

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
1	id	int(11)			No	None		AUTO_INCREMENT
2	drug_id	int(11)			Yes	NULL		
3	patient_id	int(11)			No	None		
4	frequency	varchar(255)	latin1_swedish_ci		No	None		
5	route_to_administration	varchar(255)	latin1_swedish_ci		No	None		
6	date	date			No	None		
7	user_id	int(11)			No	None		
8	qty	int(11)			No	None		
9	unit_price	double			No	None		
10	total_price	double			No	None		

Figure 39 prescription relation

3.9.1.9 Roles

This relation defines the possible user roles that exist on the system. Figure 40 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**role**	varchar(255)	latin1_swedish_ci		No	*None*		

Figure 40 user roles relation

3.9.1.10 Stores Requests

This relation will store and queue the requests to stores for dispatching requested items from departments of the clinic. Figure 41 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**department_id** 🔗	int(11)			No	*None*		
☐	3	**storecard_id** 🔗	int(11)			No	*None*		
☐	4	**quantity_requested**	int(11)			No	*None*		
☐	5	**quantity_delivered**	int(11)			No	*None*		
☐	6	**date**	date			Yes	*NULL*		

Figure 41 stores requests relation

2

3.9.1.11 Store Cards

This relation is a working that that will record details of the inventory movement. Figure 42 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**item**	varchar(255)	latin1_swedish_ci		Yes	*NULL*		
☐	3	**upc**	varchar(255)	latin1_swedish_ci		Yes	*NULL*		
☐	4	**date**	date			No	*None*		
☐	5	**max_stock_level**	int(11)			No	*None*		
☐	6	**reorder_level**	int(11)			No	*None*		
☐	7	**unit_of_issue**	int(11)			No	*None*		
☐	8	**department_id** 🔗	int(11)			No	*None*		
☐	9	**stores_qty**	int(11)			No	*None*		
☐	10	**issued_qty**	int(11)			No	*None*		
☐	11	**balance**	int(11)			No	*None*		

Figure 42 Stores Card relation

3.9.1.12 Suppliers

This relation is a reference table that will store details of all suppliers. Figure 43 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**supplier_name**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	3	**supplier_address**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	4	**supplier_phone**	varchar(25)	latin1_swedish_ci		No	*None*		
☐	5	**supplier_email**	varchar(255)	latin1_swedish_ci		No	*None*		

Figure 43 Suppliers relation

3.9.1.13 Users

This relation is a reference table that will store details of all the system users. Figure 44 shows the relation:

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra
☐	1	**id** 🔑	int(11)			No	*None*		AUTO_INCREMENT
☐	2	**first_name**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	3	**last_name**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	4	**username**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	5	**password**	varchar(255)	latin1_swedish_ci		No	*None*		
☐	6	**role_id** 🔗	int(11)			No	*None*		
☐	7	**created**	datetime			No	*None*		
☐	8	**modified**	datetime			No	*None*		

Figure 44 Users relation

3.9.2 ENTITY RELATIONSHIP MODELING

Entity Relationship Modelling [8] is a model that shows how data entities of a system are linked to one another. It consists of entities, attributes and the relationships that exist amongst them. Figure 45 below is a representation of our proposed database schema for the proposed system which has been normalized to 3NF. Figure 32 shows the relation:

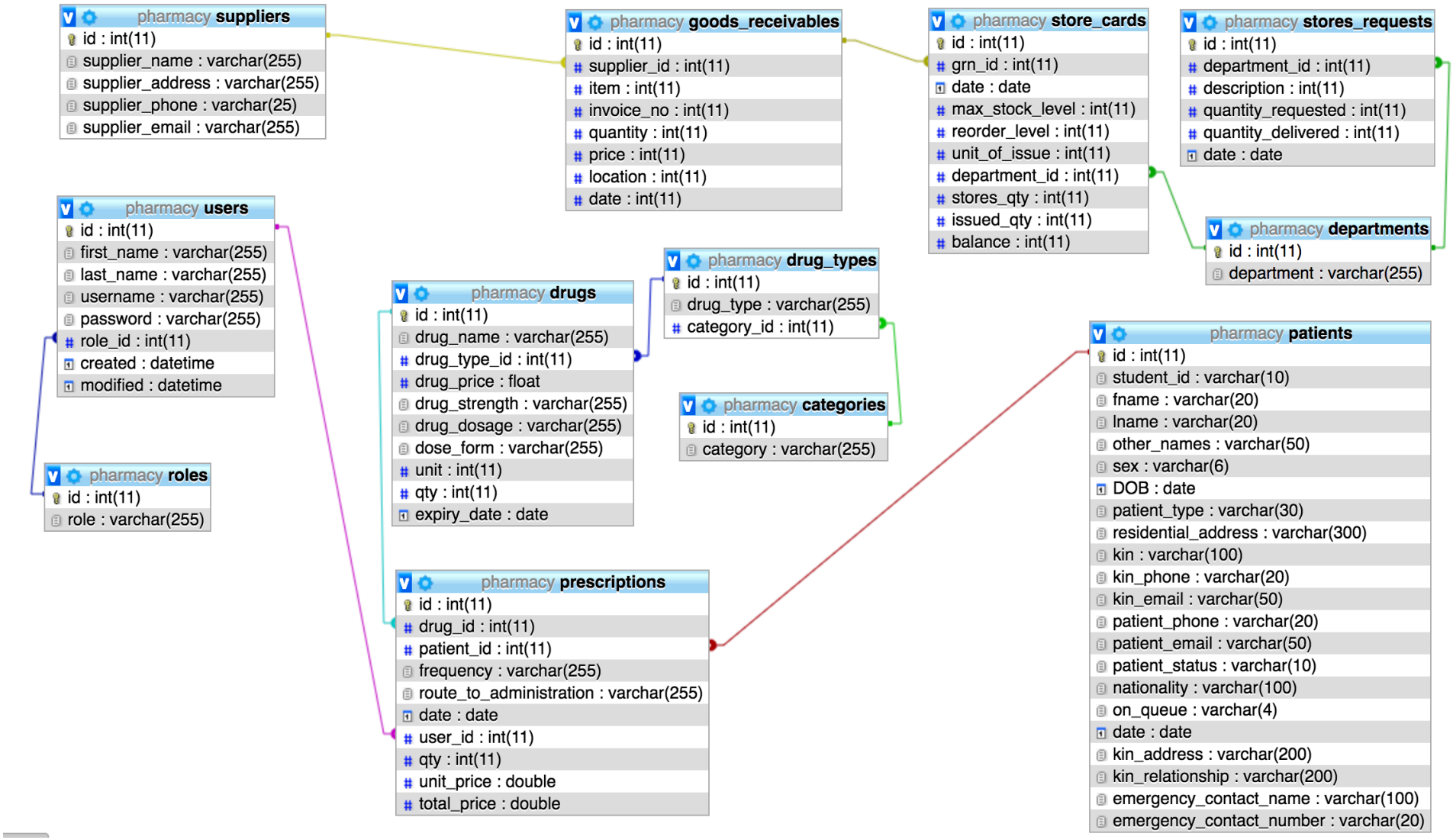


Figure 45 Proposed Entity Relationship Model

3.10 USE CASE Diagrams and Documentation

Use Cases are a tool used in Unified Modelling Language. They are used for describing user interactions with between users and a system [54][8]. Use cases are characterized by users being represented as actors, oval shapes with a verb as use cases and shows dependency amongst the functionalities by either left or right dependency. The use cases below show the proposed prototype and the user interactions with the system. The primary users identified are clinicians, registry staff, pharmacy staff, laboratory staff and nurses. Each of the use case will be followed by a use case documentation below.

3.10.1 Proposed Use Case Diagram for Registry Staff

Figure 46 and table 9 show the the Use Case for registry staff and its documentation respectively:

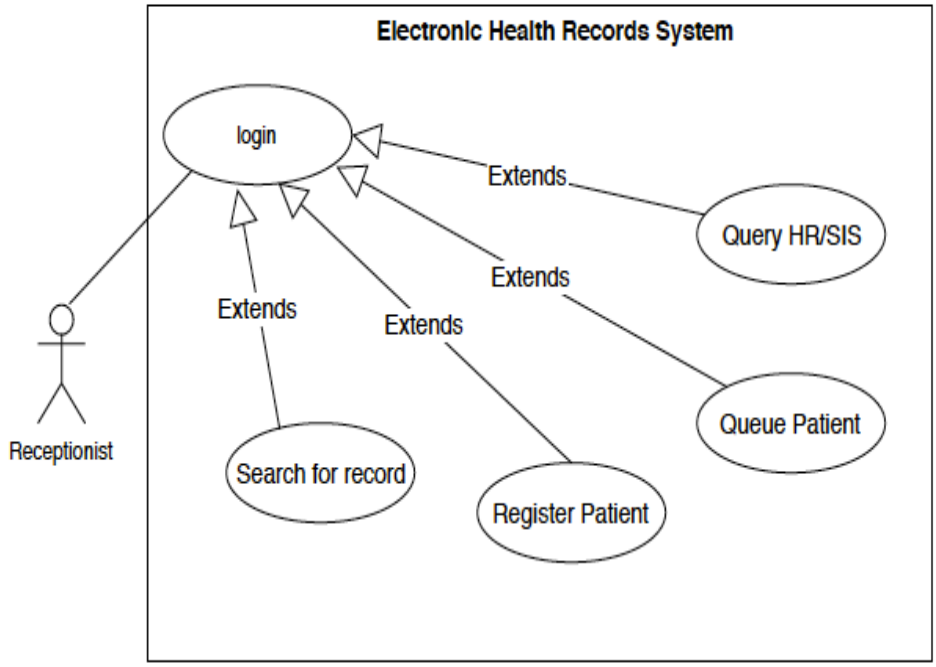


Figure 46 (Registry Clerk Use Case)

Table 9 (Queue Patient Use Case Documentation)

Use Case	Search / Queue Patient / Register
Actor	Receptionist (Registry Clerk)
Pre-condition	User must be logged in

Flow of events	1. User searches for patient record 2. User selects the patient 3. User selects the Treatment or Consulting Room 4. User selects the personnel to attend to the patient 6. User submits
Alternatives	• User clicks add new patient • User enters biodata for patient • User submits patient information • If the patient details already exists, the system rejects the submission and asks the user to submit correct details
Post-condition	Patient is queued for diagnosis or treatment

3.10.2 Proposed Use Case Diagram for Clinician

Figure 47, table 10 and table 11 show the Use Case and Use Case documentation for the clinicians respectively:

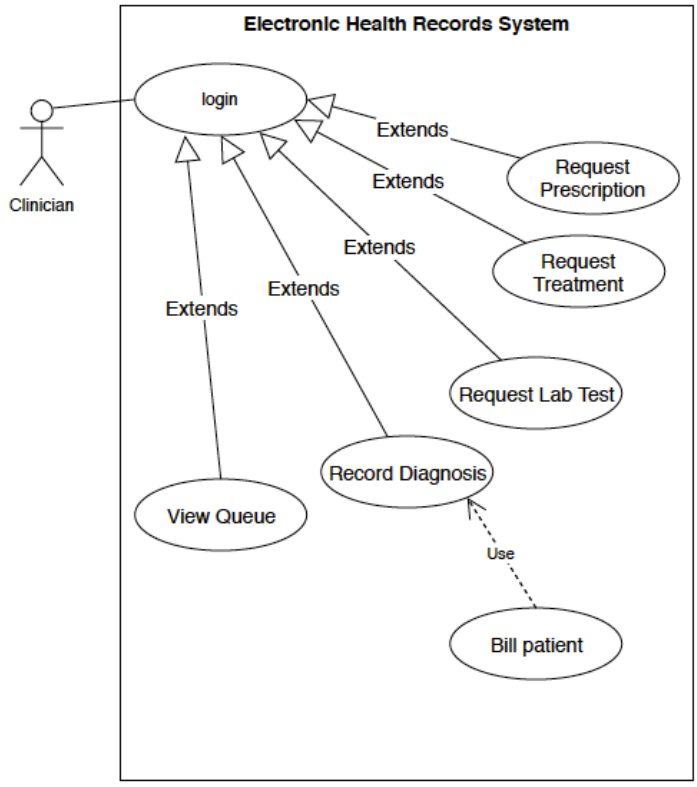


Figure 47 (Clinician Use Case)

Table 10 (Lab Test, treatment and Prescription request Use Case Documentation)

Use Case	Request Prescription / Treatment /Lab Test
Actor	Clinician
Pre-condition	Patients must be on Queue
Flow of events	1. User retrieves patient from the Queue 2. User enters all diagnosis information 3. User clicks and submits request for pharmacy to dispense medication
Alternatives	1. User retrieves patient from the Queue 2. User enters all diagnosis information 3. User clicks and submits request treatment of the patient
Alternatives	1. User retrieves patient from the Queue 2. User enters all diagnosis information 3. User clicks and submits request for lab test
Post-condition	Patient is Queued at appropriate station of health care

Table 11 (Patient Billing Use Case Documentation)

Use Case	Patient Billing
Actor	Clinician
Pre-condition	Patients must be on Queue
Flow of events	1. User queues patient in appropriate healthcare station queue 2. System bills patient based on the tests, treatment or number of drugs
Alternatives	1. If patient is on the scheme, the bill is updated on the University otherwise, the bill is charged to the patient
Post-condition	Patient is billed for the services at UNZA Clinic

3.10.3 Proposed Use Case Diagram for Lab Technician

Figure 48 and table 12 show the Use Case and Use Case documentation for lab technicians respectively:

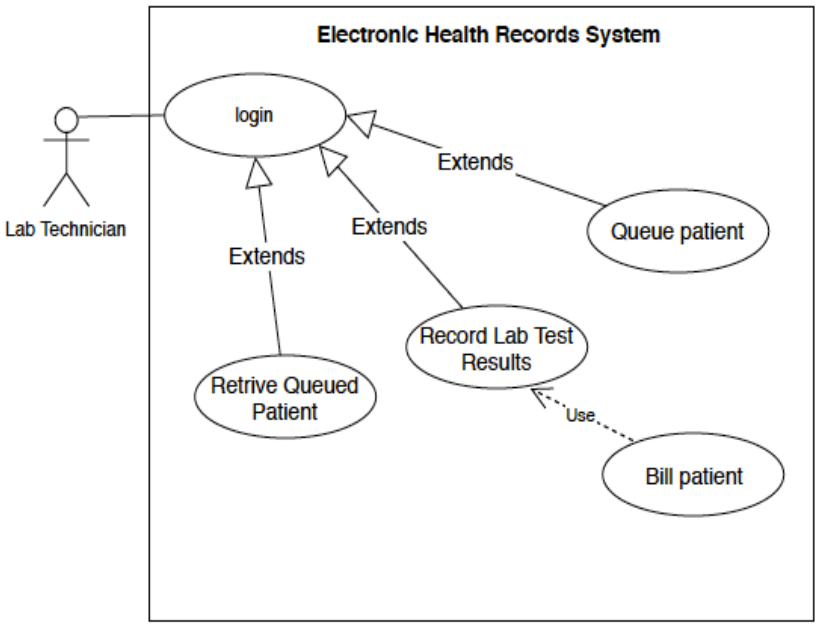


Figure 48 (Laboratory Staff Use Case)

Table 12 (Record Lab Test Use Case Documentation)

Use Case	Queue / Record Lab Test
Actor	Laboratory Technician
Pre-condition	Patients must be on Queue
Flow of events	1. User selects patient 2. User selects lab test to be performed 3. User enters lab test results
Post-condition	Update system with Lab results

3.10.4 Proposed Use Case Diagram for Nurse

Figure 49 and table 13 show the Use Case and Use Case documentation for nurses respectively:

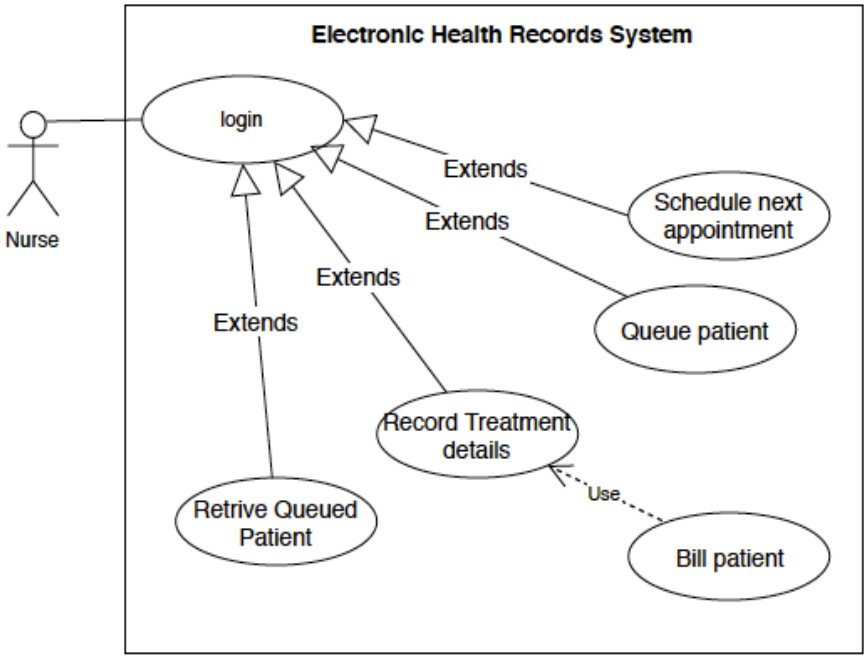


Figure 49 (Nurse Use Case)

Table 13 (Treatment & Appointment Use Case Documentation)

Use Case	Treatment / Schedule appointment
Actor	Nurse
Pre-condition	Patient must be on queue
Flow of events	1. User selects the patient from queue 2. User updates patient record with treatment information 3. System bills the patient
Alternatives	1. User select the patient from queue 2. User selects officer for appointment
Post-condition	Treatment and billing is updated

3.10.5 Proposed Use Case Diagram for Pharmacist

Figure 50 and table 14 show the Use Case and Use Case documentation for pharmacists:

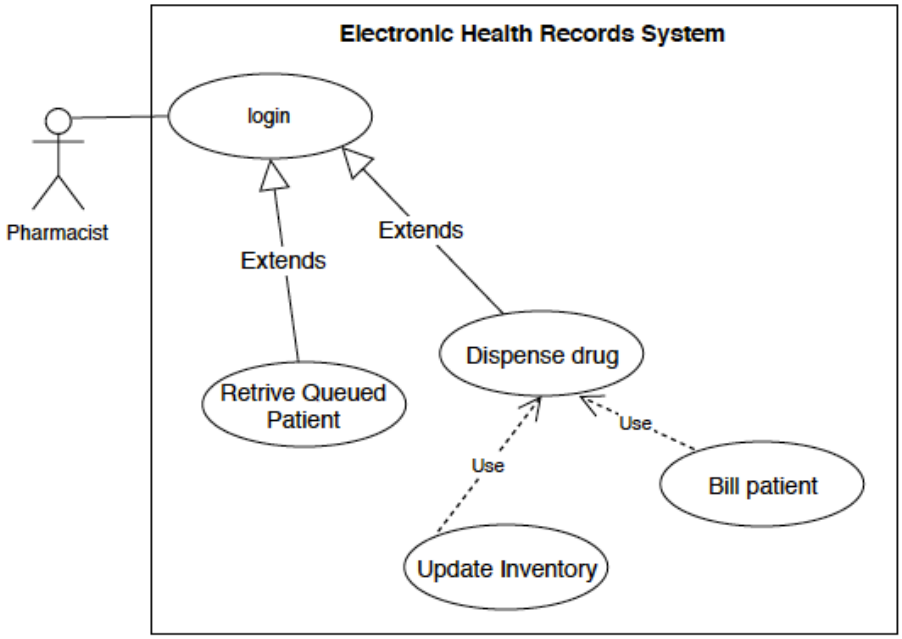


Figure 50 (Pharmacist Use Case)

Table 14 (Dispense Drug Use Case Documentation)

Use Case	Dispense Drug
Actor	Pharmacist
Pre-condition	User must be logged in
Flow of events	1. User selects patient from Queue 2. User selects drug and dispenses
Alternatives	• If drug is not available, user selects alternative medication
Post-condition	Drug is dispensed

3.11 SYSTEM ACTIVITY DIAGRAM

In the Unified Modeling Language (UML), systems are modelled using various diagrams to show different states and interactions of the system. Activity diagrams are used to show the flow of activities performed by a system. They are more less like flow charts with extended capabilities including branching, parallel flow, etc. Figure 51 below shows the main activity diagram for the proposed system:

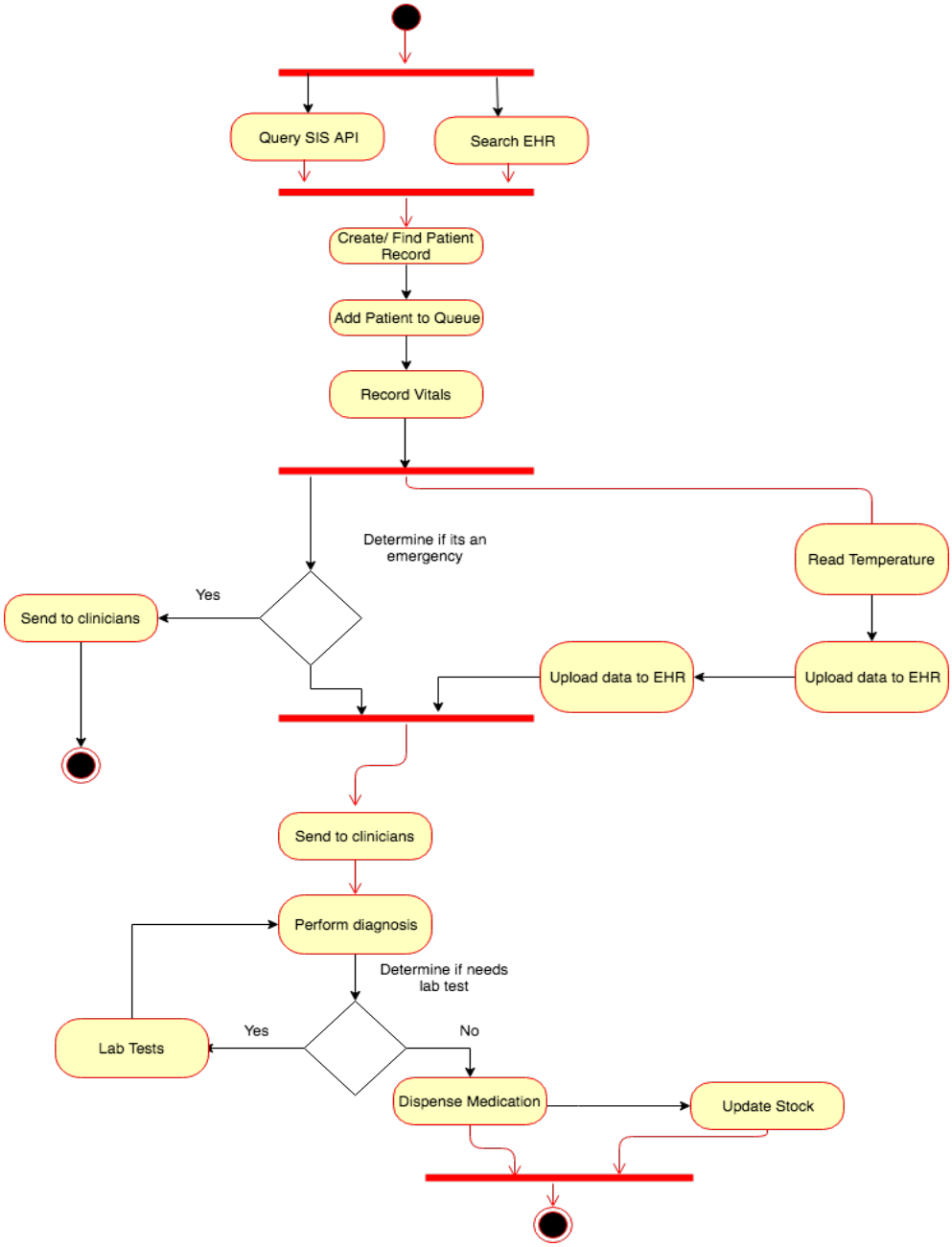


Figure 51 System Activity Diagram

3.12 SYSTEM SEQUENCE DIAGRAM

Sequence diagrams are used to depict interaction amongst system objects over time whilst passing and sharing messages.

3.12.1 Registration of Patients

The activity diagram in figure 52 shows the registration workflow and how the API, Registry Clerk, SIS, EHR and the QUEUE objects interact in the process of registering a patient. At the end of this activity, the patient is logged on a queue on the system. Figure 52 shows the sequence diagram for patients.

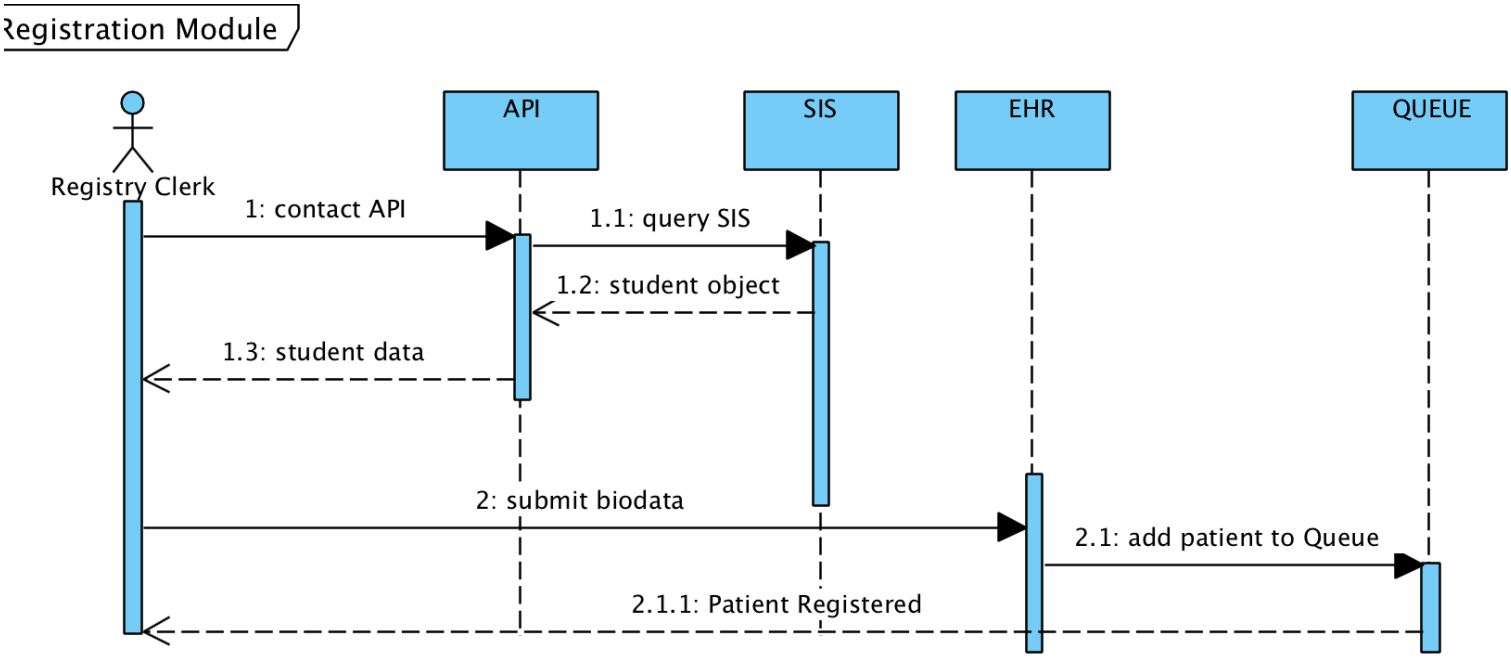


Figure 52 Sequence Diagram for Registering a Patient

3.12.2 Inventory Management Module

In the activity diagram in figure 53 below, we depict how the objects pharmacist, stores officer, scanner and EHR objects relate and interact with each other. At the end of this activity process, there is stock management that takes place in terms of recording what has left the store and what has remained.

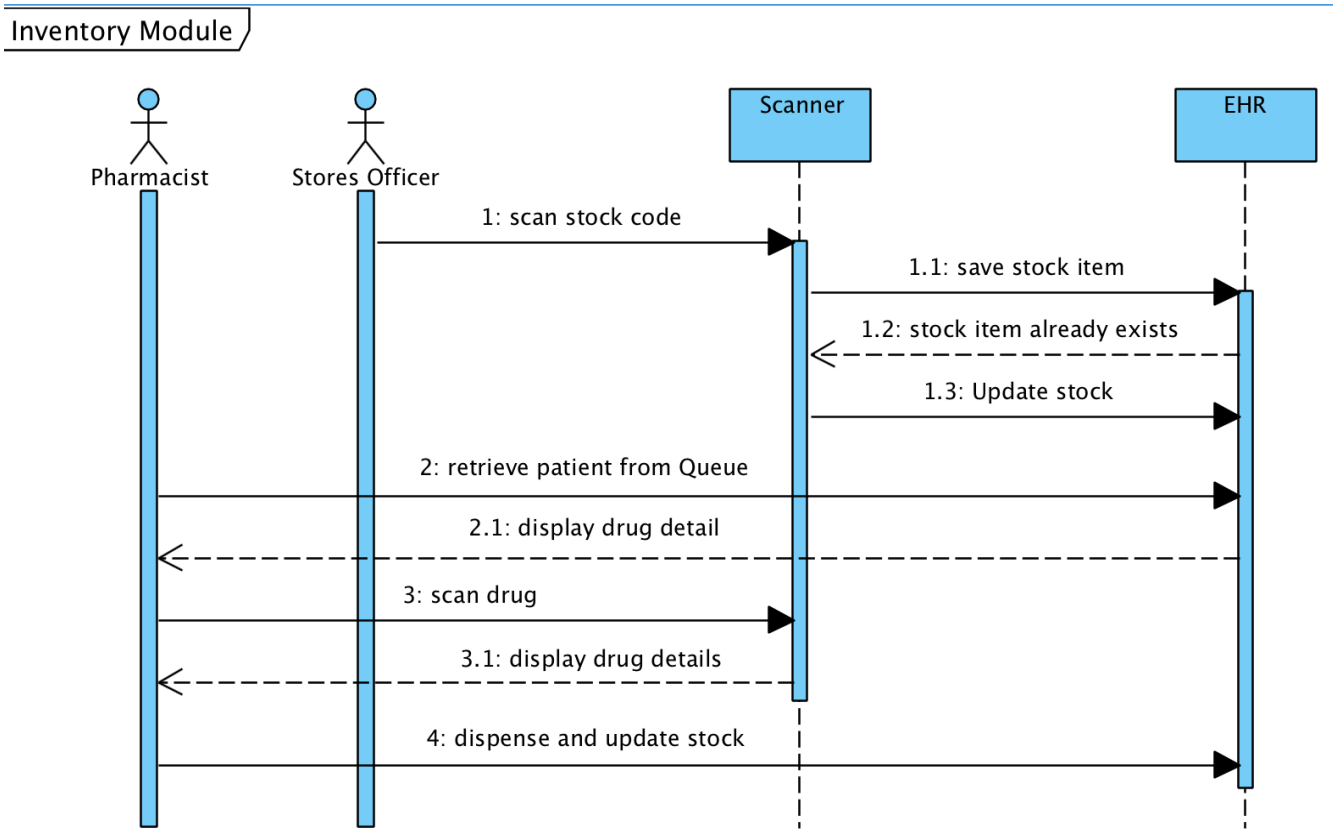


Figure 53 Sequence Diagram for Inventory Management

3.12.4 Patient Queue Management

In the activity diagram in figure 54 below, we show how the clinician, pharmacists, Queue, laboratory technician and EHR objects interact. The process shows how the patient record moves from one status to another on the system.

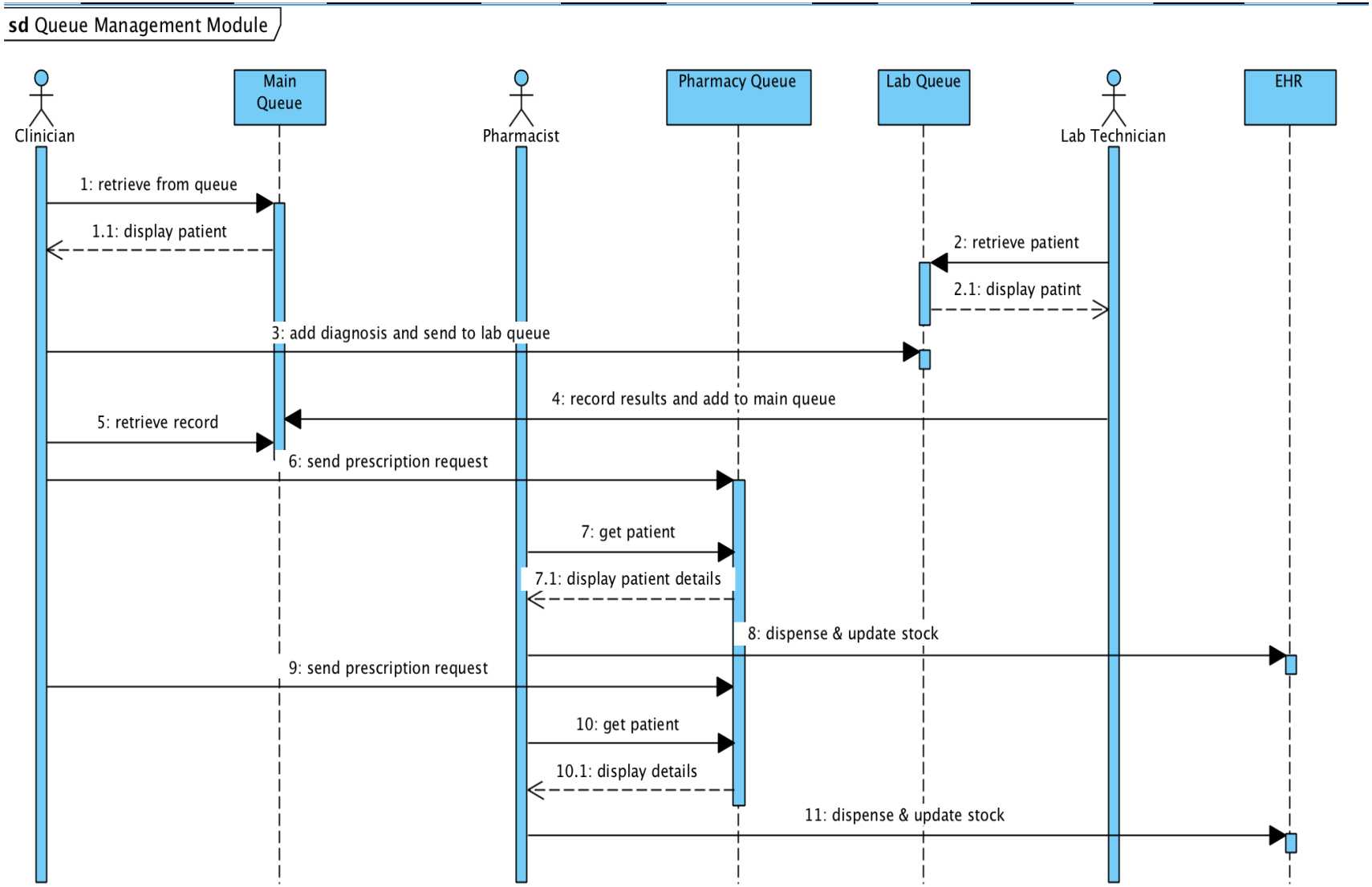


Figure 54 Patient Queue Management

3.13 Application Requirements

The proposed system model is a web application that has been developed using open source platforms. The model was developed with Object Oriented Programming (OOP) concepts using CakePHP framework and C/C++. Table 15 below shows the software and hardware requirements of the developed application

Table 15 Hardware and Software Requirements

Hardware Requirements	Software Requirements
RAM (Minimum of 4 GB)	**Any of the stated OS** • **Windows 7 or above** • **Linux Ubuntu 16(Recommended)** • **MacOS Sierra or High Sierra**
HDD (Minimum of 25 GB	**WAMP or XAMPP stack**
At least 2GHz dual core Processor	**CakePHP 2.6 framework**
At least VGA capable of 1024 x 768 screen resolution	**Relational Database Management System** **NB: Either Oracle, MySQL or PostgreSQL can be used**
Arduino UNO or Arduino MEGA **LM 35 Temperature Sensor** **TMP 36 Temperature Sensor** **GSM-GPRS S900 Shield** **Active Simcard** **Jumper cables** **Breadboard** **Sound buzzer** **Bar code reader**	**Arduino IDE 1.8.4**

3.14 SYSTEM IMPLEMENTATION

The proposed system has interfaces such as the few that have been sampled in this report showing various functionalities that are provided for. Figure 55 below is the dashboard which is the landing page of the application.

Figure 55 System Dashboard

The figure 56 below is the interface for the patient queue in the the pharmacy module. The user can see the patient list in using a First In First Out (FIFO) system.

Patient Queue

10 Show entries

Search:

patient_id	fname	lname	sex	DOB	patient_type	Actions
00152418	RODGER	SINKALA	male	1998-07-30	student	Dispense
00152710	JOY	MUZYAMBA	female	1999-03-07	student	Dispense
009693	KINGFORD	HAAKALAKI	male	1990-12-21	staff	Dispense
2016142157	PLAXIDES	PUMULO	female	1999-02-05	student	Dispense
73814	AARON	MWIINGA	male	1993-01-31	student	Dispense
N7793	FUMU	MWANDILA	male	2014-03-13	non UNZA	Dispense
N9010	KAMBUKWE	KAYOMBO	male	1985-08-16	non UNZA	Dispense

Showing 1 to 7 of 7 entries

‹ Previous 1 Next ›

Figure 56 Patients from EHR system linked to Pharmacy System

The EHR and Pharmacy and Inventory System are two discrete systems and where left this way to prove the theory of structural interoperability. The two applications have different internal structures and data is kept differently. However, these two system share patient information. The patient records in the EHR is input in the way the inventory is going to be affected in the pharmacy and inventory system. This patient information is pulled from the EHR every time a user hits the URL / pharmacy/patients/. This is the trigger point of the interoperability between the two applications and they are able to share patient information and what medication has been assigned to the patient by the consultants.

Figure 57 below is a screenshot of the Goods Receivables interface. When the items have been delivered by the supplier, then each item's details are captured in the pharmacy and inventory system that are dispensable from the pharmacy and stores.

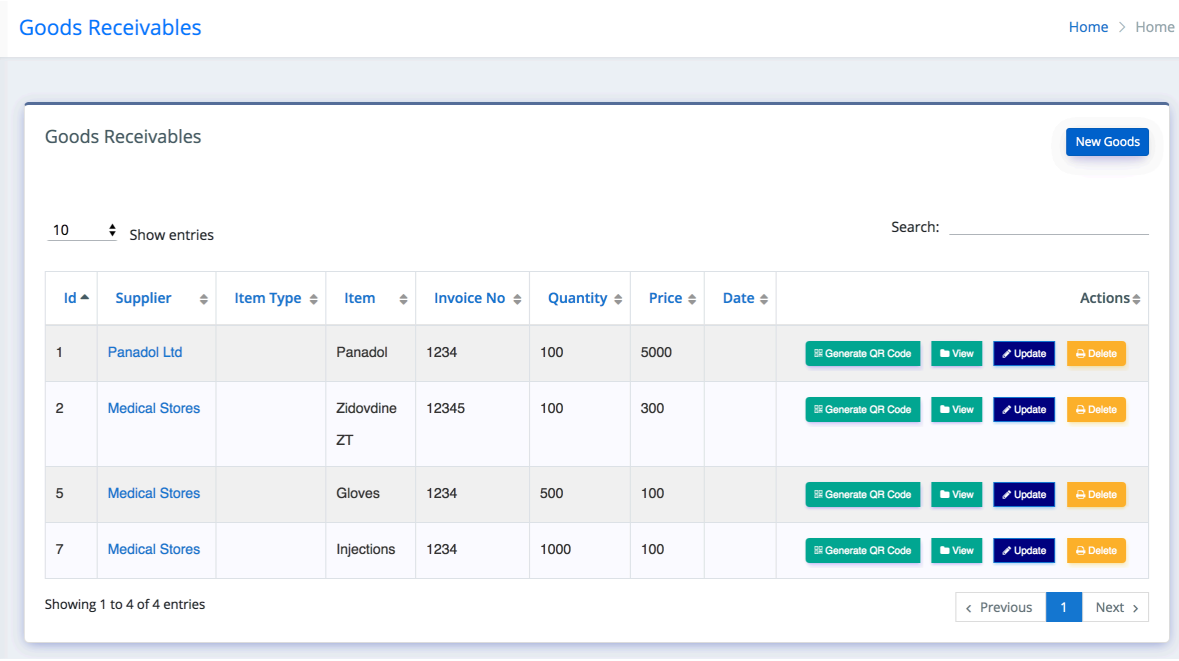


Figure 57 Goods receivables

Once the record has been created, a QR code is associated with the record that can be generated and printed then attached to the drug container. By so doing, we are able to scan the code later using a smart phone or tablet with the QR code scanner application and it will open application with the interface that will show us information about the drug and options that available for action such as update stock which makes the necessary adjustments upwards or downwards thereby automating the process of inventory control. This reduces the time of tallying and checking later on how much stock is left.

An example of a QR code that would be generated from the system with the information contained in it would be this QR Code in figure 58. The QR code contains a URL that points to the identified record by a unique number assigned to it. As long as the mobile device is within the same network as the main EHR application, going to this URL takes you to the record in the QR code. In this example, the URL that has been scrambled in the QR code is;

http://pharmacy/GoodsReceivalbes/manage/7

Where http is the protocol used, pharmacy is the name of the application, GoodsReceivables is the Controller, manage is an action in the controller and 7 is the identifying number for the specified stock item.

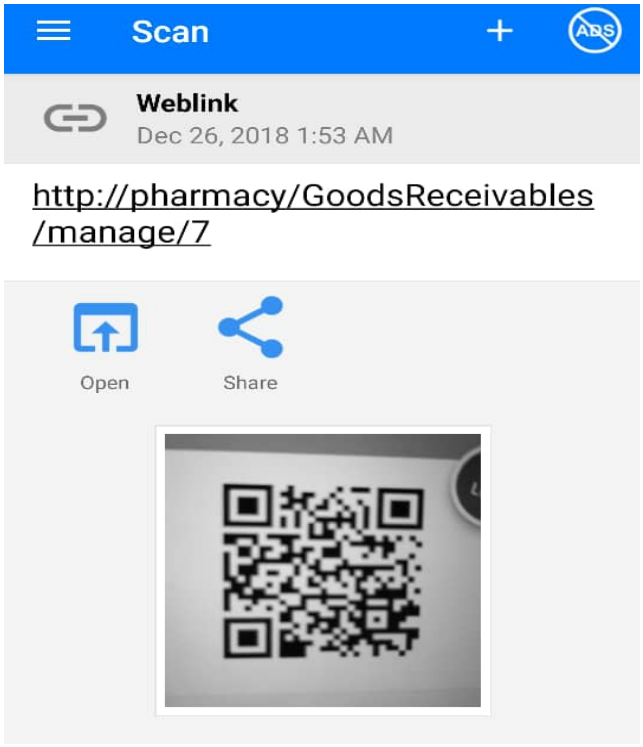


Figure 58 Example of generated QR code

Figure 59 below is a screenshot that shows the entry of stock to the main inventory in the system. The user captures all the necessary details that can not be captured by the barcode and makes the input box for scan UPC code have access, scans the product and the system checks if that UPC code exists, if the code exists then the system does an update else the system captures the item as new stock

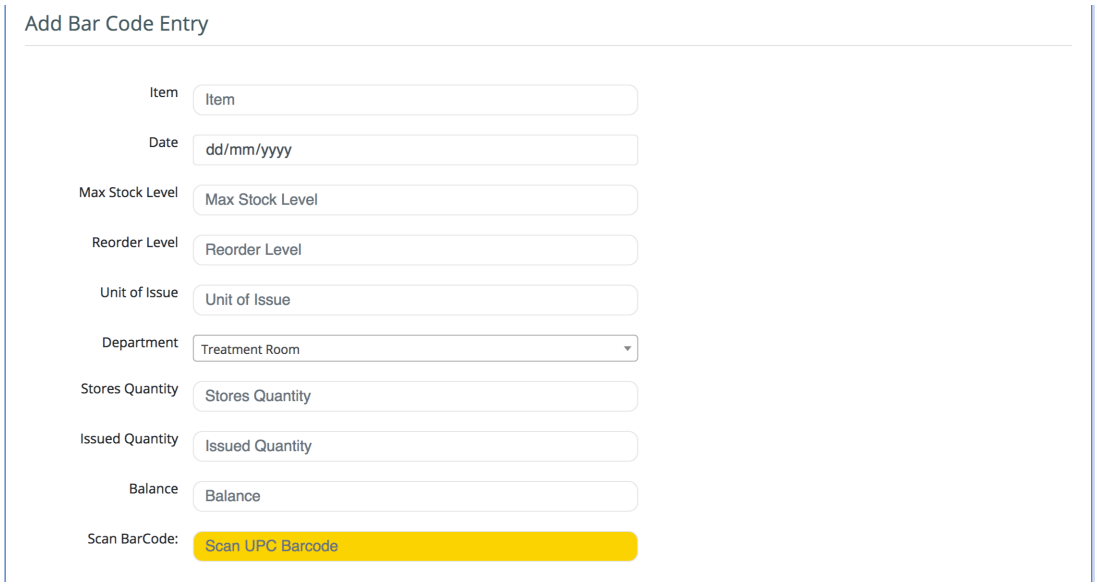


Figure 59 Barcode aided Stock Entry

Figure 60 below shows the screen that the staff in stores will see as requests from the various departments that require a transfer of stock. From this interface, the user is able to issue out stock and the deductions are done in the background.

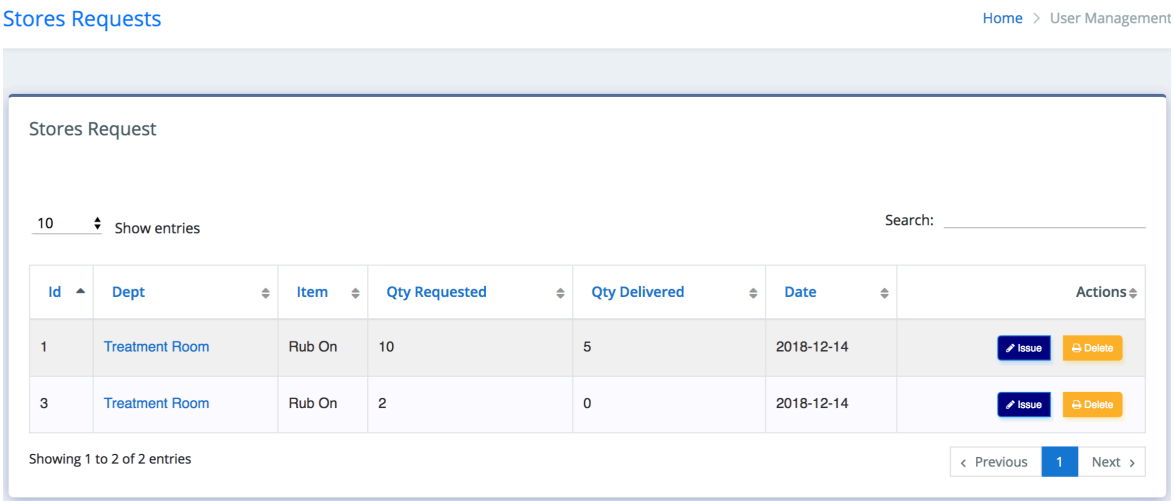


Figure 60 Stores Requests

Figure 61 below shows a screenshot of the transfer of stock to the requesting department. This transfer can only be done upon the verification code being scanned off the stock that is being transferred. The verification code is the UPC code. The two codes i.e. the one stored

with the stock record and that of the physical must match for the transfer to occur as a error reduction measure.

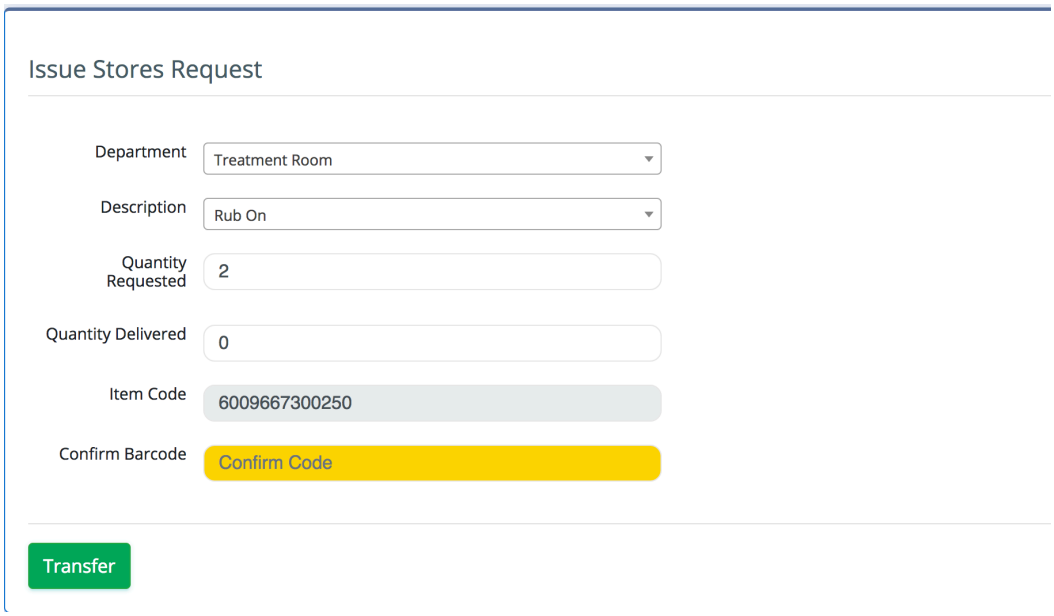


Figure 61 Stores requests interface

Figure 62 below is screenshot of data capture and scanning the UPC code into the system to update the record of the stock. This is part of the inventory management that has been developed for the prototype.

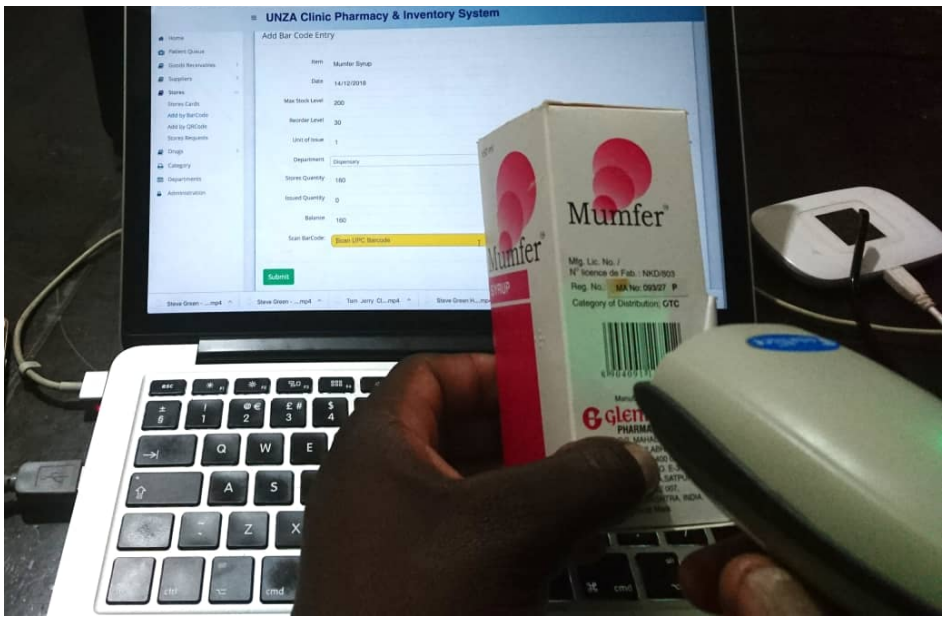


Figure 62 Scanning medicines into system

3.15 TEMPERATURE SENSORS CONFIGURTATION

Figures 63, 64 and 65 show how the temperature sensing components were assembled and the output that was provided to the application both serial out and to through http. The application reads the temperature of the environment continuously and sends data to the hosted application. We used the GSM-GPRS Sim900 shield which is able to connect to a network and also for internet access, we had to make sure that the SIM card in use is configured as such and is loaded with data bundles.

When reading the temperature, the patient has to hold the sensor for at least a period of one minute and that data is sent using the GSM shield as a GET Request and written to the database against the patient's record. Code listing is given in appendix 9

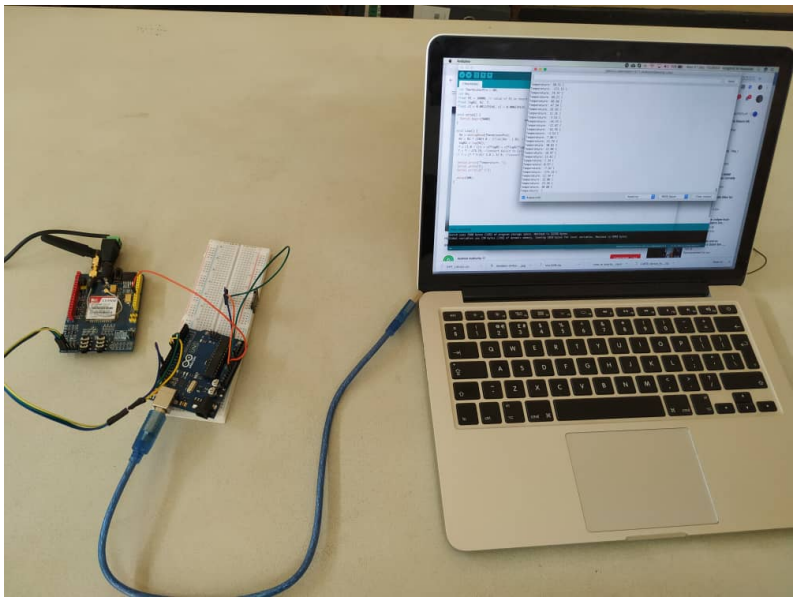


Figure 63 overview of sensing components output

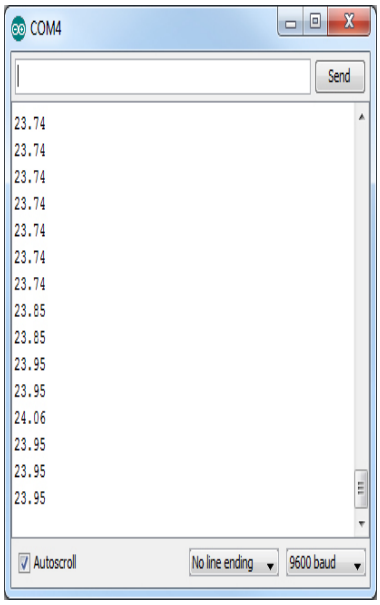


Figure 64 Serial

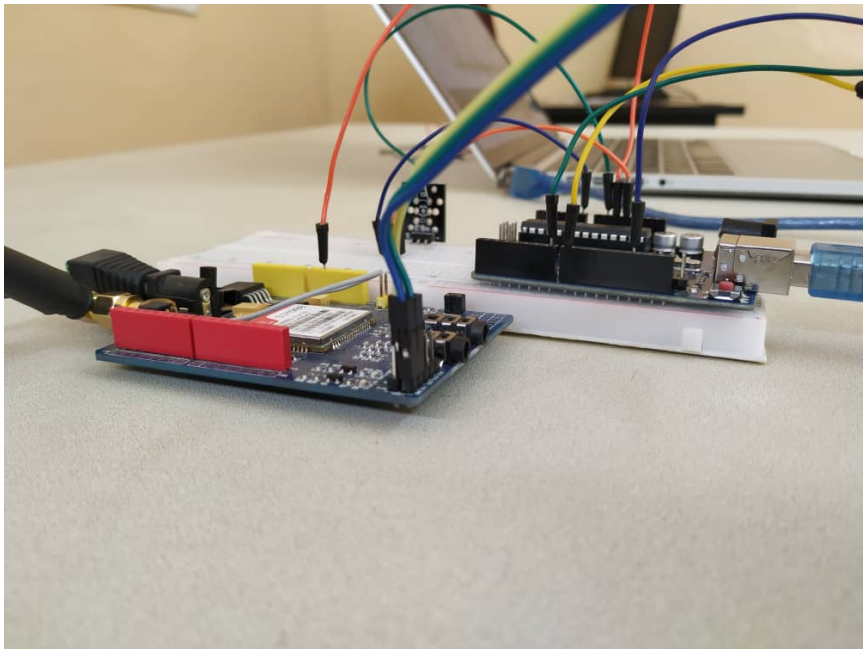


Figure 65 GSM shield connected to Arduino

3.16 Summary

This chapter was based on the methodologies that were used in this study. The chapter was composed of the following aspects; Sampling and data collection, analysis of the currently used documents, baseline study, proposed workflow, proposed model, proposed concept use case and use case documentation and system implementation details.

CHAPTER FOUR: RESEARCH FINDINGS

4.1 Introduction

This chapter discusses the results of the various methodologies that were used in this research. It chapter covers the results from the baseline study, business process mapping, the system implementation details and finally the summary of the chapter.

4.2 Baseline Study Analysis

We got some of the key questions that were asked to both clients and healthcare providers to present in this paper. The first one is that we compared the results of the question on the integration of the current computerized system at the clinic with other administrative systems of the university. The results showed us that both health practitioners and clients thought that this would reduce the queues and the time spent for identifying the client. The results were as follows among the clients and healthcare providers respectively:

As earlier indicated in chapter 3, our key informants were the healthcare providers. At the time of this research, we interviewed a total of 13 health experts. These are distributed as indicated in table 16 below;

Table 16 Healthcare respondents

Target Group	Frequency	Percent
Administrative /Support staff	4	30.8
Nurse	3	23.1
Pharmacy Staff	1	7.7
Clinical Officer	4	30.8
Medical Doctor	1	7.7
Total	**13**	**100.0**

From our baseline study, 91.67% of the student respondents thought that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic while 8.33% indicated that they did not think that efficiency would be achieved because of an electronic records system. Figure 66 below shows a graph for the analysis:

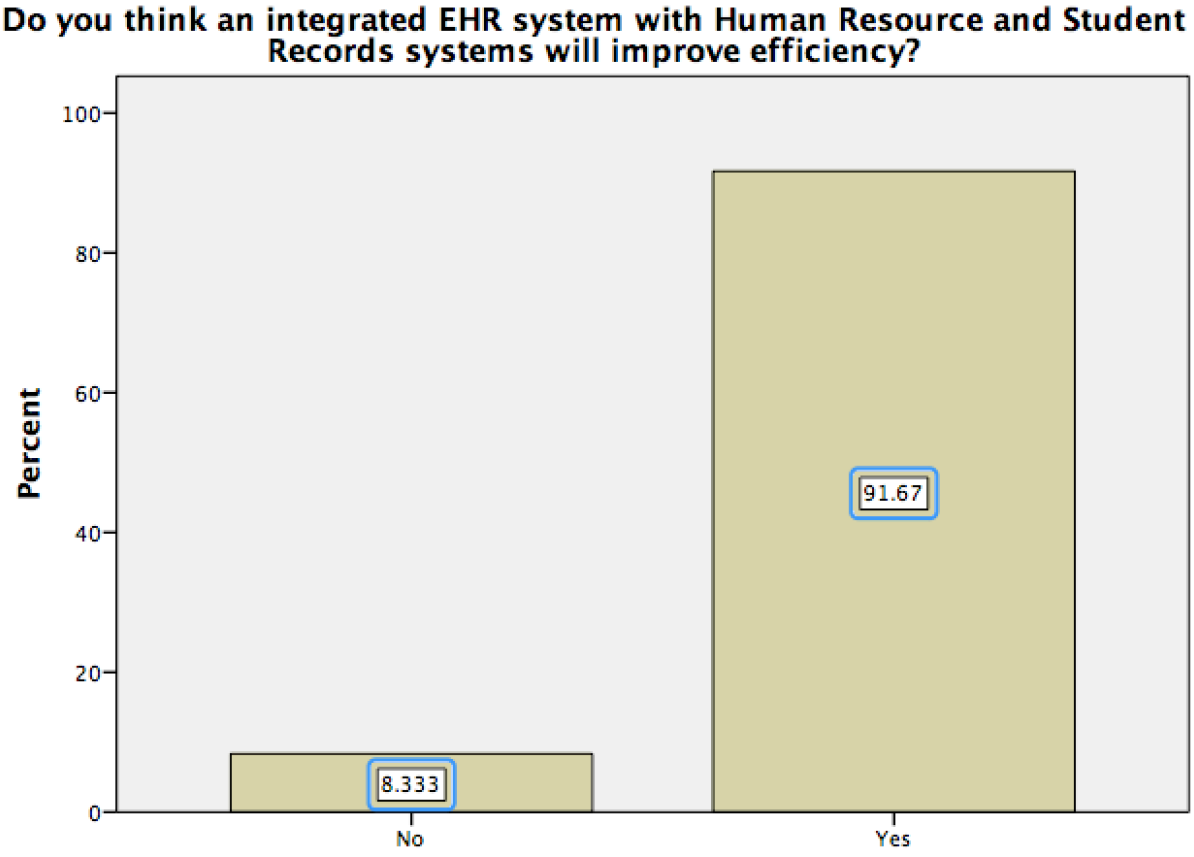


Figure 66 Analysis on usage of EHR

For the same question as above, the results from health care providers, 72.73% of the respondents thought that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic where as 18.18% did not respond and 9.09% did not agree. Figure 67 below shows a graph for the analysis:

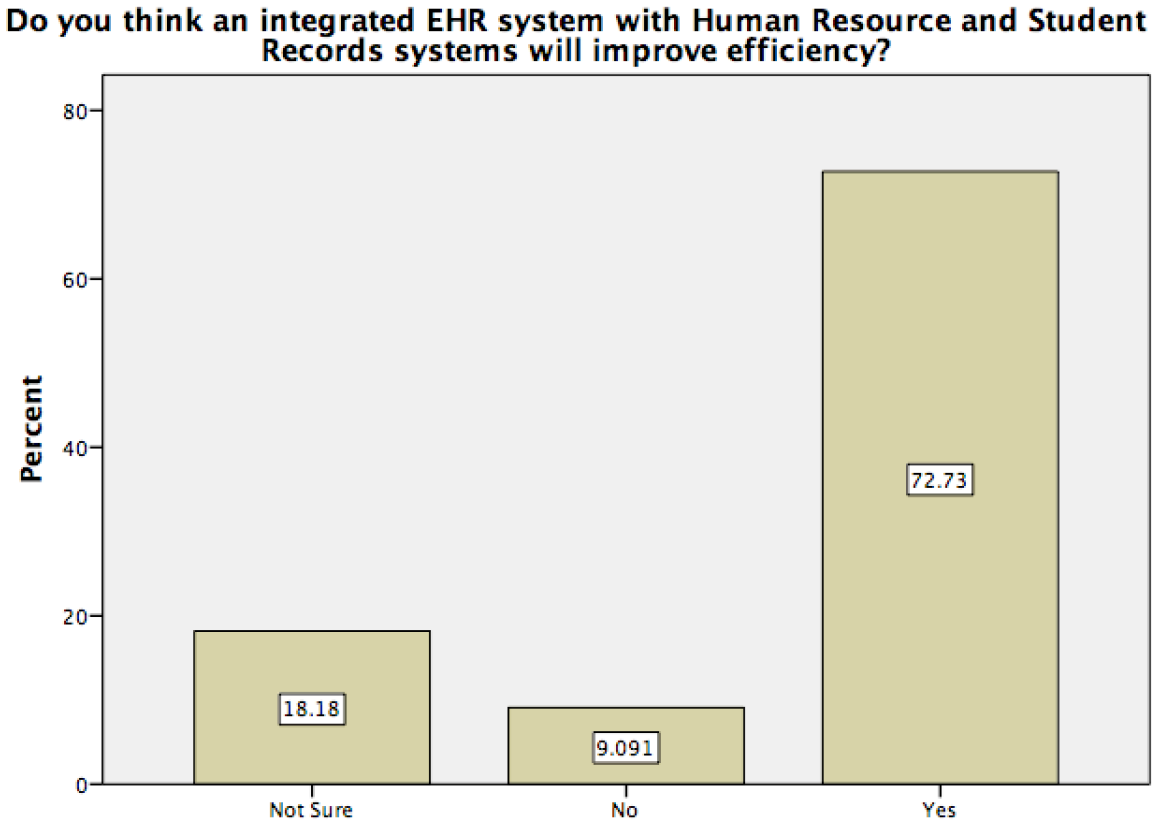


Figure 67 Analysis on EHR

Related to the question of a computerized integrated EHR system, many respondents recommended improve efficiency, there was need to eliminate most of the aspects that lead to have patients moving wit papers given to them by the various offices to carry patient data. It was also observed that the registry, for example, which does handle a lot of paper work is small and can be decongested by introducing an electronic way of filing patient records and this will lessen the time spent to collect the patient record cards in circulation at the end of the day.

Further, we discovered that the process of presenting the laboratory results to the attending clinicians was for many a challenge which affected the patient queue time at the facility. Many respondents indicated that there was a major delay and that it was not very clear how lab results were to be handled. In the recommendations, respondents indicated the need of delivering the lab results through other means other than the patient would be a better option. Lastly, a number of respondents in agreeing with integrating the Clinic System did indicate that members of staff and their dependants find it lengthy to first of all get a personnel data form from administration to be identified as being a member of the clinic scheme.

The same applied to the student populace, since the student has to produce a confirmation slip to prove their registration status. Student that come to the clinic may not have this document in their possession and may be inconvenienced yet the SIS has current information regarding their status. Such administrative data could be shared with the respective offices and avoid duplication of work.

The respondents reviewed that 20% were not sure if lab results were delivered systematically from the lab. 40% of the respondents disagreed, 24% agreed, 8% strongly agreed and 8% strongly disagreed. We observed that Lab results are normally given to the patient to carry on a piece of paper that is normally stapled to the requesting office of the clinicians. This in itself compromises on the confidentiality of patient clinical records. It was recommended by the respondents that to improve the quality of the service, the clinic should provide an electronic means of sending the results without passing them through the hands of the patient. This will result to high levels of confidentiality and decongesting the laboratory area which normally has people waiting for their results. Figure 68 below shows a graph for the analysis:

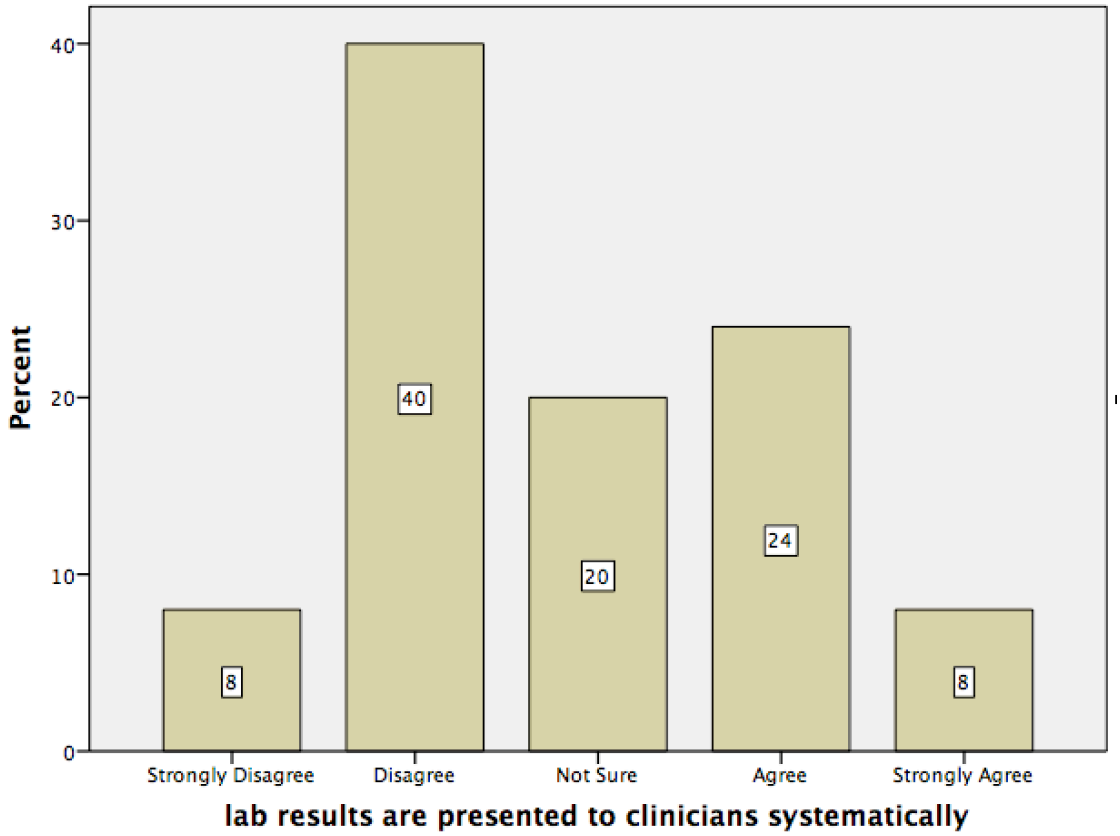


Figure 68 Analysis on lab results delivery

With regards the stoking of drugs and dispensation, the respondents were asked if all the medication that was prescribed was collected from the facility. The response indicated a

larger portion of those that got some of the medication and not all of it. Figure 69 below shows a graph for the analysis:

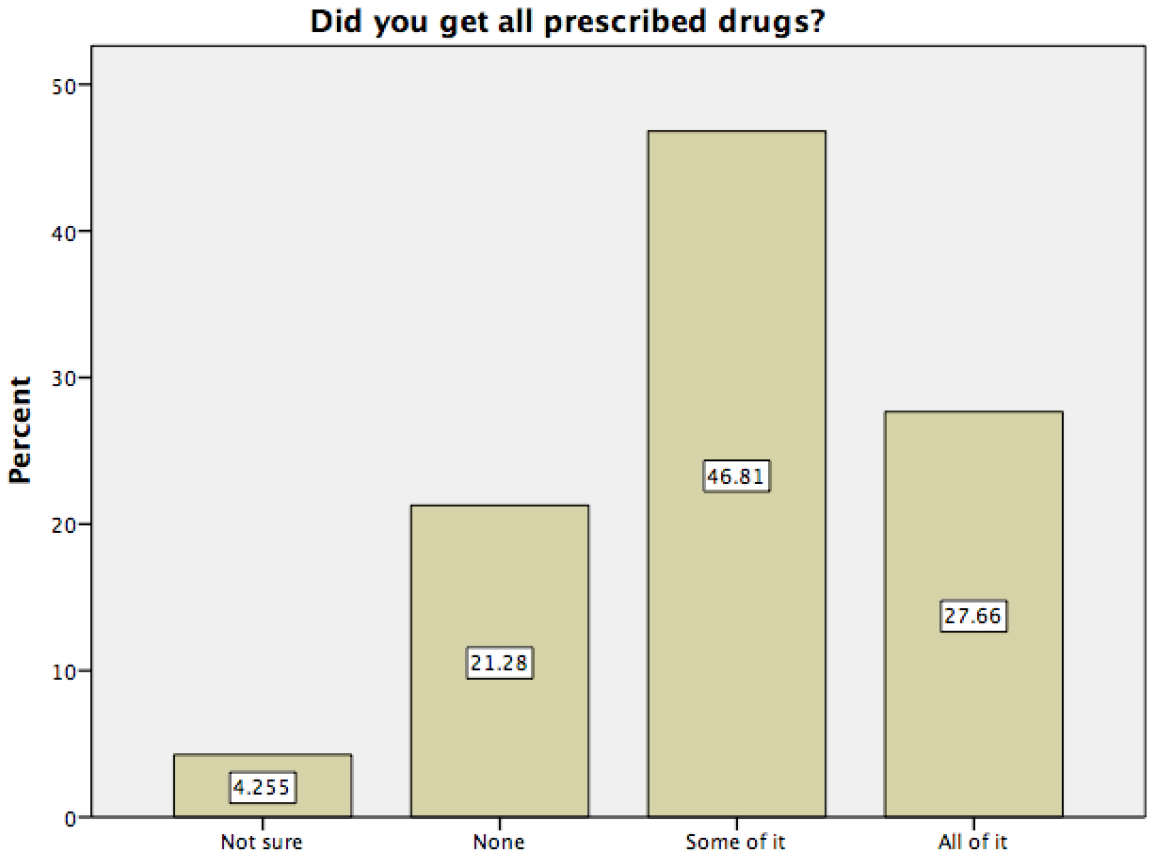


Figure 69 Analysis on Prescribed Medicine

From our baseline study, 4.255% of the respondents reported they were not sure if they got all the prescribed medication, 21.28% reported that they didn't get any drugs at all, 46.81% got some of it and 27.66% reported that they got all the medication that was presribed. This was either due to the unavailability of the prescribed drugs and an alternative drug was given or simply the patient was asked to get a prescription and buy the drug from a chemist.

In line with introducing computerised systems in healthcare in the university context, we asked our respondents how comfortable they were to have their patient history and records kept in a computerized system and the results indicated that the majority of the respondents were comfortable and in agreement that their records could be computerized. Figure 70 below shows a graph for the analysis:

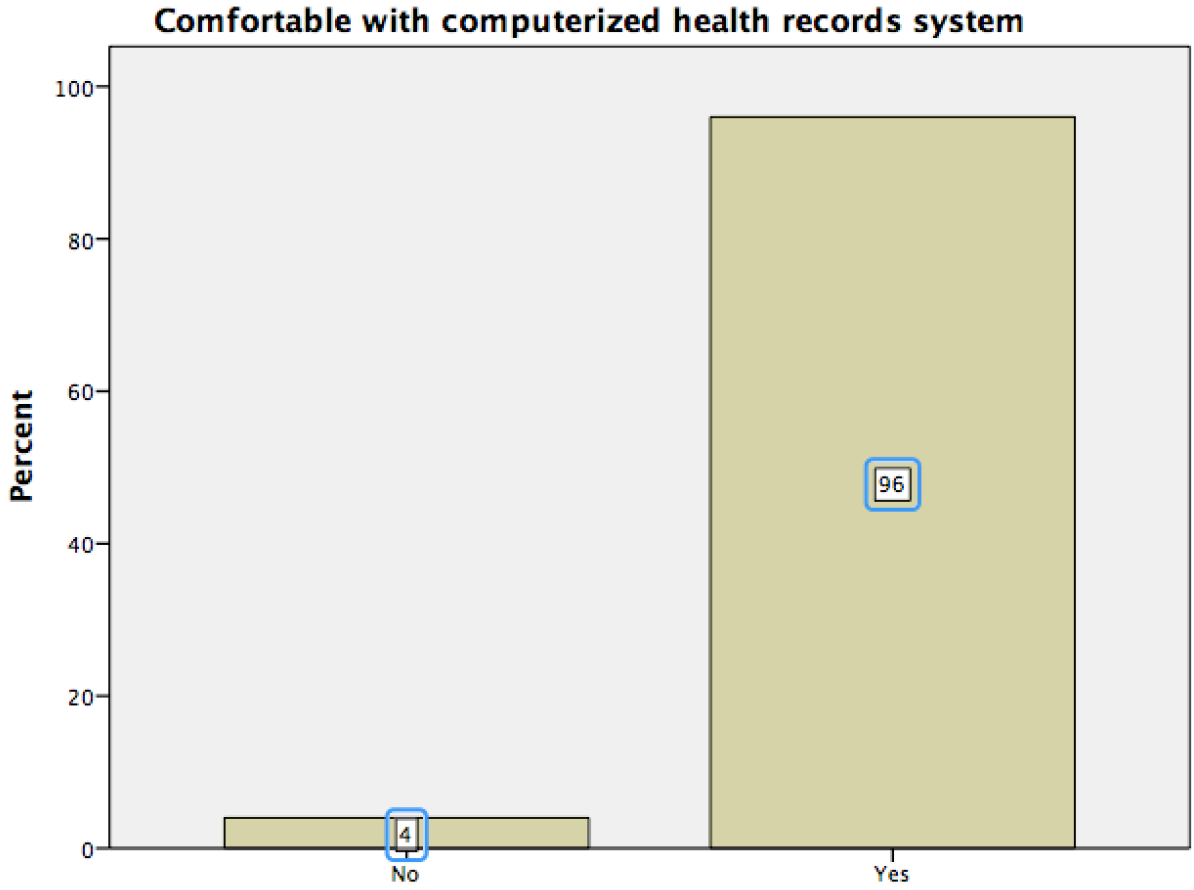


Figure 70 Analysis on confidence with EHR

When asked how comfortable the respondents were with computerized health records, an overwhelming 96% of the respondents agreed that they were comfortable with digitizing their records and keeping them on an electronic system for both students and staff whereas 4% were not in agreement.

Lastly, the healthcare providers were asked to indicate how long the process of generating of reports and statistics on their day to day operations. The results below indicate that at most, the process was averagely lengthy. There were a large portion of respondents that did not answer this question too and an almost equal portion shared the view that the process was either short or long. Figure 71 below shows a graph for the analysis:

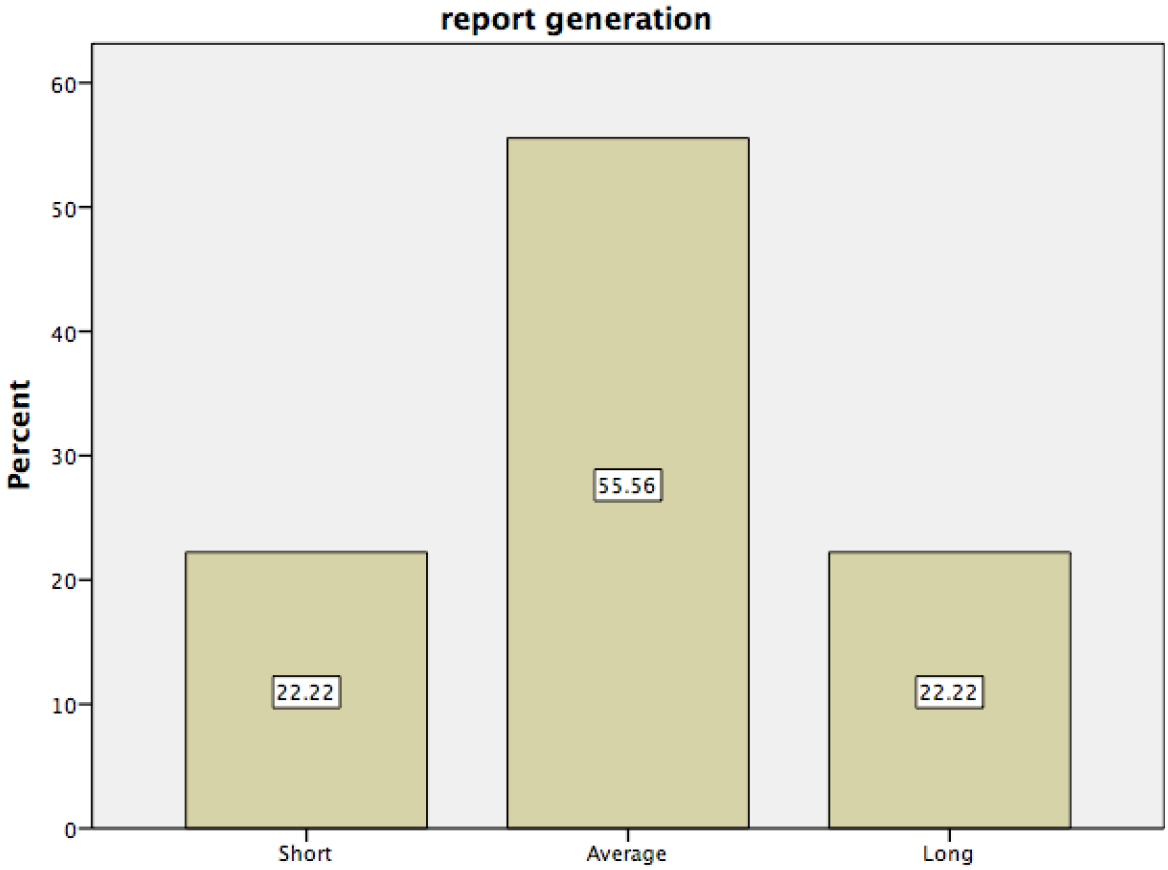


Figure 71 Report generation Analysis

Lastly, health care providers were asked to rate how long it takes them to generate reports is in the current setup and 22.22% of the respondents said it was short, 22.22% said it was long, and 55.56% of the respondents said the process was average. Though the questionnaire results seem to be balanced across the board on the generation of the reports at the end of the day, month or quarter, our results during the observations and interviews we took indicated otherwise. We discovered that the clinic does record a lot of data as it attends to the patients and this data is just entered mostly in books. To tally this information at the end of the reporting period such as a quarter really took a lot of time from the health care provider. A very good example is that of the stores of the clinic, we discovered that a lot of time was taken to do inventory management. This results in running low on stock without the clinic realizing in time that the restock levels are below minimum in some cases.

From this baseline study, we found out that generally the clients of the Clinic desire to see a more automated process at the Clinic. Information generated by the different experts that will attend to a patient is either transferred to another office using the patient or there is no

complete systematic method to do so. The Clinic has introduced an intermediary checkpoint to determine the severity of the case and an assigning desk. This desk is manned by nurses that take the vitals. Even though this step has been introduced to better the queue time for the patient, it was observed using observation method and also from the responses in the baseline study that the strategy is still manual and does not increase efficiency as expected.

The laboratory and Pharmacy which are normally also a bottleneck in the process still have a less organized way of handling and disposing off clinician requests. It was also discovered that lab results are sent back to the requesting clinician through the patient. This came out strongly in the recommendations of the respondents as an undesired process. We propose that the lab could instead electronically forward the results securely to the requesting clinician only. This would mean that the functionality of making such as request as a lab test and dispensation of drugs could be limited to only clinicians.

4.3 Development of Prototype

The proposed prototype was developed using Object Oriented Programming in PHP. The framework that was used in developing the prototype is CakePHP 2.6 along side boostrap 4 for the User Interface (UI). CakePHP is a free open-source, rapid development PHP MVC framework that developers can take advantage of to develop high-end web applications. The framework is helped us to develop a system that uses standard conventional coding standards that implemented an easy to maintain application. Being a framework, we took advantage of the code generation using bake console for CRUD operations to do the boiler-plate operations and scaffolding then built on top of the structure that was built. Lastly, we used CakePHP for its use of well-known software engineering concepts such as design patterns, convention over configuration and association data mapping. Below in figure 72 is the dashboard of the application that was built

Figure 72 User Dashboard

For the database end, we implemented our database as designed in the methodology using MySQL Server 5.6. MySQL is the most popular open-source database that provides support for PHP. It is a robust Relational Database Management System. We chose MySQL database server because it can not only run an instance even on a low-end desktop computer and for it's light-weight architecture but also for its support by PHP and it's frameworks.

We used Apache2 the HTTP Server. The Apache HTTP Server, since it's launch around 1995 has probably been the most popular web server on the Internet. We chose Apache for its cross-platform compatibility and it being light-weight since for this system, optimal performance was highlighted it the requirements.

To integrate temperature sensing and sending data to the application, we connected an Arduino to the computer that was housing the application through an GSM-GPRS shield and were able to send our data to an API which writes into our MySQL database some information about the reading taken. Using the TMP 36, an example of the data reading is seen in figure 73 below:

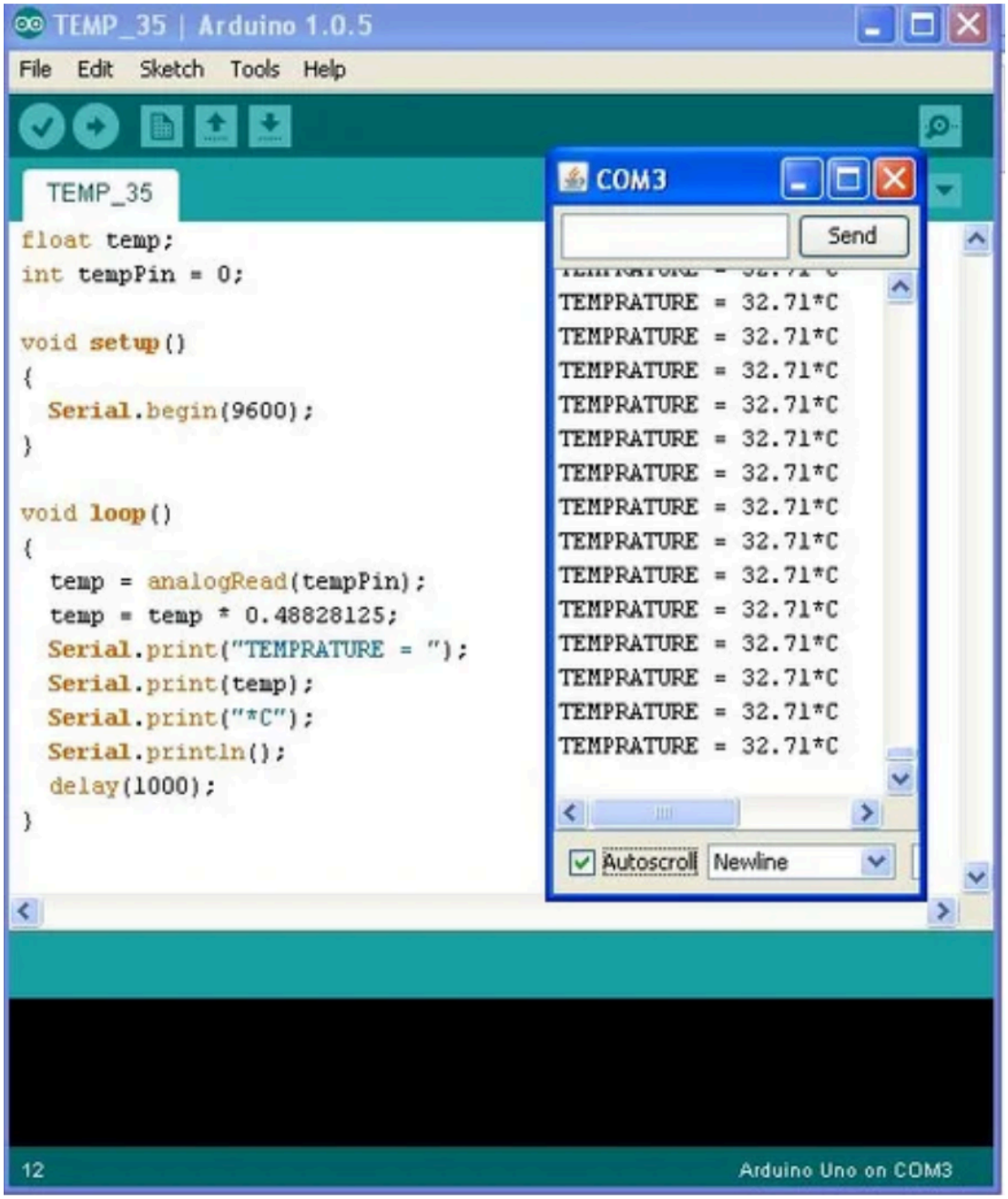


Figure 73 Serial reading of TMP36

4.4 Summary

This chapter focused on the discussing the results of the methodologies used in this research. This process was done in following the methodologies used in addressing the objectives that were identified at the beginning of the research. The chapter covered discussion of the results in the baseline study and system implementation details of the proposed model.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

5.1 Introduction

This chapter discusses the research findings. It covers the results from the baseline study, business process mapping, the objectives that have been addressed and future works.

5.2 Discussion

Healthcare Information Systems will always contain volumes of data. As the number of services and systems increase, it is important that we have a quick of querying and retrieving necessary information whilst making sure that the authorized users have access to this information. There are many technologies and implementations that have worked elsewhere around the subject of interoperability in healthcare. This study considered the Zambian context which is still struggling with technologies as it is a developing country. We intended to use the cheapest, easiest yet scalable and sustainable architectures to implement. In our study, we discovered that this implementation has not yet been explored and used in the context of a learning institution where systems are built in-house. Our motivation was [46] [53][89] where the aim was to implement an interoperable EHR system by implementing a Service Oriented Architecture (SOA), usage of Barcoding to reduce on errors and finally monitoring of health parameters respectively. This research has been conducted on the premise of the fact that nothing of this nature of research has been conducted neither in Zambia nor at a University Healthcare facility to the knowledge of the researchers.

We therefore chose to implement an API between the SIS and the Clinic's EHR system which implements the required interoperability. We also introduced temperature sensing in this model to improve efficiency. This was achieved by using microcontrollers to handle that for us and directly inject the results into the patient's record without manual intervention on scribbling n pieces of paper. Furthermore, we have designed and implemented a model that incorporates inventory management into the EHR, a component that is missing in the current setup. In this implementation, we learnt that the use of technologies such as QR codes and Barcode can be actively used in drug dispensary activities thereby improving the error rates and cutting down on time of report generation. And stock taking. This model presents benefits of scalability, low-cost, interoperability, high availability of information, quick decision making and efficiency in attending to the patients whilst we acknowledged that the

ICT skills gap needed to be narrowed to fully benefit from the advantages of using this model. With the above mentioned aspects of the system that has been developed in this prototype, we are confident that it is possible to achieve higher effectiveness and better performance of an electronic health records system using mostly open source technologies that do not require huge implications.

5.3 Baseline Study

From our baseline study that was conducted at the clinic, 31.54% of the student respondents, 82% of the healthcare providers indicated that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic. We observed that the laboratory process was affecting the efficiency of the clinic's effectiveness because 20% of the respondents were not sure if lab results were delivered systematically from the lab whilst 40% disagreed. The process needed to be made effective especially in the means of sharing lab findings with the necessary offices. Lastly, we noticed that challenge of not receiving the medications that was prescribed by the clinicians through the dispensary would be reduced by automating the movement and tracking of drugs and other related items in the stores.

5.4 Developed Prototype

In responding to the objectives and research questions that were raised at the beginning of this research study, an evaluation of the performance of the currently implemented modules of the EHIMS at UNZA Health Services Unit was conducted and a performance matrix was developed and reported in this research paper. It was clear from the evaluation that the system was missing some vital aspects such as the inventory management and the laboratory module was not completely functional. We addressed this in the proposed prototype that was developed. We also used a questionnaire to do part of this evaluation and the results were reported in the chapter that discussed the results and research findings.

The second objective of this paper was to design a model for the optimization of the current EHIMS in order to achieve structural interoperability with the University's Human Resource and Student Information Systems. In this research, we only managed to design and develop a model that would implement an API interoperability with the Student Information System.

We could not manage to perform direct interoperability with the Human Resource System because the current system used is a proprietary desktop application which has no mechanisms of sharing data with other application apart from extras of excel formatted data. We therefore focused most of the efforts in implementing the interoperability with the open-source SIS system. From our model, we are able to pass a student's computer number and retrieve the vital shared information and record it on our clinic system at the point of registering the patient.

Finally, in attempting to improve the services and performance of the clinic system, we have introduced a number of technologies in the architecture. We introduced barcoding for quick input of information into the system and for tracking records. We also introduced temperature sensing and automated the means of transferring this data via a GSM-GPRS and Ethernet Shield that were controlled using an Arduino. This automation is in itself a small version of the implementation of concepts of the Internet of Things in eHealth systems.

5.5 Conclusion

As seen in the previous section, the two research objectives and 2 research questions that were asked in the first chapter of this research were met apart from the interoperability of the model with the Human Resource System. Figures 29 and 30 show the model concepts that were used to come up with the proposed solution for the healthcare system. We believe that the model that has been developed will add to the performance improvement of the current system and contributes to the knowledge of the development of eHealth systems in developing countries where currently trending technologies could be very expensive to acquire and implement.

Following the research findings, we also recommend that for any eHealth system to achieve maximum performance improvement to the manual systems that most healthcare facilities have been using, there is need to have capacity building for the health providers. This is in line with the usage of technologies so that this does not become a reason to slow down the officers in executing their duties due to the use of technology or concentrating on entry of data to the system. Due to this reason, it is important in designing eHealth systems to consider quick ways of capturing data and this research does highlight this and proposed technologies that would help in this aspect.

5.6 Recommendations

In the qualitative part of the questionnaire, the respondents were requested to provide any recommendation for the improvement of the health care facility's efficiency. Most of the respondents recommended that to improve efficiency at the Clinic, the following were the recommendations that were common across the respondents:

- A computerized system that would allow for electronic transfer of data amongst the departments administering healthcare to the patient
- Implementation of Electronic Records keeping of patient information
- Procedures of the clinic and it's workflow should be clear to patients
- The need to integrate the clinic system with HR system to avoid sending back member of staff that may not have a personnel data form when they go to the clinic
- Need for quicker services at laboratory rather than waiting longer periods for results
- Need for training staff in usage of ICTs to support the implementation and success of an electronic system
- To provide computers at every health care point that the patient will be seen by a health expert at the clinic.

5.7 Future Work

This study adds to the understanding of the use of Web Services, bar-coding and sensing of primary health parameters in the design and implementation of Electronic Health Record Systems. There is still a lot of software development that needs to be done in the Zambian context to mitigate the challenges of interoperability in the health sector. The Ministry of Health has indicated in it's annual reports [19] that there are many isolated systems that are not interoperable. As part of future works,

1. Build a model that will help in implementing a nationwide interoperable Health Information System.
2. Building of a complete EHR including billing and invoicing functionality
3. To automate all departments at the clinic and build an ERP based application
4. Transforming all 1D UPC Barcode to 2D QR Code for easy of scanning and reduced error percentage when scanning. 2D codes will ensure that more data is kept on the code that relates to the product to be saved in the database. This may require business process re-engineering in the way the processes flow at the clinic and in the usage of

the application. Possibly, an introduction of a mobile application will be useful for even quicker and more accurate inventory management.

5. To integrate more sensors for all other health vitals' readings that are checked at a clinic visit will make a robust eHealth architecture.

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LIST OF APPENDICES

Appendix A: Algorithm for Pharmacy API

```
<?php
App::uses('AppController', 'Controller');
App::uses('HttpSocket', 'Network/Http');


 * @property Patient $Patient
 */
class PatientsController extends AppController
{
//this api reads from the api clinic EHR system
//all the information of the patient is kept in that system
   public function index($id = null)
   {
      //use cakephp socket object to get data in json format from a url of another application
      $HttpSocket = new HttpSocket();
      $response = $HttpSocket-
>get('http://localhost/clinic/modules/pharmacy/patient_api');
      //decode from json to array
      if(!empty($response)){
         $data[] = json_decode($response,true);
         $this->set('patients', $data);
         $this->set('_serialize' , 'patients' );
      }
   }


}
```

Appendix B: Algorithm for API on Clinic EHR System

```
<?php
require('../../classes/connect_db.php');
$result = mysql_query("SELECT
pq.patient_id,p.fname,p.lname,p.sex,p.DOB,p.patient_type
FROM clinic_records_master.patient_queue pq
inner JOIN clinic_records_master.patient p on p.patient_id = pq.patient_id
WHERE pq.location='pending pharmacy'");
$patientQueue = array();

while($rows = mysql_fetch_assoc($result)) {
   $patientQueue[] = $rows;
}
$queue = json_encode($patientQueue);

$ch = curl_init('http://localhost/pharmacy/Patients/getPatient');
curl_setopt($ch, CURLOPT_CUSTOMREQUEST, "POST");
curl_setopt($ch, CURLOPT_POSTFIELDS, $queue);
curl_setopt($ch, CURLOPT_RETURNTRANSFER, true);
curl_setopt($ch, CURLOPT_HTTPHEADER, array(
      'Content-Type: application/json',
      'Content-Length: ' . strlen($queue))
);
curl_setopt($ch, CURLOPT_TIMEOUT, 5);
curl_setopt($ch, CURLOPT_CONNECTTIMEOUT, 5);
//execute post
$result = curl_exec($ch);
//close connection
curl_close($ch);
echo $queue;
?>
```

Appendix C: Algorithm for API- Pharmacy Module

```
$HttpSocket = new HttpSocket();
$response = $HttpSocket->get('http://localhost/clinic/modules/pharmacy/queue_api');
//decode from json to array
if(!empty($response)){
   $data[] = json_decode($response,true);
   $this->set('patients', $data);
   $this->set('_serialize' , 'patients' );
}
```

Appendix D: Algorithm for Stock Requests

```
public function request() {
   if ($this->request->is('post')) {
      $this->StoresRequest->create();
      if ($this->StoresRequest->save($this->request->data)) {
         $this->Session->setFlash('The stores request has been saved','success');
         $this->redirect(array('action' => 'index'));
      } else {
         $this->Session->setFlash(__('The stores request could not be saved. Please, try
again.'));
      }
   }
   $this->loadModel('StoreCard');
   $items = $this->StoreCard->find('list', array('fields'=>array('id','item')));
   $departments = $this->StoresRequest->Department->find('list',
array('fields'=>array('id','department')));
   $this->set(compact('departments','items'));
}
```

Appendix E: Inventory Management Algorithms

```
public function issue($id = null) {

 $this->loadModel('StoreCard');

   if (!$this->StoresRequest->exists($id)) {
      throw new NotFoundException(__('Invalid stores request'));
   }

   $checkStock = $this->StoresRequest-
>find('first',array('conditions'=>array('StoresRequest.id'=>$id)));
   $reqData = array();
   $stockData = array();

   if ($this->request->is('post') || $this->request->is('put')) {

      if($checkStock['StoreCard']['upc'] !=$this->request['data']['StoresRequest']['upc']){
         //build the array here
         $items = $this->StoresRequest->StoreCard->find('list', array('fields'=>array('id','item')));
         debug($this->request['data']['StoresRequest']);
         $requestData['id'] = $id;
         $requestData['quantity_delivered'] = $this-
>request['data']['StoresRequest']['quantity_delivered'];

         if ($this->StoresRequest->save($requestData)) {
            //second saving here for storecards entity

            $stockData['id'] =  $checkStock['StoresRequest']['storecard_id'];
            $stockData['balance'] =  $checkStock['StoreCard']['stores_qty'] - $this-
>request['data']['StoresRequest']['quantity_delivered'];

            $this->StoreCard->save($stockData);
            $this->Session->setFlash('The stores request has been saved','success');
            $this->redirect(array('action' => 'index'));
         } else {
            $this->Session->setFlash(__('The stores request could not be saved. Please, try again.'));
         }
```

```
        }else {
            $this->Session->setFlash('UPC code missmatch. Please scan the correct UP Code','warning');
        }

    } else {
        $options = array('conditions' => array('StoresRequest.' . $this->StoresRequest->primaryKey =>
$id));
        $this->request->data = $this->StoresRequest->find('first', $options);
    }

    $items = $this->StoresRequest->StoreCard->find('list', array('fields'=>array('id','item')));
    $departments = $this->StoresRequest->Department->find('list',
array('fields'=>array('id','department')));
    $myitem = $this->StoresRequest->find('first',array('conditions'=>array('StoresRequest.id'=>$id)));
    $this->set(compact('departments','items','myitem'));
}
```

Appendix F: Algorithm for GSM/GPRS Shield

```
// include the GSM library
#include <GSM.h>

// PIN number if necessary
#define PINNUMBER ""

// APN information obrained from your network provider
#define GPRS_APN       "GPRS_APN" // replace with your GPRS APN
#define GPRS_LOGIN     "login"    // replace with your GPRS login
#define GPRS_PASSWORD  "password" // replace with your GPRS password

// initialize the library instances
GSMClient client;
GPRS gprs;
GSM gsmAccess;

// This example downloads the URL "http://arduino.cc/latest.txt"
```

```
char server[] = "arduino.cc"; // the base URL
char path[] = "/latest.txt"; // the path
int port = 80; // the port, 80 for HTTP

void setup()
{
 // initialize serial communications
 Serial.begin(9600);
 Serial.println("Starting Arduino web client.");
 // connection state
 boolean notConnected = true;

 // Start GSM shield
 // pass the PIN of your SIM as a parameter of gsmAccess.begin()
 while(notConnected)
 {
   if((gsmAccess.begin(PINNUMBER)==GSM_READY) &
       (gprs.attachGPRS(GPRS_APN, GPRS_LOGIN, GPRS_PASSWORD)==GPRS_READY))
     notConnected = false;
   else
   {
     Serial.println("Not connected");
     delay(1000);
   }
 }

 Serial.println("connecting...");

 // if you get a connection, report back via serial:
 if (client.connect(server, port))
 {
   Serial.println("connected");
   // Make a HTTP request:
   client.print("GET ");
   client.print(path);
   client.println(" HTTP/1.0");
   client.println();
 }
```

```
  else
  {
    // if you didn't get a connection to the server:
    Serial.println("connection failed");
  }
}

void loop()
{
  // if there are incoming bytes available
  // from the server, read them and print them:
  if (client.available())
  {
    char c = client.read();
    Serial.print(c);
  }

  // if the server's disconnected, stop the client:
  if (!client.available() && !client.connected())
  {
    Serial.println();
    Serial.println("disconnecting.");
    client.stop();

    // do nothing forevermore:
    for(;;)
      ;
  }
}
```

Appendix B: Questionnaire for Health Practitioners

The University of Zambia

School of Natural Science

A Model for an Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit

---

Kingford M. Haakalaki (Student ID: 2016145698)

MSc in Computer Science,

For more information or any queries, kindly get in touch on 0977-526193

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a Master of Science in Computer Science. As partial fulfilment for the award of a Master of Science degree, I am conducting a baseline study on: "***Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit"***

You have been purposively sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with

maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.
Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (Jackson.phiri@cs.unza.zm)
Head of Department: Mrs. Monica M. Kalumbilo – Kabemba (computer.studies@unza.zm)

Survey for Health Care Providers

SECTION A: BIO DATA

Please tell us about yourself:

1. Gender:

Female	Male

2. Age:

Above 50 years 4	39-49 years 3	28-38 years 2	16-27 years 1

3. Your expertise:

Medical Doctor 6	Clinical Officer 5	Pharmacy staff 4	Laboratory staff 3	Nurse 2	Administrative/ Support Staff 1

4. Your current educational level:

PhD 6	Master's Degree 5	Bachelor's Degree 4	Advanced Diploma 3	Diploma 2	Certificate 1

5. Years of service at UNZA clinic:

Above 15 yrs 5	11-15 yrs 4	7 - 10 yrs 3	3 - 6 yrs 2	Below 3 yrs 1

SECTION B: GENERAL INFORMATION

We would like to ask you some questions regarding the efficiency of the UNZA Clinic in delivering Health Care. Please answer the questions that apply to you either by tick, circle or filling in respectively.

1. For **Reception staff**, respond using the key provided to rate the patient record creation, retrieval and update. Please provide an answer for both where a patient is either on the UNZA Clinic scheme or not on the scheme

   1 = Very Poor; 2 = Poor; 3 = Average; 4 = Good; 5 = Very Good

Office	Record Creation		Record Retrieval		Record Updates	
	Scheme	Non-Scheme	Scheme	Non-Scheme	Scheme	Non-Scheme
Reception						

2. For **Clinicians**, circle a rating for how you rate the management of queues for screening at UNZA Clinic

Office	**Queue Management**				
Consulting Room	1	2	3	4	5

3. For **Laboratory staff**, circle a rating for how you rate the management of queues for laboratory services at UNZA Clinic

Office	**Queue Management**				
Laboratory	1	2	3	4	5

4. For **Pharmacy staff**, circle a rating for how you rate the management of queues for dispensation of drugs at UNZA Clinic

Office	**Queue Management**				
Pharmacy	1	2	3	4	5

5. For those that work in stores, pharmacy, laboratory and SAO for each of the scenarios given below, kindly respond using the key provided to rate how efficient recording of stock and updating of stock is at UNZA Clinic. Please **circle** your answer in the table
(If you are not involved in receiving and updating stocks, please indicate **N/A** _____)

1 = Very Poor; 2 = Poor; 3 = Average; 4 = Good; 5 = Very Good

Office	Recording of stock received					Updating Stock records				
SAO	1	2	3	4	5	1	2	3	4	5
Laboratory staff	1	2	3	4	5	1	2	3	4	5
Pharmacy staff	1	2	3	4	5	1	2	3	4	5

Stores officer	1	2	3	4	5	1	2	3	4	5

6. For staff from finance, how do you rate the generation of a bill for fee paying patients?

Long **3**	**Average** **2**	**Short** **1**

7. Kindly rate the process of preparing reports and generation of statistics?

Long **3**	**Average** **2**	**Short** **1**

8. Does the current system allow you to use the standard best practices in your line of work?

YES **3**	**NO** **2**	**Not Sure** **1**

9. Are you aware of any standards in your line of work from a regulatory body?

YES **3**	**NO** **2**	**Not Sure** **1**

10. If you answer to question 8 is YES, please give one or two examples of such standards?

    _____

    _____

11. How do you rate your ICT skills?

Very Strong 5	Strong 4	Average 3	Weak 2	Very Weak 1

12. Are you comfortable with using a computerized/electronic health records system?

YES	NO

13. For Pharmacy staff, does the current system help to track dispensing of drugs and inventory?

YES	NO

14. For staff from reception, does the current system capture all biographical data?

YES	NO	Not sure

SECTION C: GENERAL INFORMATION

15. Do you think a computerized health system that is integrated to essential systems such as Human Resource and Student Records System will cut down on queues, delays and enhance efficiency in the processes of the UNZA Health Services Unit?

YES	NO	Not sure

16. What measures can be put in place to improve the efficiency of the delivery of health care in general (reception, lab, pharmacy..etc)?

_____

_____

THANK YOU FOR YOUR PARTICIPATION

Appendix C: Questionnaire for Members of Staff

The University of Zambia

School of Natural Science

A Model for an Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit

---

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Project Supervisor: Dr. Jackson Phiri (Jackson.phiri@cs.unza.zm)
Head of Department: Mrs. Monica M. Kalumbilo – Kabemba (computer.studies@unza.zm)

Survey for Staff

SECTION A: BIO DATA

Please tell us about yourself:

1. Gender:

Female	Male

2. Age:

Above 50 years 4	39-49 years 3	28-38 years 2	16-27 years 1

3. Staff Category:

MMS 5	UNZALARU 4	UNZAPROSU 3	UNZAAWU 1

4. Current educational level:

PhD 6	Master's Degree 5	Bachelor's Degree 4	Diploma 3	Advanced Diploma 2	Certificate 1

5. Years of service at UNZA:

Above 30 yrs 5	21-30 yrs 4	11 - 20 yrs 3	5 - 10 yrs 2	Below 5 yrs 1

SECTION B: GENERAL INFORMATION

We would like to ask you some questions regarding your experience with the quality of service at the UNZA clinic. Please answer the questions that apply to you either by tick, circle or filling in respectively.

6. Are you on UNZA Clinic scheme?

Yes	No

7. If the answer to Q1 above is YES, how is the verification process when you visit the health service facility?

Long 3	Average 2	Short 1

8. Is the UNZA Clinic your usual Health Care Provider?

Yes	No

9. How long have you been coming to UNZA Clinic?

5yrs or more	At least 3 yrs but less than 5 yrs	At least 1 yr but less than 3 yrs	At least 6 months but less than 1 yr	Less than 6 months

10. In the last 12 months, how many times have you visited UNZA Clinic?

5 or more	4	3	2	1	0

11. In the number of times you were attended to at UNZA Clinic, did you get the prescribed medication from there?

Yes 4	No 3	Some of it 2	Not all 1

12. For each of the statements below, circle on the response that best characterizes how you rate the services provided by UNZA Clinic, where:

1 = Strong Disagree; 2 = Disagree; 3 =Not sure; 4 = Agree; 5= Strongly agree

Question	Strongly agree	Agree	Not sure	Disagree	Strongly Disagree
1) The registration process for a first time patient is clear and straightforward.	5	4	3	2	1
2) For a registered patient, it is easy to retrieve your record at the reception	5	4	3	2	1
3) The process of being seen by medical experts e.g. doctor, clinical officers, nurses (i.e. clinicians) is done in a systematic way	5	4	3	2	1
4) The process of having laboratory tests done and presenting the results from the lab to the attending clinician is done is in a systematic way	5	4	3	2	1
5) The process getting the prescribed medicine is done in a systematic way	5	4	3	2	1

13. Would you recommend UNZA Clinic to anyone?

Yes	No

14. Are you comfortable with your health records being kept in a computerized system?

Yes	No

15. Do you think a computerized system that is integrated to systems such as Human Resource will cut down on delays and bring about efficiency in the processes of the UNZA Health Services Unit?

Yes	No

SECTION C: RECOMMENDATIONS

16. What measures can be put in place to improve the efficiency of the delivery of health care in general at UNZA Clinic?

---

17. Any other useful information?

THANK YOU FOR YOUR PARTICIPATION

Appendix D: Questionnaire for Dependants & Community

The University of Zambia

School of Natural Science

A Model for an Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit

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Head of Department: Mrs. Monica M. Kalumbilo – Kabemba (computer.studies@unza.zm)

Survey for the Community and UNZA Staff Dependents

SECTION A: BIO DATA

Please tell us about yourself:

1. Gender:

Female	Male

2. Age:

Above 65 yrs 5	56-65 yrs 4	46-55 yrs 3	36-45 yrs 2	16-35 yrs 1

3. Level of education:

PhD 7	Master's Degree 6	Bachelor's Degree 5	Advanced Diploma 4	Diploma 3	Certificate 2	GCE 1

4. Please mark below which one applies to you?

Spouse to UNZA staff 3	Dependent to UNZA staff 2	From Community around UNZA 1

SECTION B: GENERAL INFORMATION

We would like to ask you some questions regarding your experience with the quality of service at the UNZA clinic. Please answer the questions that apply to you either by tick, circle or filling in respectively.

5. Are you on the UNZA Clinic Medical Scheme?

Yes	No	Not sure

6. When you visit UNZA Clinic, how long does it usually take to retrieve your record?

Long 3	Average 2	Short 1

7. Is UNZA Clinic your usual Health Care Provider?

Yes	No

8. How long have you been coming to UNZA Clinic?

5yrs or more	3 yrs but less than 5 yrs	1 yr but less than 3 yrs	6 months but less than 1 yr	Less than 6 months

9. In the last 12 months, how many times have you visited UNZA Clinic

5 or more	4	3	2	1	0

10. During your last time visit at UNZA Clinic, did you get the prescribed medication from there?

Yes I got everything 4	Yes but no all 3	I didn't get any 2	No prescription was given 1

11. For each of the statements below, circle on the response that best characterizes how you rate the services provided by UNZA Clinic, where:
1 = Strong Disagree; 2 = Disagree; 3 =Not sure; 4 = Agree; 5= Strongly agree

Question	Strongly agree	Agree	Not sure	Disagree	Strongly Disagree
6) The registration process for a first time patient is clear and straightforward.	5	4	3	2	1
7) For a registered patient, it is easy to retrieve your record at the reception	5	4	3	2	1
8) The process of being seen by medical experts e.g. doctor, clinical officers, nurses (i.e. clinicians) is done in a systematic way	5	4	3	2	1
9) The process of having laboratory tests done and presenting the results from the lab to the attending	5	4	3	2	1

clinician is done is in a systematic way					
10) The process getting the prescribed medicine is done in a systematic way	5	4	3	2	1

12. Would you recommend UNZA Clinic to anyone?

Yes	No

13. Are you comfortable with your health records being kept in a computerized system?

Yes	No	Not sure

SECTION C: RECOMMENDATIONS

14. What measures can be put in place to improve the efficiency of the delivery of health care in general at UNZA Clinic?

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15. Any other useful information?

THANK YOU FOR YOUR PARTICIPATION

Appendix E: Questionnaire for Students

The University of Zambia

School of Natural Science

A Model for an Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit

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Kingford M. Haakalaki (Student ID: 2016145698)

MSc in Computer Science,

For more information or any queries, kindly get in touch on 0977-526193

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a Master of Science in Computer Science. As partial fulfillment for the award of a Master of Science degree, I am conducting a baseline study on: "***Electronic Health Information Management System with Structural Interoperability in heterogeneous environments for Continued Health Care: A Case Study of the University of Zambia Health Services Unit"***

You have been purposively sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.
Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (Jackson.phiri@cs.unza.zm)
Head of Department: Mrs. Monica M. Kalumbilo – Kabemba (computer.studies@unza.zm)

Survey for Students

SECTION A: BIO DATA

Please tell us about yourself:

1. Gender:

Female	Male

2. Age:

Above 50 years 4	39-49 years 3	28-38 years 2	16-27 years 1

3. Student Category:

Full-time 5	Parallel 4	Distance 3	Fast Track 2	Part-time 1

4. Programme Level:

PhD 5	Master's Degree 4	Bachelor's Degree 3	Diploma 2	Certificate 1

5. Year of study:

6th year 6	5th year 5	4th year 4	3rd year 3	2nd year 2	1st year 1

SECTION B: GENERAL INFORMATION

We would like to ask you some questions regarding your experience with the quality of service at the UNZA clinic. Please answer the questions that apply to you either by tick, circle or filling in respectively.

6. Are you on the UNZA Clinic scheme or benefiting from the services provided by the clinic?

Yes	No	Not sure

7. If the answer to Q1 above is YES, rate your record retrieval when you visit the health service facility?

Long 3	Average 2	Short 1

8. Is the UNZA Clinic your usual Health Care Provider?

Yes	No

9. How long have you been coming to the UNZA Clinic?

5yrs or more	At least 3 yrs but less than	At least 1 yr but less	At least 6 months but	Less than 6 months

	5 yrs	than 3 yrs	less than 1 yr	

10. In the last 12 months, how many times have you visited the UNZA Clinic?

5 or more	4	3	2	1	0

11. In the number of times you were attended to at the UNZA Clinic, did you get the prescribed medication from there?

Yes I got everything 4	Yes but no all 3	I didn't get any 2	No prescription was given 1

12. For each of the statements below, circle on the response that best characterizes how you rate the services provided by UNZA Clinic, where:

1 = Strong Disagree; 2 = Disagree; 3 =Not sure; 4 = Agree; 5= Strongly agree

Question	Strongly agree	Agree	Not sure	Disagree	Strongly Disagree
11) The registration process for a first time patient is clear and straightforward.	5	4	3	2	1
12) For a registered patient, it is easy to retrieve your	5	4	3	2	1

record at the reception					
13) The process of being seen by medical experts e.g. doctor, clinical officers, nurses (i.e. clinicians) is done in a systematic way	5	4	3	2	1
14) The process of having laboratory tests done and presenting the results from the lab to the attending clinician is done is in a systematic way	5	4	3	2	1
15) The process getting the prescribed medicine is done in a systematic way	5	4	3	2	1

13. Would you recommend UNZA Clinic to anyone?

Yes	No

14. Are you comfortable with your health records being kept in a computerized system?

Yes	No

15. Do you think a computerized system that is integrated to systems such as Student Records System will cut down on delays and bring about efficiency in the UNZA Clinic attending to you on your next visit?

Yes	No

SECTION C: RECOMMENDATIONS

16. What measures can be put in place to improve the efficiency of the delivery of health care in general at UNZA Clinic?

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17. Any other useful information?

THANK YOU FOR YOUR PARTICIPATION