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A Model for an Electronic Health Management Information 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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***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 though 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 Electronic Health Records 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 (2) objectives. 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. A model has been proposed to address the second objective for the design of a prototype with interoperability. In order to achieve an interoperable eHealth Records System, we have investigated and proposed a Service Oriented Architecture using Web Services**

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

I. Introduction

Information Communication Technologies (ICTs) have over the years become an integral part of business operations today. They are commonly referred to as the backbone of the business world regardless of the field. There are various technologies at our disposal that support various business processes ranging from wearable devices, Mobile Applications, Web Applications, Web 2.0 Tools, the Internet of Things (IoT) and Pervasive Computing. [4][18] With a wide base of these available technologies that have surfaced due to the growth of the internet technologies, we have seen the shift in how medical experts gather patient history, analyze and process the results.

In Electronic Health (eHealth) and Mobile Health (mHealth) applications over the years and many more technologies have changed the way healthcare is given. [1] It is, therefore, important to use computational systems as aids in providing useful information to health professionals at various level for decision making processes.

With the vast number of systems and technologies being used to gather patient history, records, analyze and processy, the major challenge in this field is interoperability. [1] Health Care organizations tend to generate and keep large volumes of data every single day. 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.

The University of Zambia (UNZA) Clinic Electronic Records (EHR) in particular, 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 has two (2) specific objectives; To evaluate the performance of the currently implemented modules of the EHR at UNZA Health Services Unit and to design a model for the optimization of the current EHR in order to achieve structural interoperability with the University's Human Resource, Accounting and Student Information Systems and develop a prototype.

This paper comprises of the following sections; Section II has the literature review, Section III describes the Methodology used, while Section IV introduces the Proposed Prototype design. Section V is dedicated to the analysis and discussion of the results and section VI has the Conclusion. Finally, Section VII makes recommendations for future works

II. LITERATURE REVIEW

In this section, we searched Academic databases to find literature and filtered by subject relevance to health and Physical Sciences and Engineering, Life Sciences and Health

Sciences. The following vital literature for this paper is review in brief:

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. [1] states that 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.

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 [5]. Interoperability is not only a technology implemented in systems but it may also be implemented amongst components that need to exchange data. [14] [15][16] indicate that 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". [12] 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. 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. There are mainly four levels of interoperability that are used in systems namely; Foundational, Structural and Semantic.

[2] However, Interoperability, is still a major challenge health 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. [3] 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. [6] According to Ministry of Health (MoE) in Zambia, there are many eHealth solutions that have been introduced and implemented in many healthcare providing organizations but these are not in any way bringing efficiency by means of being interoperable thereby making interoperability a matter of concern in health systems. [20] which was conducted in Zambia also indicated findings that proved that though ehealth systems do exits in Zambia, a common problem that needs to be solved is interoperability. [20] recommends that scalability and interoperability should be the focus area of the government through researchers and software developers.

STANDARDS IN HEALTH INFORMATION TECHNOLOGY

[15] 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. There are a number of standards that have been developed to be able to achieve this and some of them include International Standards Organization (ISO) 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. [15] summarizes the common models and standards of achieving healthcare interoperability as Message related as implemented by the 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).

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. [17] states that HL7 Version 3 which is a Reference Information Model (RIM) forms the foundation for all information modelling within the HL7. This model [17] 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.

[15] [16] Development of EHRs requires that the most recently models and frameworks are used and referenced. [12] suggests that 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. The use of XML in this model makes it easier to integrate with other interoperability frameworks such as SNOMED for clinical terms

ENABLING TECHNOLOGIES FOR DEVELOPING INTEROPERABLE E-HEALTH SYSTEMS

[1] 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. This review

includes some of the commonly used technologies that in their nature add value to the development of health care systems.

EXTENSIBLE MARK-UP LANGUAGE – XML

Extensible Mark-up Language (XML) [11] 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. 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. [19] confirms that using XML it is possible to make disparate systems to communicate by exchanging XML messages.

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§. [11] 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. [19] XML is still a preferred standard of data exchange between inter-enterprise applications on the internet because it is not machine specific and because it is not a programming language.

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. [13] 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 [13], JSON is becoming more and more of an obvious choice over XML for web services

WEB SERVICES

[16] 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 1 below depicts the relationship in the structure of a web service in relation to that of the internet.

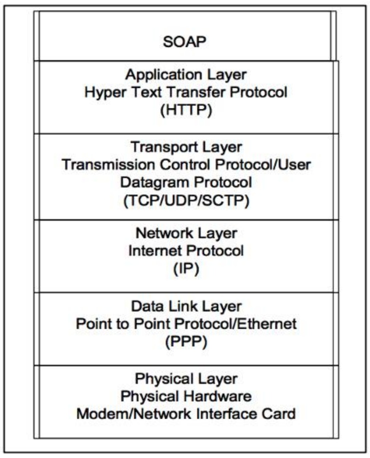

Figure 1

Web services also provide a standard way of sharing information between heterogeneous systems. This is because of the standards that are used. Figure 2 shows the main features of the web service namely: Simple Object Access Protocol (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.

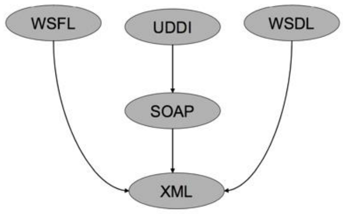

Figure 2

REPRESENTATIONAL STATE TRANSFER (REST) WEB SERVICES

[16] states that 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). [16] compares REST and SOAP and concludes that REST language is based on the use of nouns and verbs. Thereby, 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. [17] Because of the design pattern of REST web services, they are seen to be lightweight and simple to implement. 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, [17] prefers REST to SOAP due to the outcome of the end-to-end delays and network load tests that were conducted. Figure 4 depicts an example from of a restful architecture

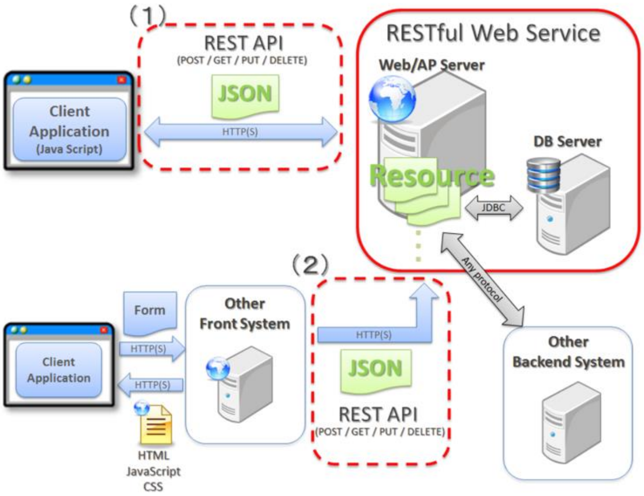

Figure 3

III. METHODOLOGY

In this section, first we explain the method used to evaluate the performance of the currently used Electronic Health Records System. We mainly used Observation to learn the processes and a Questionnaire for data collection.

BASELINE STUDY

A baseline study was conducted targeting students, healthcare providers, staff and the surrounding community including staff dependents. Respondents were randomly picked at the clinic as they visited the health facility whilst our key informants were the healthcare providers;

PROPOSED PROTOTYPE

The following algorithm is proposed to be used for non-emergency cases where the work flow is going to be followed in its normal progression.

Step 1: BEGIN
Step 2: ACCEPT Patient Identification Number
Step 3: IF Patient exists, then Check Patient Category
Step 4: IF Patient Category is Student, then QUERY Student Information System for Biodata and Registration Status else, the Patient must be identified as a non-scheme Patient
Step 5: IF Patient Category is staff, then QUERY Human Resource for Biodata and confirm scheme status else, the Patient must be identified as a non-scheme Patient
Step 6: IF Patient Category is Staff Dependent, then QUERY Human Resource for Biodata and confirm scheme status else, the Patient must be identified as a non-scheme Patient
Step 7: QUEUE Patient for screening
Step 8: Clinician retrieves Patient details and vitals
Step 9: Clinician performs and records diagnosis
Step 10: Clinician SELECTS request for lab test, treatment or prescription
Step 10: Clinician determines if Patient is OPD or IPD
Step 11: IF lab test is selected, then Patient is QUEUED at the lab. Test details and results are recorded and QUEUE with Clinician
Step 12: IF treatment is selected, then Patient is QUEUED at the treatment room. Treatment is administered and next appointment is CREATED on system
Step 13: IF prescription is selected, then Patient is QUEUED at the Pharmacy. Dispensation is recorded and BILLING is done IF Patient is OPD and non-scheme
Step 14: IF BILLING was done PRINT receipt at Registry
Step 15: END

PROPOSED MODEL WORKFLOW

Figure 5 below shows the main algorithm for attending to a patient. The workflow depicts a best case scenario where there is no emergency or special case. In this workflow, the system is responsible for queueing the patient record in the right order before an attending officer. Once an officer closes a transaction, the record is updated and moved to the next status.

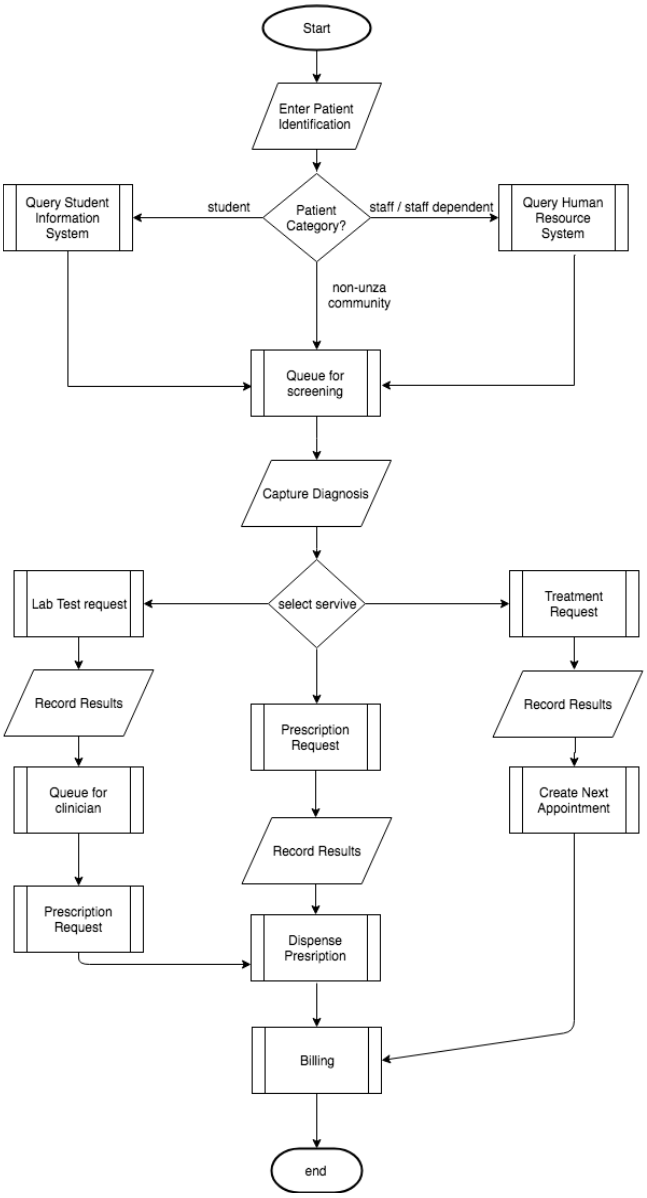

Figure 4

PROPOSED MODEL CONCEPT

Our Proposed model will run as an independently setup application and linked to the other administrative system by exposing a web service on the end of the EHR system. Being proprietary systems, the Human Resource and Accounting Systems will need to provide an extract of data either in CSV or Excel format for the EHR system to and read from there. As regards the Student Information System which is an in-house built system, we believe that we will be able to extend the Web Service functionality to this system.

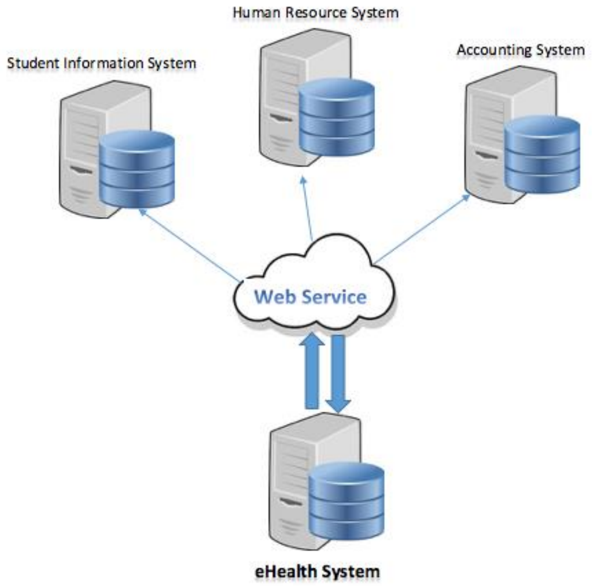

Figure 5

USE CASE DIAGRAMS

The use cases below show the proposed prototype and the user interactions with the system. The primary actors and their use cases identified are receptionist in figure 7, clinicians in figure 8, laboratory technician in figure 9, nurse in figure 10 and pharmacist in figure 11.

Proposed Use Case Diagram for Registry Staff

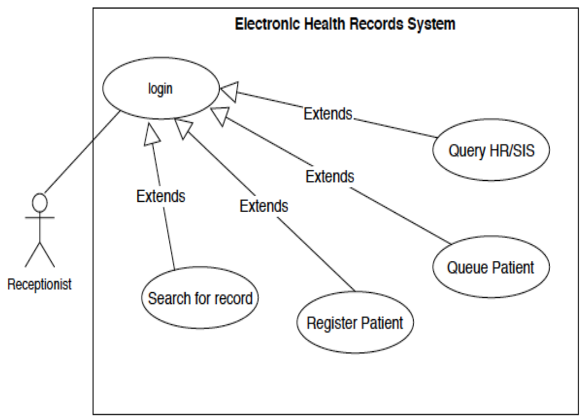

Figure 6

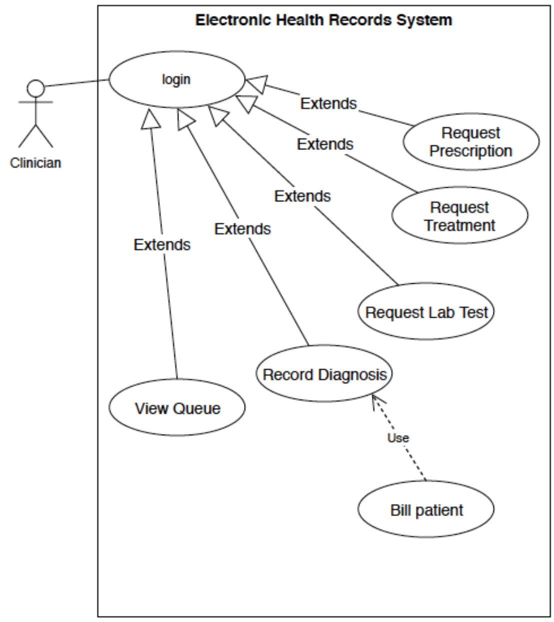

Figure 7

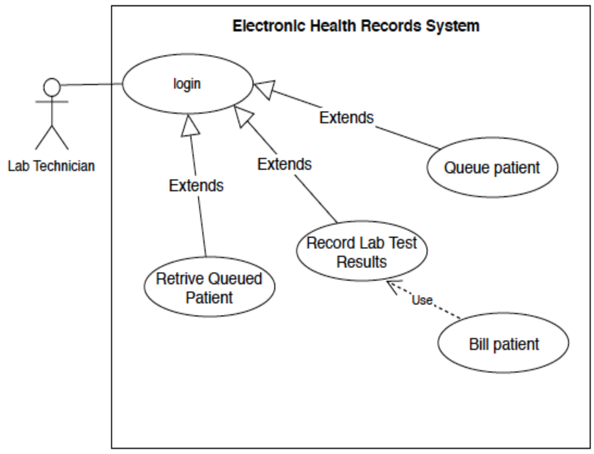

Figure 8

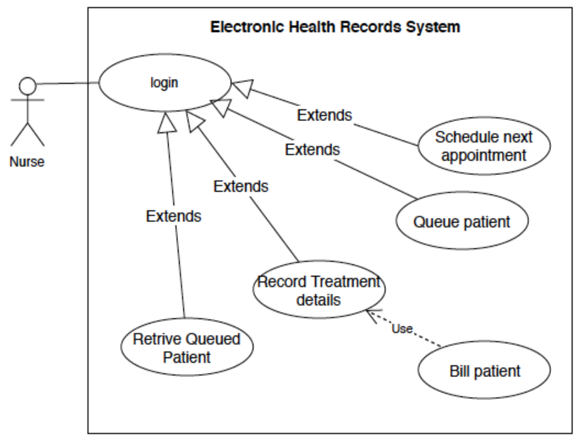

Figure 9

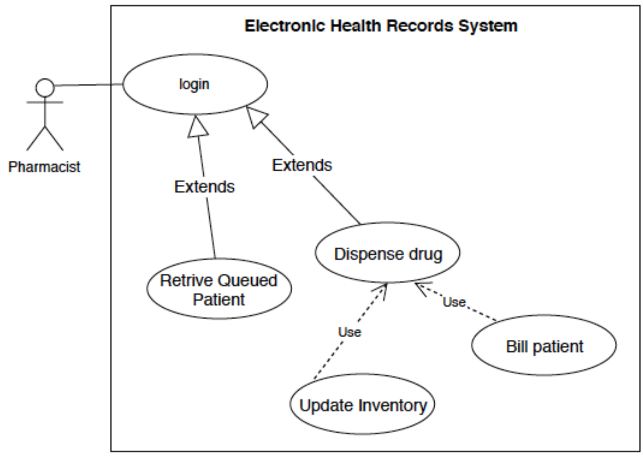

Figure 10

IV. RESULTS AND DISCUSSIONS

A total of 150 questionnaires were administered of which 88 were correctly filled in and returned and 62 of them were either collected without any feedback or were not answered. From our key informants, the key informants were represented through those that resounded to our questionnaire as follows in the sample that was used; 3 Nurses. 4 Administrative Officers, 1 Pharmacy staff and 5 Physicians.

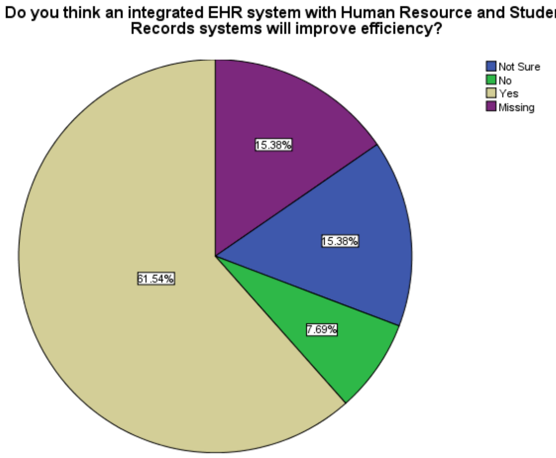

Figure 11

From our baseline study, figure 12 shows that 31.54% of the student respondents thought that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic. 15% did not respond, 7.69% did not agree and 15.38% were not sure.

For the same question as above, figure 13 below shows that of the results from health care providers, 82% of the respondents indicated that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic where as 10% did not respond and 8% did not agree.

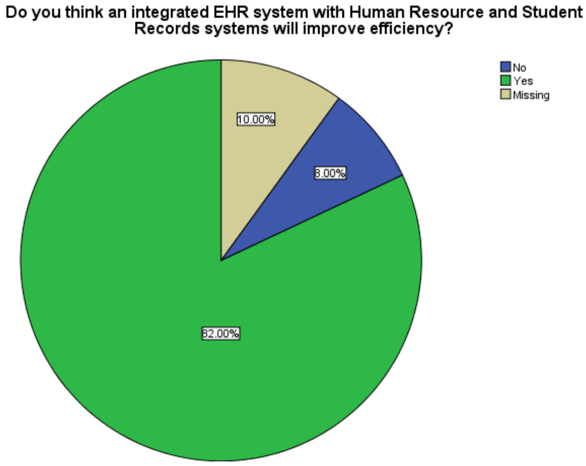

Figure 12

Further, the results showed us that 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. Figure 14 shows the results:

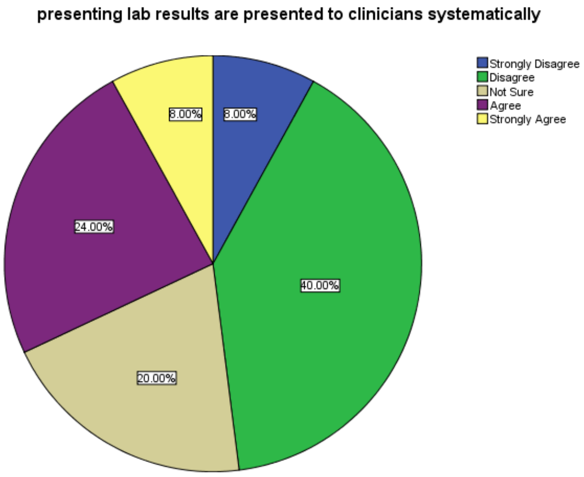

Figure 13

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.

In figure 15, 31.54% of the student respondents thought that an integrated Electronic Health Records system would be a vital step towards improving efficiency at UNZA Clinic. 15% did not respond, 7.69% did not agree and 15.38% were not sure.

We also asked the 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 16 shows the results quantitatively;

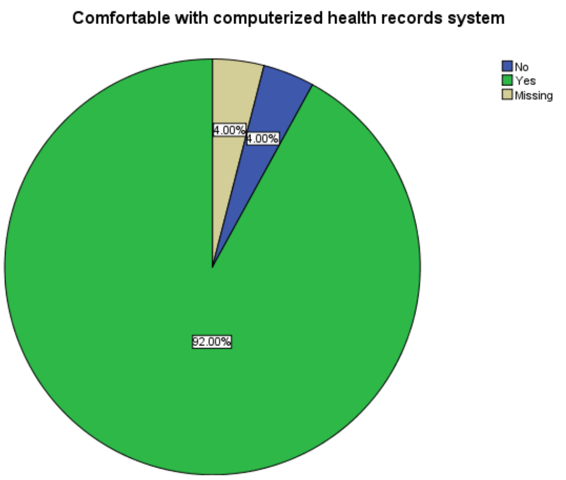

Figure 14

When asked how comfortable the respondents were with computerized health records, an average of 92% of the student and staff agreed whereas 4% did not respond and 4% disagreed.

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.

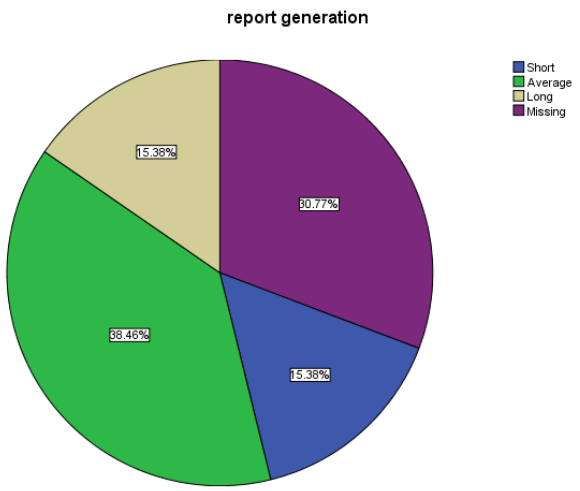

Figure 15

Lastly, health care providers were asked to rate how long it takes them to generate reports is in the current setup and 15.38% of the respondents said it was short, 15.38% said it was long, 30.77% did not respond and 38.46% of the respondents said the process was average.

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 that indicated a computerized system, electronic transfer of data amongst the departments administering healthcare to the patient, electronic record keeping of patient information were the main issues that needed to be addressed to achieve better efficiency amongst other administrative concerns.

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.

Further, the Clinic mostly serves members of staff, their dependents, and the student populace. These already have their information either in the Human Resource or Student Information Systems. As part of the process of verifying that a student is registered or an individual is a member of staff or a dependent, the clinic always has to ask for a registration confirmation slip in the case of a student or a personnel data print out. This process brings about delays and duplication of work due to the heterogeneity of the systems. This information can be harmonized by way of introducing interoperability amongst these key systems for the to be able to pass current information that is required in at the UNZA Clinic.

V. CONCLUSION

This study considered evaluating the performance of the UNZA eHealth System and proposed a model that implements interoperability to enhance the performance and efficiency. A baseline study was conducted to ascertain the challenges that both clients and users of the current system at the UNZA Clinic. From the methodology used, it was observed that lack of interoperability negatively affected the business processes of the Clinic.

To achieve interoperability, this paper proposes RESTful Web Services using JSON. We considered the fact that these RESTful Web Services, any other application that would need to request for information from the EHR system or vise-versa, all that these applications would need is to implement the specifications of the Web Service that has been built. This model will present benefits of scalability, low-cost, interoperability, high availability of information, quick decision making and efficiency in attending to the patients whilst we acknowledge that the ICT skills gap needs to be addressed to fully benefit from the advantages of using this model. Further, we considered the case study as a pilot of the Zambian scenario which is still struggling with technologies as it is a developing country and many eHealth systems are still operating in isolation.

VI. FUTURE WORKS

This study adds to the understanding of the use of Web Services in the implementation of Electronic Health Record Systems. There is still a lot of development that needs to be done in the Zambian context to mitigate the challenges of interoperability in the health sector. [6] The Ministry of Health has indicated in it's annual reports that there are many isolated systems that are not interoperable. As part of future works, the proposed model for UNZA Clinic will be developed and implemented as a learning platform for the greater nationwide interoperability problem of Health Information Systems in Zambia that needs to be solved.

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