



University of Fort Hare
Together in Excellence

**Building a Semantic Web-based E-Health
Component for a Multi-purpose
Communication Centre**

A thesis submitted in fulfilment of the requirements for the degree of

Master of Science

in

Computer Science

by

Bulumko Hlungulu

Declaration

I, Bulumko Hlungulu (200507979) hereby declare that the content of this work is my own original work and all information extracted from other sources is acknowledged as such.

Signature: _____

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Publications

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Hlungulu B., Kunjuzwa D. T., Ndlovu N., Samalenge J., Ngwenya S., Thinyane M. And Terzoli A., *Technology Solutions to Strengthen the Integration of Marginalized Communities into the Global Knowledge Society*, IST Africa, Durban, South Africa, 2010.

Hlungulu B., Thinyane M. and Terzoli A., *Building an E-Health Component for a Multipurpose Communication Centre for a Marginalized community using FOSS*, Proceedings of ZAWWW-2010 Conference, UKZN, Durban, South Africa, 2010.

Abstract

Rural communities have limited access to health information which is made available on the internet. This is due to poor infrastructure (i.e., lack of clinics or Internet access) and that gives them problems in accessing information within the domain of health. The availability of Information and Communication Technologies (ICTs) in a rural community can provide the community with a number of beneficial solutions to their problems as they maximize the potential of knowledge sharing and delivery. This research seeks to make use of ICTs deployed in the community of Dwesa, in order to contribute to improving the health standards of the community. It seeks to accomplish this by carrying out an investigation and literature review with the aim of understanding health knowledge sharing dynamics in the context of marginalized communities. The knowledge acquired will then be used in the development and implementation of a semantic web-based e-Health portal as part of the Siyakhula Living Lab (SLL) project. This portal will share and deliver western medical knowledge, traditional knowledge and indigenous knowledge. This research seeks to make use of a combination of Free and/or Open Sources Software in developing the portal to make it affordable to the community.

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Acronym

| | |
|-------|--|
| CSS | Cascading Style Sheets |
| FOSS | Free and Open Source Software |
| HTML | Hyper Text Markup Language |
| ICT | Information and Communication Technology |
| ICT4D | Information and Communication Technology for Development |
| JS | Java Script |
| LAMP | Linux, Apache, MySQL, PHP |
| OWL | Web Ontology Language |
| PHP | Hypertext Preprocessor |
| RAP | RDF API for PHP |
| RDF | Resource Description Framework |
| RDFS | RDF Schema |
| SLL | Siyakhula Living Lab |
| VoIP | Voice over Internet Protocol |
| VSAT | Very Small Apache Terminal |
| W3C | World Wide Web Consortium |
| WiMAX | Worldwide Interoperability for Microwave Access |

CHAPTER

ONE

Introduction

1 Chapter One: Introduction

This chapter introduces the research that is to be undertaken. It accomplishes this by providing brief background information on the research. Then it discusses the problem statement, objectives of this research, methodology and the importance of this work. Finally, it discusses the structure of the ensuring dissertation.

1.1 Background Information

The Internet has brought an exponential growth of the number of connected people to it that added up to 70 million at the end of 1998 across the globe and in 2002 statistics indicated that one in ten people in South Africa were able to use the Internet (Makofske & Almeroth, 2008; Jakachira, 2010). This exponential growth in the number of connected people indicates that the Information and Communication Technologies (ICTs) or the Internet can be successfully used in delivering different kinds of services to desiring communities. The availability of ICTs has resulted in the development of different eServices (for example, e-Government, e-Judiciary, e-Commerce, e-Health, etc) for delivering different services to communities. The ICTs have a potential of delivering solutions for community needs and ensuring that the communities' expectations are met if they can be used to their full potential (Jakachira, 2010).

Access to health information is one of the services that communities are in need of. The Electronic Health (e-Health) system is a system whose main focus is on delivering health information to the users and also facilitates communication between health system users (for example, between physicians and patients), thereby facilitating health knowledge sharing (Hlungulu & Thinyane, 2009). There are many Information and Communication Technology for Development (ICT4D) projects in South Africa that supports the implementation of ICTs in marginalized communities for rural development (Scott, 2010). Implementation of an e-Health system in marginalized communities using the available ICTs can provide such communities with numerous benefits because it addresses the lack of health information that influences each and every decision that they make concerning their health (Hlungulu & Thinyane, 2009).

1.2 Problem Statement

People who reside in rural areas are unnecessarily exposed to health ailments because they have inadequate health facilities and health information (Hlungulu *et al*, 2010). The problem is that they have poor infrastructures such as the lack of clinics, Internet access, inadequate roads, electricity, etc. This makes it difficult for SA Department of Health to deliver services to them. In most cases rural communities have clinics that they can use, but they are few and that makes them not to be effective because people living far from them need to travel long distances to get there. This situation causes them suffer due to the misdistribution of resources and also less or limited access to healthcare resources that are available in urban areas (Hlungulu & Thinyane, 2009). Most of the problems that are encountered by rural communities can result in death, in addition to waste of resources and waste of money (Maheu *et al*, 2001). The problems referred to here are those that are a result of missusage of first aid or lack of it.

In communities like Dwesa (i.e., the research location of this project) there are people who would like to make use of Traditional medicine and there are diseases that are best cured by traditional medicine which the community is in position of. In order for them to make use of this kind of medicine they need proper information on how to use it. This information can be accessed from traditional doctors or practitioners, only few in rural areas. In addition to this, there is also indigenous health knowledge that is available within the community. This information can be useful if it can be collected, stored and shared properly.

To address the above mentioned health problems, rural communities need to have access to ICT infrastructures that are not available in most rural areas in South Africa. Access to ICT infrastructures would give community members an opportunity to receive relevant health information through an e-Health system that this research is proposing. The implementation of an e-Health system can solve these problems because it addresses the issue of the lack of health information (Hlungulu *et al*, 2010). The availability of relevant medical information influences each and every decision that rural communities make concerning their health (Maheu *et al*, 2001). With better knowledge or more sufficient

information and great awareness, the people of Dwesa and other rural communities, can make positive decisions regarding their health.

1.3 Research Objectives

The overarching aim of this research is to make use of ICTs deployed in Dwesa, through the Siyakhula Living Lab (SLL) project, to make a contribution towards improving the health standards of the community (Hlungulu & Thinyane, 2009). In addition to this, this research also tries to promote the usage of ICTs deployed in Dwesa by community members by developing one of its useful web applications.

The main objectives of this research are:

- To undertake an investigation and a literature review to understand the knowledge dynamics around health information sharing, especially in the context of the community of Dwesa.
- To make use of the acquired knowledge to develop and implement an e-Health portal for the Dwesa community.
- To make use of semantic web technologies in developing different knowledge repositories for isiXhosa traditional medicine knowledge and indigenous knowledge as part of the data layer of the e-Health system.
- To test and evaluate the implemented e-Health portal.

The question that these objectives attempts to answer is:

Can the semantic web-based e-Health portals be effectively used in facilitating the sharing and delivery of health knowledge in marginalized communities?

1.4 Methodology

System development is an important process that requires a well structured methodology to make sure that the system meets its intended requirements (Bell *et al*, 1992). There are several models that can be used in developing a system, for the purpose of giving a

prescriptive on how a system should be developed (Scacchi, 2001). Bell *et al* (1992) classified the models into the following:

- Waterfall model
- Exploratory programming model
- Prototyping
- System assembly from reusable components

In the development of the system under study, the waterfall model was considered and used because of its advantages that best suites the development of this system, such as its (SoftDevTeam, 2010):

- Simplicity
- Easy to manage
- Works well for smaller projects where requirements are very well understood

The waterfall model views system development as a process where software evolution proceeds through an orderly sequence from one phase to another as depicted in Figure 1 below (Scacchi, 2001; Bell *et al*,1992). The first step in the waterfall model is determining the possibility of achieving the intended results (successful development and implementation of the system). With the ICTs deployed in the Dwesa community the development and implementation of this system is possible.

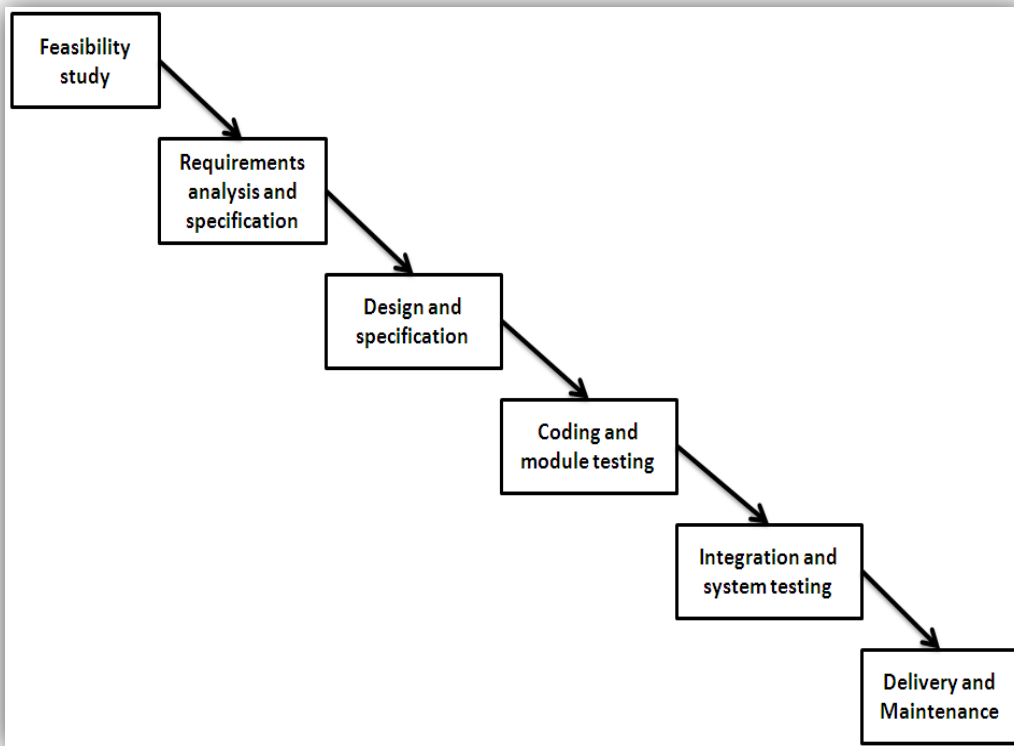


Figure 1: Waterfall model adopted from Scacchi (2001)

Interviews, field visits and a literature review are the methods that were used in dealing with requirements analyses and specifications therefore qualitative research was used. These methods were based on field visits to Dwesa.

- **Field Visits**

The researcher visited the research location for eight weeks in different months during the research period (23 months). These field visits aided in the process of learning the network infrastructure (discussed in Chapter Two) that is deployed in Dwesa and made it easy to communicate and interact with the community members. The knowledge that was acquired, regarding the infrastructure, helped in the formulation of recommended combination of software that was used in the development process of this system. These field visits made it easy for the developer to conduct interviews with the community members.

- **Interviews**

During this process different people from different backgrounds were interviewed. Among those people there were students, teachers, nurses, traditional doctors and/or practitioners as well as the community members. These interviews helped in designing the system because the developer discovered what is expected by the community.

- **Literature Review**

Apart from the interviews, a literature review was also conducted. The main reason for carrying out the literature review was to uncover knowledge on how best the ICTs in marginalized communities can be used for delivering health knowledge. The literature review that was carried out in the research location also helped in the selection of the preferred technologies that were used in other developed SLL projects.

1.5 Significance

This research seeks to develop and implement a semantic web-based e-Health system that will provide the Dwesa community with solutions to health issues that they encounter. This system will help members of the community to improve their health standards by serving as a knowledge repository. This e-Health system will also enable effective communication between both health workers and community members in this community. The nurses will be allowed on the system to disseminate health information to the community and share information with each other. This e-Health platform will also be used to deliver traditional and indigenous solutions to health issues, which can be used by the rural disadvantaged communities. To accomplish this, the system will be built on top of medical ontology that is entirely based on isiXhosa traditional medicine collected from traditional Doctors.

1.6 Thesis Overview

This section gives a brief description of the rest of the dissertation:

- **Chapter 2, Literature Review**

This chapter presents the literature review that has been conducted for this study. This chapter starts by discussing the concept of ICT4D in marginalized communities. An introduction to the research area and the SLL project is included here. It then explores the concept of health in rural areas and, finally, it looks into the concept of semantic web and its importance to e-Health.

- **Chapter 3, System Requirements**

This chapter discusses the system requirements of the semantic web-based SLL e-Health portal for the community of Dwesa. It gives a description of both functional and non-functional system requirements. As part of the functional system requirements this chapter also discusses the use-case diagrams that represent direct functionalities of the system.

- **Chapter 4, Design of the System**

This chapter will discuss the design of the SLL project's e-Health Portal. This chapter begins by giving an introduction to the SLL e-Health system architecture. It then discusses the backend of the portal developed by this research.

- **Chapter 5, Implementation and System Testing**

This chapter will be discussing the implementation of the coded medical ontology, indigenous knowledge repository and health information storage. In addition, this chapter will also discuss the management and presentation of the information stored in the back-end of this system. Finally, it discusses the testing and evaluation of the system.

- **Chapter 6, Conclusion**

This chapter concludes the dissertation by giving the summary of research, achievements and finally, it makes a suggestion of future extensions to this project.

1.7 Summary

This chapter provided background information for this research. It then presented the problem statement, aims and objectives of this research. It also outlined the significance of this work and highlighted the structure of the rest of the document. The next chapter will focus on the literature review that was carried out during the research period.

CHAPTER

TWO

Literature Review

2 Chapter Two: Literature Review

Information and Communication Technologies (ICTs) have the potential to eliminate the problem of limited access to knowledge, health knowledge in particular, hence they are the ideal tool to be used for information delivery in marginalized communities (Hlungulu & Thinyane, 2009). E-Health portals have been built using these ICTs for the purpose of delivering health information to communities and facilitation of health knowledge sharing between the users (Sadeghi *et al*, 2007). The development and implementation of an e-Health component for marginalized communities can help build health awareness and improve the quality of health in these communities.

There are many e-Health portals that have been developed but there are very few portals designed specifically for rural communities. This study develops and implements an e-health component for the marginalized rural community of Dwesa, as discussed in Chapter One. This portal will give the community an opportunity to share health information and learn new thing through the portal. In addition to that, this portal will a special feature that will allow the community to share indigenous knowledge and deliver traditional ways of treating ailments. In order for this kind of research to be successful an understanding of the ICT4D domain and health information systems is needed.

This chapter presents the literature review that has been conducted or this research. It starts by discussing the concept of ICT4D in marginalized communities. It then moves onto the concept of e-Health; in rural areas specifically. Finally, it looks at the relevance of the semantic web in e-Health information systems.

2.1 Information and Communication Technologies for Development (ICT4D)

ICT infrastructure is required in order for an e-health portal to be developed for a certain community. ICTs are technologies that can be used to link information technology devices with communication technologies (Chapman *et al*, 2002). Ingale (2010) defined ICT as different forms of technologies that are used for transmitting, storing, creating, displaying, sharing and/or exchanging information electronically. Radios and televisions

are the old, or traditional, types of ICT and means of delivering information to communities (COFISA, 2008).

COFISA (2008) states that 73.5% of rural community members in South Africa have access to radios, 47.4% have access to television, 3.2% have access to computers and 0.7% have internet access. These percentages indicate that even though radios and televisions are not effective in delivering health care information, they cannot be ignored because they are the ICTs that are most often available in marginalized communities. Radio and television play a role of connecting communities to the outside world and ignore the role of the management, storage and effective sharing of indigenous knowledge among community members themselves that these new ICTs offer (Chapman *et al*, 2002; COFISA, 2008). Apart from this, ICTs also grant community members access to more information that is available on the web and also gives them an opportunity to create links for partnerships in information sharing (Chapman *et al*, 2002).

The above mentioned percentages of computer access, internet and cellular phones indicate that new ICTs are slowly penetrating marginalized communities and require ways to add computing and internet functionality (Heeks, 2008). If these new ICTs can be used to their full potential, they can aid the improvement of individual knowledge sharing skills by facilitating indigenous knowledge sharing (Chapman *et al.*, 2002).

ICTs have proved to have a great impact in marginalized communities because they play the role of facilitating the following in rural communities (COFISA, 2008):

- Poverty alleviation
- The development of local economies
- The achievement of basic standards of health, safety and other developmental infrastructure and services
- The encouragement and empowerment of people to invest in their communities
- Cultural regeneration, including the development and integration of indigenous knowledge systems

- The long-term sustainability of livelihoods and improvements in the quality of life

In order for ICTs to play their above mentioned roles there is a need for proper education, training and support on ICTs amongst the community that is going to use the technology (COFISA, 2008; Sadeghi *et al*, (2007). “Failure to do so usually leads to users being intimidated by the technology and frustrated when they cannot get it to do what they want” (Sadeghi *et al*, 2007).

To prevent this failure, the implementation of ICTs for rural development purposes in developing countries comes with the following characteristics (COFISA, 2008):

- Supply-driven introduction of ICTs into communities
- Assumption that the introduction of ICTs into a given social and economic system will economically result in development
- The creation of special vehicles to introduce ICTs into rural communities
- Decisions regarding the needs of target audiences, technology choices, and methods of implementation and awareness raising are made by more knowledgeable experts
- Lack of institutional capacity building within implementation agents on multi-purpose users of ICTs

Because of the potential that ICTs have they are used as a major tool in narrowing the digital divide. Digital Divide is a term that refers to the gap between those who enjoy the benefits of Information Technology (for example, the Internet), and those who do not have access to those benefits (Thinyane *et al*, 2007). The digital divide is primarily caused by the lack of connectivity to relevant information. The main cause of this lack of connectivity is the high cost of acquiring and installing the ICT infrastructure. Another factor that contributes to the increase in the digital divide, beyond the connectivity and affordability of ICT infrastructure, is the capability (i.e., computer literacy level) of the community users (Thinyane *et al*, 2007).

2.2 The Siyakhula Living Lab (SLL) project

The e-Health system that has been developed in this research forms part of the eServices bundle that is implemented within the Siyakhula Living Lab project. The SLL project is Information and Communication Technologies for Development (ICT4D) project that is undertaken in Dwesa, a rural area in the Eastern Cape province of South Africa (Hlungulu *et al*, 2010). It is a joint venture between the Telkom Centre of Excellence of the University of Fort Hare and Rhodes University with the support of the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA) (Dalvit *et al*, 2007).

2.2.1 Dwesa (The Research Location)

Dwesa is a rural area located in the Eastern Cape Province of South Africa (see Figure 2). Dwesa is administered by the Mbashe Municipality (with main offices situated in Idutywa) which falls within the Amathole District Municipality (main offices situated in East London) (Timmermans, 2004). Dwesa is approximately 50 km away from Willowvale and 75 km away from Idutywa (Timmermans, 2004; Dalvit *et al*, 2007). These two towns are the closest towns to Dwesa. The total population of this community is 15000 (Timmermans, 2004). This community is made up of people who speak isiXhosa and these people depend primarily on pensions, grants, remittances, livestock production, local resource utilization, subsistence farming and limited tourist-based jobs (Scott M, 2010).



Figure 2: Transkei and the Dwesa region (Dalvit *et al.*, 2007)

Dwesa has a coastal nature reserve that was the site of one of the first land restitution projects in post-apartheid South Africa (Dalvit *et al.*, 2007). This nature reserve attracts tourists, mainly South Africans, during holiday periods and as such provides the potential for both eco and cultural tourism due to its rich cultural heritage and the marine conservation project undertaken at the nature reserve (Dalvit *et al.*, 2007). The nature reserve does not benefit the community directly because the revenues are redirected to administrative government offices in Bisho and this community only benefit by promoting local crafts. This community also lacks basic infrastructure such as electricity, roads, telecommunication facilities and clinics (Hlungulu and Thinyane, 2009).

“In many ways, Dwesa is a representative of many rural realities in South Africa and Africa as a whole” (Dalvit *et al.*, 2007), hence the Telkom Centre of Excellences hosted by the University of Fort Hare and Rhodes University initially developed an e-commerce platform that is suitable for rural areas in 2004 for this community (COFISA, 2008). The purpose of the development of this platform was to promote eco-tourism in this community and to give the community an opportunity to advertise and sell their locally produced arts, crafts and music (COFISA, 2008). The SLL project ICT infrastructure is currently deployed in five different schools (Mpume Junior Secondary School, Ngwane Junior Secondary School, Nondobo Junior Secondary School and Mtokwane Junior Secondary School) due to several considerations.

- **Mpume**

This school was the first school to be considered as an ideal site for the installation of equipment due to the availability of electricity and location (Dalvit *et al.*, 2007). In this school the following ICTs were installed (Scott, 2010; Dalvit *et al.*, 2007):

- VSAT connection (satellite dish, indoor unit and cabling)
- WiMAX (Alvarion Breezemax CPE outdoor unit, and CPE indoor unit, wall mounting)
- A server (LTSP, HTTP, MySQL)
- 6 client PCs
- An 8 port DLink switch
- A VoIP phone

In this school the computer lab is housed in the staff room because that was the only secure place at the time. The SLL project intends to convert one of the classrooms into a computer lab and they are hoping that it will be fully furnished by 2011.

- **Ngwane**

Ngwane Junior Secondary School was the second school to be considered as an ideal Siyakhula Living Lab Digital Access Node (Scott, 2010). The deployment at this school is important as it hosts the BreezeMax WiMAX base station crucial for the backbone

connection of the Siyakhula Living Lab network, and needless to say, this school is in the line of sight of all the other DANs in the area. In addition, the community and school are completely committed to ICT use – they independently fundraised and furnished the first 20 computers ever installed in the school. Currently, Ngwane. currently hosts the following ICT infrastructure components:

- 20 nanoware system units and LCD monitors
- WiMAX BreezeMax indoor unit
- WiMAX BreezeMAX CPE and WiFi
- Server, router, VoIP phone

- **Nondobo and Mtokwane**

These are also in line with Mpume and the following equipment was installed in both schools (Dalvit *et al.*, 2007):

- WiMAX (AlvarionBreezemax CPE outdoor unit, and CPE indoor unit)
- A client PC
- A VoIP phone

2.2.2 Developed applications

As the SLL project is being driven by the University researchers (Rhodes and Fort Hare), they play a major role in developing useful applications for the community seeking to improve ICT usage. There are several projects that have been developed and deployed.

- **The e-Commerce Platform**

The e-Commerce platform tries to promote tourism in Dwesa, and to advertise locally produced arts, crafts and music (COFISA, 2008). This was achieved by implementing an e-Commerce platform that is simple, user-friendly and robust, with good functionality aiming at overcoming the tough conditions often experienced in rural areas (Njeje, 2008).

- **The e-Government Platform**

The e-Government platform tries to provide government-to-citizen communication between the community of Dwesa and the government (Jakachira *et al.*, 2008). It

accomplishes this by allowing Dwesa community to have access to application forms for IDs, birth, death certificates and government grants (Jakachira *et al*, 2008). It also allows users to launch reports and complaints to various government departments (Jakachira *et al*, 2008).

- **M-Payment System for Service Delivery in a Wireless Village Context**

This project focuses on developing and implementing mobile applications for a completely rural community to improve their standard of living and enhance the business prospects of community entrepreneurs (Mpofu *et al*, 2009). This system offers two mobile applications that deliver services to the rural community for transferring money and buying electricity (Mpofu *et al*, 2009).

- **A Help-Desk System**

This project developed a system that will help unskilled and semi-skilled rural ICT users to benefit from computer services by giving them a consistent, essential and reliable assistance (Makombe *et al*, 2008).

- **The e-Judiciary Platform**

This project tries to reduce the weaknesses that are faced by the legal system and in the administration of justice by means of traditional procedures such as inconsistency and lack of certainty in decision making and in punishing offenders (Scott, 2010). This will be accomplished by the implementation of an e-Judiciary platform that facilitates the maintenance of a legal relationship between rural leaders, community members and the urban justice system (Scott, 2010).

- **User Driven Telephony Services**

This project aims to develop a user-driven telephony framework for the community of Dwesa. This will be accomplished by implementing a framework that will allow community members to develop their own audio-based services which will later be accessed on their phones using ICTs that are deployed there (Kunjuzwa *et al*, 2009).

- **Services for Personal Communication**

The main aims of this research were to develop and deploy SOA wrappers for communication modules (SMS, MMS, eMail and IM) (Samalenge and Thinyane, 2009).

These services will be developed and deployed as web services and they will be consumed over the Dwesa network (Samalenge and Thinyane, 2009).

- **Cost Sharing and Revenue Management System for SLL Project**

The study will address the issue of sustainability at the SLL project through revenue generation and management (Ngwenya *et al*, 2009). The major focus of this project is on context sensitive technological solutions to be used in charging for internet usage, and other ICT services in marginalized communities. Architecture of billing schemes that consist of conventional and non conventional schemes will be used to explore fair charging mechanisms for the people of Dwesa (Ngwenya *et al*, 2009).

2.3 Health Care Delivery in Marginalized Communities

Health care is one of the most important services that communities need to gain access to (Hlungulu & Thinyane, 2009). Health is not the absence of ailments or diseases but can be considered as the state of complete physical, mental and social well being of an individual (Ekwuruke, 2005). Most marginalized communities have little or no access to health services due to the following reasons (Ekwuruke, 2005):

- Problem of insufficient health centres or services.
- Problem of accessibility to the available health care centres, due to the spatial inefficiency of their distributions.
- Inefficiency of the available health care facilities
- Ratio of insufficiently trained medical personal/physicians to the existing population of a particular area.

Marginalized community members rely heavily on health knowledge that comes from clinics which are few and not easily accessible (Ekwuruke, 2005). This causes community members to suffer from inadequate health facilities, health awareness and lack of health information (Hlungulu *et al*, 2010). In most health centres in rural communities, there are no medical doctors because most rural community members rely on subsistence farming to sustain their lives and that makes it difficult to afford medical doctors (Ekwuruke, 2005).

2.4 Health Care delivery in the Community of Dwesa

The community of Dwesa relies on health clinics for health care knowledge/services. In this community there are two clinics, one in Mpume village (Msendo Clinic) and the one in Nqabara (Nqabara Clinic). These clinics provide services such as family planning, voluntary counselling (HIV), treating minor ailments, chronic diseases, and infant delivery. Community members do not trust giving birth at the clinic and they prefer to travel to urban areas because there are no medical doctors in these clinics. The nearest hospitals are approximately 49 km away. These hospitals are Tafalofefe Hospital and Madwaleni Hospital. In the case of emergencies the nurses normally use their cell phones and call 112 (i.e., the emergency hotline). This method is not fast because, according to community members it can take up to 4 hours for an ambulance to arrive there.

2.5 Electronic Health (e-Health)

Among the roles that ICTs play, they also play a major role in the achievement of basic standards of health in communities (COFISA, 2008). They deliver this through different forms (for example, e-Health, telehealth and m-Health). E-Health is the use of ICTs to deliver health knowledge (i.e., health care information) and facilitate health knowledge sharing between the users and to exchange health information when distance separates the users (Sadeghi *et al*, 2007; Ikhu-Omoregbe, 2008). Sadeghi *et al* (2007) further categorizes e-Health into three different types of activities, e-Health being educational, clinical and administrative.

2.5.1 The Educational Activities

The educational content in an e-Health portal allows the delivery of health knowledge to the communities. Sadeghi *et al* (2007) stated that this knowledge delivery can come in the form of a health awareness course which can be accessed over the internet. In this there can be different sources of information, for example, volunteers from around the globe, health professionals, medical residents etc., and gathering this information and storing it somewhere produces a useful knowledge repository (Sadeghi *et al*, 2007). Ikhu-Omoregbe (2008) also states that an e-Health system with educational functionality delivers:

- Information for health promotion and awareness, medical education, health and biomedical research, evidence-based medicine, and e-learning
- Information for health information system
- Information for health care delivery
- A platform to render health related services to patient such as medical diagnosis, patient care, after care interactions, training, etc

The implementation of e-Health educational activities in ICT platforms can solve many problems because it addresses the problem of a lack of medical health knowledge which influences decisions that communities make concerning their health (Hlungulu & Thinyane, 2009).

2.5.2 The Clinical Activities

These are the activities that occur between patients and health professionals. Here the system acts as an online clinic or hospital to patients. The medical professionals are able to communicate with patients, diagnose and prescribe the kind of medication that the patient needs to take (Sadeghi *et al*, 2007). By doing this patients will be brought to light because they will be able to diagnose themselves using the information that will be stored in the repository and information from health professionals seeing a medical specialist (Ikhu-Omoregbe, 2008).

With these different activities Frasier *et al* (2008) explained that e-Health can help in mitigating the absence of health specialists in resource poor environments, such marginalized communities. The existence of these activities (educational, clinical and administrative) depends primarily on ICTs and e-Health System Users.

2.5.3 E-Health System Users

E-Health system users can be classified into several categories. Users can be patients, researchers, clinicians (i.e., doctors and nurses) and administrators (Daragmi *et al*, 2008). A proper e-Health system needs to deliver different user interfaces for these different kinds of users. For example, the clinicians interface needs to be able to allow doctors and nurses to interact and deliver assistance to patients' problems and also allow them to share information amongst each other.

Daragmi *et al* (2008) also mentioned that the usability of the system is of great importance to the users and that it can be achieved by developing a system that is able to accommodate different user functionalities. It is also important to provide the e-Health users with an introduction to the system because, in order for users to benefit, it requires a skill set or literacy (Norman & Skinner, 2006). The lack of this skill set usually results in users being intimidated by the technology when they cannot make it to do what they desire (Sadeghi *et al*, 2007). To prevent this, a system developer has to consider making use of semantic web tools to ease system usage with users.

2.6 Semantic Web

The Internet is used by many users for different reasons. It is, first and foremost, used as a source of information. They need to take time and use their literacy skills to interpret the information available and see if it is what they are looking for themselves because machines cannot interpret the information for them (Sadeh & Walker, 2003).

The new emerging Semantic Web seeks to address the above mentioned problem because its main goal is to make information meaningful to users by making it understandable to the machines, thereby allowing enhanced information discovery data exchange and integration (Oldakowski *et al*, 2005; Ohler, 2008). Semantic web is a “World Wide Web Consortium (W3C) initiative which aims to provide a common framework for data sharing and reuse across applications, enterprise and community boundaries” (Reynolds *et al*, 2005:4). Sadeh & Walker (2003) emphasize that Semantic Web is not a separate web; rather, it is an extension to the current one, but on Semantic Web information is given a well defined meaning for the purpose of helping people and machines to work in cooperation.

Semantic web is a web where the focus is on the meaning of words rather than the words themselves and its focus is only on the sharing of knowledge rather than information (Mazzocchi, 2000). “Information becomes knowledge after semantic analysis is performed” (Mazzocchi, 2000). Unlike Hypertext Markup Language (HTML), Semantic web displays meaningful information by tagging information with descriptors (Ohler,

2008). Adding to that it also allows users to find a relationship between tagged information by using inference rules (Ohler, 2008).

Semantic Web has an architecture that is based on a hierarchy of languages, with each language making use the features and extending the capabilities of the layers below (Horrocks *et al*, 2005). The main purpose of this architecture is to perform tasks such as the representation of the structure of data, meaning of data, the formal common agreement about meaning of data and finally enables the intelligent reasoning with meaningful data. The architecture referred to here is illustrated in Figure 3 and it is showed in a form of a semantic web stack diagrams. According to Horrocks *et al* (2005), as a result of the work of the W3C, the ontology layer in Figure 3(A) has been represented by Web Ontology Language (OWL) and the focus is now on the rules layer. The representation of the semantic web stack has changed to Figure 3(B).

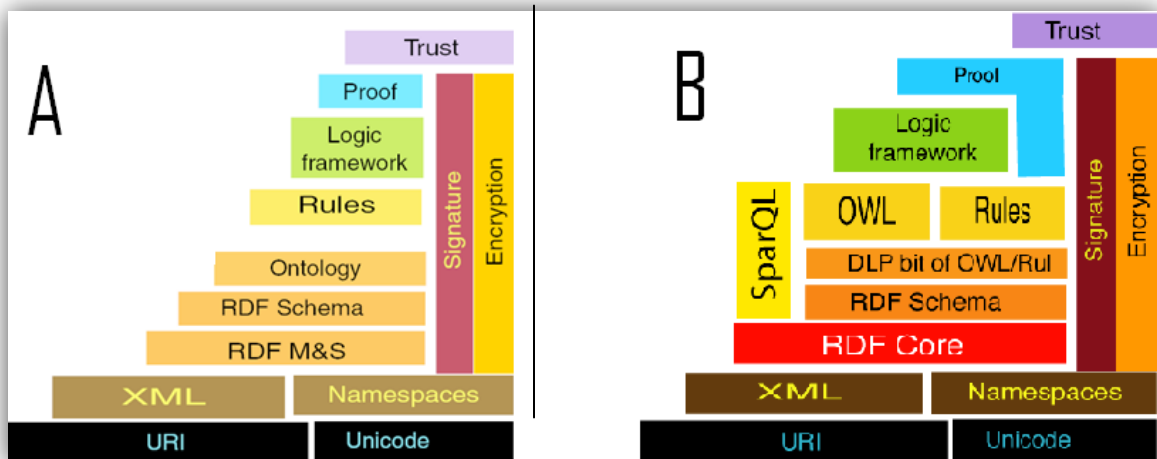


Figure 3: Semantic web stack (Berners-Lee, 2003; Berners-Lee, 2005)

“The Semantic Web relies heavily on the formal ontologies that structure underlying data for the purpose of comprehensive and transportable machine understanding” (Maedche & Staab, 2001:1).

2.6.1 Semantic Web Related Work

This sub section discusses work that was found to be related to our semantic web-based e-Health system.

2.6.1.1 E-Learning Scenario using the Semantic Web

The work that is discussed is based on the implementation of a learning system (e-Learning). This work sought to make use of semantic web technologies in implementing a system that was going to offer an ontology based description of content, context and structure of the knowledge (Stojanovic *et al*, 2001). The main role of the ontology in this work was to formally give a description of shared meaning of vocabulary of knowledge used in the system (Stojanovic *et al*, 2001). This was accomplished by setting ontology constrains to provide mapping between symbols used and their meaning.

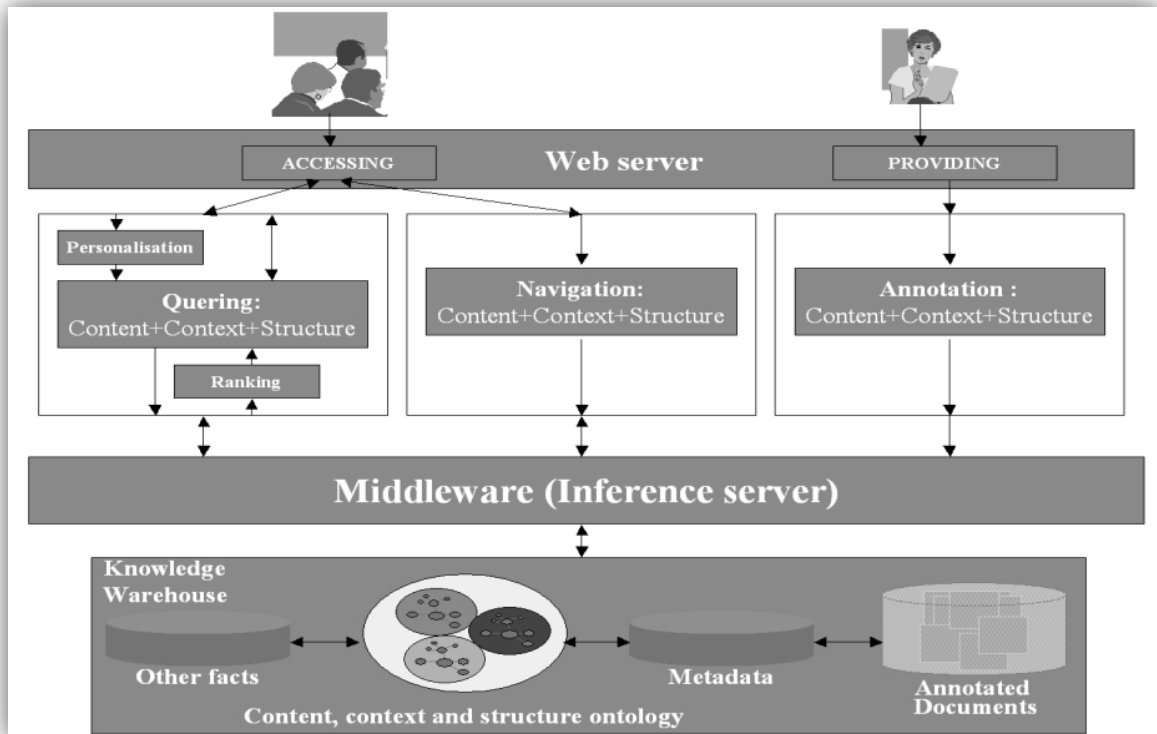


Figure 4: Architecture of the Semantic Web-based e-Learning Scenario (Stojanovic *et al*, 2001)

Figure 4 shows the architecture of the developed above described system. This system was developed to have different core modules that correspond to different activities in the e-Learning environment. These core activities perform the functions of providing information from authors and the purpose of granting learners access to the learning material by querying and browsing.

2.6.2 Ontologies

The Semantic Web Ontologies are “data schemas, providing a controlled vocabulary of concepts, each with an explicitly defined and machine processable semantics” (Maedche & Staab, 2001:1). Ontologies “are mainly used for classifying vocabulary of knowledge systematically, define the relation of the vocabulary by property, and be able to describe meaning of the vocabulary and the relation in a form of a hierarchy” (Minegishi *et al*, 2008). The main aim for developing an ontology is to enable people, organizations and software systems to communicate concisely among themselves (Uschold & Gruninger, 1996). Some of the reasons behind developing an ontology are (Noy & McGuinness, 2001):

- To share a common understanding of the structure of information among people or software agents.
- To enable the reuse of domain knowledge.
- To make domain assumption explicit.
- To separate domain knowledge from the operation knowledge.
- To analyze domain knowledge.

2.6.2.1 Types of Ontologies

Bodenreider & Burgun (2005) state that ontologies can be categorized according to the domain they represent or the level of detail of knowledge they provide. Bodenreider & Burgun (2005) divided ontologies into the following categories (see Figure 5):

- **General Ontologies**

This kind of ontology represents knowledge at an intermediate level of detail. In this kind of ontology upper levels (see Figure 5 below) usually reflects the theories of time and

space and provide notions to which all concepts in existing ontologies are necessarily related (Bodenreider & Burgun, 2005).

- **Domain Ontologies**

This kind of ontology represents knowledge about a particular part of the world of knowledge and also reflects the underlying reality through a theory of the domain represented (Bodenreider & Burgun, 2005). For example, the domain ontology can focus only medical knowledge.

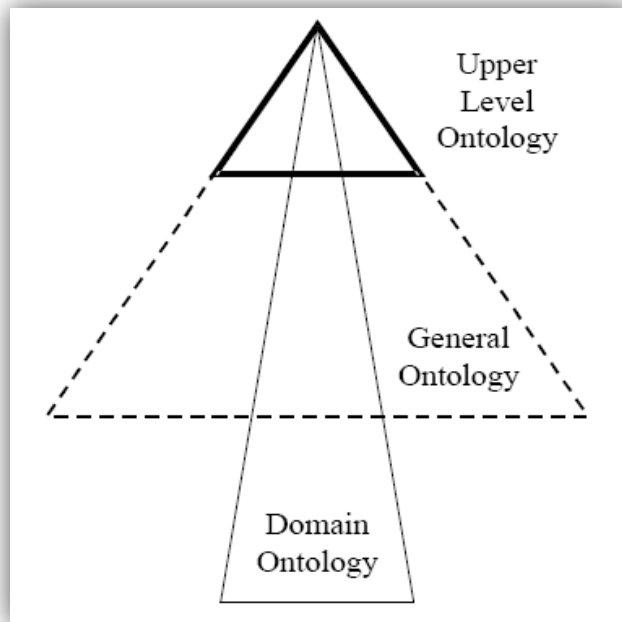


Figure 5: Kinds of ontologies (Bodenreider & Burgun, 2005)

Ontologies have been used as a source of knowledge in a certain domain, for example Medical Subject Headings (MeSH) and Unified Medical Language System (UMLS). UMLS and MeSH are medical ontology knowledge base meant to help a medical information system to understand the meanings of the concepts, terms and their relationships in the biomedical and health domain (Kogilavani & Balasubramanie, 2009).

There is a study that was carried out in India by Kogilavani and Balasubramanie in 2009. The main objectives of the study were to find a helpful solution for users who want to search for specific topics in medical information in the web search engine. The main

problem is that the current search engines lack deep perceptions of natural languages and artificial intelligence (Kogilavani & Balasubramanie, 2009). The main idea behind this study was to develop a system that would summarize medical documents by making use of MeSH, document clustering and a summarization technique (Kogilavani & Balasubramanie, 2009). Document clustering enables the grouping of similar documents together (Kogilavani & Balasubramanie, 2009).

2.6.2.2 Ontology Languages

- **RDF**

Resource Description Framework (RDF) is a language that provides a common data representation that can be used for the exchange and integration of machine readable information (Reynolds *et al*, 2005). RDF represents information by means of atomic logical statements (Reynolds *et al*, 2005). These statements represent information as sets of triplets that can be exchanged over the web (Reynolds *et al*, 2005; Oldakowski *et al*, 2005). The RDF statements consist of a *Subject* (resource being described), *Predicate* (property or relation being described) and an *Object* (property value) as illustrated in Figure 6 below (Reynolds *et al*, 2005; Oldakowski *et al*, 2005).

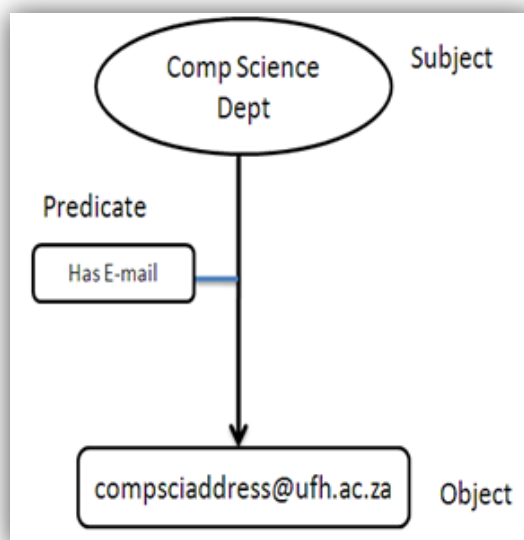


Figure 6: Subject predicate and object.

In summary, the RDF layer provides means for exchanging data that is “only useful for machine processing for the applications that exchange or share a common model of domain, hence there is a need for support for the specification and relation of vocabulary elements that can be used” (Reynolds *et al*, 2005:6).

- **RDFS**

Resource Description Framework Schema (RDFS) is the base language that is used for describing RDF ontologies by providing facilities for defining class hierarchies, property hierarchies and range declaration of properties (Reynolds *et al*, 2005). `rdfs:Resource`, `rdfs:Class`, `rdfs:Literal`, `rdfs:Datatype`, `rdfs:domain`, `rdfs:range`, `rdfs:type`, `rdfs:subClassOf`, `rdfs:subPropertyOf`, `rdfs:label`, `rdfs:comment`, `rdfs:seeAlso` and `rdfs:isDefinedBy` are the main constructs of RDFS (Brickley & Guha, 2004).

- **OWL**

Web Ontology Language (OWL) is an extension of RDFS that enriches axioms that can be stated about classes and properties in a domain model (Reynolds *et al*, 2005). OWL also has tools for declaring the features of properties, restrictions on classes, class relationships and necessary conditions for classes (Reynolds *et al*, 2005). OWL has the following components (Horridge, 2009):

Individuals

OWL Individuals are used for representing objects of the domain that the users are interested in (Horridge, 2009).

Properties

OWL properties are mainly used for specifying the relationship between two individuals or instances; instances can be either a class or individual (Horridge, 2004). There are two types of OWL properties (Object properties and Datatype properties (Horridge, 2004). Object properties are properties that are used for linking individual instances to each other whereas datatype properties link individuals to an XML Schema Datatype value (Horridge, 2009). OWL Object properties have characteristics that enforce the enrichment of the meaning of

properties (Horridge, 2009). These characteristics are Functional, Inverse functional, Transitive, Symmetric, Asymmetric, Reflexive and Irreflexive properties (Horridge, 2009).

Classes

The main function of classes in the ontology is to classify certain individual instances of domain accordingly (Horridge, 2009). For example, in a class of medicine one can find instances of medicine.

2.6.3 Semantic Web Application Programming Interfaces (APIs)

There are several application program interfaces for manipulating ontologies, among the different APIs, such as JENA, Redland, Sesame and RAP can be mentioned. RAP is discussed in detail hereafter because from the preliminary analysis, it is the API that is most applicable in the context of this research.

- **RAP (RDF API for PHP)**

RAP is a “semantic web toolkit for PHP developers that allow parsing, manipulating, storing, querying, serving and serializing of RDF graphs” (Oldakowski *et al*, 2005:1). The RAP persistent storage has two classes, i.e. DbStore and DbModel. DbStore is used for the creating, storage, and retrieval of RDF models and the DbStore is used for storing the RDF graphs in a database (Westphal & Bizer, 2004). According to Westphal & Bizer (2004), RAP has three different implementations of model APIs, MemModel, DbModel and InfModel (InfModelF and InfModelB):

- MemModel (Memory Model) – Model that stores its RDF graphs in memory and does not support inference, as inferencing is an extension to it.
- DbModel (Database Model)
- InfModel (Inferencing Model)

- **DbModel**

DbModel is a RAP model that stores RDF graphs or models in a database and it provides methods for manipulating the stored model (Westphal&Bizer, 2004). Figure 7 below

illustrates how the DbModel works in a database. The DbModel was used in querying statements in the coded medical ontology with RDQL as it provides methods for manipulating RDF graphs.

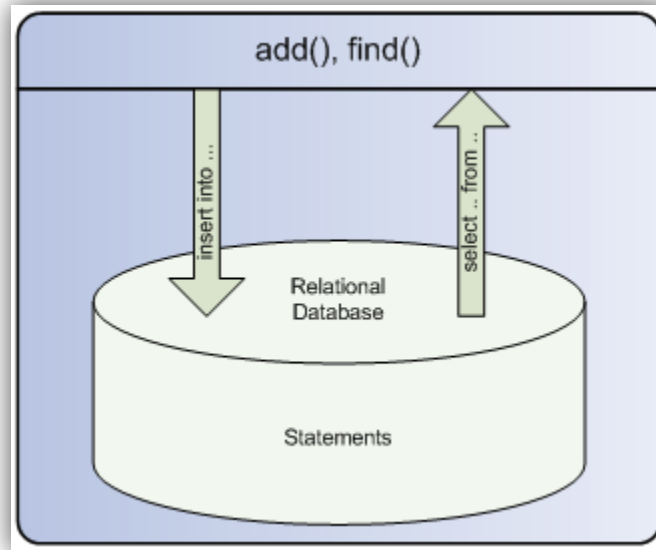


Figure 7: A database Model (Westphal & Bizer, 2004)

- **InfModel**

InfModel is the only reasoning engine that is implemented in RAP and it extends MemModel by adding to it the ability to infer additional statements (Oldakowski *et al*, 2005). InfModel supports the following RDFS and OWL constructs (Westphal & Bizer, 2004):

- rdfs:subclass
- rdfs:subProperty
- rdfs:range
- rdfs:domain
- owl:sameAs
- owl:inverseOf

and some of these constructs were used in the coded medical ontology that was developed in this research developed. In addition, the InfModel supports these inference rules, RDFS Rule 6, 8, 10, 12 and 13 (Westphal & Bizer, 2004). RAP was used in the development of the system because the projects that are part of the SLL project were implemented in PHP. In addition, PHP is an interpreted language and that improves the speed of the development cycle because an interpreted language “enables you to perform incremental, iterative development and testing without going through a compile-test-debug cycle each time you change your code”(Vaswani, 2005:8).

The InfModel is extended into (Westphal & Bizer, 2004):

- InfModelF – inference model that uses a forward chaining algorithm. This model performs best if the model does not change much and it is queried a lot.
- InfModelB – inference model that uses a backward chaining model. This model is recommended if the model:
 - Changes a lot
 - Have a lot of RDFS statements
 - Is not queried a lot

2.7 Related Work

This section discusses work that has been undertaken in other contexts to provide e-Health services.

2.7.1 E-Health Rwanda

Rwanda is one African country that has a population of approximately 9.5 million with an annual growth rate of 2.8% (Frasier *et al*, 2008). In trying to overcome the health problem, Rwanda had 366 health centres, 33 district hospitals and 5 referral hospitals. By the end of 2005 Frasier *et al* (2008) indicated that Rwanda had 85 deaths per 1000 births and HIV/AIDS was up to 3% of the entire population. According to Frasier *et al* (2008), Rwanda is one of the countries that has high levels of poverty and is still developing its health care infrastructure.

In trying to accomplish the development of healthcare infrastructure the Government of Rwanda and several Non-Governmental organizations integrated technology into its health care system in attempt to overcome the problem. This integration led to the development of six entities/programs in health information technology in Rwanda. Some of the programs that are running there are described below:

- **OpenMRS (Open Source Medical Record System)**

The OpenMRS is a free and open source medical records system that was initially implemented in August 2006 (Frasier *et al*, 2008; RITA, 2007). The OpenMRS is used for keeping track of patient-level data (Frasier *et al*, 2008).

- **Telemedicine**

According to Frasier *et al* (2008), telemedicine is the use of communications and information technology to deliver health and health care services, information and education where participants are geographically separated. The main reason behind this work is to reach out to environments where resources are poor by connecting health providers with specialist doctors located outside of those environments and who are able to train future doctors in rural areas (Frasier *et al*, 2008). In dealing with this, two projects were undertaken (Frasier *et al*, 2008):

- The first effort was to make use of ICT and connect district hospitals to referral hospitals so as to be able to store and forward asynchronous telemedicine immediately.
- The second effort was to create a universal platform for biomedical imaging using Digital Imaging and Communications in Medicine (DiCom) platform in Rwanda.

- **HMIS (Health Management Information systems)**

The major goals of HMIS are to “integrate data collection, processing, reporting, and use of the information necessary for improving health service effectiveness and efficiency through better management at all levels of health services”(Frasier *et al*, 2008).

- **E-Learning**

According to Frasier *et al* (2008), there is not much work that has been done in Rwanda in terms of formal e-Learning. Frasier *et al* (2008) explain that there have been some instances of e-Learning being used in limited settings such as medically relevant lectures being presented over the intranet that connects to referral hospitals and open-heart surgeries and various meetings.

2.7.2 Primary Healthcare Management System in Rural South Africa

This project is part of PatHS that is developing and implementing a healthcare management system in rural South Africa (Smit and Venter, 2009). PatHS is an ongoing research project that started in 2007. The main focus of this research project is the improvement of chronic lifestyle diseases such as HIV/Aids, hypertension, diabetes and tuberculosis. It therefore aims (Smit & Venter, 2009):

- To conduct a baseline study among key stakeholders to ascertain the levels of factors involved in poor management of chronic diseases.
- To investigate applicable and efficient ways in which Information & Communication Technology (ICT) can assist in improving the chronic disease management health care system in rural areas.
- To build the capacity of rural health service staff to work with computer-based solutions for health.
- To develop a technological solution (prototype) that improves communication between the health service and the patients they serve.

This research project is taking place in a “Living Lab” ecosystem in the Bushbuck Ridge area in the Mpumalanga Province (Smit & Venter, 2009).

- **Developments**

The requirements analysis confirmed that there was a need (Smit & Venter, 2009):

- For improved patient record keeping, to enhance the collection and quality of essential data for the DHIS.

- To improve the clinical management of patients suffering from chronic ailments through easy access to previous medical history and treatment guidelines/algorithms.
- To improve referral communication between facilities.

This work involved several discussions of issues and problems with nurses, administrative staff, doctors, provincial government officials, academic researchers and local community leaders. This resulted in three community health centres (clinics) in the Bushbuck Ridge area being selected to participate in the project. These clinics are Agincourt CHC, Xanthia PHC and Thokozani PHC. Based on the requirements stated, the following modules were subsequently selected to be developed (Smit & Venter, 2009):

- Patient administration.
- Clinical management of chronically ill patients focusing on hypertension, diabetes, TB and HIV/AIDS.
- Drug inventory management.
- Clinic administration management – financial and operational data.
- DHIS reporting on essential data set.

- **Hardware Infrastructure**

Figure 8 below illustrates the hardware infrastructure at the clinics, with each clinic, having its own database server allowing it to function autonomously. In addition, a central district server that synchronizes data between clinics via a low bandwidth GPRS connection from the normal GSM cellular network is also illustrated. This figure also shows that in these clinics there is also a wireless local area network that allows nurses to move laptops to where they are required (Smit & Venter, 2009).

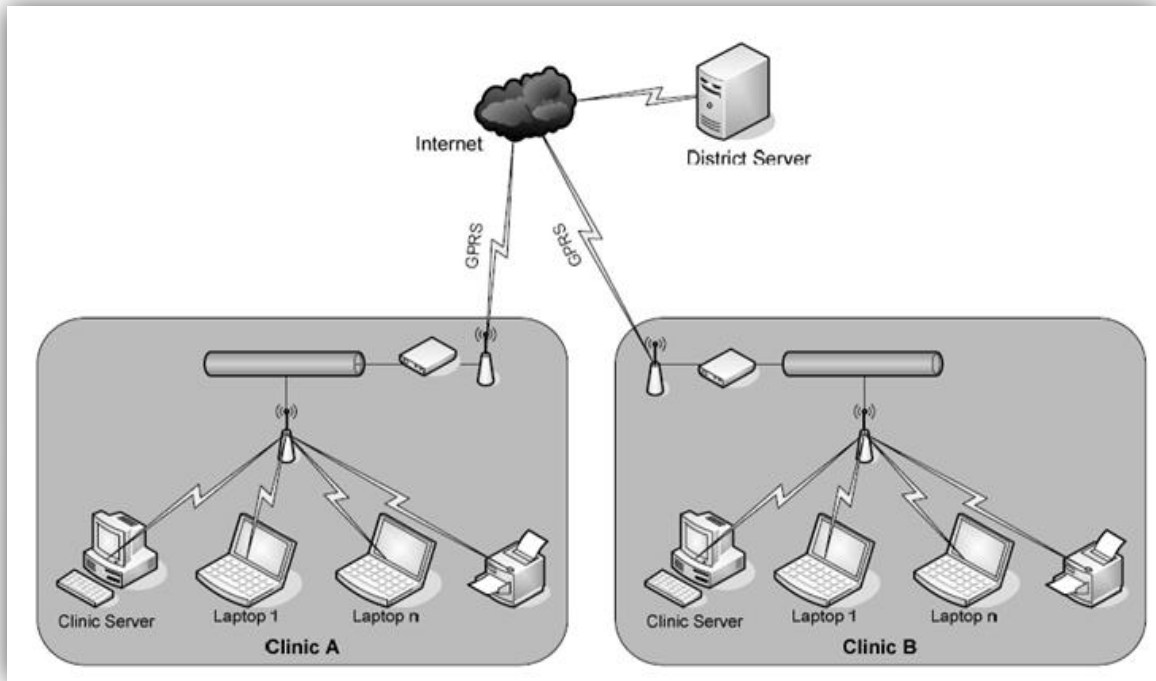


Figure 8: Project Infrastructure (Smit & Venter, 2009).

2.8 Summary

This chapter initially discussed the importance of ICT4D in developing countries. It then explained the research context and stated some of the projects that have been carried out in the past years. The different methods for delivering health knowledge in marginalized communities were discussed. This chapter finally discussed the concept of e-Health, the importance of semantic web and work that has been carried out in relation to this research. The next chapter discusses the system requirements of the semantic web-based SLL e-Health portal.

CHAPTER

THREE

System requirements

3 Chapter Three: System Requirements

This chapter discusses the system requirements of the semantic web-based SLL e-Health portal. It gives a description of both functional and non-functional system requirements. As part of the functional system requirements this chapter also discusses the use-case scenarios of the system.

3.1 Functional System Requirements

This section discusses the functional requirements based on the users' needs as specified by results from system requirements and specification. The interviews conducted in the community, as part of requirements analyses and specifications of this research provided insight to the different user needs.

3.1.1 The Nurses

The first people that were interviewed were the local nurses (i.e., nurses in Msendo and Nqabara clinic). The nurses' interviews indicated that they would like to have a system that satisfies the following functional needs:

- **Need to communicate with surrounding clinics.**

In these clinics there were phones that were installed but now they are no longer working, and the clinic nurses used to rely on these phones to communicate with other clinics when necessary. For example, in cases where there is a certain treatment that is not available at the clinic, they normally phone the clinics in other villages to find out if there is someone who can treat a patient using their cell phones. Fortunately enough, there are two projects under the umbrella of the SLL project that deal with communication methods. These are briefly described in subsection 2.3.6 in the previous chapter (User Driven Telephony Services and Services for Personal Communication).

- **Need to share information between the nurses and community health workers.**

The local clinics also hold workshops once a month to share information between each other. These workshops involve community health workers who can become part of the clinic. Since these workshops are only held once a month a more efficient system is needed so that they are able to share information more than once a month.

- **Need to disseminate information around the community**

Apart from sharing information with each other (clinics), there is also a need to disseminate the information amongst the community. They accomplish this through community meetings. There are committee members who link the clinic with the community by calling general meetings. There are also community health workers in the villages that visit the clinic once a week, and disseminate current and new health information. The need for a system that will work with the above mentioned methods is evident in this community.

Figure 9 below illustrates a use-case diagram that shows actions that can be performed by a user registered as a nurse in the system in trying to accommodate nurses' needs. A user registered as a nurse in the system can be a nurse that works in the community of Dwesa or outside Dwesa. A user registered as a nurse can disseminate health information to the system users. This system also allows these kinds of users to read health information added to the database by the nurses and to browse different content of the coded medical ontology (discussed in the next chapter). In addition, a nurse can also add indigenous knowledge into the local knowledge repository and read knowledge added by other system users. The system also allows nurses to share information online with each other.

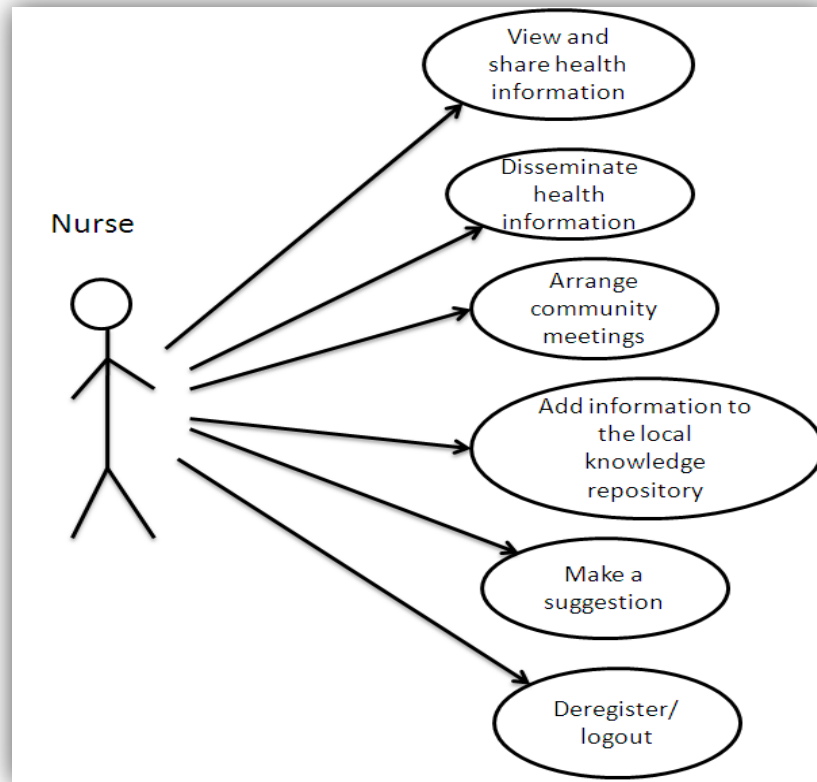


Figure 9: Nurses use-case diagram

3.1.2 Community members and students

Community members and students indicated that they would like to have a system that will:

- Facilitate health knowledge delivery.
- Facilitate indigenous knowledge sharing between them.
- Give them access to traditional ways of treating ailments.

Figure 10 below illustrates a use-case diagram that shows actions that can be performed by a user registered as a community member (normal user of the system) in accessing the content they requested. A normal user of the system can be a registered community member, student, teacher or anyone who is registered and has access to the system. A normal user cannot manage the system and cannot add health information to the health

information database. Normal users can read health information added to the database by the nurses and browse the content of the coded medical ontology (discussed in the next chapter). Normal users can also add indigenous knowledge into the local knowledge repository and read knowledge added by other system users. This system also allows normal users to view meetings and give them access to the suggestion box.

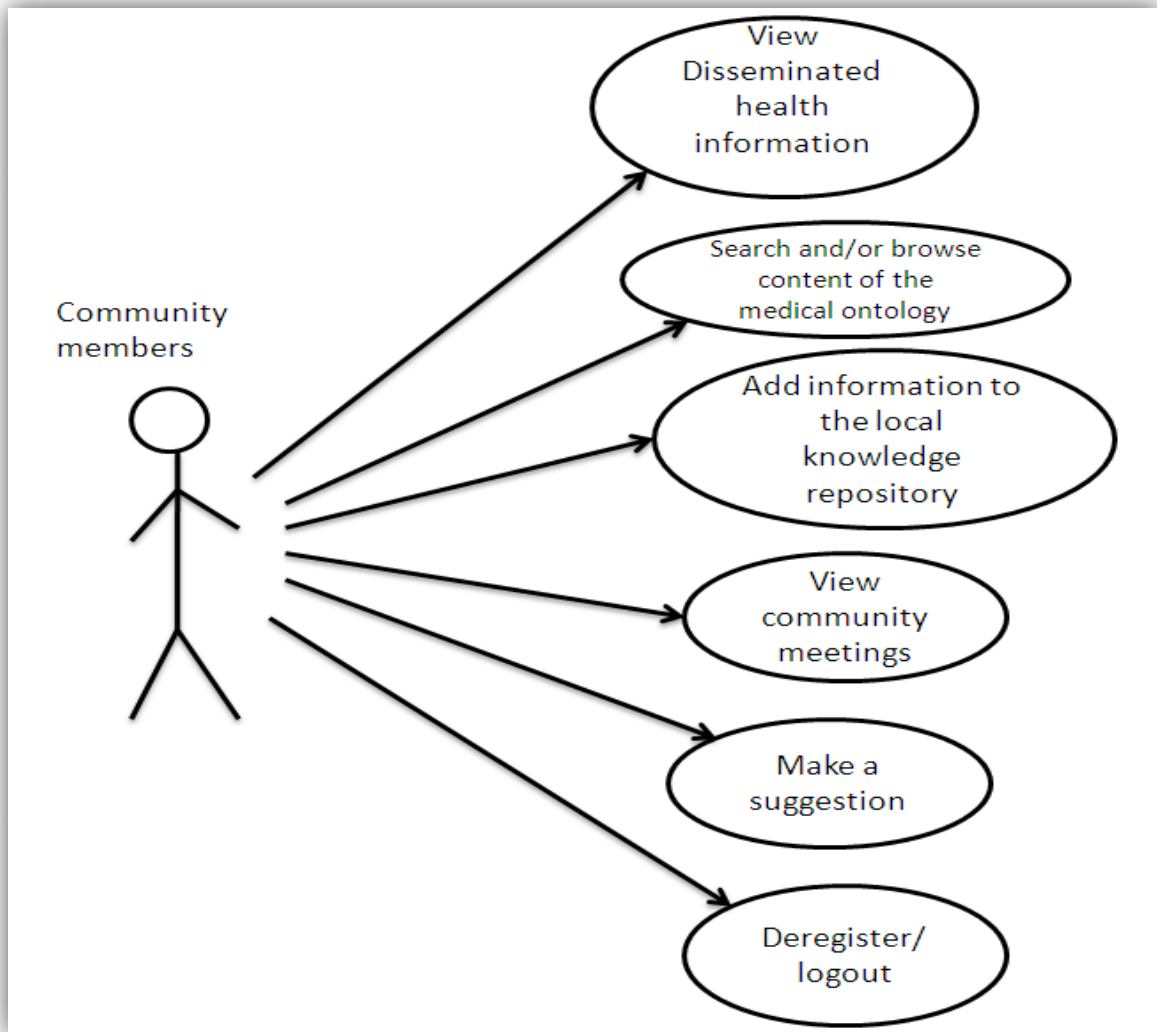


Figure 10: Community members use-case diagram

3.1.3 System Management and Accommodation of Unregistered users

In managing the system, a system administrator interface was created. Figure 11 below illustrates some of the actions that can be performed by an administrator on the system. This figure shows that this kind of user can manage community members and nurses that make use of this system.

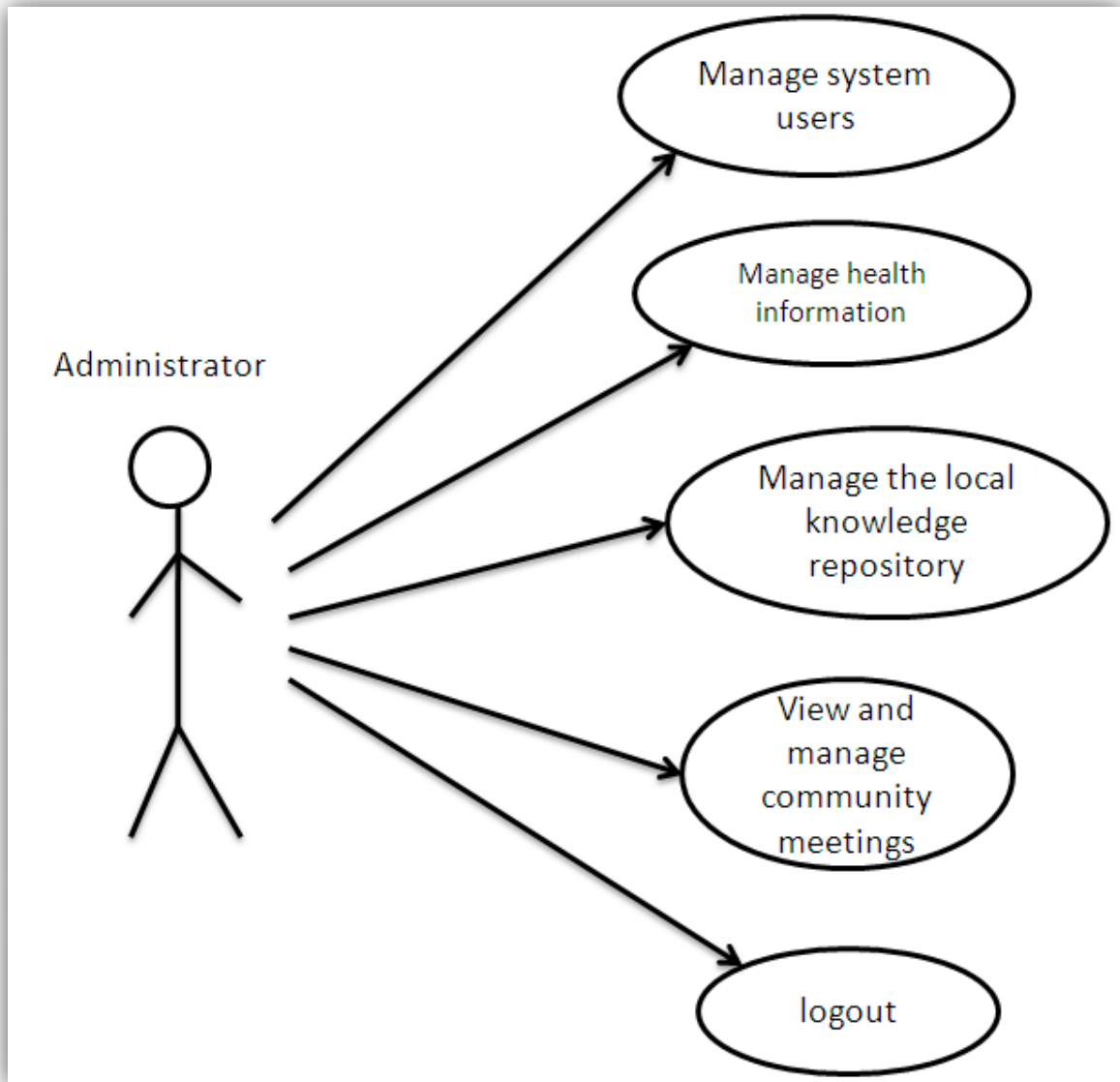


Figure 11: Administrators use-case diagram

In addition, this user is also privileged to manage health information shared and disseminated by the nurses as well as the local knowledge repository. This system then finally, allows this kind of a user to the interface that is meant for community members.

Figure 12 below illustrates some of the actions that can be performed by an unregistered user in this system. This system allows unregistered users to read health information added to the database by the nurses. The system also allows these users to make suggestions and to view called meetings.

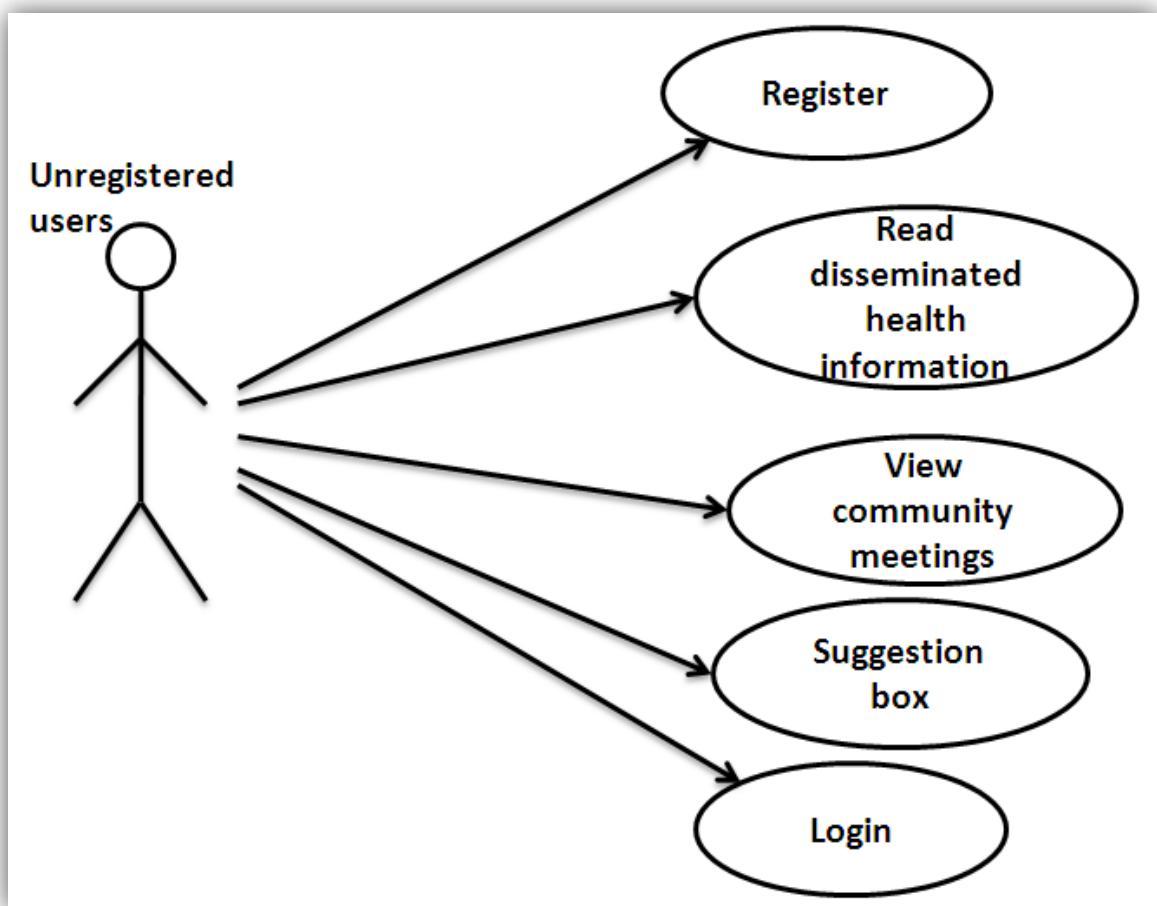


Figure 12: Unregistered users use-case diagram

3.2 Non-functional Requirements

The results from requirements analyses also confirmed that the community needs a system that has the following non-functional requirements.

3.2.1 Compatible with the ICT Infrastructure

Compatibility by definition is the ability of software to work well or communicate with each other without complications. The HTTP server in Dwesa is located in Mpume J P S, and this server is running on a Linux platform. The PCs connected to this server are also using a Linux Operating System. In developing the system the environment that the system is going to run on has to be taken into account to avoid incompatibility.

3.2.2 Affordable To the Community

The people of this community depends primarily on pensions, grants, remittances, livestock production, local resource utilization, cultivation and limited tourist-based jobs, etc,(Timmermans, 2004). This clearly indicates that this community cannot pay for an expensive system or software. As a solution to this, free or open source software was used in developing the system.

3.2.3 Simple and Intuitive

Taking into account the level of literacy in this community one can tell that they need a system that is user friendly, a straight forward system that is not going to need a manual in order for the community to engage with it.

3.3 Summary

This chapter discussed the system requirements of the semantic web-based SLL e-Health portal. It gave a description of both functional and non-functional system requirements. As part of the functional system requirements this chapter also discussed the use-case diagrams of the system users. The next chapter will discuss the design of the system.

CHAPTER

FOUR

Design of the System

4 Chapter Four: Design of the System

The previous chapter was focussing on the system requirements of the semantic web-based SLL e-Health portal. It provided a description of both functional and non-functional system requirements. This chapter will discuss the design of the SLL project e-Health Portal. This chapter begins by providing an introduction to the SLL e-Health system architecture. It then discusses different ways in which the technologies described in the previous chapter were used.

4.1 System Architecture

Figure 13 illustrates the system architecture of the SLL e-Health portal that was developed by this research. This figure shows the architecture that has a system back-end and a front-end.

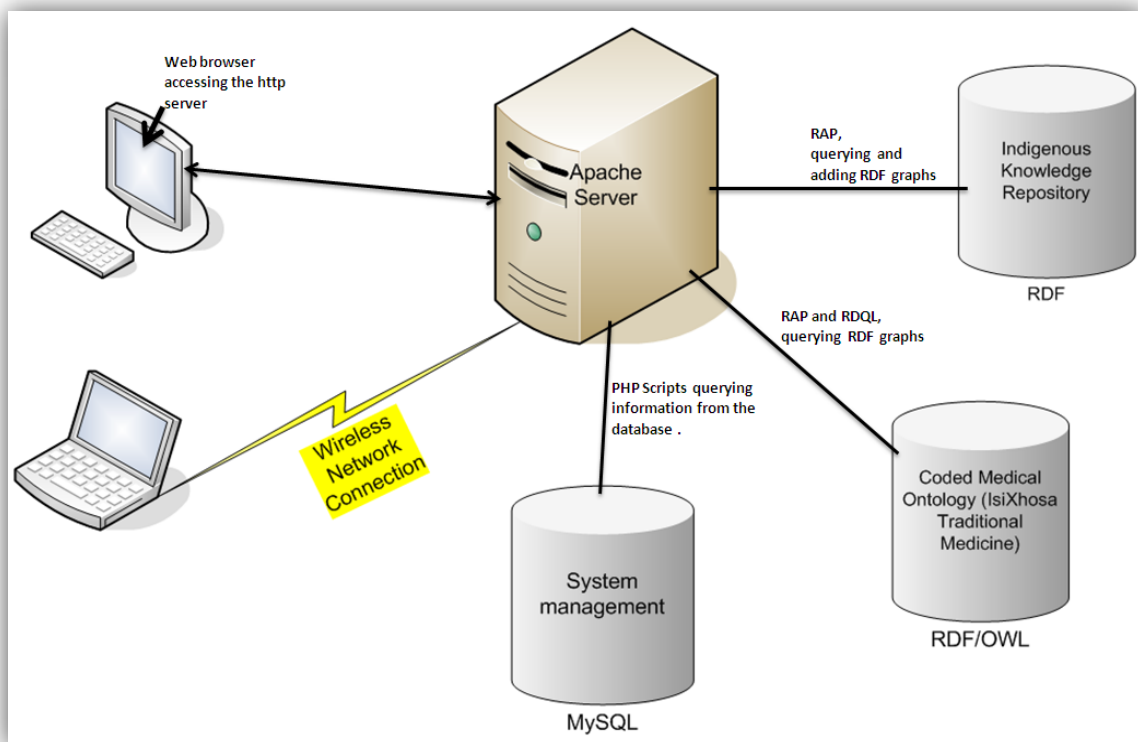


Figure 13: SLL e-Health system architecture

The back-end of the system refers to the management and administration of a portal as it allows control over the system from updating to maintenance whereas the front-end refers to the interface that directly interacts with the user.

4.2 Back-end of the SLL e-Health

“The purpose of the system back-end is to support front-end services and allow users who interact with applications on the front-end system to make requests on the back-end system” (Scott, 2010). In order to support the front-end services the SLL e-Health portal has the back-end system that is composed of a server (apache) and three different MySQL databases. The server is responsible for storing and serving of the PHP files stored in it. The three different databases are responsible for storing or managing different kinds of information as MySQL is a relational database management system.

4.2.1 Coded Medical Ontology

The database labelled *Coded Medical ontology* illustrated in Figure 13 represents a repository of knowledge that contains isiXhosa traditional medicine. The information stored in this database is in the form of ontology RDF/OWL statements. This research made use of Protégé in generating the RDF/OWL statements stored in the database. Protégé is a platform independent java application that is used for developing OWL Ontologies (Horridge, 2009).

The domain of knowledge in the coded medical ontology is divided into several classes of concepts that offer a clear distinction between different kinds of traditional medicine and ailments cured by the medicine. Protégé OWL classes are seen as sets that contain certain individuals (Horridge, 2009). In the developed ontology there are two different major classes, one that contains subclasses of medicine and one for ailments cured by the medicine covered. The individual instances of information in these classes precisely meet the requirements for membership of each class.

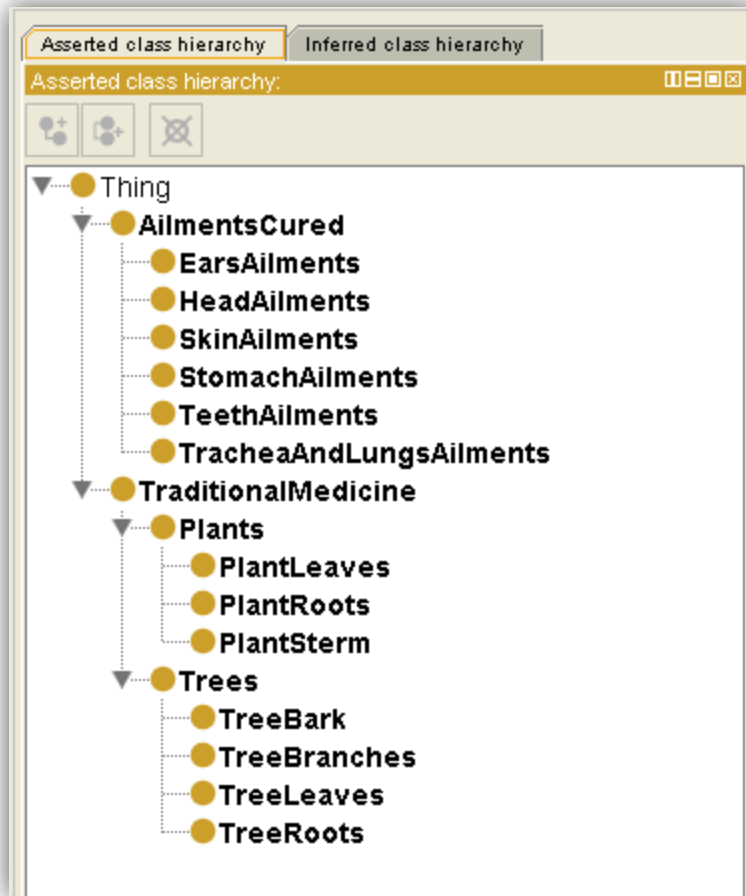


Figure 14: Classes and subclasses of the developed medical ontology

Figure 14 illustrates classes of the developed medical ontology. In this ontology there are two classes, *AilmentsCured* and *TraditionalMedicine*. These two classes have several subclasses that further classify the domain, as illustrated in Figure 14. Logically the contents or individuals that are contained in the *TraditionalMedicine* class cure those contained in *AilmentsCured* class and vice versa. To define the relationship between the contents of these classes object properties were used. As illustrated in Figure 15 below, the developed medical ontology has two important object properties. Their main purpose is to define the relationship between medicine and ailments.

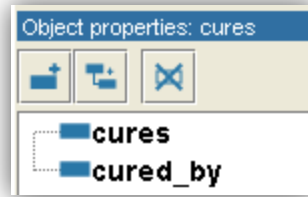


Figure 15: Object properties of the developed ontology

For example, *Umhlonyane* (Wormwood) is used for curing *Ukhohlokhohlo* (Cough) as illustrated in Figure 16 (Individuals and Property assertions column).

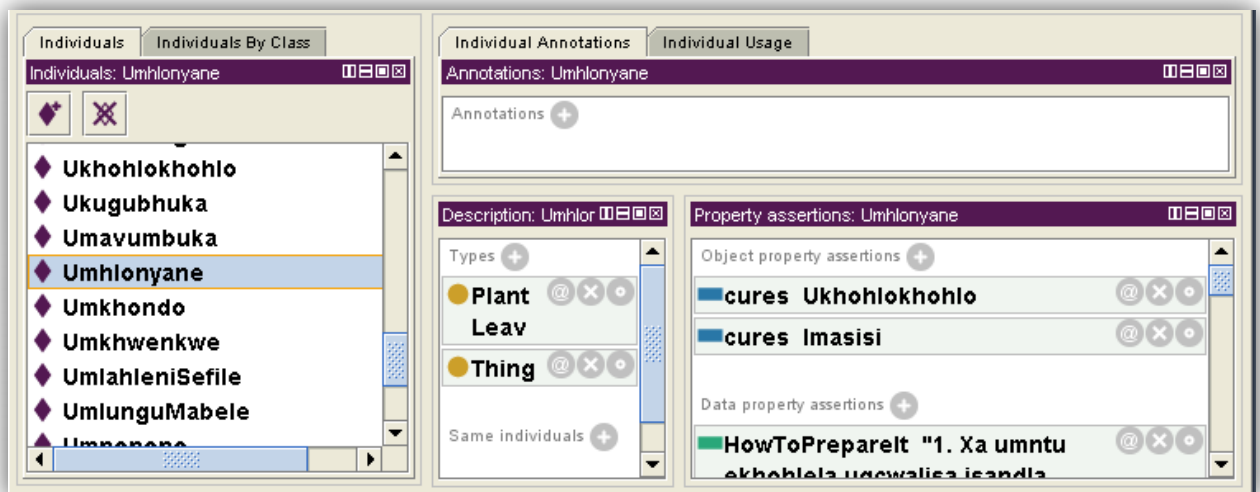


Figure 16: Relationship between individuals

The details about individual are specified using Data property assertions. Figure 17 illustrates all the data properties that were created in the development of the ontology. Each instance in the ontology has its own combination of data properties describing it. The data properties of the medicine are the name of medication, description, useful part, how to prepare it, dosage, storage, area found and transplantability. The ones for ailments

are the name of ailment and its symptoms. Protégé generates (saves statements in) an RDF/OWL file upon completion of the ontology development.

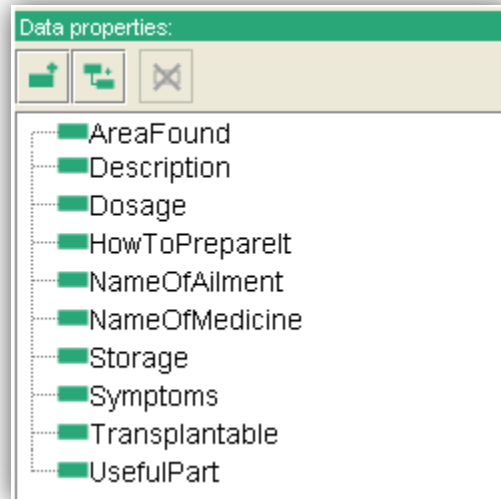


Figure 17: Data properties of the developed ontology

4.2.2 Local Knowledge Repository

The database labelled *Indigenous Knowledge Repository* illustrated in Figure 13 represents a repository of knowledge that contains information about local ways of treating ailments (indigenous health knowledge). This database stores information collected by the web interface from users of the system. RAP is used for collecting information from users and generating RDF graphs from the collected information and then stores the graphs in a persistent storage. The database *Indigenous Knowledge Repository* (persistent storage for created RDF graphs) contains the tables that are illustrated in Figure 18 below. These tables are generated by RAP DbStore when it executes the PHP instruction that creates tables.

| Tables_in_indigenousKnowledge |
|-------------------------------|
| dataset_model |
| datasets |
| models |
| namespaces |
| statements |

Figure 18: Database tables in the indigenousKnowledge database

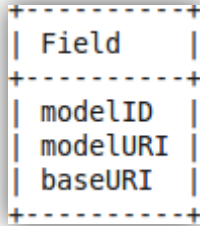
The information that is collected from the users through the developed web interface consists of the name of medication, the area that it is found, an accurate description of the medicine, the useful part of it, directions on how to use it, dosage, information on whether the medicine can be planted at home, information on the ailments that this medicine cures. Figure 19 below shows the statements table which serves as a permanent storage of triplets generated by RAP using the information collected by the web interface in developing RDF graphs.

| Field |
|------------|
| modelID |
| subject |
| predicate |
| object |
| l_language |
| l_datatype |
| subject_is |
| object_is |

Figure 19: Statements table

The RDF graphs are stored in the form of models with a unique identifier that is used for identifying the model stored, i.e. modelURI and modelID. This information is stored in a different table called the *models* table shown below (Figure 20). In addition to these

tables, a MySQL database table that collects the username and name of medicine each time a user adds information to the local knowledge repository was created.



The diagram shows a rectangular box with a dashed border and small crosshair symbols at the corners. Inside the box, the text is organized into four rows, each starting with a vertical bar on the left side. The first row contains the word 'Field'. The second row contains 'modelID'. The third row contains 'modelURI'. The fourth row contains 'baseURI'.

| |
|----------|
| Field |
| modelID |
| modelURI |
| baseURI |

Figure 20: Models table

4.2.3 System Management

The database labelled *System Management* illustrated in Figure 13 represents a MySQL database that is responsible for managing the users of this system. In addition to the management of this system the database also plays an important role in knowledge sharing between health workers and the dissemination of information amongst community members.

4.2.3.1 Knowledge Sharing Between Health Workers and the Dissemination of Information Amongst Community Members

The developed MySQL database (System management) contains different tables that are meant for storing different information. Figure 21 shows all the MySQL tables that are contained in this database.

| Tables_in_ehealthdatabase |
|----------------------------|
| Administrators |
| LocalKnowledgeParticipants |
| RegistrationTable |
| health_awarenes_knowledge |
| meetings |
| shared_knowledge |
| suggestions |

Figure 21: System management tables

- **The health_awarenes_knowledge Table**

This table contains health information that the nurses would like to disseminate to the community. The information stored in this table is available to all system users who want to read it. Figure 22 below illustrates a database table that has five fields. These fields contain different information:

- Username: The username identifies the source of information or represents the person that inserted the information. This username can later be used by system users when they want to know more information, for example the username can be used when one wants to retrieve an email address of a specific nurse.
- title: The title of the information listed is stored in this field. This system sends an email to users when there is new information to notify them about it, the title is also used as the subject of those emails.
- content: This field serves as storage for the actual information that the health workers want to disseminate in the community.
- summary: This field contains the summary of the content. The summary is the one that will be passed around with emails to give users an idea of what the content is all about.

- date: This field will contain the date of the day that information was disseminated.

| |
|----------|
| Field |
| Username |
| title |
| content |
| summary |
| date |

Figure 22: Health information table

- **The shared_knowledge Table**

This table will contain health information that the nurses would like to share among themselves and health community workers. The information stored in this table is accessible to users who are registered as nurses. Figure 23 below illustrates a database table that has five fields. These fields contain different information:

- title: The title of information is stored in this field. As this system sends an email to users registered as nurses when there is new information shared to notify them about it, the title is also used as subject of those emails.
- content: This field serves as storage of the actual information that the users registered as nurses want to share.
- summary: This field contains the summary of the content. The summary is the one that will be passed around with emails to give users registered as nurses an idea of what the content is all about.
- date: This field will contain the date of the day on which the information was shared.

| Field |
|----------|
| Username |
| title |
| content |
| summary |
| date |

Figure 23: Health knowledge sharing table

- **The Meetings Table**

As part of these tables we also created an additional table that allows users registered as nurses to post information about meetings. Figure 24 illustrated below shows a table that is meant for capturing information about called meetings. This table has five fields, i.e. one for username of the nurse that is submitting the information, agenda of the meeting, date, time and the venue.

| Field |
|----------|
| username |
| agenda |
| date |
| time |
| venue |

Figure 24: Meetings table

4.2.3.2 The System Users Management

The developed system uses a pre-registration database table to grant users access to the content stored in it. Figure 25 illustrates a pre-registration table that keeps personal information of users of this system.

| Field |
|---------------------|
| Title |
| FirstName |
| Surname |
| DateOfBirth |
| Gender |
| WorkPlaceName |
| Occupation |
| PostalAddress |
| WorkPlaceAddress |
| PhysicalAddress |
| EmailAddress |
| WorkTelephoneNumber |
| CellNumber |
| SecretQuestion |
| Answer |
| Username |
| Password |
| Role |

Figure 25: Registration table

As system users perform different tasks/roles in the facilitation of sharing and delivering knowledge in this system. The system makes use of Role (see Figure 25) to manage the actions that can be performed by each user of the system. When an administrator approves that a user is a nurse the content in that field is changed.

4.3 Summary

This chapter discussed the design of the developed system focusing primarily on the components that are sitting on the system back-end. This discussion included the design of the developed coded medical ontology, design of the indigenous knowledge repository and health information storage. In addition, it looked into the user management of this system. The next chapter will focus on the implementation of the system.

CHAPTER

FIVE

Implementation of the
System

5 Chapter Five: Implementation and System Testing

This previous chapter discussed the design of the developed system by focusing on the components that are sitting on the system back-end. This chapter will discuss the implementation of the coded medical ontology, indigenous knowledge repository and health information storage. Moreover this chapter will also be discussing the management and presentation of the information stored in the back-end of this system. Finally, it will discuss the testing and evaluation of the system.

5.1 Coded Medical Ontology

The information that is stored in the generated RDF/OWL file (see 4.2.1, last paragraph) needs to be made available to system users and that is where the persistent storage of RAP comes into play. To make use of a persistent storage there are processes that need to be carried out. These processes are the uploading and querying of RDF graphs.

5.1.1 Uploading the RDF/OWL Generated File

The process of uploading generated RDF/OWL file contents involves the generation of a memory model and uploading or storing the generated memory model in a database. The memory model is a temporal storage that stores RDF statements in an array in the system memory (Westphal & Bizer, 2004). With storing statements in the memory model there is one big disadvantage, after finishing the execution of a PHP script, all models created and manipulated would be lost, hence storing model in a database was considered (Westphal & Bizer, 2004; Oldakowski *et al*, 2005). “Storing models in a database not only saves main memory, but moreover allows quick access to RDF data by using the internal indexing and query optimization capabilities of the database” (Oldakowski *et al*, 2005: 5).

RAP provides system developers with a user interface that allows users to easily store RDF statements in database storage. In addition to that it is also possible to create a code with PHP that can upload statements to the database with RAP. Listing 1 shown below illustrates instructions that can be used in storing the RDF file contents in the persistent storage.

```

$mysql_database = ModelFactory::getDbStore('mysql', 'localhost', 'medical_ontology', 'bulumko', 'sajbbz');
$mysql_database->createTables('mysql');
$memModel = ModelFactory::getDefaultModel();
$memModel->load("isiXhosaTraditionalMedicine.rdf");
$modelURI = "http://www.dzweza.com/medical_ontology";
$mysql_database->putModel($memModel, $modelURI);

```

Listing 1: Uploading RDF file to a database storage

The first instruction in Listing 1 creates a database connection, it passes the parameters of the database driver, host name, name of the database, username and password. The second instruction calls a method that creates the appropriate MySQL tables (illustrated in Figure 18) as it is always necessary to create these tables when using the database persistence for the first time (Westphal & Bizer, 2004). The third instruction creates a default memory. The created model serves the purpose of containing the content (statements) of information stored in an RDF file temporarily. The sixth instruction stores the memory model created, together with the model URI defined in the fifth instruction as its unique identifier in a MySQL created database.

5.1.2 Querying the RDF Statements Stored

The information stored in a database is stored as sets of triplets (RDF statements) which consist of subject, predicate and object. There are different languages that are used for querying RDF graphs. In this study RDQL was used, which is defined as “a query language for extracting information from RDF graphs” by (Oldakowski *et al*, 2005: 7). The main goal in the implementation of the coded medical ontology was to grant users of the system access to the content stored in it. As the information was added in the ontology as individual instances with datatype properties, the subjects of each individual has:

<http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#>

as part of its subject and the name of either medicine stored or ailment. For example, an individual (Umhlonyane) has:

<http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#Umhlonyane>

as its subject. (<http://www.semanticweb.org/ontologies/2010/1/> is automatically assigned by Protégé and it can be changed).

The information about each individual instance of this ontology, either medicine or ailments is stored as datatype. In accomplishing the querying of content (medicine/ailments) a web interface that allows users to type the name of a medicine or ailment they are interested in was created. Figure 26 below illustrates part of the HTML instructions that creates the form displayed below the black line in the figure.

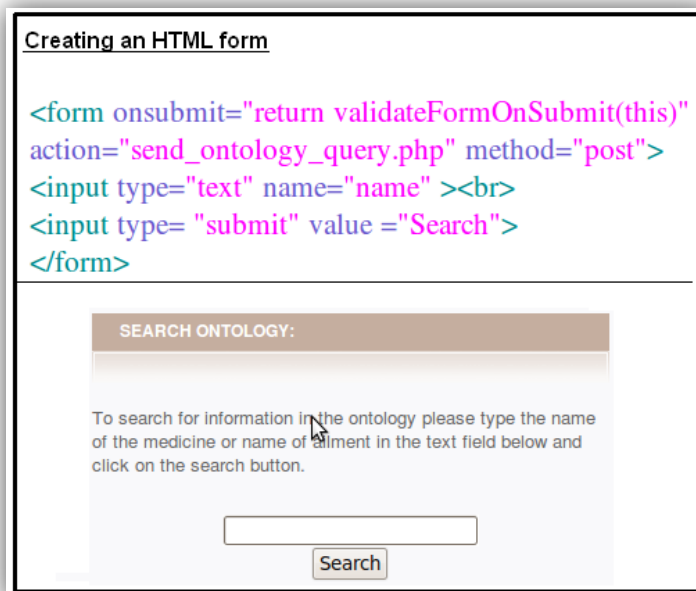


Figure 26: Search Form

When a user clicks on the Search button Java Client Side Script verifies the text field. Basically it checks if the field is not empty, then if it is not empty it sends the typed text

to the server as post method. The PHP script that handles the search first assigns the posted to a variable after creating connections to the database and getting the list of all models stored as shown in Listing 2.

As RDQL searches the ontology with the subject of a statement, a combination of <http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#> with the posted text makes the subject of an individual that is requested by the user as illustrated in Listing 2. With the subject created it is possible to query the data properties of an individual that matches the created subject.

```
$mysql_database = ModelFactory::getDbStore('mysql', 'localhost', 'rap_data', 'bulumko', 'sajbbz');
$list = $mysql_database->listModels();
$modelURI = "www.dwesaontology.org";
$dbmodel = $mysql_database->getModel($modelURI);
$name = $_POST["name"];
if ($name == "")
    $name = $_GET['nam'];
$subject = "http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#";
$fullSubject = $subject.$name;
```

Listing 2: Creating subject to be queried

Listing 3 illustrates a code that is used in this system for querying the data properties of an individual that is a medicine. This Listing first writes an RDF SQL query that queries an ailment with the subject created. It then executes this query and gets an RDQLResultIterator. Then it prints out the result labels as they are indicated in SELECT and the content i.e. data properties of the individual found serialized to string.

```

$query1 = '
SELECT ?NameOfMedicine, ?Description, ?UsedForCuring, ?HowToPrepareIt,
        ?Dosage, ?Storage, ?AreaFound, ?Transplantable, ?UsefulPart
WHERE (<'.$fullSubject.'>,
<http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#NameOfMedicine>,
?NameOfMedicine),
.....Continues.....
(<'.$fullSubject.'>,
<http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#Transplantable>,
?Transplantable);

$rdqIter = $dbmodel->rdqIQueryasIterator($query1);
$result_labels=$rdqIter->getResultLabels();
while ($rdqIter->hasNext()) {
    $curren_result=$rdqIter->next();
    for ($j=0; $j <count($result_labels); $j++){
        $label = $result_labels[$j];
        $remove = "?";
        $replace = "";
        $newlabel = str_replace($remove, $replace, $label);
        echo "<b>" . $newlabel. "</b><br>";
        $result = $curren_result[$result_labels[$j]]->toString();
        echo substr($result, 9, -54). "<br><br> ";
    }
}

```

Listing 3: Querying medicine

There is an additional query that makes use of an object property *cures*. The reason behind creating this second query was to create a way that allows users to see the ailments cured by the matched individual as well. In addition to that, links to information cured by found individual are created as well. This is all accomplished by the code illustrated in Listing 4 below.

```

$query2 = '
SELECT ?cures
WHERE (<.$fullSubject.>,
      <http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#cures>,
      ?cures)';
$rdqIter = $dbmodel->rdqQueryasIterator($query2);
$result_labels=$rdqIter->getResultLabels();
$count = -1;
while ($rdqIter->hasNext()) {
    $curren_result=$rdqIter->next();
    for ($j=0; $j <count($result_labels); $j++){
        $result = $curren_result[$result_labels[$j]]->toString();
        $count = $count+1;
        $array[$count] = substr($result, 87, -2);
    }
};
if ($newlabel != "")
    echo "<b>AILMENTS CURED BY THIS MEDICINE:</b>";
for ($k = 0; $k <= $count; $k++)
    echo "<ul><li><a href=query_ailment.php?nam=". $array[$k]. ">". $array[$k]. "</a></li></ul>";

```

Listing 4: Querying ailments cured by found medicine

Figure 27 illustrates part of the result of Listing 3, with regard to information about how to store the found medicine, area where it is found and so on. At the bottom there is a result of Listing 4, where the heading and links to information about ailments that are cured by this found medicine. When a user follows a link that is displayed there a PHP script that is similar to the one that handles medicine queries is called. This script is the exact opposite of the one that queries medicine, this script queries and displays information about ailments and links that lead to medicine that cures the found ailment. To accomplish this, this PHP script makes use of a GET method in retrieving the variable that belongs to a clicked link as shown in Listing 2.

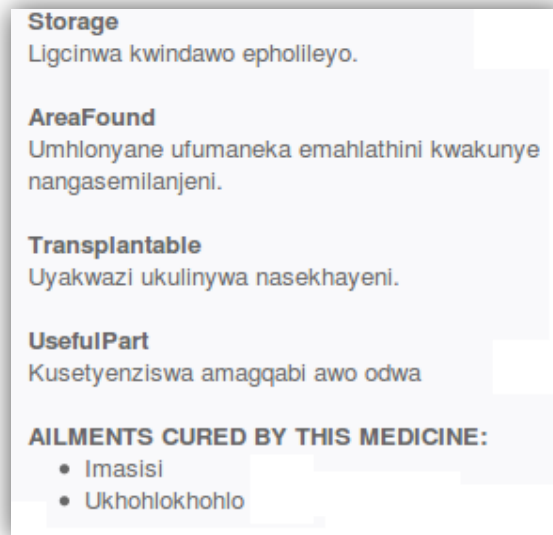


Figure 27: Searched information displayed in a web interface

In a situation where the query sent came with nothing, the script redirects the search to another script that searches for an individual that is an ailment. In cases where the query does not bring any results, an error message is sent to the user advising him/her to follow the link that displays the list of links to all the medication and ailments in the ontology.

To accomplish this, a PHP script that makes use of the RDQL query was created. This script queries all the resources in the ontology with the name of the medicine and returns the name of the medicine found as illustrated in Listing 5. The ailments stored in the ontology are also listed at the bottom of the page.

```
$query1 = '
SELECT *
WHERE (?resource,
      <http://www.semanticweb.org/ontologies/2010/1/isixhosaTraditionalMedicine.rdf#NameOfMedicine>,
      ?NameOfMedicine)';
$rdqlIter = $dbmodel->rdqlQueryasIterator($query1);
$result_labels=$rdqlIter->getResultLabels();
```

Listing 5: Querying all resources in the ontology

The main reason behind listing the content of the ontology was to ease the search mechanism; with everything displayed a user can easily browse the content. To accomplish this Listing 6 prints the name of the resource as a link with a parameter that can be retrieved in the next page and a link displaying the name of the medicine or ailment. When a user clicks on a displayed link, a PHP script that queries the medicine or ailment will execute the script that is used for searching.

```
while ($rdqllter->hasNext()) {
    $current_result=$rdqllter->next();
    echo "<br>";
    echo "<a href=send_ontology_query.php?nam=";
    for ($j=0; $j <count($result_labels); $j++){
        $label = $result_labels[$j];
        $result = $current_result[$result_labels[$j]]->toString();
        if ($label == "?resource"){
            echo substr($result, 87, -2);
            echo ">";
        }
        else{
            echo substr($result, 9, -54);
            echo "</a>";
        }
    }
}
```

Listing 6: Presenting the content of the ontology

5.2 Indigenous Knowledge Repository

In the implementation of the Indigenous Knowledge Repository there are three steps that were followed. These steps are:

- The development of the interface (form) that will allow users to enter information into the database.
- Making use of the collected information in developing RDF statements as the information is stored in the form of an ontology.

- Finally, searching and browsing of the content that is stored.

5.2.1 Development of the Form

The form developed was based on the information that needs to be stored. The information about a medicine that the system collects from users is composed of the following:

- Name of medicine.
- Area in which the medicine is found.
- Description of the medicine.
- Useful part.
- Directions on how to prepare and use the medicine.
- Dosage.
- Storage.
- Information on whether the medicine can be transplanted.
- Name of an ailment or ailments that the medicine cures. (they can be more than one)
- Symptoms of ailment or ailments. (they can be more than one)

Figure 28 illustrates forms that are used for collecting information from a user of this system. The form on the left collects the name of medicine and the number of ailments that the medicine cures. When a user clicks on the next button the name of the medicine is stored along with the username of a user that is inserting the information in a database table for the purpose of identifying users who inserted the information. This information can be useful in cases where a user inserted misleading information intentionally. As there are two fields in this form the second field gets the number of ailments that the medicine to be inserted cures. This number is then used for creating form(s) for inserting information about ailments cured by the medicine as part of the form displayed on the right of Figure 28.

Please fill in the details required by the form below and click on the submit button to add information to the repository:

Name of Medicine:

Number of ailments cured by this medicine:

Please complete the form below and click on the submit button to add information to the repository:

Medicine:

Name of medicine:

Area found:

Description:

Useful part:

How to use it:

Dosage:

Storage:

Transplantable:

Ailment(s):

Ailment 1

Name of ailment:

Symptoms:

Figure 28: Indigenous knowledge form

5.2.2 Capturing of the Indigenous Knowledge

When a user clicks on the submit button on the form illustrated on the right of Figure 28 a PHP script that processes the information executes. This script makes use of RAP classes and creates a Resource Centric Model API (ResModel API). ResModel “represents an RDF graph as a set of resources having properties” (Oldakowski *et al*, 2005: 3). Oldakowski *et al* (2005) also state that ResModel API enables users to “manipulate and navigate through an RDF graph in a much more comfortable way”.

Figure 29 illustrates how ResModel was used in modelling of the indigenous knowledge repository of the developed system.

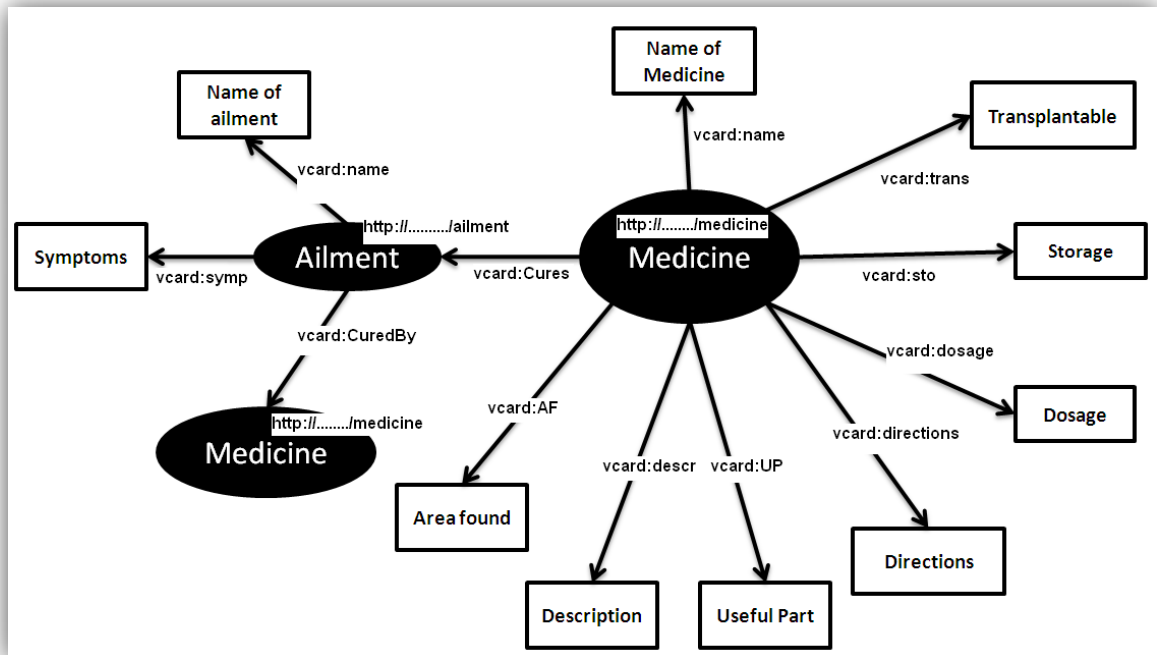


Figure 29: Model design adopted from Westphal & Bizer (2004)

Listing 7 below shows parts of the PHP script that stores indigenous knowledge to the database. The information that comes from the users is used for creating literals because this information is the actual property of the resource. This information is stored in the column of objects in the statements table (explained in Chapter 4, subsection 4.2.2). Line 14 in this segment creates the resource (medicine) making use of the name of the medicine posted and \$URI in line 6. The Listing then creates the properties in line 16. These properties are used to define the relationship between a literals and a resource. Then lines 20 and 21 add all the properties to the resource centric model created in the database.

```

2  $model = ModelFactory::getResModel(DBMODEL, "http://www.dwesa.org/local_knowledge/");
3  $nameofmedicine = $_POST["nameofmedicine"];
4  $cures = $_POST["cures"];
5  .....Continues.....
6  $URI = "http://www.dwesaontology.org/";
7  $medicineURI = $URI.$nameofmedicine;
8  define('VCARD_NS', 'http://www.w3.org/2001/vcard-rdf/3.0#');
9  // Create the Literals
10 $name = $model->createLiteral($nameofmedicine);
11 $cures = $model->createLiteral($cures);
12 .....continues.....
13 // Create the resource
14 $medicine = $model->createResource($medicineURI);
15 // Create the Properties
16 $vcard_name= $model->createProperty(VCARD_NS.'Name');
17 $vcard_cures= $model->createProperty(VCARD_NS.'Cures');
18 .....continues.....
19 // Add the property to the model
20 $medicine->addProperty($vcard_name, $name);
21 $medicine->addProperty($vcard_cures, $cures);
22 .....continues.....

```

Listing 7: Capturing indigenous knowledge

5.3 PHP MySQL Queries

This sub-section focuses on the implementation of the database labelled *System Management* illustrated by Figure 13 in Chapter Four. As this database is meant for managing users, disseminating of health information, setting meetings, sharing of health information etc., different actions on the tables of this database need to be performed. Among the actions that can be performed on a MySQL database Inserting, Deleting, Querying and Updating were considered in implementing this database.

5.3.1 Inserting Information to a Database Table

The main purpose of a database table is to keep records that are stored in it. The records are stored in an already existing database table by making use of the MySQL command called INSERT. This command was used in different tables such as the registration tables, meetings table, knowledge sharing table, health information table and so on. Listing 8 below shows how the INSERT command was used in inserting records in tables

of the developed system. The code displayed below first creates a connection, selects the database and then insert records posted into the meetings table.

```
$connection = mysql_connect("host", "username", "password");
mysql_select_db("ehealthdatabase", $connection);
if (mysql_query("INSERT INTO meetings (
    username,
    agenda,
    date,
    time,
    venue
)
VALUES (
    '$_POST[username]',
    '$_POST[agenda]',
    '$_POST[date]',
    '$_POST[time]',
    '$_POST[venue]'
)"))
    $msg = 1;
else
    $msg = 2;
mysql_close($connection);
```

Listing 8: Inserting records to MySQL tables

5.3.2 Deleting Records Stored in the Tables

As part of managing information there is always a need for deleting records in database tables. The removal/deletion of unwanted information from a MySQL database table is handled by the DELETE command (Vaswani, 2005). This kind of operation is mainly used by registered users for the purpose of de-registering themselves when they no longer want to have accounts on this system. It is also used by administrators for removing old/expired meetings and to deregister users. Listing 9 below illustrates a PHP code that deletes records in a database where username and password are similar to those specified.

```

$connection = mysql_connect("host", "username", "password")
mysql_select_db("ehealthdatabase", $connection);
if(mysql_query("DELETE FROM citizenRegistrationTable
WHERE username = '$_POST[username]'
AND password = '$_POST[pswd]'
")
)
    $msg = 1;
else
    $msg = 2;

```

Listing 9: Deleting records in the database

5.3.3 Retrieving Information Stored in the Database Tables

The information that is stored in a database is stored for different reasons such as safety, easy sharing and so on. In order for system users to access information stored in the database there is a need to retrieve the stored information. The system makes use of a SELECT method in retrieving the stored information. Listing 10 below illustrates a PHP code that queries information from MySQL meetings database table and displays it in a web page.

```

$connection = mysql_connect("host", "username", "password");
mysql_select_db("ehealthdatabase", $connection);
$result = mysql_query("SELECT * FROM meetings");
while ($row = mysql_fetch_array($result)){
    echo "Meeting posted by<b>".$row['username']."</b><br>";
    echo "<b>Agenda:</b>".$row['agenda']."<br>";
    echo "<b>Date:</b>".$row['date']."<br>";
    echo "<b>Time:</b>".$row['time']."<br>";
    echo "<b>Venue:</b>".$row['venue']."<br>";
}
mysql_close($connection);

```

Listing 10: Displaying the content stored in the database tables

5.4 Front End Interface

Figure 30 below illustrates a welcome page interface of the developed web interface. The different users have an interface that looks the same. Access to the content of this system is provided to users by links in the menu. The menu of each user is generated based on the role that a user plays in the system and which is accomplished by making use of PHP Sessions. In arranging the content of each webpage CSS and HTML were used.



Figure 30: Web interface screen shot

The developed web pages of the system have a header at the top of the web page as illustrated in Figure 30. The header is composed of the name of the website and a burner. On the left just below the header there is a menu. The menu displayed in Figure 30 is meant for users who are not registered and it also acts as a welcome page. The menu contains links that allow users to perform actions that are meant for unregistered users.

The content of information that users are interested in is displayed on the right of the website just below the header as illustrated in Figure 30. The forms of this system are managed by Java Script (JS).

5.5 System Testing, Evaluation and Results

The developed system went through a process of system testing and evaluation for the purpose of verifying if the developed system fulfils its intended functional and non-functional requirements as specified in Chapter Three. To accomplish this, the following steps were followed:

- Deployment of the prototype
- A proper introduction of the system to the users
- Evaluation

The first step was the deployment of the prototype in one of schools in the community of Dwesa for the purpose of making it accessible to Dwesa community members for system testing. The prototype was deployed in the Ngwane J. S. S. server (local hosted server) because this school is one of schools that have a proper lab. During the deployment stages of the web application, it was discovered that there were no incompatibility issues regarding software applications as the system was developed on a platform that is similar to the one that the prototype was deployed in.

After the prototype was deployed, community members were called to occupy the computers in the lab. A proper introduction to the system was made and there were no difficulties because community members had a basic understanding of the procedure since there are several web applications similar to this that were previously tested; such as e-Commerce, e-Government and e-Judiciary. In addition, some people who participated attend regular computer literature classes that take place in the schools. As the system was also meant to be used by nurses for sharing knowledge and the dissemination of information, nurses' points of view were needed as well; for this reason they were also asked to attend the system testing.

After the introduction, the users were given some tasks to perform on the system to test if the system meets the functional and non-functional requirements that were specified. Users were given some time to perform the tasks that were given and after that evaluation forms were distributed. The questions in the evaluation form were issued in order to evaluate/ test the system functionality that was proposed (discussed in Chapter Three).

5.5.1 Evaluation Form Feedback

This sub-section discusses the feedback from the evaluation forms regarding those questions that focus on functional requirements and usability testing. It first discusses the feedback that came from questions that were meant for nurses in the system and then discusses feedback from community members.

5.5.1.1 Feedback from the Nurses (Functional Evaluation)

Figure 31 below shows a pie chart based on the feedback gained from 10 nurses who participated in the testing of the system. The question that was answered by the nurses is Question 2 (a) in the questionnaire in Appendix A.

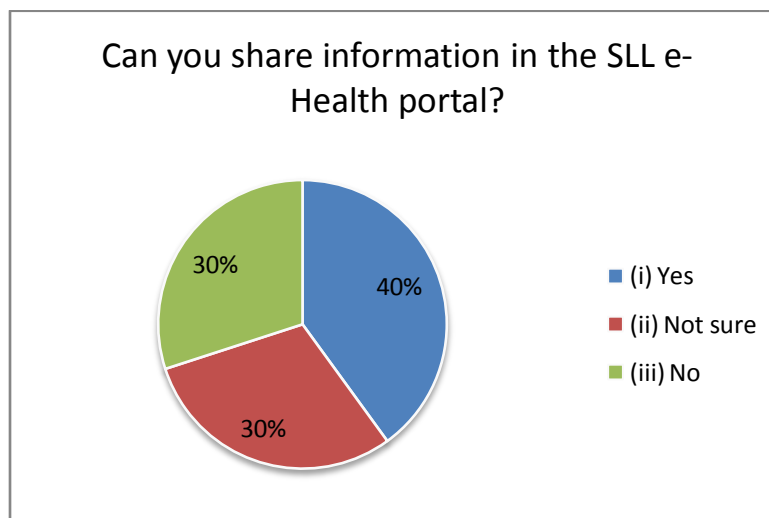


Figure 31: information sharing in the SLL e-Health portal

This question tried to ascertain whether the nurses can share information on the developed system. The results indicated that 4 out of 10 nurses who participated could

share health information on the system, 3 out of 10 had no idea how to do this and the remaining 3 was not sure as illustrated in Figure 31.

The pie chart shown in Figure 32 is constructed from responses to Question 2 (b) in the questionnaire. This question was trying to discover whether the nurses can view and read information that is shared on the system by other nurses. The results shown by this pie chart depicts that 6 out of 10 nurses who participated can read information shared by other nurses in the SLL e-Health portal, 1 had no idea on how to perform this task and the remaining 3 was not sure.

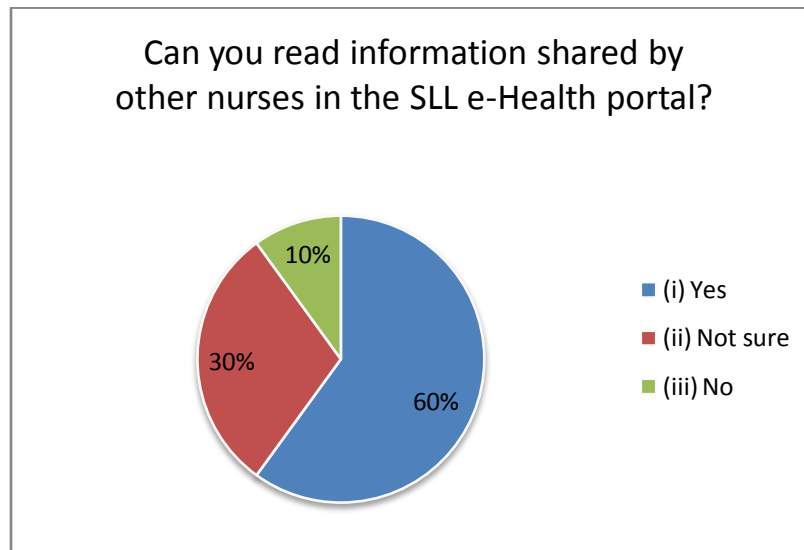


Figure 32: Shared knowledge retrieval

The pie chart in Figure 33 depicts the feedback gained from Question 2 (c) in the questionnaire. This question tried to find out if the nurses could disseminate health awareness information in the SLL e-Health portal for the community members. The chart indicated that 4 out of 10 of the nurses who participated were able to disseminate health awareness information in the SLL e-Health portal, 3 had no idea on how to perform the task and the other 3 was not sure.

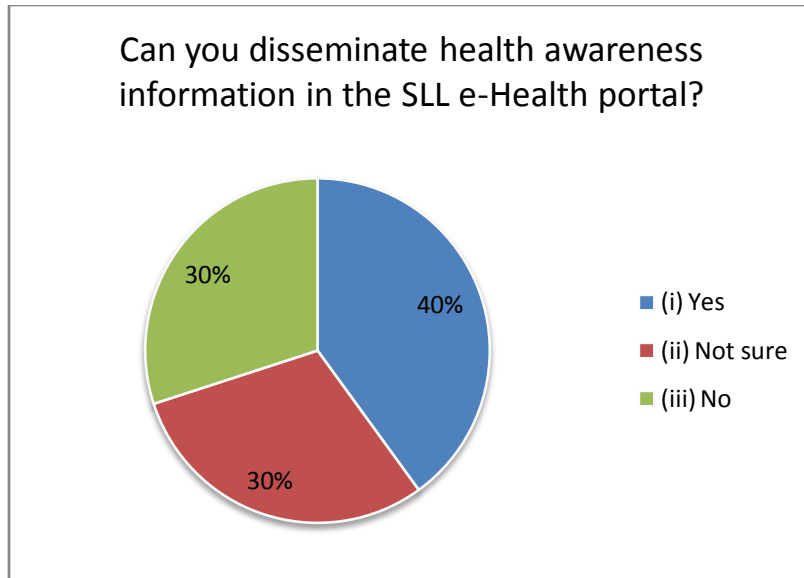


Figure 33: Information dissemination

5.5.1.2 Questions for the Community Members

Question 3 (a) in Appendix A tried to ascertain whether the 20 community members and students who participated can read health awareness information disseminated by the nurses in the SLL e-Health portal after it was introduced to them.

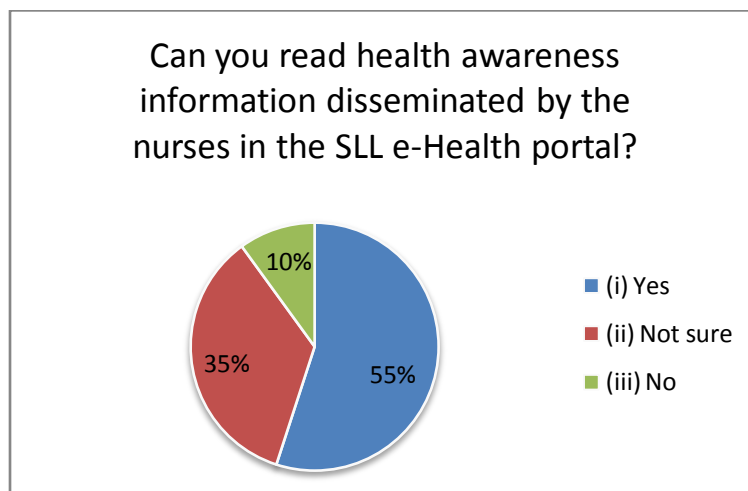


Figure 34: Retrieval of health information by community members

The chart shown in Figure 34 indicated that 55% of the community members and students who participated are able to read the health awareness information disseminated by the nurses in the system, 10% had no idea on how to do this and 35% were not sure.

The pie chart in Figure 35 depicts the results of the feedback to Question 3 (b) in the questionnaire. This question tried to judge whether community members and students are able to search and browse traditional health information stored in the medical ontology of the SLL e-Health portal. This chart indicates that 55% of community members and students who participated are able to search and browse traditional health information stored in the medical ontology of the system, 20% had no idea on how to do this and 25% were not sure.

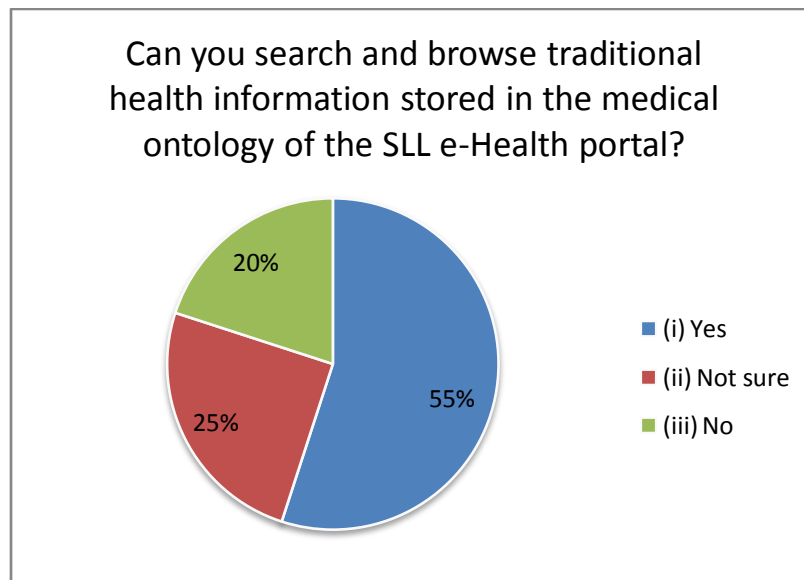


Figure 35: Browsing of the coded medical ontology

The pie chart in Figure 36 is constructed from the responses to Question 3 (c) in the questionnaire. This question tried to find out if community members and students can add indigenous health information to the local knowledge repository of the SLL e-Health portal. The chart (shown in Figure 36) indicates that 45% of the 10 nurses can add indigenous health knowledge to the system, 30% could not perform the task and 25% were not sure.

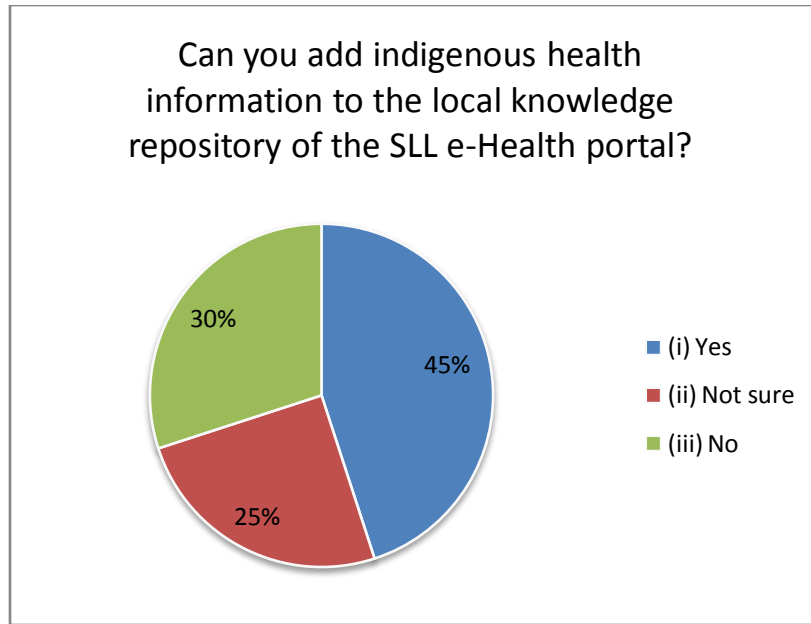


Figure 36: Indigenous knowledge sharing

5.5.1.3 Usability Testing (Section B, in Appendix A)

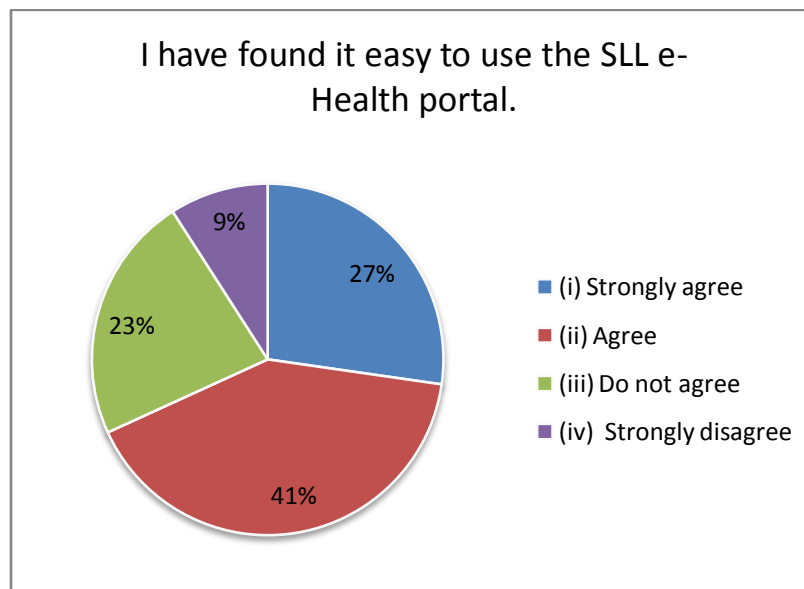


Figure 37: Usability evaluation

Figure 37 illustrates a pie chart that is constructed from the feedback regarding the ease with which the users are able to use the SLL e-Health portal. The feedback from the chart

indicates that 68% of all (22) users who participated in the testing found the system easy to use and 32% of them did not find it easy to use.

Figure 38 below shows a pie chart constructed from the feedback which attempted to find out if users have found it easy to learn the SLL e-Health portal. The feedback from the chart indicates that 59% of all users found the system easy to learn and 41% of them did not find it that way

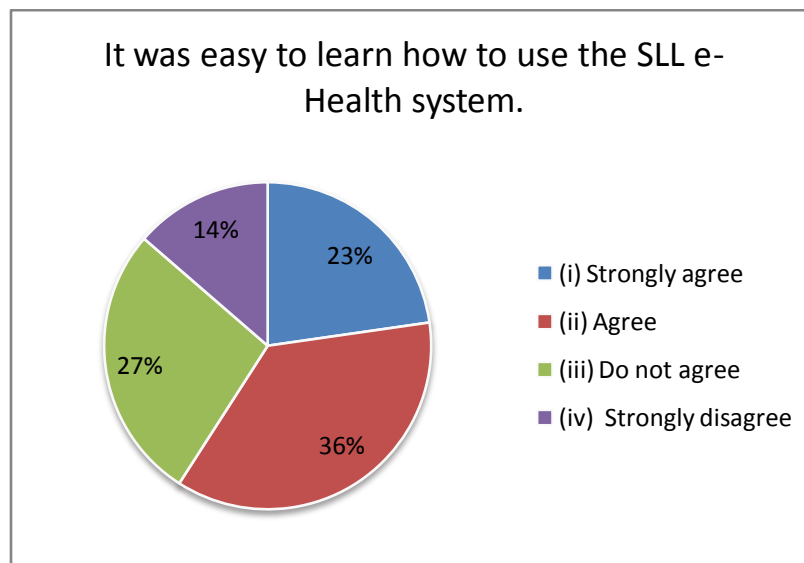


Figure 38: Learnability testing

The other results of the evaluation are included in APPENDIX A.

5.6 Results/Discussion

The evaluation results indicated that the community is happy with the developed system as it represents the transformation of their ideas. The evaluation was focusing on the functionality requirements and the usability of the system. The functionality of the developed system is based on the functional and non-functional requirements that were specified by the community (see Chapter Three).

In addition the results illustrated that the community members (intended system users) are slowly engaging with the technology that is deployed in the community. These results clarify this because a reasonable percentage could perform the tasks that were part of the evaluation and relatively small percentage could not perform certain tasks. The reason for this was discovered by study that was carried in the community in 2009 and 2010. The results indicated that the community feels that the systems developed for them should be localized (translated to their language) (Scott, 2010).

To accommodate these requirements, almost 80% of the system was made to be the preferred language as it is not possible to translate everything to their language without altering the meaning of the content. The effect of this is reflected by the results in the evaluation form.

5.7 Summary

This chapter discussed the implementation of the coded medical ontology, indigenous knowledge repository and health information storage. It also discussed the presentation of the knowledge stored in the back-end of this system. Finally it discussed the results obtained from the testing of the system prototype.

CHAPTER

SIX

Conclusion

6 Chapter Six: Conclusion

The previous chapter discussed the implementation of the system. This chapter concludes the dissertation by summarising the research, and its achievements. As part of that it also discusses the challenges encountered and limitations to this research. Finally, it makes suggestions for future extensions to this project.

6.1 Summary of Research

This research addressed the issue of inadequate health facilities and health knowledge in marginalized communities such as Dwesa. This is resultant of the availability of ICTs in rural communities which has the potential to provide these communities with a number of beneficial solutions to their problems and improve knowledge sharing and information delivery. This research made use of the ICTs deployed in the community of Dwesa (SLL project).

This was accomplished by developing and implementing a semantic web-based e-Health portal as part of the Siyakhula Living Lab (SLL) project. This portal will share and deliver western medical knowledge, traditional knowledge and indigenous knowledge. This research made use of a combination of Free and/or Open Source Software in developing the portal so that it could be made affordable to the community.

Protégé, RAP and RDQL are the semantic tools that were used in the implementation of the coded medical ontology and indigenous knowledge repository. The coded medical ontology stores RDF/OWL graphs created from isiXhosa Traditional medicine information collected from a traditional Doctor. The indigenous knowledge repository keeps RDF graphs of information that is collected by the developed web user interface produced by this research. These RDF graphs are created by RAP resource centric model user interface. In availing the stored information and assisting health workers in the dissemination and sharing of health information the research made use of LAMP architecture.

6.2 Achievements

This research has undertaken an investigation in the form of interviews in the community of Dwesa during the field visits in order to gain an understanding of knowledge sharing dynamics around health information sharing in this community and to perform a requirements elicitation. In addition, this research also carried out a literature review based on e-Health and health information sharing in rural areas across the globe. As part of the literature review, a survey on semantic web was also carried out for the purpose of finding a means as to how it can best be used in the research context.

The knowledge acquired was then utilized in the development and implementation of a semantic web-based e-Health system. The developed system contributes in this community by performing the following tasks in facilitating knowledge sharing and delivery in the community of Dwesa:

- It allows nurses to disseminate information to the community members.
- It allows nurses to share information amongst themselves.
- It provides the community with access to isiXhosa traditional medicine knowledge and allows community members to share indigenous health knowledge as part of the e-Health system.

Finally, this research has managed to carry out evaluation and system testing of the prototype of the developed e-Health system in an attempt to find out if the system meets its requirements. Scientifically speaking, this research managed to make it possible to achieve these above mentioned achievements by making use of combination of computer science technologies. In addition to that contribution, this research has broken a new ground for future researchers to advance the implemented by adding features that are not implemented.

6.3 Challenges and Limitations

As part of the requirements that were specified, the intended system users indicated that they would like to have access to traditional health information. The sources of this

information are traditional doctors or practitioners. Getting this information was challenging because the traditional doctors were incredibly resistant in providing the information. The reason behind this is that they held the belief that the system designer would make use of the information and construct a traditional pharmacy. In addition to this they also feared that the project would expose their secrets which would cause them to lose the value they have.

In the implementation of the system the designers were limited to the use of the DbModel in querying the ontologies because in RAP there is no method that loads the DbModel or memModel into an infModel. RAP only allows developers to load models stored in an RDF/OWL file into an inference model. The only way to accomplish this was to first print the model stored in the database into a file and loads it into an inference model. In addition to this, RAPs “performance cannot compete with other reasoning engines implemented in Java or C” (Oldakowski *et al*, 2005:4). Apart from that, “RAPs inference support works fine with medium sized graphs and relatively small RDFS schema data” (Oldakowski *et al*, 2005:4)

6.4 Future Work

- As an extension to the developed system, it would be important to avail the content of the data layer of this system in an audio interface.
- As the developed system only has two ontologies, a connection to other external medical ontologies would be of great importance.
- Implementation of inference in the developed ontologies.
- The developed system only caters for computer web browsers, the development of a system interface that will also cater for mobile phones is needed as most people in the community have access to these.

6.5 Summary

This chapter concluded the dissertation by providing its summary and achievements. As part of that it also discussed the challenges encountered and limitations to this research. Finally, it made suggestions for future extensions to the research.

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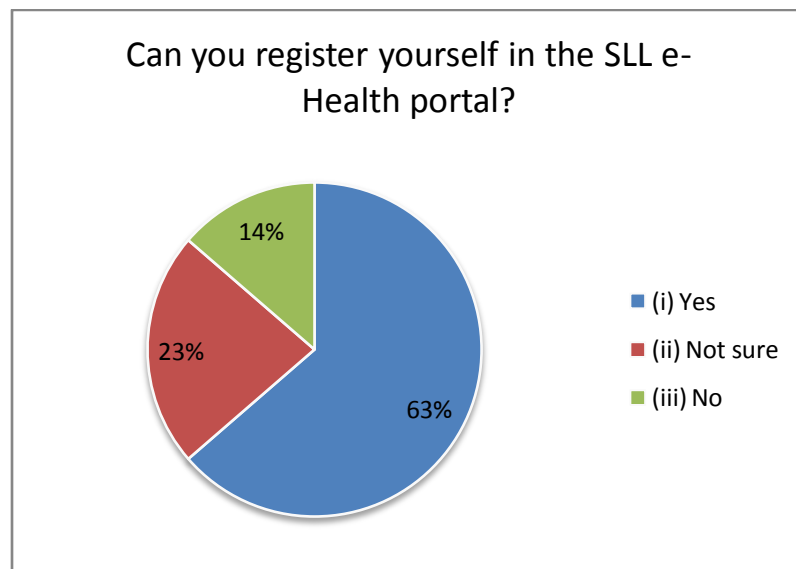
8 APPENDIX A

Questionnaire

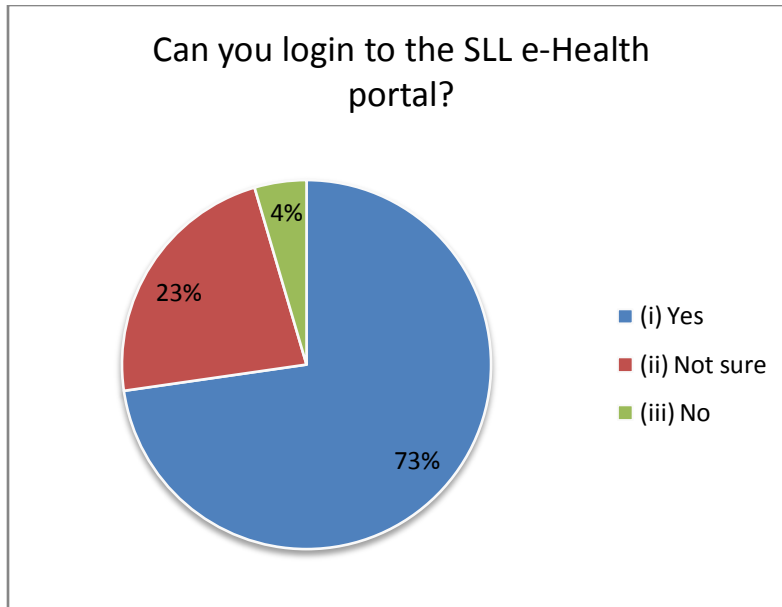
SECTION A: Functional Evaluation

Question 1: General functional evaluation questions

- a) Can you register yourself in the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No

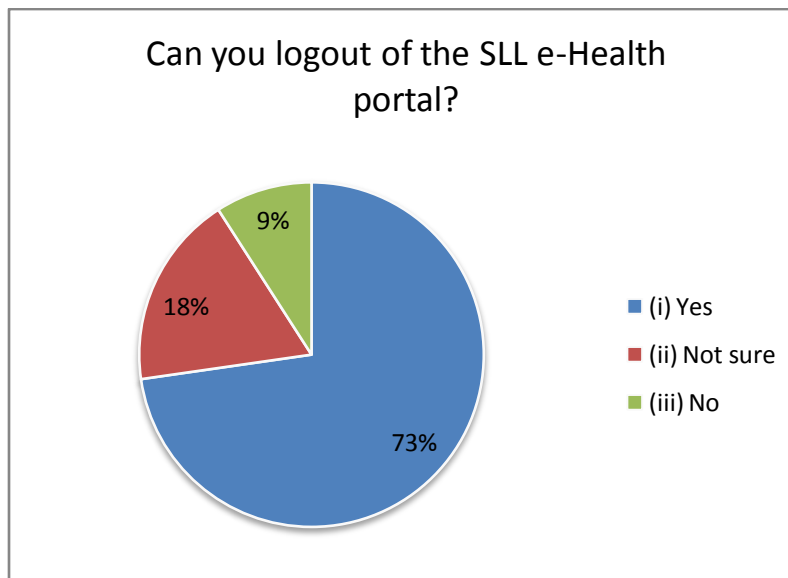


- b) Can you login to the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No



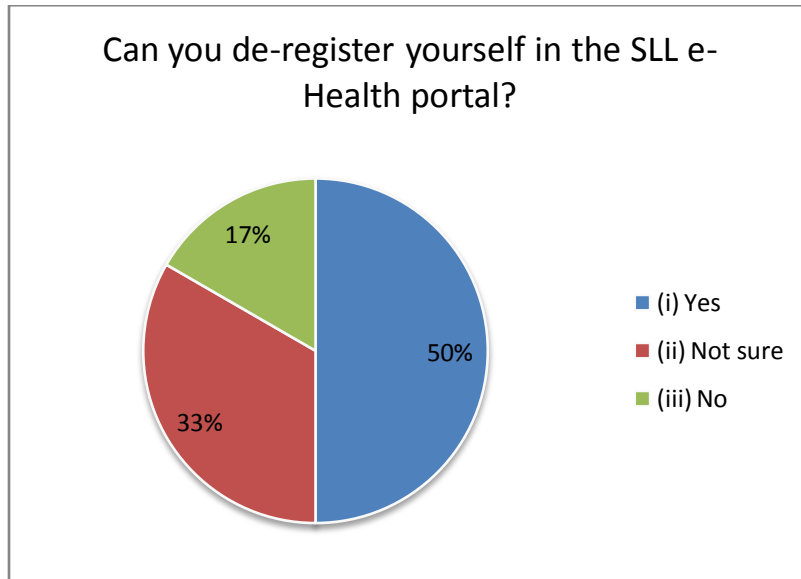
c) Can you logout of the SLL e-Health portal?

- (i) Yes
- (ii) Not sure
- (iii) No



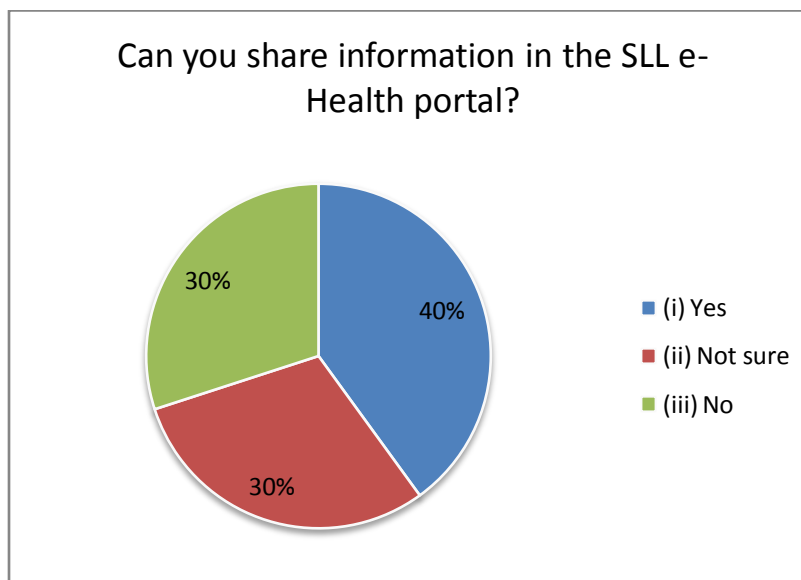
d) Can you de-register yourself in the SLL e-Health portal

- (i) Yes
- (ii) Not sure
- (iii) No

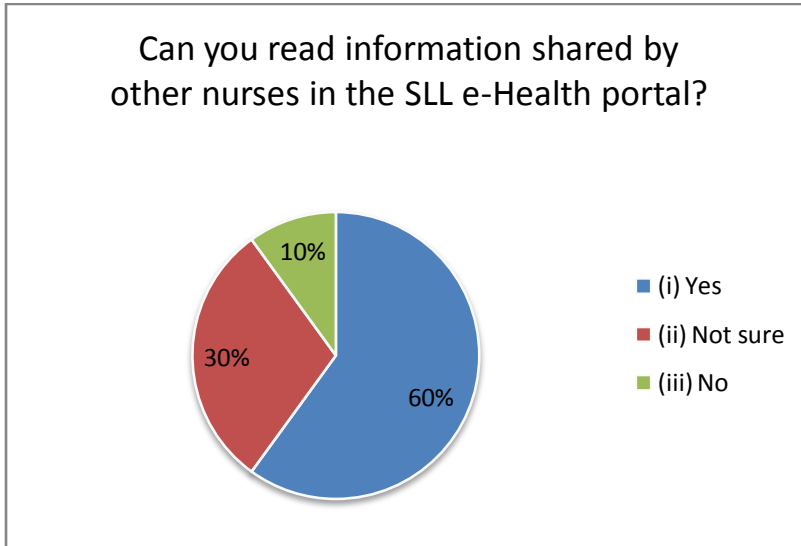


Question 2: Questions for the Nurses

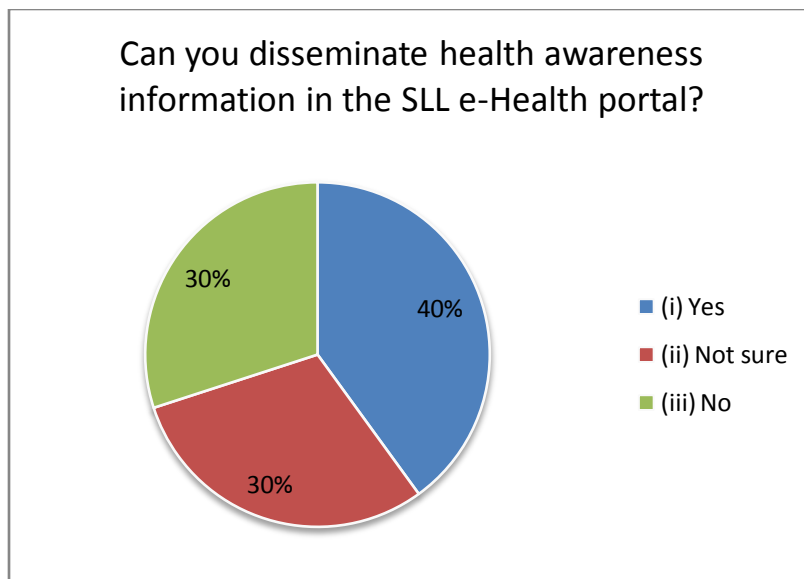
- a) Can you share information in the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No



- b) Can you read information shared by other nurses in the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No



- c) Can you disseminate health awareness information in the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No



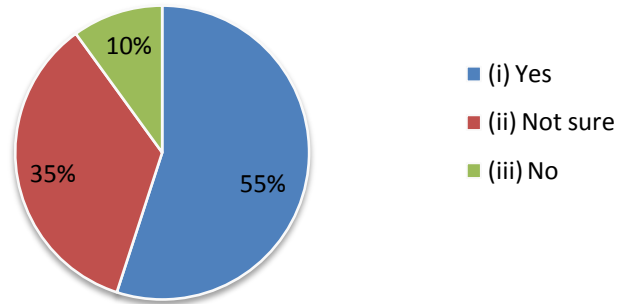
- d) Can you send a message that calls a community health meeting using the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No



Question 3: Questions for the Community members

- a) Can you read health awareness information disseminated by the nurses in the SLL e-Health portal?
- (i) Yes
 - (ii) Not sure
 - (iii) No

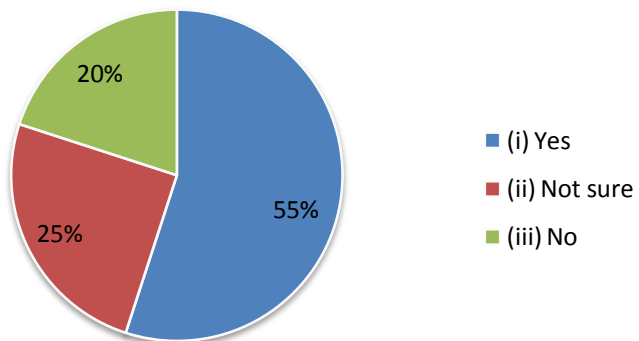
Can you read health awareness information disseminated by the nurses in the SLL e-Health portal?



b) Can you search and browse traditional health information stored in the medical ontology of the SLL e-Health portal?

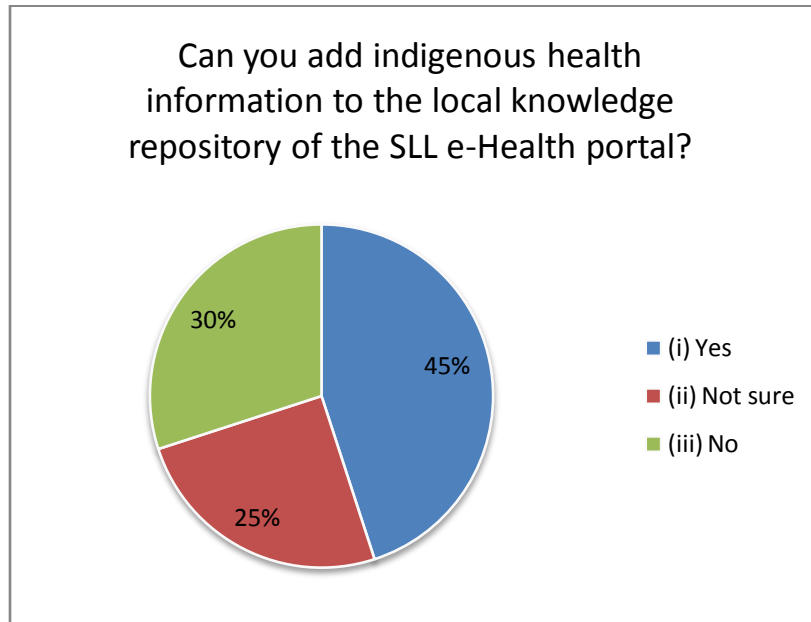
- (i) Yes
- (ii) Not sure
- (iii) No

Can you search and browse traditional health information stored in the medical ontology of the SLL e-Health portal?



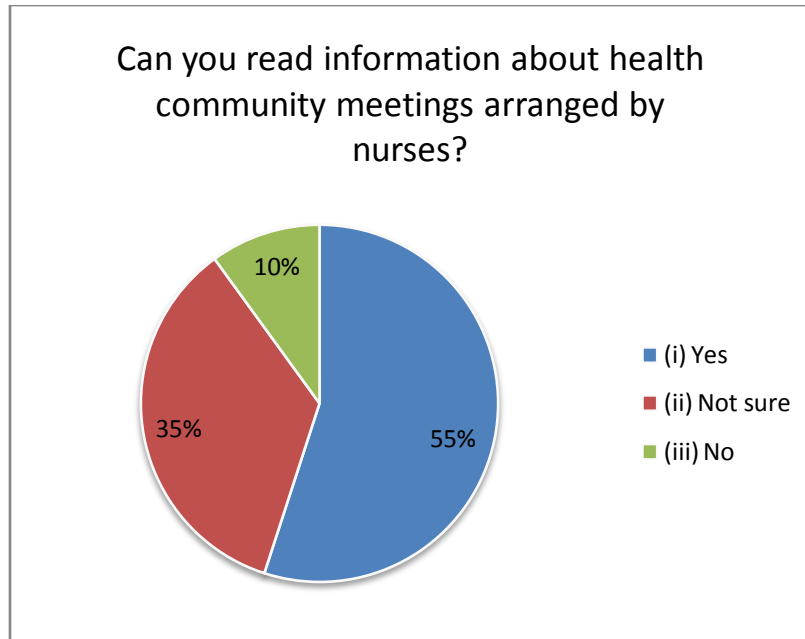
c) Can you add indigenous health information to the local knowledge repository of the SLL e-Health portal?

- (i) Yes
- (ii) Not sure
- (iii) No



d) Can you read information about health community meetings arranged by nurses?

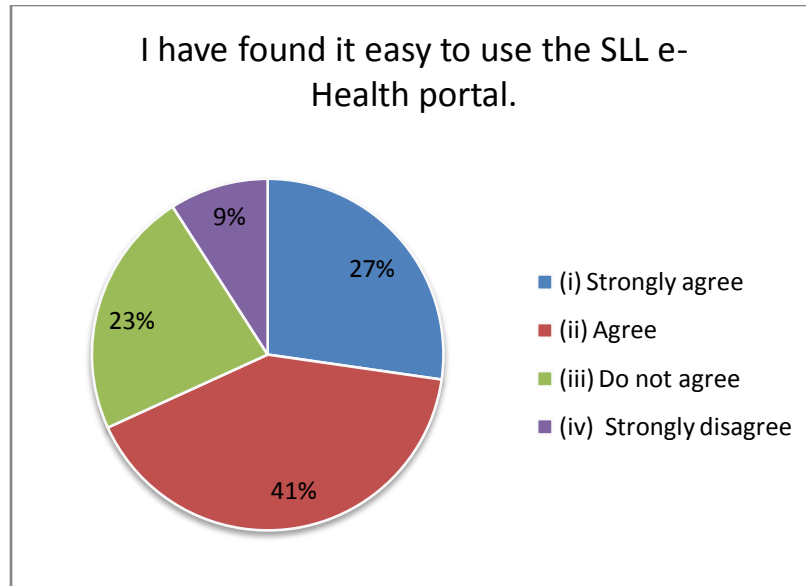
- (i) Yes
- (ii) Not Sure
- (iii) No



SECTION B: Usability testing

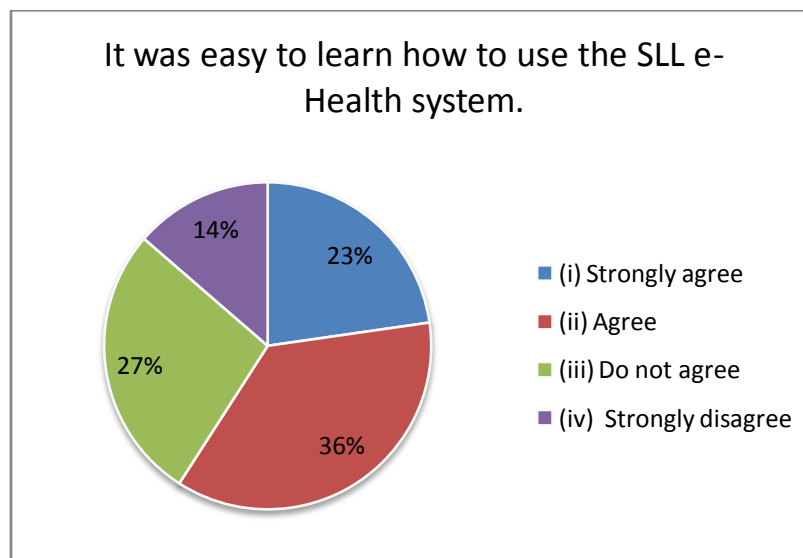
Question 1:

- a) I have found it easy to use the SLL e-Health portal.
- (i) Strongly Agree
 - (ii) Agree
 - (iii) Do not agree
 - (iv) Strongly disagree



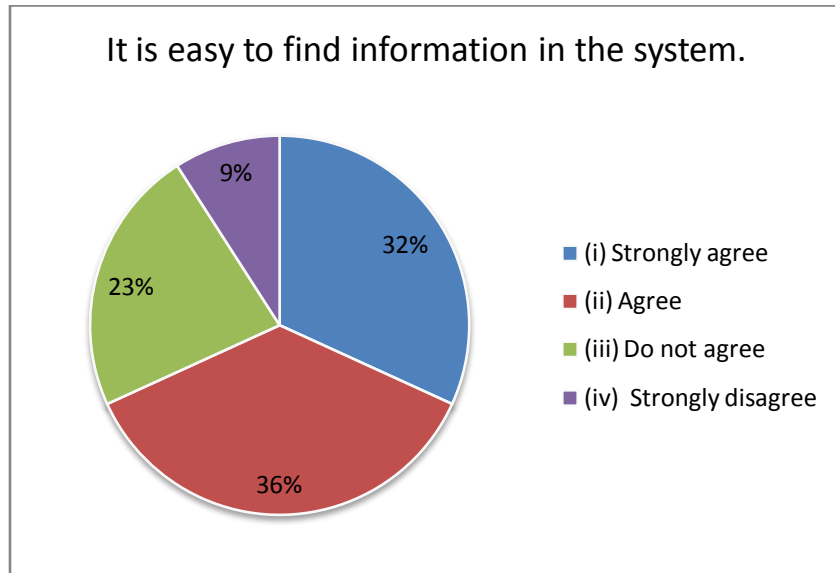
b) It was easy to learn how to use it.

- (i) Strongly agree
- (ii) Agree
- (iii) Do not agree
- (iv) Strongly disagree



c) It is easy to find information in the system.

- (i) Strongly agree
- (ii) Agree
- (iii) Do not agree
- (iv) Strongly disagree



d) I am able to use the system on my own without any assistance.

- (i) Strongly agree
- (ii) Agree
- (iii) Do not agree
- (iv) Strongly disagree

I am able to use the system on my own without any assistance.

