



University of Fort Hare
Together in Excellence

**Developing a help-desk system for a multi-purpose
ICT platform in a marginalised setting**

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

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By

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Abstract

Attempts to bridge the digital divide between urban and rural Information and Communications Technology (ICT) users have led to the deployment of ICT platforms in remote rural areas. This puts an increased demand for skilled support in rural ICT platforms to assist users in resolving technical problems that they face on a daily basis. A web based help desk system is developed and implemented to allow knowledge sharing and collaboration amongst users and experts as a way of ensuring the technical sustainability of the Siyakhula Living Lab, a remote rural based Information and Communications Technology (ICT4D) intervention.

The research describes the use of Transactional and Innovation & Creative knowledge management strategies and their associated applications such as case-based reasoning (CBR) methods and collaborative knowledge approaches to develop a help desk support system for a geographically distributed multipurpose ICT centre in Dwesa, a rural remote area in the Eastern Cape Province, South Africa.

The system implemented in this study has been validated for functional adequacy and usability within the Siyakhula Living Lab. The results of the evaluation are presented in this thesis to provide the initial validation of the effectiveness of the help desk system.

Keywords: ICT4D, ICT, Case-Based Reasoning; Collaborative Knowledge, Technical Sustainability, Help Desk Systems, Siyakhula Living Lab Forums, Issue Tracking, Rural Users, South Africa

Dedication

I dedicate this study to my late father, Mr. Bernard Makombe who passed away on the 19th of May 2000. My dedication extends to my mother, Mrs. Susan Makombe, for all the support she gave in trying times. I am indebted to them for their influence on me.

Declaration

I, Farai Makombe (200303538) hereby declare that the content of this thesis is my own original work. Information extracted from other sources is acknowledged as such.

Signed: _____

January 2011

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Finally, I thank God for making this research possible.

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1 Chapter 1: Research Introduction

1.1 Research Context

Our study area is the Siyakhula Living Lab, a multi stakeholder operation that consists of academia, industry, government and marginalized communities to facilitate user-driven innovation in the ICT4D domain. The Siyakhula Living Lab is currently in its incubator stage with technical and financial support being provided by the Telkom Centres of Excellence in Developmental E-Commerce at Fort Hare and Rhodes Universities. Services available to the community include web-based applications such as e-Government, e-commerce (a virtual shopping mall allowing users to sell their products online), e-health, a police reporting portal, computer literacy training-learning (students and teachers), printing services and Internet Protocol (IP) phones. Access to services is possible with four access and control points conveniently spread across a radius of 45km².

1.2 Research Problem

ICT4D interventions receive support from various stakeholders involved such as government departments, non-governmental organizations and research institutes during the early stages. After the initiation stage, sustainability issues arise when the project's ownership is transferred to the community. The official handover of the project introduces a technical skills gap which needs to be filled as technical experts withdraw from active involvement in the project. This increases the demand for skilled support in the rural ICT platforms so as to assist users on a regular basis. Employing technical experts on a permanent basis places financial strain on these community owned projects since they do not operate on a high budget.

Under these circumstances technical sustainability becomes an issue, hence the need to find a low cost solution to assist users in resolving problems encountered in their routine usage of ICT services. The focus of this research is to find low cost solutions to ensure the technical sustainability of the Siyakhula Living Lab.

The ICT centre is operating with positive participation from the local community and researchers from the afore-mentioned universities; however, users sometimes face problems ranging from hardware to software. Under these conditions, a timely response to the problems encountered becomes an issue since the network administrators are university academics located more than 300km away from the Siyakhula Living Lab. Since visits by the experts is periodical due to the distance from the site, local community users are then forced to resort to making phone calls to report problems and get instructions on how to solve them. This tends to be time consuming and costly considering the location and the high unemployment rate within the community. In order to provide essential, effective and continuous support to such a rural setup, with few or nonexistent ICT skilled people, an intelligent help-desk system needs to be developed, implemented and tested. This will, in turn, foster sustenance and optimum utilisation of the ICT centre resources by the community with the conclusion of the incubation period.

1.3 Research Objectives

The main goal of this research is to implement a help desk system to foster the technical sustainability of the Siyakhula Living Lab. The list hereafter, outlines the research objectives towards achieving the research goal:

- Investigate the issue of technical sustainability within ICTD interventions.
- Understand collaborative knowledge sharing and problem solving approaches relevant for ICTD contexts.
- Identify the key requirements for a help-desk system for the Dwesa community.
- Implement the help desk system to provide a platform for knowledge sharing and problem solving in the Dwesa context.
- Test and validate the effectiveness of the developed system.

1.4 Research Methodology

The entire premise of this research is to promote the technical sustainability of the Siyakhula Living Lab by developing a web-based help desk system to facilitate knowledge sharing. To achieve this we had to look at the impact of ICTs and associated benefits with regard to knowledge sharing. A detailed discussion of Information and Communications Technology for Development (ICT4D) follows, coupled with an account of how the Siyakhula Living Lab fits into this paradigm. We also address sustainability issues within the Siyakhula Living Lab and how they are being addressed. This research involves knowledge sharing, hence the need to understand the knowledge dynamics within the study area and identify knowledge management strategies to facilitate technical sustainability in the Siyakhula Living Lab through collaborative knowledge sharing. Transactional and Innovation & Creative knowledge management strategies were found suitable for addressing our research objective since they help to strike a balance between tacit and explicit knowledge forms within the problem solving context in the Siyakhula Living Lab by allowing the integration of case based reasoning concepts and collaborative knowledge sharing approaches.

As part of the innovation & creative knowledge management strategies, the research looks into internet discussion forums, internet tutorials and frequently asked question websites as possible ways of encouraging knowledge sharing within an ICT4D context. The case-based reasoning problem solving approach was found as a suitable transactional knowledge management strategy suitable for our research due to its capability to map past solutions to new problems and its ability to be used in problem domains that are not well understood. We also had to consider issue tracking as part of the problem solving strategy.

For the domain analysis, an in-depth study of the Siyakhula Living Lab ICT4D interventions was critical to gaining a better understanding of our target users. This included baseline assessments to gather the user requirements, level of computer literacy as well as conducting training sessions to make users comfortable with the use of computers. As part of our development strategy, we had to look for a low cost solution to developing such an application resulting in modelling our system using free and open source software. Using such software makes our application compatible across various platforms whilst, at the same time, allowing other developers to modify the application. Taking our target domain into consideration, rapid prototyping was

implemented in the software development process as we had to reconsider the user requirements as well as the level of literacy for such a system. To assess the overall success of our system, functional testing was done to ascertain whether the functional requirements had been met. Usability testing was also done to check the overall user's perception of the application.

1.5 Motivation

In a bid to avoid a digital dilemma where deployed ICTs are not helping to improve the lives of marginalized communities, our research addresses the critical factors behind designing an integrated help and support application to foster the technical sustenance of the Siyakhula Living Lab, a multi-purpose ICT platform which has been deployed in Dwesa, (marginalized setting along the Wild Coast of the Eastern Cape Province, South Africa). Although there are a number of commercial Case-based Reasoning help-desk application available, they are costly, tailor-made (to a specific type of application) and are less adaptable to multi-purpose ICT application centres where user experiences are essential in the formulation of cases. The system should be user friendly and flexible enough to adapt to any Telecentres or similar ICT facility in developing countries. The system would also provide the following added benefits:

1. Cost effective technical sustainability solution for the Siyakhula Living Lab.
2. Reduced turnaround time in solving problems by offering users around the clock technical assistance in their daily use of computers.
3. Increased user participation as a result of collaborative knowledge sharing in resolving problems.
4. Traceable personal computer literacy level indicator by awarding users points each time they contribute to resolving commonly faced problems.

1.6 Deliverables

A scalable, user friendly and multi-lingual web based support help desk application to facilitate knowledge sharing and foster self sustenance as well as reducing the turnaround time for resolving issues.

1.7 Thesis outline

The rest of the thesis is structured as follows:

Chapter 2 [Literature Review] Reviews the relevant literature behind ICT4D, Collaborative Knowledge Management and Case-based reasoning concepts

Chapter 3 [System Design] Gives a detailed outline of the system design by paying attention to the overall system requirements.

Chapter 4 [Implementation] Discusses how the different technologies were combined to develop the application.

Chapter 5 [Testing & Results] Outlines the set testing strategies and the derived results.

Chapter 6 [Conclusion & Future Work] Provides feedback of the lessons learnt from the development and deployment of the system, its strengths, shortcomings and further elaborates possible aspects of future development.

2 Chapter 2: Literature Review

2.1 Introduction

This chapter explains impact of Information and Communications Technologies (ICT's) and how they have reshaped the lives of people by allowing them to engage in the active creation and sharing of knowledge. A detailed discussion of Information and Communications Technology for Development (ICT4D) follows, coupled with an account of how the Siyakhula Living Lab fits into this paradigm. The chapter provides a view of the sustainability issues being addressed within the Siyakhula Living Lab and how we intend to facilitate technical sustainability in the Siyakhula Living Lab through collaborative knowledge sharing. Knowledge management is introduced, followed by an explanation of the tacit and explicit forms of knowledge management with respect to the problem solving process in the Siyakhula Living Lab. An analysis of knowledge management strategies emphasize understanding on how they influenced the multifaceted approach of incorporating Transactional and Innovation & Creative knowledge management strategies to develop a collaborative knowledge management helpdesk system.

2.2 Information and Communications Technologies for Development (ICT4D)

Advancements in Information and Communications Technology (ICT) have led to a drastic rise in the global use of technology in general, with society shifting from a hierarchical industrial model to a horizontally- organized networked society. This has been made possible through rapid deployment of the internet along with interconnected devices for communication, such as mobile phones, which has brought an unprecedented proliferation of and openness in the access of information and services as compared to the conventional print media.

Web 2.0 has opened endless opportunities to everyone who has internet connectivity as it allows them to contribute knowledge rather than only consuming information as is the case of the traditional print media. This is evident from the proliferation of wikis, file sharing sites, web

blogs as well as social networking sites such as Facebook. The notable impact of Web 2.0 was in the 2008 American Presidential race where the incumbent President, Barack Obama, made innovative use of social networking websites and mobile phones to mobilize and garner support from the electorate. This brought active participation from the general populace as they felt included in their candidate's policy and vision for the country through the openness and inclusive nature of his campaign approach. Another recent example of the power of the people in ICT was in early 2009 when Facebook was forced to return to its old look since users had organised themselves to protest their lack of consultation in the decision making process when switching to the new look of their social networking website.

Wireless infrastructure and mobile internet such as Wi-Fi and VSAT are now widely available, challenging the global telecommunications industries. Mobility represents a paradigm shift not only in technology but, more importantly, in the business of providing services. Where operators had previously held the key to service concepts, business models and terms of delivery, the user has emerged as a demanding and powerful stakeholder. This setup has helped the spread of ICTs on a global scale with new players such as developing countries joining the fold, particularly remote and disadvantaged communities, in a bid to overcome the barriers associated with the digital divide. This in turn gave rise to a new research field known as Information and Communications Technology for Development (ICT4D) which aims to provide the benchmarks and initiatives to spearhead the adoption of ICT in developing countries and disadvantaged communities in particular. This bold initiative has been backed by many influential organizations with the former United Nations Secretary General Mr. Kofi Annan in his millennium report challenging Silicon Valley companies to assist in promoting the use of ICT in developing countries. Mr. Kofi Annan highlighted the importance of developing countries benefitting from opportunities brought about by the digital revolution, and stressed the vital role that volunteers play in bridging the digital divide between industrialized and developing countries, in key fields such as health, education, income generation, gender equity, environment and humanitarian aid. Two conferences were held to honour this noble call with the first UN backed World Summit on the Information Society held in Geneva, Switzerland in 2003 and a follow up conference hosted in Tunis, Tunisia in 2005. The conferences recommended 17 May as World Information Society Day.

User generated content and user driven innovation behind Web 2.0 have democratized the Internet with the users of products and services participating in the co-creation of products and services. New terms “prosumer” (producer + consumer) and “prosumption” (production + consumption) have emerged to describe the approaches that incorporate customers into the value production process (Bollier, 2007). Due to the interactive nature of ICT technologies, such as Web 2.0, openness has become an increasingly critical component of ICT4D in a bid to promote that users reap the full benefits associated with the initiative; hence, the acronym is further expanded to Open ICT4D. This openness promotes a uniform knowledge dissemination platform regardless of the social status of the users. Open ICT4D organizes social activities in such a way that there is unrestricted access and participation. Figure 1 below shows the different ICT4D activities on a scale of openness, from basic access to collaboration.

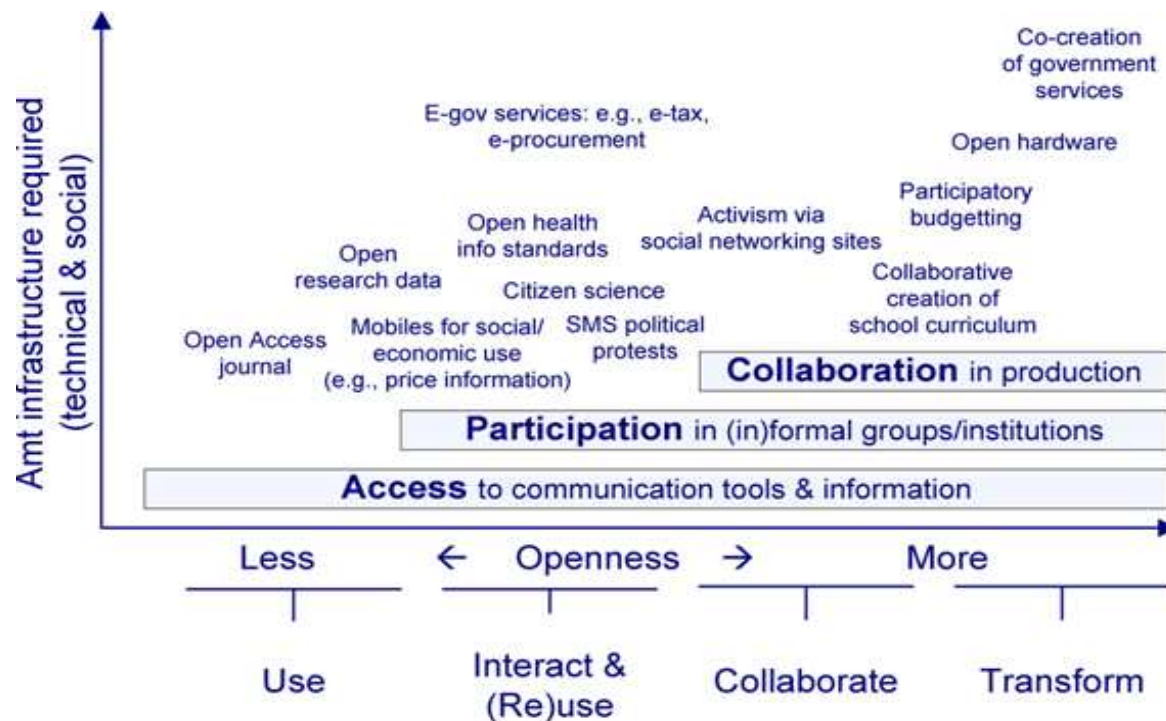


Figure 1: Different ICT4D activities on a scale of openness, from more closed to more open. (Smith, M & Engler, N.J, et al., 2008)

In our case the Open ICT4D initiative under review is modelled after Living Labs with different applications operating on open hardware and software as a way of reducing operating costs. Living Labs spans across different domains with an emphasis on promoting coordination, peer production, user driven innovation and user generated content due to the minimal restrictions of such structures. In ICT's Living Labs encourage societal involvement in a user-centric research methodology for sensing, prototyping and simultaneously eliminating the Pilot Syndrome associated with most ICT4D projects. Below is a diagram showing the action space for Living Labs in ICT projects. Living Labs also act as testing grounds to assess local challenges that become global solutions.

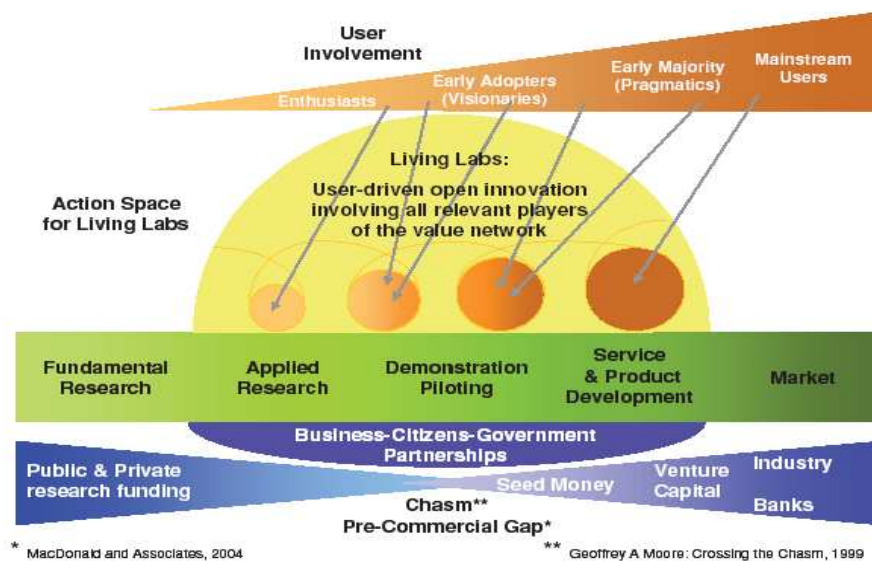


Figure 2: Action space for Living Labs along the technology adoption cycle adapted from the European Union Brochure for Living Labs for user-driven open innovation, 2009.

Living Labs empower end-users, to influence the development of innovative services & products that eventually could benefit the whole society. In turn industry partners will develop tailor made applications for the community based on the user requirements. In our case the project has evolved to include generic communication services (Internet, GSM, etc.) such as applications such as e-health, e-commerce and e-government for the rural communities in Dwesa, Eastern Cape, South Africa. Living Labs facilitate the integration of technological innovation in society and increase return on investments in ICT research.

The aforementioned benefits associated with Open ICT4D and Living Labs initiatives alone cannot guarantee the success of these projects in the long run. This then brings the need to identify the proper sustainability structures. The section below looks at the sustainability issues behind ICT4D projects in general with an emphasis on technical sustainability, which our research seeks to address.

2.3 Sustainability Issues behind ICT4D initiatives

The ICT sector has emerged against the backdrop of the global information revolution and the continuing reality of massive poverty in developing countries. The emphasis of the ICT4D sector is not so much on the development of a global ICT industry but rather on the application of ICT for human development. A growing perspective in the field is also the need to build projects that are sustainable and scalable, rather than focusing on those which need to be propped up by huge amounts of external funding without which they are unable to survive. Deploying technologies alone is not enough for poverty reduction, there is also a need to allocate resources development and training. The cost effectiveness of ICT4D projects cannot be measured in the short term; this gives rise to the need to include Living Labs as a way of fostering sustainability and scalability of ICT4D projects for the early assessment of the socio-economic implications of new technological solutions by demonstrating the validity of innovative services and business models to the end users.

A recent interview by Rogers (2011) with academia and professionals around Africa felon why most information and communications for development (ICT4D) projects fail revealed the following insights:

1. Results not directly tied to improving economic condition of end user
2. Not relevant to local contexts, strengths, or needs
3. Not understanding infrastructure capacity
4. Underestimating maintenance costs and issues
5. Projects supported only by short-term grants
6. Solutions are not looking at the whole problem
7. Projects built on condescending assumptions

The shortcomings addressed above bring the need for sustainability issues to be addressed when dealing with ICT4D projects. There are four components when considering sustainability: Social, political, technological, and economic. The political aspect of sustainability means that local and national politics, policies, and individuals can affect your project in positive ways. It has been studied that most successful ICT projects are a result collaborative multi-stakeholder initiatives involving the Government, Non-Governmental Organisations, academia, the community as well as other donor and funding agencies. The Siyakhula Living Lab is embedded in the following regional and international innovation systems:

1. Telkom Centres of Excellence (CoE) at the Universities of Fort Hare and Rhodes University
2. Technology and Human Resources for Industry Programme (THRIP) of the Department for Science and Technology of South Africa,
3. Cooperation Framework on Innovation Systems between Finland and South (COFISA), a programme of the South African and Finnish governments.

Social Sustainability looks at the social and cultural context of the domain area of ICT platform and its capacity for future generations to enjoy the same or greater access to deployed resources as the current generation. The initial step to social sustainability is to transfer the ownership of the project to the community to foster responsibility is maintained in all aspects of the project. In our case, the social sustainability is an ongoing process where the communities are continuously trained to improve computer literacy skills as well as to stay relevant with latest services deployed. Initiatives to promote the social sustainability of the Siyakhula living Lab include the deployment of e-government, e-health and e-judiciary services.

Economic sustainability refers to the financial viability of the project in the long run. Economic sustainability is also closely related to the technical considerations of the project, where the deployed technologies should easily scale with the changing times without the need to reinvest huge amounts of money to make the project stay relevant to the changes in technology. An initiative implemented as to make the Siyakhula Living lab economically sustainable is the e-commerce platform allowing rural community users to earn extra income for themselves by selling their wares on a global market. In addition to the e-commerce intervention, a Revenue Management Architecture has been deployed in the Siyakhula living Lab as a way of ensuring

financial sustainability by billing internet usage according to tailor made metrics specific to the community such as age, annual income and usage.

Technological sustainability within an ICT4D intervention is the ability to keep the deployed applications robust with the capacity to scale according to time with minimum downtime, hence allowing clients and users to focus on their field of expertise. In our case, users of the Siyakhula living lab sometimes face problems ranging from hardware to software related issues.

Responding timely to the problems faced becomes an issue since the network administrators are university academics located more than 300km away. Local community users are forced to resort to making phone calls to report the problems and get instructions on how to solve them. This tends to be time consuming and costly considering the location and the high unemployment rate within the community. To ensure technical sustainability under these conditions there is need to deploy robust infrastructure and skilled personnel to handle issues which may rise from time to time due to increased usage of the ICT platform. However, deploying skilled personnel is difficult due to the location and the level of financial sustainability of these ICT4D projects. Our research seeks to address this problem by finding innovative ways to ensure that problems faced by community users are addressed faster, and at a lower cost to reduce financial strain caused by hiring technicians to handle random problems from time to time. As noted earlier in this chapter, Living Labs promote take a user-centric research approach for sensing, prototyping and simultaneously eliminating the Pilot Syndrome associated with most ICT4D.projects. In our case, we take advantage of this approach by proposing collaborative knowledge creation as a way of ensuring technical sustainability. Our model of collaborative knowledge creation is through the use of a helpdesk system which integrates various knowledge creation and sharing approaches to assist rural ICT users in Dwesa in sharing experiences to solve problems.

2.4 Knowledge Management

Knowledge Management (KM) comprises a range of strategies and practices used in an organization to identify, create, represent, distribute, and enable adoption of insights and experiences represented in any of the three elements [Structural, Human and Social] of intellectual capital.(Seemann et al, 1999) . It requires turning personal knowledge into corporate knowledge than can be widely shared throughout an organization and appropriately applied. In our case, we intend to use the knowledge management approach to develop a helpdesk system which allows community members to create, share and manage knowledge to help resolve routine problems faced when using services within the Siyakhula Living Lab.

Knowledge systems dynamics differ from one community to another based on numerous factors. Some of the factors that characterize different communities and that directly influence the usage and exchange of knowledge include: the levels of social stratification and the relationship between the different strata, the general power relation dynamics, and the extent of communal orientation within the community. These factors have a direct bearing on the realization of knowledge systems in communities and form part of the critical points of departure in the implementations of knowledge systems for different communities. For example, a knowledge system developed for a fairly egalitarian community where there is a cultural sense of openness and sharing would implement far less features around confidentiality and privacy than for a society with opposite cultural orientation.

This section therefore highlights the different factors and the associated dynamics that are specific to the Dwesa community, that have direct bearing of the realization of a knowledge platform for that community. These factors are characteristic of other similarly rural, marginalized, African communities.(Thinyane et al,2009)

The dynamics of knowledge within the Dwesa community can be broken down to two fundamental approaches to knowledge management, tacit and explicit knowledge. The *tacit knowledge* approach emphasizes understanding the kinds of knowledge that individuals in an organization have,

moving people to transfer knowledge within an organization, and managing key individuals as knowledge creators and carriers. By contrast, the *explicit knowledge* approach emphasizes processes for articulating knowledge held by individuals, the design of organizational approaches for creating new knowledge, and the development of systems (including information systems) to disseminate articulated knowledge within an organization (Sanchez,2006).

In our case, tacit knowledge is defined as the personal user experiences with regards to solving problems faced when using computers on a daily basis. This knowledge is not actually expressed but resides in individuals or teams and we want to tap this kind of knowledge to be available to everyone by developing a system which promotes knowledge sharing.

On the other hand, explicit knowledge is representational, codified and conveyed to others through dialog, demonstration, or media such as books, drawings, and documents. This kind of knowledge is generated by experts in the form of tutorials on how to carry out particular tasks.

In this research, we seek to achieve a trade-off between these two knowledge approaches to facilitate access of knowledge harnessed from both users and experts on one platform. In order to develop a system which will achieve such, we need to understand knowledge management strategies, their applications and associated technologies.

2.5 Knowledge Management Strategies

Derek Binney (2001) provides a collection of KM elements and their associated applications. He focused on KM activities and grouped them into six categories. The collection of these elements is referred to as the KM spectrum. The KM spectrum can be used to help organisations assess where they are in KM terms. For each of these categories of KM, Binney reflects aspects of both the knowledge-centred classification of KM and the business perspectives classification of KM as shown in the diagram below.

	Transactional	Analytical	Asset Management	Process	Developmental	Innovation and Creation
Knowledge Management Applications	▪ Case Based Reasoning (CBR) ▪ Help Desk Applications ▪ Customer Service Applications ▪ Order Entry Applications ▪ Service Agent Support Applications	▪ Data Warehousing ▪ Data Mining ▪ Business Intelligence ▪ Management Information Systems ▪ Decision Support Systems ▪ Customer Relationship Management (CRM) ▪ <i>Competitive Intelligence</i>	▪ Intellectual Property ▪ Document Management ▪ Knowledge Valuation ▪ Knowledge Repositories ▪ <i>Content Management</i>	▪ TQM ▪ Benchmarking ▪ Best practices ▪ Quality Management ▪ Business Process (Re)Engineering ▪ Process Improvement ▪ Process Automation ▪ Lessons Learned ▪ Methodology ▪ <i>SEI/CMM, ISO9XXX, Six Sigma</i>	▪ Skills Development ▪ Staff Competencies ▪ Learning ▪ Teaching ▪ Training	▪ Communities ▪ Collaboration ▪ Discussion Forums ▪ Networking ▪ Virtual Teams ▪ Research and Development ▪ <i>Multi-disciplined Teams</i>

Figure 3: KM applications mapped to the elements of the KM spectrum adapted from Binney (2001)

2.5.1 Transactional Knowledge Management

Knowledge is embedded in technology. In analytical KM applications, large amounts of data or information are used to derive trends and patterns – making apparent that which is hidden due to the vastness of the source material and turning data into information, which, if acted on, can become knowledge. Transactional KM relies on case-based reasoning principles where past solutions are used to solve future similar cases. In this case the knowledge is pre-packaged and provided to the user in the course of interacting with the system in a transaction to assist in addressing a customer problem. Examples of transactional KM include help desk, customer service, order entry and field support applications. (Binney,2001)

2.5.2 Analytical Knowledge Management

Knowledge is derived from external data sources, typically focusing on customer-related information. Analytical KM provides interpretations of, or creates new knowledge from, vast amounts or disparate sources of material. Analytical KM applications have focused on customer-related information to assist marketing or product development functions (Yoon, 1999). Traditional analytical KM applications such as management information systems and data warehousing have analyzed the data or information that is generated internally in companies. (Binney, 2001)

2.5.3 Asset management Knowledge Management

Explicit management of knowledge assets (often created as a by-product of the business) which can be reused in different ways. Asset management KM focuses on processes associated with the management of knowledge assets. This involves one of two things: (Binney, 2001)

- (1) The management of explicit knowledge assets which have been codified in some way (Guthrie and Petty, 1999).
- (2) The management of intellectual property (IP) and the processes surrounding the identification, exploitation and protection of IP (Teece, 1998). IP has been included in the asset management category rather than the innovation and creation category as most of the literature around IP tends to discuss the assets as a product of some other business process.

Once created in this way, the assets then need to be managed. Once captured, the assets are made available to people to use as they see fit. This element of the spectrum is directly analogous to a library, with the knowledge assets being catalogued in various ways and made available for unstructured access and use. (Binney, 2001)

2.5.4 Process-based Knowledge Management

The process-based KM element covers the codification and improvement of process, also referred to as work-practices, procedures or methodology. Process-based KM is often an outgrowth of other disciplines such as the TQM and process reengineering (Binney, 2001). The knowledge assets produced in this category are also known as “engineered assets” in that they often involve third parties or specialists working with practitioners or subject matter experts (SMEs) to document these best practices in standard formats. Process knowledge assets are often improved through internal lessons, learned sessions, formal engineering of process by internal best practice selection, and codification and external benchmarking (Feltus, 1995; Hill, 1999; O’Dell and Grayson, 1999; Powers, 1995).

2.5.5 Developmental Knowledge Management

Developmental KM applications focus on increasing the competencies or capabilities of an organization's knowledge workers. This is also referred to as investing in human capital (Edvinsson and Malone, 1997). The applications cover the transfer of explicit knowledge via training interventions, or the planned development of tacit knowledge through developmental interventions such as experiential assignments or membership in a community of interest. This area of KM is taking on renewed significance with the emergence and ascendancy of the knowledge worker. Investing in developing the knowledge and capabilities of a company's workforce is becoming a measure of the value of an organization because this investment is now seen as increasing the knowledge content and capability of an organization. At the same time, such an investment also helps to attract the best knowledge workers in a highly competitive knowledge worker market. In addition to traditional training in "explicit knowledge" often related to products, disciplines and technologies, there is an emerging emphasis on developing "learning organization" and collaborative skills. Communities where people can exchange ideas and learn from each other are another emerging form of tacit knowledge. (Binney, 2001)

2.5.6 Innovation & Creation Knowledge Management

Innovation/creation-based KM applications focus on providing an environment in which knowledge workers, often from differing disciplines, can come together in teams to collaborate in the creation of new knowledge. There is still a role for individual innovation; however, innovations are increasingly coming from the marriage of disciplines and teamwork. (Binney, 2001)

Figure 4 below shows improved KM spectrum with associated applications they enable within each classification.

	Transactional	Analytical	Asset Management	Process	Developmental	Innovation and Creation
Knowledge Management Applications	- Case-Based Reasoning (CBR) - Help Desk Applications - Customer Service Applications - Order Entry Applications - Service Agent Support Applications	- Data Warehousing - Data Mining - Business Intelligence - Management Information Systems - Decision Support Systems - Customer Relationship Management (CRM) - Competitive Intelligence	- Intellectual Property - Document Management - Knowledge Valuation - Knowledge Repositories - Content Management	- TQM - Benchmarking - Best practices - Quality Management - Business Process (Re)Engineering - Process Improvement - Process Automation - Lessons Learned - Methodology - SEI/CMM, ISO9XXX, Six Sigma	- Skills Development - Staff Competencies - Learning - Teaching - Training	- Communities - Collaboration - Discussion Forums - Networking - Virtual teams - Research and Development - Multi-disciplined Teams
Enabling Technologies	- Expert Systems - Cognitive Technologies - Semantic Networks - Rule-based Expert Systems - Probability Networks - Rule Induction, Decision Trees - Geospatial Information Systems	- Intelligent Agents - Web Crawlers - Relational and Object DBMS - Neural Computing - Push Technologies - Data Analysis and Reporting Tools	- Document Management Tools - Search Engines - Knowledge Maps - Library Systems	- Workflow Management - Process Modeling Tools	- Computer-based Training - Online Training	- Groupware - e-Mail - Chat Rooms - Video Conferencing - Search Engines - Voice Mail - Bulletin Boards - Push Technologies - Simulation Technologies
Portals, Internet, Intranets, Extranets						

Figure 4: KM applications mapped to the elements of the KM spectrum adapted from Binney (2001)

Our research is centred on fostering technical sustainability through knowledge sharing and the diagram below helps us to choose the appropriate KM classification to fit our problem domain. Our proposed choice of the KM classifications to use in our research is a combination of the Transactional and Innovation and Creation models due to their ability to allow the development of applications which encourage knowledge collaboration through different innovative strategies while at the same time allowing knowledge reuse over time by incorporating case-based reasoning strategies.

In the following section, we are going to look at the Transactional and Innovation and Creation enabling technologies which we are going to implement in our research to allow community users of the Siyakhula living Lab to collaborate in the problem solving process.

2.6 Innovation & Creation Enabling Technologies

2.6.1 Forums

Community user groups are a great way to leverage knowledge amongst users. They act as a great meeting place for people to connect with one another, find areas of common interest, and explore technical problems. Popular areas for forum themes are technology, computer and/or video games, sports, music, fashion, religion, and politics. Users can remain anonymous or register with the forum and then subsequently log in, in order to post messages. Unlike chatroom messages, these helpdesk messages are permanently archived which makes them useful in a help and support application by allowing users to reuse solved cases in the future. Internet forums are common in several developed countries with Japan's 2channel handling two million posts per day (Naohiro Matsumura et al 2003). The popularity of forums is evident from the trend amongst most websites which incorporate user forums to offer support to their customers. In our case users have to register to be able to share knowledge.

Critical success factors for a user forum:

1. Quality control through group moderation, peer review and facilitation.
2. No limits to thinking; or the promotion of creative thinking.
3. Strong group membership feedback.
4. Knowledge base of archived threads.

2.6.2 Issue tracking

Our help and support system makes deals with problem resolution and, at times, the complexity of the issues encountered requires expert intervention. This then results in the need of an issue tracking feature to be incorporated into our help and support system for users to be able to monitor their progress after submitting them for expert feedback. Each issue in the system may have an urgency value assigned to it, based on the overall importance of that issue. Critical issues are the most severe and usually take precedence over low urgency issues. Other matters to consider when attending to issues include the date of submission and detailed descriptions of the problem being experienced. The issue tracking process is moderated by the system administrator who assigns open issues to experts according to their level of expertise with the user being sent

an automatic email to update them of the status of their problem and the person to contact for any further enquiries.

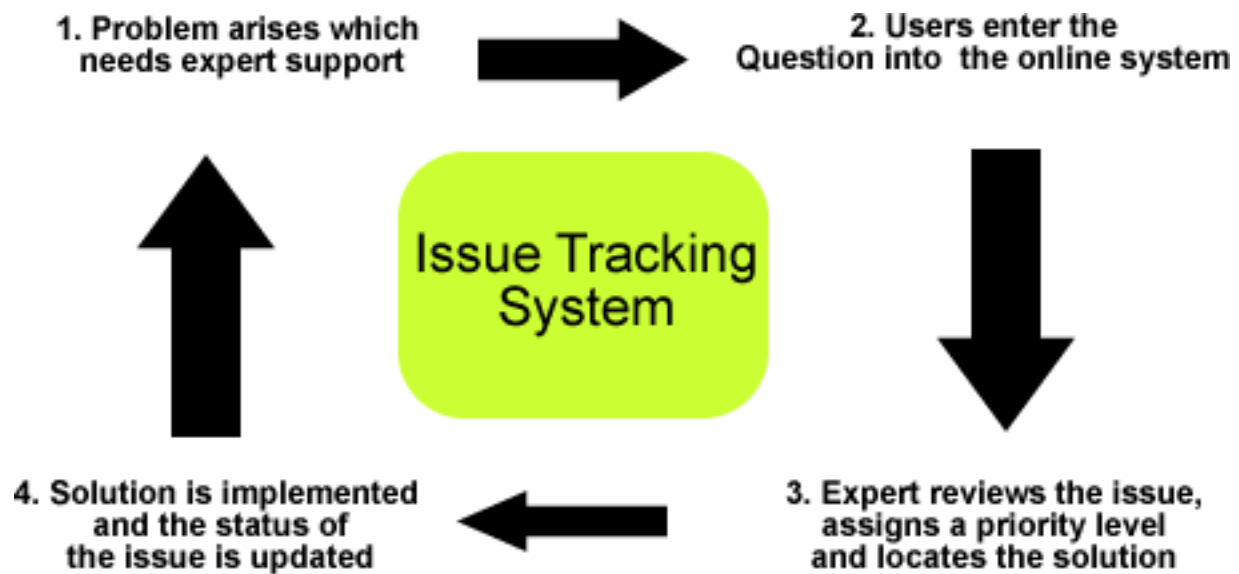


Figure 5: Issue tracking system

2.6.3 Tutorials

Internet computer tutorials come in the form of a screen recording, a written document (either online or downloadable), or an audio file, with detailed instructions on how to carry out a particular task. Tutorials can be basic or comprehensive depending on the complexity of the task at hand; they are useful in helping a user to understand the concepts necessary to undertake a task. In our case, tutorials compiled by experts are made available to users in order to assist them in understanding concepts of interest. Users can teach themselves what they need to know via online manuals and tutorials at their own pace and time. A good computer tutorial delivers the right knowledge content in a single and organised manner.

2.7 Transactional Enabling Technologies

2.7.1 Case-based reasoning

Common problem-solving approaches in knowledge engineering are rule-based reasoning, model-based reasoning, and case-based reasoning (Luger, G.F. & Stubblefield, W.A., 1998). Knowledge engineering is an ongoing process and research has shown that case-based reasoning

is suitable for developing help desk systems for domains with commonly occurring problems due to its capability to map old solutions to new cases (Watson & Marir, F. 1994).

Rule-based reasoning and case-based reasoning have emerged as the two most important and complementary reasoning methodologies in the field of artificial intelligence (AI). Our research aims to exploit case-based reasoning (CBR) concepts and, to a lesser extent, rule-based reasoning mechanisms as a comprehensive approach to developing a robust multipurpose knowledge management help desk for the Siyakhula Living Lab. Grounding research in problem solving as an approach to artificial intelligence mainly focused on rule-based expert systems which use production rules to capture domain knowledge. However, rule-based expert systems are limited to well defined domains where problems and their associated solutions are often readily available or can easily be acquired. Rule-based problem solving systems proved to have a shorter lifespan in applications where the rules have to be changed regularly, since expanding a rule-based case database system requires one to rewrite the rules (Watson, I & Marir, F., 1994). The aforementioned feature of rule-based knowledge systems make them rigid and inflexible to adaptation for incremental sustained learning where a new experience is retained each time a problem has been solved. This also means that the process of learning as a by-product of problem solving is eliminated hence the need to develop problem solving systems to counter for such shortfalls.

Due to the repetitive nature of some problems, it is natural that people analyse new problems by creating solutions using previous experiences. This gave rise to the need to model how human reasoning works rather than sticking to a rigid set of rules. This, in turn, gave birth to case-based reasoning as an interdisciplinary problem solving paradigm which integrates a variety of other disciplines such as cognitive science, legal reasoning and machine learning. Though the field is relatively new, its foundations trace back to the late 1970s with Roger Schank as the most notable proponent of the theory. A major contribution to the CBR mechanism was the study of human story understanding which led to investigations of the role of memory in understanding (Schank, 1982). The use of precedents in legal reasoning helped to model CBR systems along the use of past cases as the basis of solving present and future problems.

Schank formalised the idea of human problem solving by referring to the structure used in the conceptual memory that stores information about stereotypical situations as *scripts* from which humans can base their expectations and draw conclusions. CBR is memory based unlike other problem solving approaches in artificial intelligence; it reflects the human use of remembered problems and solutions as a way for finding solutions to new problems. Problem solving in CBR is based on the premise that similar problems have similar solutions, and research has shown the premise to hold an expectation for simple scenarios (Faltings, 1997), and is empirically validated in many real-world domains. CBR systems are also known as knowledge management tools due to their ability to create, interpret, disseminate, retain as well as refine knowledge.

In simple terms, CBR solves a problem by obtaining a problem description, measuring the *similarity* of the problem at hand with past problem cases and their associated solutions. After retrieving a couple of similar cases, and attempting to *reuse* their solutions, there is a need to *adapt* the closest past solution to account for differences in problem descriptions in the event that the cases in the legacy database do not fit well with regards to solving the new problem (De Mantaras R.L, McSherry D, Leake, et al 2005). This evaluation process is either done automatically by the system or handled by the domain expert if the problem is complicated (Chan C.W, Chen, L and Geng L, 2000). After revision of the proposed solution, if required in the light of its evaluation, the problem description and its solution can then be stored or retained *as* a new case. The storage of the new case is part of the learning process since the system has used a past case and adapted it to the new environment as a way of coming up with a new solution (Aamodt A. & Plaza E., 1994).

In CBR terminology, a case usually denotes a problem situation. A previously encountered situation that has been saved in the legacy case database for future use is referred to as a past case, stored case or retained case. Correspondingly, a new case or unsolved case is the description of a new case to be solved (Kolodner, 1993). Case-based reasoning systems have traditionally been used to perform high-level reasoning in poorly understood problem domains. Such problem domains can be adequately described using discrete representations and require continuous interaction, adaptation and learning within the environment. CBR systems provide an explanation that is generally much easier to understand and more compelling than a chain of rules. This increases the understanding of the way in which the system operates, and at the same

time boosts the user's confidence in the system since it is usually easier to learn by retaining a concrete problem solving experience than to generalize from it. An unsuccessful attempt to solve a particular problem leads to the need to identify and store the reason for failure. This will in turn help to avoid repeating the same mistake in the future (Gonzalez, L.M., Giachetti, R.E, Ramirez, G., 2005).

Knowledge management is an ongoing process and research has shown that case-based reasoning (CBR) is suitable for developing help desk systems for domains with commonly occurring problems due to its capability of mapping old solutions to new problem cases (Watson, I. & Marir, F., 1994). Figure 6, below is a simplified diagram of the problem solving cycle.

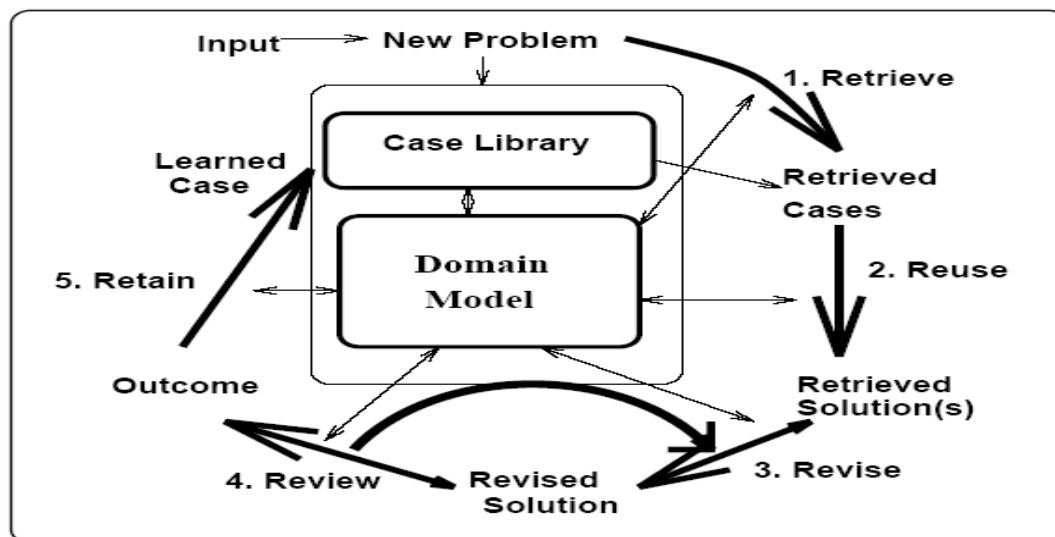


Figure 6: Classic model of the problem solving cycle adapted from Aamodt & Plaza (1994)

Aamodt & Plaza's (1994) classic model of the problem solving cycle in CBR categorized the core problems addressed by the model as follows:

1. Knowledge representation
2. Retrieval methods
3. Maintenance

2.7.2 Knowledge representation

A case-based reasoning system relies heavily on the structure and content of the collected cases; hence, good knowledge representation methods are critical to the overall competency of the system. When writing the cases there is need to reduce data, and select only the necessary key processes. It is almost impossible to represent a realistic case in all its natural complexity, therefore splitting the case into smaller, important components becomes necessary. When creating the case, it will be good to embed clues to solving the case in various locations (Jarz, E. M., Kainz, G. A., & Walpoth, G., 1997).

A major issue to consider when representing cases is the inseparability problem. It is therefore important to structure the content of the case memory in order to allow efficient retrieval of cases that are similar to any new problem at hand. This can be achieved by good memory organization through the use of indices to allow for an efficient case search and matching process (McSherry, D., 2002). Proper use of indices will help to structure the relationships between cases and parts of different cases. For the purposes of retrieval, a case-based reasoning system uses a *similarity measure*. Based on the specific measure employed, the system associates a numerical value with each case indicating the similarity between this case and the problem under consideration. The basic idea is that cases with the highest similarity are retrieved from memory. The solutions of the retrieved cases are then combined to create a solution for the new problem. This will help to distinguish between cases that have different solutions. In addition, general adaptation heuristics for modifying past cases to fit new cases are required in order to ease the learning process. Several different similarity measures have been designed, most frequently with a specific domain of application in mind (Aamodt, A. & Plaza, E. 1994), although a combination of both models can be used to exploit their advantages. .

2.7.2.1 Guidelines for case representation

A case is “a contextualized piece of knowledge representing an experience that teaches a lesson fundamental to archiving the goal of the reasoner” (Kolodner, 1993). Typically, there are three major parts of a case:

1. Representation used in knowledge base.

2. Number of features that are used to match cases during search.
3. Complexity and the number of cases.

He further breaks down the three major parts of a case as follows:

1. Problem description
2. Solution
3. Outcome

Major Parts	Contents
Problem Description	1. Goals 2. Constraints 3. Features of a problem situation and the relationship between its parts
Solution	1. Solutions 2. Reasoning steps 3. The set justifications for decisions
Outcome	1. Actual outcome 2. Explanation of the expectation failure 3. Repair strategy 4. Pointer to next attempt at solution

Figure 7: Contents of the Major Parts of a Case adapted from Kolodner (1993)

Watson and Doyle structured case representation by splitting the structure into problem and solution spaces. The description of the problem resides in the problem space with stored solutions being in the solution space. This structure uses a similarity measurement to find the best matching case. The diagram below shows a schematic outline of case representation

structure in terms of the problem space and solution space with “R” denoting retrieval and “A” for adaptation.

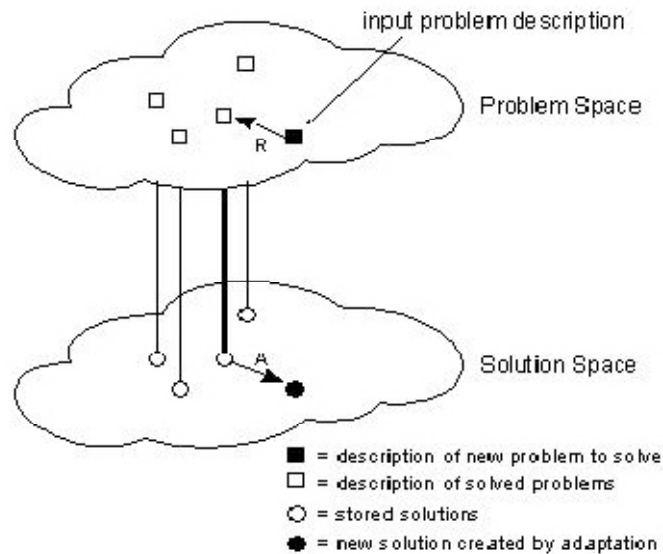


Figure 8 : Relationship between problem and solution spaces in CBR adapted from Doyle, et.al, (1998)

2.7.2.2 Indexing

Indexing is a technique used for the efficient organization of memory when storing cases. An index is a data structure to be used for case storage and the facilitation of quick retrieval.

Hammond (1989), proposed guidelines on indexing:

1. Should show the purpose for which the case will be used.
2. Be predictive.
3. Be specific and abstract enough to allow for later matching of similar cases.
4. Knowledge base is adjusted for future use.

The indexing process can either be automated or non-automated depending on the types of cases to be represented by the case-based system. For instance, complex cases would require non-automated methods while in well understood problem domains automated methods will be more

applicable. In the next section, we discuss two influential case memory models for case representation in CBR systems, namely Schank and Kolodner's Dynamic Memory Model and the Category-exemplar model of Porter & Bareiss (1990).

2.7.2.3 The Dynamic Memory Model

The understanding behind dynamic memory is that remembering, understanding, experiencing and learning are interrelated and cannot be separated from each other (Kolodner, 1993). From the basic principles behind the CBR paradigm, we predict solutions to new situations by recalling similar past experiences. If the expectations are met we feel that we understand; whereas if they are not met, learning then takes place through finding explanations by recalling past cases with similar features. Hence, there is a need for the same knowledge structure to be used for remembering, understanding, experiencing, and learning to ensure the above-mentioned interrelations are met.

The theory of dynamic memory deals with the relationship between knowledge structures in memory and the implications of the structuring for the enhancement of matching processes. These knowledge structures are called episodic memory organisation packets (E-MOPs). The case memory in Schank's Dynamic Memory Model is a hierarchical structure of E-MOPs. MOPs represent knowledge about classes of events, especially complex events, which illustrates the formation of episodic long-term memory. The episodic memory provides the ability to generalise about episodes or events from a particular experience. According to this theory, understanding of a new episode (case) includes finding the best knowledge in memory that can be used to make predictions from it. Finding this knowledge is equivalent to integrating the new episode with what is already in the memory. As the reasoning proceeds, the case base is constantly adjusted and updated when new experiences demand it, for example, on the basis of mismatches or failures. Thus, the episode will get better integrated and more reliable when making predictions about the new episode being derived.

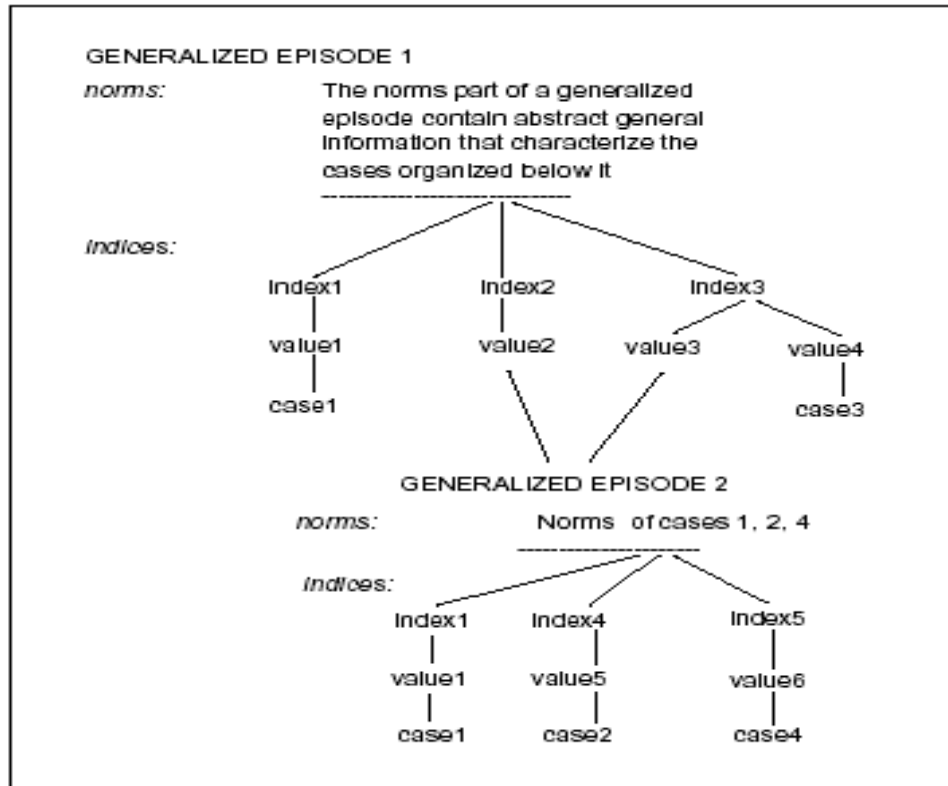


Figure 9: Structure of Cases and generalized episodes adapted from Aamodt & Plaza(1994)

The figure above, generalizes the dynamic memory model outlining the structure of cases and generalized episodes. The basic idea, as outlined by the diagram above, is to organize specific cases which share similar properties under a more generalized structure known as a generalized episode (GE). A GE is composed of three objects: *norms*, *cases* and *indices* (Aamodt, A. & Plaza, E. 1994). Norms are features common to all cases indexed under a GE. Indices are features which discriminate between a GE's cases. An index may point to a more specific generalised episode or to a case, and is composed of an index name and an index value. The case-memory is a discrimination network where nodes are either a GE, an index name, index value or a case. Index name-value pairs point from a GE to another GE or case.

The primary role of a GE is to act as an indexing structure for the storage, matching and retrieval of issues. Thus, the memory is dynamic in that similar parts of two cases are dynamically generalized into a new GE, with the cases being indexed under the GE by their differences. For practical reasons, when using this method one has to limit the number of permissible indices to a

vocabulary in order to counter an explosive growth in the number of indices as case numbers increase (Aamodt, A. & Plaza, E. ,1994).

There are consequences of this view of dynamic memory from an perspective of AI such as expert systems. Programmers often try to build complete and error-free programs, however, observations on the past examples of expert systems indicated that they are not fully robust, they lack a reliable case database and their algorithms did not include any attempt to find the most relevant story related to their experiences to aid processing (Chan C.W, Chen, L and Geng L, 2000). Therefore, expert systems need to have dynamic memory structures that change each time the program is called into use. There is a difference between what people say they know and how what they said is grounded in their experience. People are modified by their experience and so the program should also be modified in the same way.

2.7.2.4 Category Exemplar Model

In this model the case memory is a network structure of categories, semantic relations, cases and index pointers with each case being associated with a category. Cases are also referred to as exemplars. Different case features are assigned different levels of importance in describing a case's membership category. A feature is described by a name value pair and a category's exemplars are stored according to their degree of prototypicality to a category. Categories are inter-linked within a semantic network containing the features and intermediate states referred to by other terms (Aamodt, A., 2004). In this model a case is associated with a category and an index may point to a case or a category. The indices are of three kinds:

1. Feature Links
2. Case Links
3. Difference Links

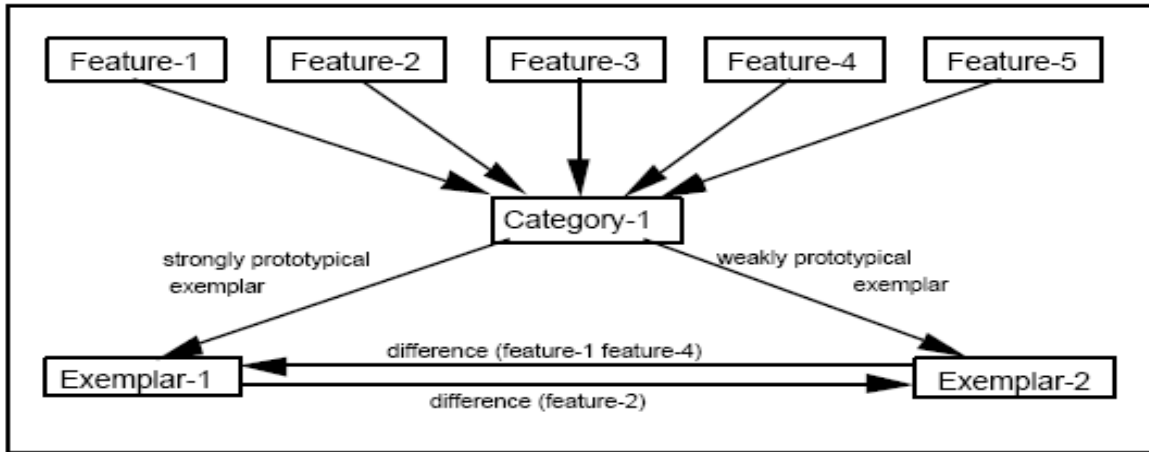


Figure 10: The structure of Categories, Features and Exemplars, adapted from Aamodt(2004)

The diagram above shows feature links pointing from problem features to cases or categories. Case links point from categories to associated cases (exemplar links) and difference links point from cases to neighbour cases that only differ in one or a small number of features. Locating a case that meets the keywords of an input description is done by linking the input features of a problem case to a pointer to the category that contains most of the features. When a reminding points to a particular category, the links to its most archetypal cases are traversed, and these cases are returned. A new case is stored by looking for a matching case, and by establishing the appropriate feature indices. In situations where a found case has slight differences to the input case description, either the new case will not be saved or the two cases are merged by following the classification links in the semantic network (Gonzalez, L.M et.al, 2005).

2.7.3 Retrieval methods

The competence of a CBR is highly dependent on the ability to retrieve cases which fit well the scope or description of the new problem. Case retrieval is a combination of search and matching techniques to retrieve the cases which are most similar to the current problem using retrieval algorithms. In this research we intend to use a combination of the nearest neighbour inductive retrieval algorithms for the retrieval process.

The retrieval process begins with the definition of the problem and ends with a best match to the search problem as shown by the series of steps below (Smyth, B. & McKenna, E., 2001):

1. Identify features
2. Initial Match
3. Search
4. Select

The problem identification process involves taking note of the input descriptors with an attempt to categorize known descriptors of the problem within its context. To understand the problem the CBR system filters irrelevant problem descriptors such as common used word connectors and checks if the input descriptors fall within the context of the existing semantic network. If the input descriptors are abstract, descriptors other than those given as input may be inferred by using a general knowledge model or by retrieving related previous case features as the expected features of the new case. Cases can be retrieved by searching an indexing structure, searching a model of the general domain or by following direct index pointers from problem features. This study uses the indexing structure to ensure that useful cases are retrieved without extensive computation. This is made possible by creating indexing vocabularies to describe cases, so that the explicit description of a case captures the features that determine its relevance (Luger, G.F. & Stubblefield, and W.A., 1998).

2.7.3.1 Retrieval algorithms

The most frequently used methods for case retrieval are nearest neighbour, induction, knowledge guided induction and template retrieval. In the following paragraphs we are going to look briefly at the nearest neighbour and induction retrieval algorithms. These methods can be used alone or combined into hybrid retrieval strategies.

2.7.3.1.1 Nearest-Neighbour Retrieval

Similarity between stored cases and the new/target case is based on matching a weighted sum of features. Therefore, this approach is more effective when the case base is relatively small. Kolodner (1993) used an evaluation function below to compute the nearest-neighbour.

$$similarity(Case_I, Case_R) = \frac{\sum_{i=1}^n w_i \times sim(f_i^I, f_i^R)}{\sum_{i=1}^n w_i}$$

Where:

w_i is the importance weight of a feature,

sim is the similarity function of features,

f_i^I and f_i^R are the values for feature i in the input and retrieved cases respectively.

Figure 9, below, displays a 2-dimensional space showing a scheme for nearest-neighbour matching. *Case3* is selected as the nearest neighbour because it is more similarly close to New Case (NC) than any other stored cases in the 2 dimensional space.

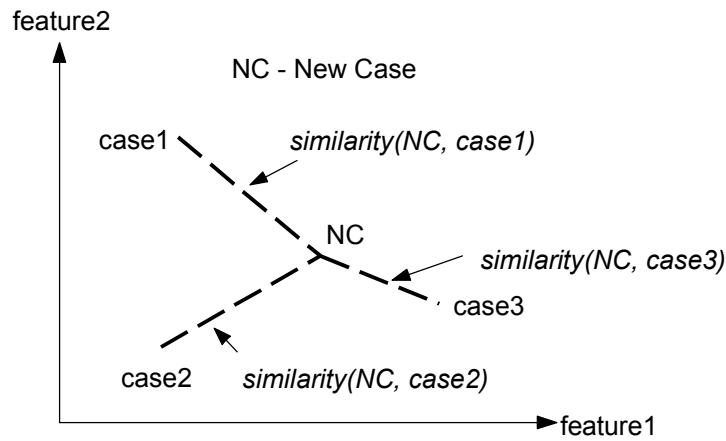


Figure 11: How to find the nearest neighbour of the new case (Aamodt, A. & Plaza, E., 1994)

2.7.3.1.2 Inductive Retrieval algorithm

In inductive retrieval, we use past cases to extract rules or formulate decisions. The method finds a target case-based on an index source case and cases are then divided into a decision tree structure. This approach is very useful when a single case feature is required as a solution, and when that case feature is dependent upon others. The inductive retrieval algorithm can be combined with the nearest neighbour retrieval algorithm. In this case the former retrieves a set of matched cases and the nearest-neighbour retrieval algorithm then ranks the matching cases according to their similarity to the target case.

2.7.4 Maintenance

Studies by Wilson & Leake (1998), defined knowledge base maintenance in terms of maintenance policies and the dimensions along which alternative policies may differ. In this framework case-base maintenance policies are grouped in terms of how they gather data relevant to maintenance decisions, how they determine when to perform maintenance operations, the nature of possible maintenance operations, and how the selected maintenance operations are executed. The set maintenance operations may target different knowledge containers and may be applied at different times or to varying portions of the case base.

Knowledge base maintenance is critical to the overall performance of case-based reasoning systems as the case base grows over time. There is a need to understand the core issues that underlie the maintenance process, namely: Retain, Review and Restore and their relationship to the overall CBR process. The improvised CBR cycle diagram below emphasizes the importance of maintenance in modern CBR which proposes that the concept of maintenance should encompass the Retain, Review and Restore stages of the CBR cycle (Iglezakis *et al.*, 2004).

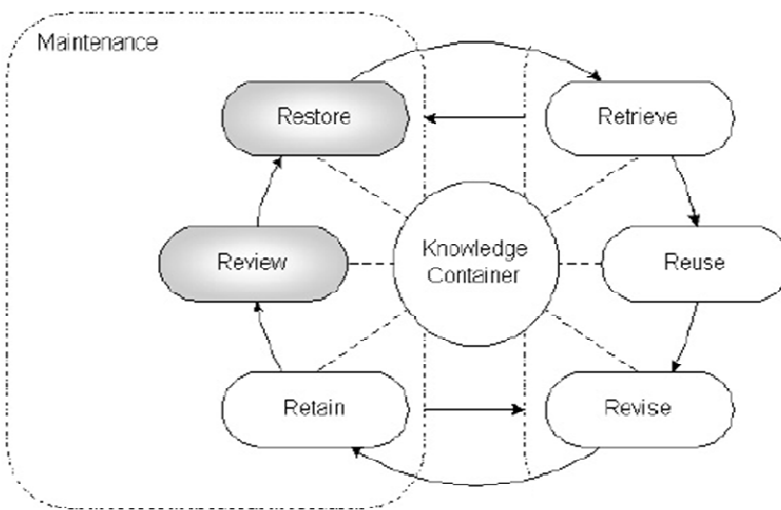


Figure 12: Maintenance process in relation to the CBR cycle (Iglezakis *et al.*, 2004)

Case adaptation is the process of altering retrieved cases when reproducing solutions for new problems as part of CBR maintenance. It may be the most important step which adds

intelligence. Case adaptation improves the overall problem solving ability of CBR. The following two adaption techniques are used most often in CBR systems.

2.7.4.1 Structural Adaptation

In this structure, formulas and rules are directly applied to a stored solution in the CBR library. The CBR system adapts a case and matches it with a new problem when the case is applied to these rules and formulas.

2.7.4.2 Derivational Adaptation

This technique reuses the rules and formulas to come up with a new solution to a current problem. Retrieved solutions should be stored as an additional case in the CBR library to allow later reuse as part of a new solution to future cases. Several techniques are used in CBR for simple to complex cases. (De Mantaras et al, 2005)

There is a need to determine how best to control the addition and deletion of cases in a bid to maintain a competent CBR system. Before adding a case it is necessary to check the following conditions:

1. whether it is a viable alternative that does not yet exist in the case base
2. whether it subsumes or can be subsumed by an existing case
3. whether it can be combined with another case to form a new one
4. whether the new case would cause an inconsistency

In a bid to meet the abovementioned conditions, introspective learning techniques can be used to examine the issue of index refinement in response to retrieval failures. Another approach involves the explanation of case application failures in order to determine additional indices to assign to a new case to focus future retrievals. Craw *et al.* (2001) examined the use of a genetic algorithm for refining indexing features and matching weights. The index revision approach is

based on the analysis of whether the results of retrievals can be extended for new problem scenarios without revising the planning decisions suggested by the retrieved case. Smyth & McKenna's (1998) competency model prioritises gaps in case knowledge and automatically suggests the type of cases that an author might want to consider to fill these gaps in a bid to maximize the potential coverage and contributions that are available.

To ensure consistency when maintaining the case base as a whole, McCrery's (1998) technique avoids the storing of inconsistent cases during initial case retention. Case Marker, a CBR system that uses McCrery's technique, performs background reasoning on behalf of the case author when new cases are added to evaluate the contributions of potential cases. This is done to suggest cases to add to the case library. This helps to avoid repeating the same cases in the case base by only incorporating the necessary information to be retained from the new problem solving episode into the existing knowledge. Basically, the process selects the information from the case to retain, the form to retain it, the indexing method to use for later retrieval from similar problems, and the integration method to use for the new case in the memory structure.

2.8 Conclusion

The objective of the research as afore mentioned is to promote technical sustainability by allowing computer users to collaborate and share experiences to assist in resolving future problems. Using this basis, the chapter described how knowledge management strategies can be integrated to develop a comprehensive collaborative knowledge sharing help desk application to facilitate knowledge sharing amongst the computer users from within the community. The following chapter outlines the critical design issues behind the development of the proposed system.

3 Chapter 3: Systems Design

3.1 Introduction

This chapter discusses, in detail, the design specifications of the Siyakhula Living Lab's Help and Support application. We outline the functional and non-functional requirements with respect to the design considerations gathered from the requirements elicitation process. The chapter discusses the proposed system architecture and concludes with a review of the technologies to be used in developing our system.

3.2 Requirements Elicitation

Karl Wiegers, an expert in the field, stated that the quality of a software product is dependent on the quality of its requirements. There exists a need to involve the final users of the system in getting a clear picture of what they should expect from the system. He further defined quality software requirements as non-ambiguous, feasible, consistent, prioritized, complete, editable and verifiable.

Wiegers (2003) proposed three distinct levels of requirements as:

- Business Requirements - goals of an organization, in our case the technical sustainability of the Siyakhula Living Lab.
- User Requirements - these are the requirements of the users.
- Functional Requirements - a specification of what the software must do.

The three requirements stated above are then categorized as functional and non-functional.

Figure 13 below helps to illustrate this.

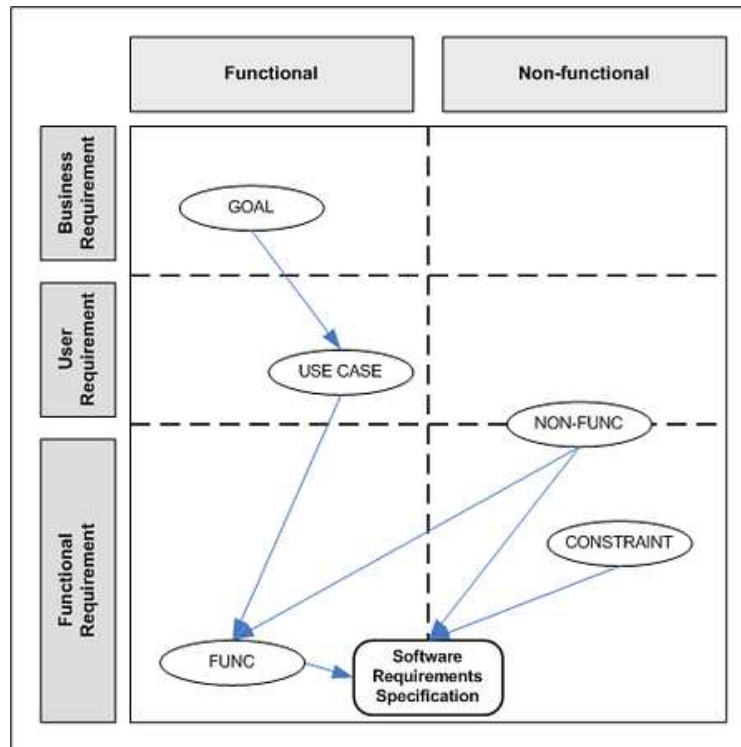


Figure 13: Requirements Classification diagram adapted from (Wiegers, 2003)

As part of the fact finding mission in developing the help and support application, the Siyakhula Living Lab research team paid monthly visits to Dwesa in the Eastern Cape of South Africa . Initial visits were primarily centred on providing training sessions as a way of equipping the rural community with basic computer literacy skills. The community benefiting from the Siyakhula Living Lab services is spread over a radius of 40km, which made the sharing of knowledge among rural users difficult, especially when users were trying to make use of their newly acquired skills. If the problem gets too complicated it would mean that users had to wait for close to a month to have their issue(s) resolved, as this is when the research team would pay another visit to train the users. Observations of the community service usage patterns as well as oral interviews were undertaken to assess what the users would expect from the help and support application as a solution to help them in resolving problems.

3.3 Non Functional requirements

Non-functional requirements depict the characteristics that the end solution must have. of the following lists captures the characteristics which we intend our solution to meet (Wiegers,2003):

- **Compatibility** - The system should be compatible with most web browsers as well as other operating systems in case of deployment.
- **Maintainability** – new features should be added with ease; faults easily fixed and should cope with a changed environment without having to make major changes to the overall system.
- **Reliability** - the system should be available at all times with all the necessary functionality available for the users.
- **Robustness** – We intend our system to be able to operate under stress or tolerate unpredictable or invalid input.
- **Security** – The system should be secure to be able to withstand attacks.
- **Usability** - The help desk user interface must be simple and appealing to the users with all the useful features clearly labelled.

3.4 Functional requirements

Functional requirements capture the intended behaviour of the system. This behaviour may be expressed as services, tasks or functions the system is required to perform. Our system should allow collaborative knowledge creation and sharing amongst users as a way of ensuring the technical sustenance of the Siyakhula Living Lab. The use case scenarios outlined in figure 14 help to define the functional requirements of our system.

3.4.1 Use Case Diagram

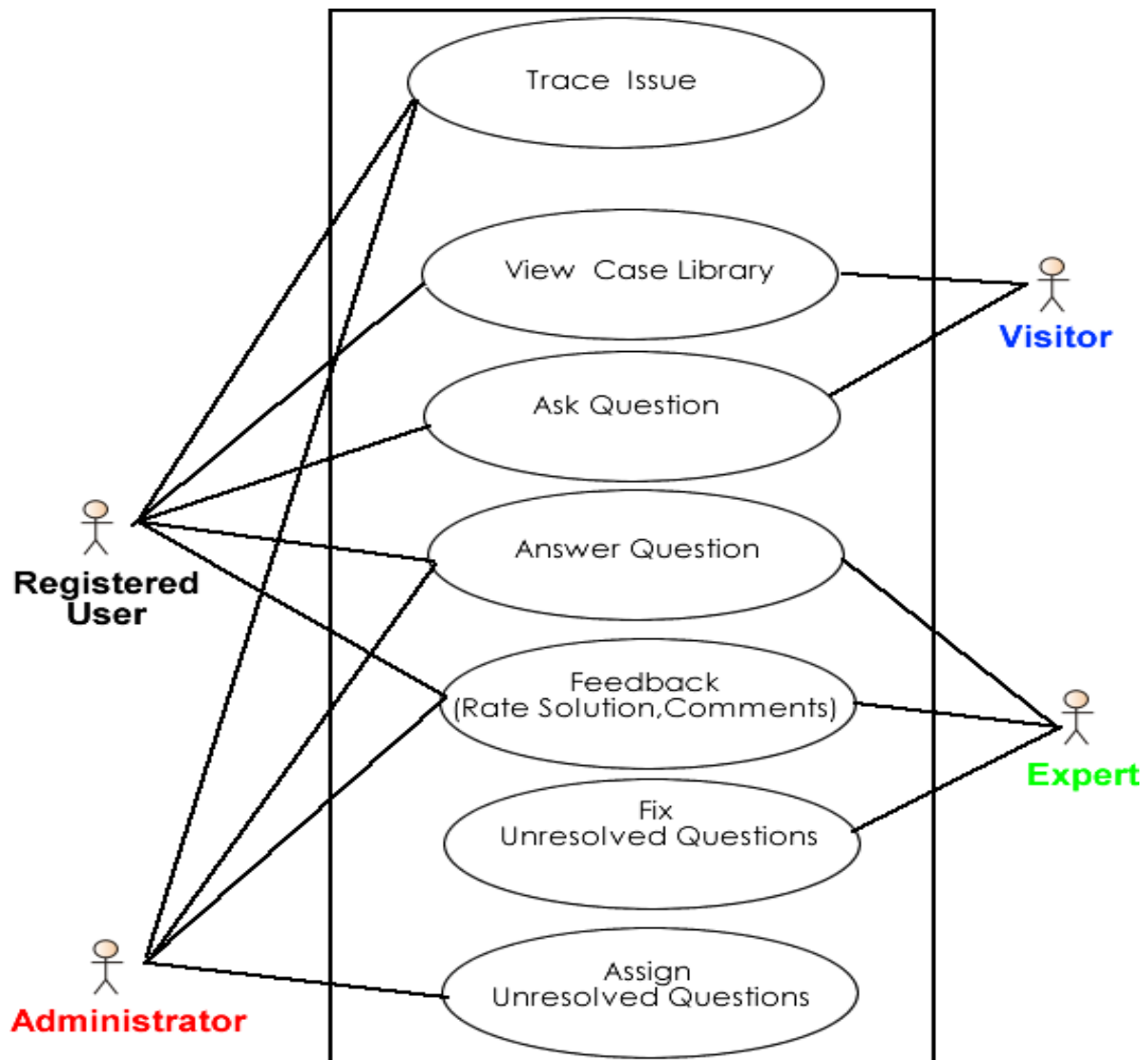


Figure 14: Top Level Use Case diagram

3.5 System Architecture

The architecture of the help and support system is shown in the figure 15 below. A three-tier approach was adopted with presentation, application processing, and data management treated as logically separate processes.

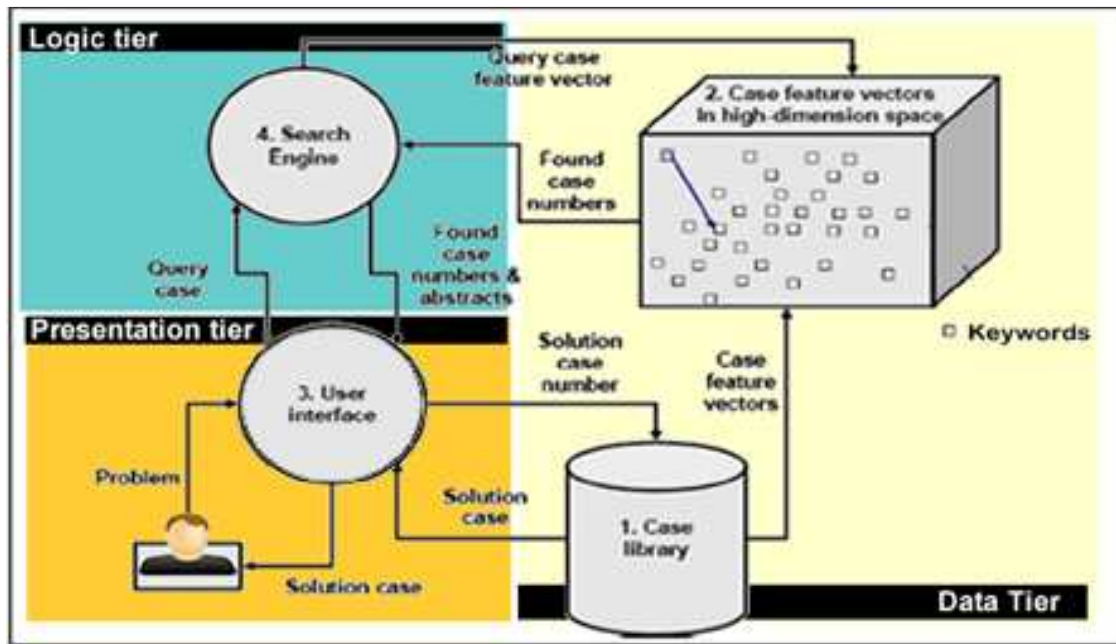


Figure 15: Systems architecture

3.5.1 Presentation Tier

User Interface

The human–computer interface is the point of communication between the human user and the computer. Our main goal with regard to the user interface is to allow effective operation and control of the application, hence there exists a need to organize the interface in a manner based on clear, consistent models that are apparent and recognizable to users without compromising the overall system requirements. According to Larry Constantine and Lucy Lockwood in their usage-centred design, a good design should be consistent, simple, flexible, tolerant and interactive in relation to application usage experience (Constantine & Lockwood, 2000). The following guidelines, as a rule of thumb, are critical to the success of the user interface of the help desk support application (Nielsen, J., & Loranger, H. 2006):

1. User control and freedom
2. Visibility of system status
3. Consistency and standards
4. Error prevention
5. Flexibility and efficiency of use
6. Aesthetic and minimalist design
7. Error recovery
8. Help and documentation

Taking system requirements into account, a user-centric approach was adopted to encourage user participation while, at the same time, considering system performance issues. Main system components such as the knowledge base, user forums, search functionality and tutorials should be easily accessible. A minimalistic approach to the look and feel of the system was done to avoid the user from being distracted from the main functionality of the system.

3.5.2 Data Tier

Information is stored and retrieved in this tier and is separated from the logic and presentation tiers to improve scalability and performance. Since our application is data driven, it is important to ensure high data quality in our application. What follows hereafter is a list of important data quality characteristics (Kahn, B., et al, 2002):

Data Quality Characteristics

1. *Relevance*: the data should be available to relevant users according to their roles.
2. *Clarity*: the data should have a clear and shared definition for the data.
3. *Consistency*: the data should not be redundant.
4. *Accuracy*: data integrity should be maintained.
5. *Completeness*: the data should be available in full without missing parts

Database design

As noted above, data should be clear consistent, accurate, relevant and complete. To achieve these standards, the database model needs to be properly structured. Using the set data requirements, figure 16 reflects the logical database design reflecting the database tables, their structure, relationships, normalization and domain. By properly setting up the correct specifications for our MySQL database to meet industry standards, we expect the help and support application to be fast, efficient and reliable.

Using correct data types and character length will contribute greatly to the query speed which is critical in the retrieval of cases. Password protected database access improves data security by preventing the unauthorized editing of data. There is also storage space efficiency, by avoiding the storage of unspecified data in our database. Proper naming of tables, and field names is important for other programmers involved in the future development of our system. Data integrity is a critical factor in the overall success of our application; making normalization an important step in the design of our database, as it minimizes the redundancy in information; this reduces the disk space occupied by the database itself. It also reduces the risk of an error affecting the information. However, our database should not be excessively normalized, since it will slow down the application during queries that require data to be retrieved from many tables. The three types of anomalies, corresponding to three types of action queries which we intend to eliminate through normalization (Date, C.J, 1999) are as follows:

1. Update anomaly – if the same data is stored in two different places, updating only one record would leave the other unchanged, thus creating confusion among users.
2. Delete anomaly – if only one record holds details regarding general information or different entities, once that record is removed, relevant information is lost.
3. Insert anomaly – if inserting a fact about some attribute requires inserting additional information about another entity or attribute.

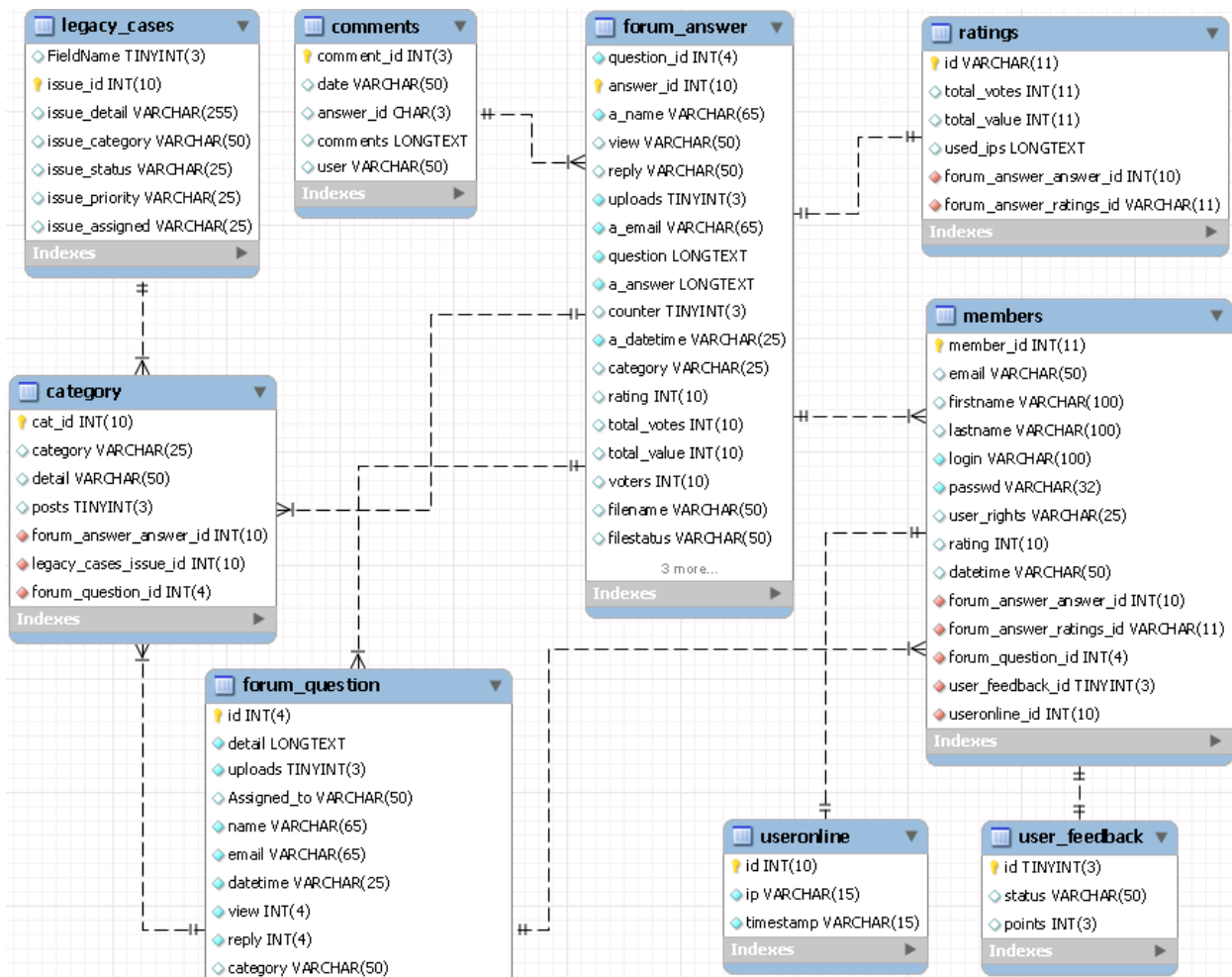


Figure 16: Logical database design

3.5.3 Logic Tier

This layer controls the application's functionality by performing detailed processing on data. Matching and indexing algorithms are critical to the whole problem solving experience in order to eliminate redundancy as well as the quality of retrieved data. An information retrieval process begins when a user enters a query into the system. Queries are formal statements of information needs, for example search strings in web search engines. In information retrieval a query does not uniquely identify a single object in the collection; instead, several objects may match the query, to different degrees of relevance. The linear search algorithm was used for database searching in our application. The algorithm goes through record by record when searching for

data. However, as the database grows larger, performance is also compromised resulting in the need to combine a linear search with indexing strategies.

To speed up data retrieval during queries, we used the search query analysis tool to index commonly asked questions and their related answers as a way of avoiding having to search the whole dataset each time a new query is made by a user. Each word within a search string is given a weight in relation to its association to a particular case as another way of indexing. The description of how the Siyakhula help desk case-based reasoning system is structured to allow efficient problem solving follows hereafter.

Our help desk is logically structured into legacy cases, stop words, case features and case feature strengths.

- A *legacy case* is a saved solution to a solved past question.
- A *stop word* is a common word filtered out before a search can begin in order to save disk space or to speed up search results. *Examples of stop words*: by, the, because, why
- *Case features* is an individual word within a string posted when a user is submitting a search. Our system stores a copy of a new case feature that ever occurs during a search. *Examples of case features*: computer, laptop, switching, server
- *Case feature strengths* link a case feature to a legacy case. A *case feature strength* has a weight that describes the relevancy of a case feature to a legacy case.

When a user asks a question, it is then broken down into individual words with *stop words* being filtered out before the search process can begin. The remaining words from the original string are then submitted to the search engine as *case features* and their *case feature strengths* are weighed in relation to a *legacy case* to determine the relevancy of a case features answer to a *legacy case*. The system will then list related legacy cases according to the relevancy of the case features to that particular legacy case. The user is then asked to rate if the displayed legacy cases help to fix their current problem. If the rating is favourable the *case feature strength* of the case features increases with the inverse resulting in a lower case feature strength. A case feature that does not find any match during the matching process will have a weakened strength in relation to the legacy case. If the system does not yield any results from the search or if the user does not find

the solutions useful, the question is then automatically posted to the user forum for discussion as a new case. Figure 17 summarizes the process described above.

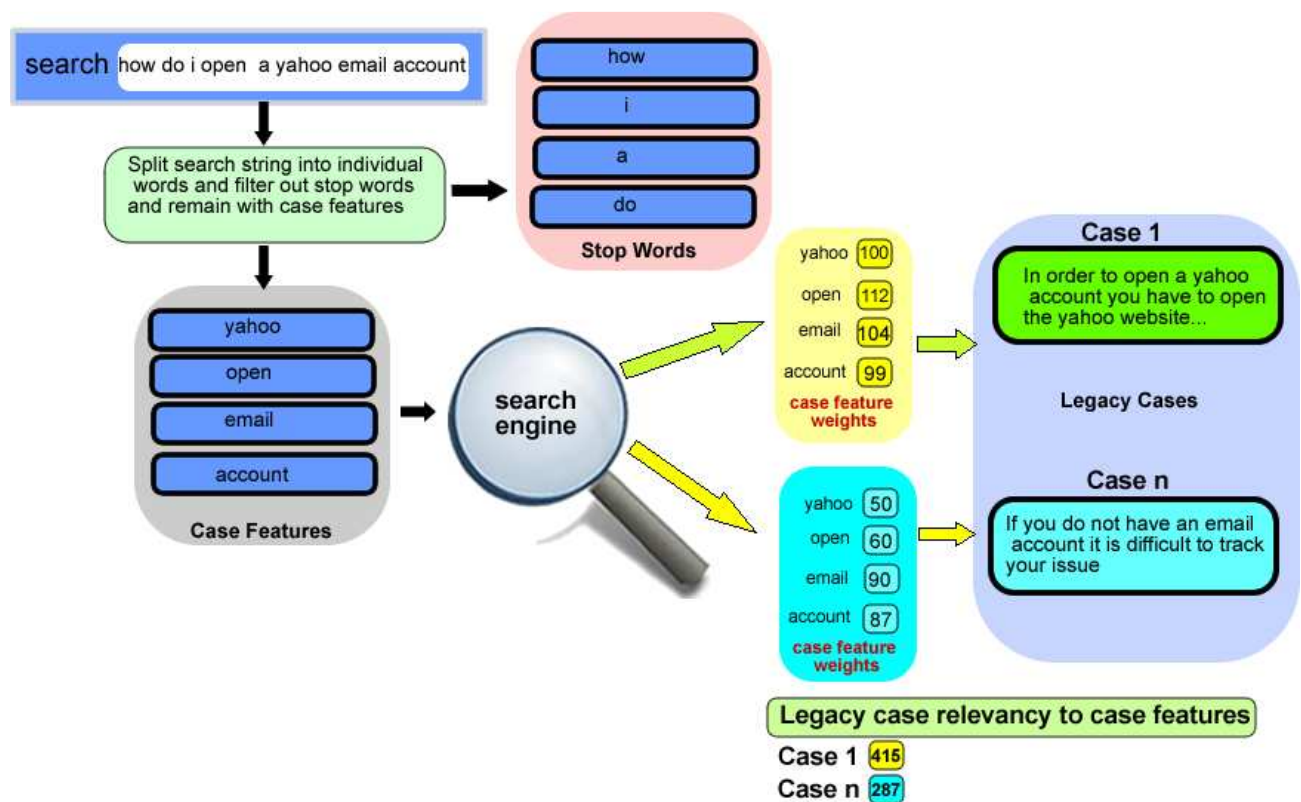


Figure 17: Relationship between case features, case feature weights and legacy cases

3.6 Relevant Technologies

We decided to use open source technologies to develop a low cost and robust application. The application has been developed in a Windows® environment using an open source technology stack called WAMP which contains Apache web server, MySQL database and PHP server side scripting language. Our application uses three-tier architecture based on the client server architecture. Three-tier architecture has the following tiers:

1. Presentation Layer
2. Logic Tier
3. Data Tier

3.6.1 Presentation Tier (Smarty Template Engine)

This layer occurs at the top of the application stack. This is where our application communicates with the client through web browsers. In our case it displays the various cases and solutions encountered by users in the Siyakhula Living Lab. In this tier, Smarty was used; it is a PHP based Templating Engine which helps to separate presentation from logic by allowing presentation features and logical aspects of an application to be developed independently of each other.

The Smarty Templating engine supports (Ohrt M., Tews U., 2010):

- Multiple caching levels for faster website loading by caching web pages.
- Plugins and add ons can be implemented by various designers to speed up development.
- Built in debugger for error handling.
- Maintainability through cleaner code organization and division of labour between designers and programmers. Designs can be changed and re-used faster.
- Security by preventing designers from tampering with the code.

3.6.2 Data Tier

To deliver web pages to clients we used the apache web server. Apache is currently the most widely used web server with the most market shares due to its compatibility with many operating system platforms. Apache can be installed separately or can come as part of the WAMP web development stack.

3.6.3 Logic Tier (PHP)

PHP server side scripting language is used to control an application's functionality by adding new capabilities as well as making more complicated operations possible on the data from the data tier. PHP provides dynamic content from a web server to a client and can run on any web server. PHP is an open-source programming language. It is primarily used for server-side

applications and the creation of dynamic web pages. PHP can be embedded into regular html code, and has a file extension of .php. Being a server side script, PHP removes the workload from client machines. This would mean that the web page would load faster since a client computer is not required to do any processor intensive work.

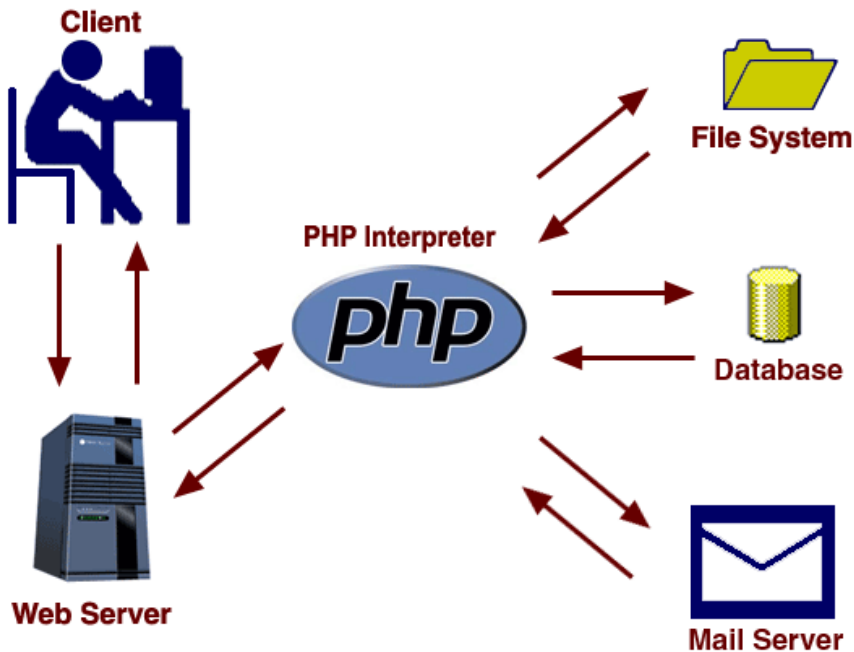


Figure 18: How PHP works (PHP Basics, 2010)

As shown in the diagram above, the PHP interpreter processes the page, communicating with file systems, databases, and email servers as necessary, and then delivers a web page to the web server to return to the browser.

The help desk application can be deployed on any operating system which runs Apache. The application will work on Apache 1.3 or Apache 2.x hosted on UNIX/Linux, OS X, or Windows. The default database server for this application is MySQL. PHP 4.3.x. version or higher is compatible with this application. All modern browsers that support CSS and JavaScript can render the application. However, minor variations in appearance may be experienced since web browsers have varying levels of compliance with Internet standards such as cascading style sheets. (PHP Basics, 2010)

3.6.4 Motivation behind using Open Source Technologies

The following points are some of the key motivations for utilizing open source technologies in this research (Muffatto, M., 2006):

- Free distribution - Developers are free to use the software and sell it as part of a compilation.
- Source code availability - Programs must not obscure the source code. Others must always be able to access, use, and build on altered source code.
- Derived works - There are no restrictions for other work based on modified code. All code remains open to the community.
- Technological neutrality - The license cannot promote certain technologies or adaptation. For example, a particular style of interface must not be favoured by the code so that others are forced to adopt this technology.
- Distribution - The open-source license and benefits must remain intact throughout the distribution path. Subsequent users must adhere to these concepts and enjoy the freedoms the license provides.

3.7 Conclusion

This chapter discussed the design of the system with an emphasis on user requirements in order to develop a cost-efficient application using open source technologies. The next chapter discusses how the design was implemented when developing the system.

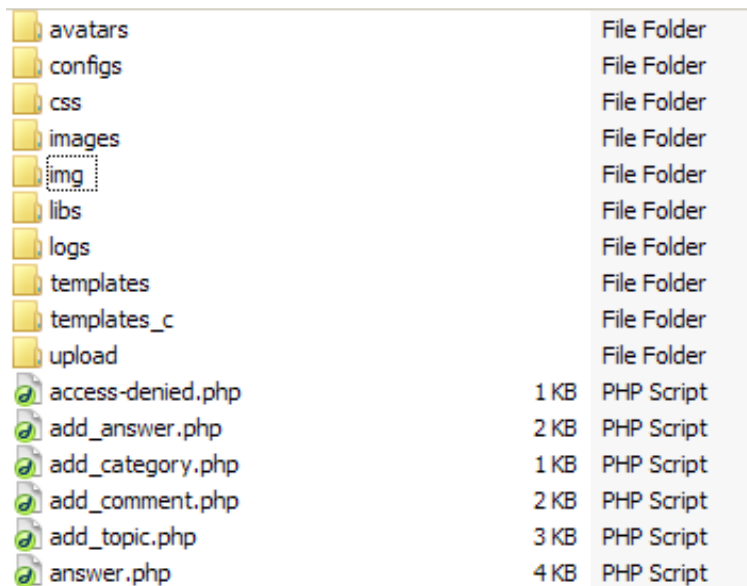
4 Chapter 4: Implementation

4.1 Introduction

This chapter looks at the implementation of the Siyakhula helpdesk system. As noted in the technologies review section in the previous chapter, the implementation of our system was done using the Apache server, MySQL database and PHP scripting language as well as the Smarty templating engine with Notepad ++ ® as our PHP source code editor on a Windows platform. This chapter considers the issues surrounding the installation, configuration and deployment of key features of our system.

4.2 System Organization

The system is hosted on a machine running Apache ® with both the database and the web server residing on one machine with PHP version 5. The application is stored within the helpdesk folder under the web server's document root. Figure 19 below shows the structure of the root folder of our application.



avatars		File Folder
configs		File Folder
css		File Folder
images		File Folder
img		File Folder
libs		File Folder
logs		File Folder
templates		File Folder
templates_c		File Folder
upload		File Folder
access-denied.php	1 KB	PHP Script
add_answer.php	2 KB	PHP Script
add_category.php	1 KB	PHP Script
add_comment.php	2 KB	PHP Script
add_topic.php	3 KB	PHP Script
answer.php	4 KB	PHP Script

Figure 19: Siyakhula help root folder

In order for the application to run, a folder called *libs* was created where the Smarty libraries, the *templates* and *templates_c* folders were extracted to store the template files and the cached templates respectively. The avatars folder contains a list of images which users can use as avatars for their profiles while other images are stored in the *images* and *img* folders. Styling sheets are stored in the *css* folder. Global configuration files such as database connection and language packs are stored in the *configs* folder. File uploads are stored in the upload folder. Folder write permission was granted to enable the web server to have write permissions on the *templates_c* and uploads folders.

4.2.1 Database Implementation

The database schema was designed preferring more tables in the database in favour of fewer columns in each table. More intricate correlations are possible by spreading data over more tables. All table names are clearly labelled according to the information they hold. The database has tables which are logically linked together by primary keys and are implemented using the MySQL relational database management system. Apache web server sits between the database and the client to facilitate data movement between the client and the database.

Our database tables are grouped into three types — kernels, associations, and characteristics.

- *Kernels* are tables that are independent entities. Below is a list of our entities:

- category
- forum_answer
- forum_question
- legacy_cases
- members

- *Associations* are tables that represent a relationship among entities.

- case_feature_vectors (relationship between question and answer entities)

- *Characteristics* are tables used to describe some other entity.

- ratings
- comments

- useronline
- user_feedback

Database authentication will frequently occur each time a database connection is made, hence there is a need to create a reusable script which contains all the connection authentication details. In our case we have the auth_database_connect.php script which can be called on a page using the PHP require once function.

```
1 <?php
2     require_once (' auth_database_connect.php')
3 ?>
```

Usage Example: (Authenticating database connection using auth_database_connect.php script)

```
1 <?php
2     define('DB_HOST', 'localhost');
3     define('DB_USER', 'root');
4     define('DB_PASSWORD', '');
5     define('DB_DATABASE', 'forums');
6 ?>
```

DB_HOST is the name of MySQL server. When the database server is on the same machine with the web server, localhost or 127.0.0.1 is used for the value of DB_HOST. For a remote database server the IP address of the database location is specified.

'DB_USER' and 'DB_PASSWORD' are valid MySQL database role based authentication credentials described in the subsection above.

DB_DATABASE is the MySQL database name.

To open a database, we have a reusable script which will be referenced to each time a database needs to be opened. For this script to work, the auth_database_connect.php script needs to be referenced each time it is used.

Usage Example: (reusable database opening script using open_database.php script)

```

1  <?php
2  $link = mysql_connect (DB_HOST, DB_USER, DB_PASSWORD);
3  if (!$link) {
4      die ('Failed to connect to server: ' . mysql_error());
5
6      //Select database
7      $db = mysql_select_db(DB_DATABASE);
8      if (!$db) {
9          die("Unable to select database");
10     }
11 }
12 ?>

```

In this application the connection is handled by the two PHP files *auth_database_connect.php* and *open_database.php*. The two PHP files are included every time a connection needs to be opened.

Usage Example: (referencing the database connection scripts)

```

1  <? php
2
3  // User authentication
4  require_once(' auth_database_connect.php');
5
6  //Connect to mysql server
7  require_once(' open_database.php');
8  ?>

```

MySQL makes use of the following PHP functions to facilitate data update, storage and retrieval:

- **mysql_connect()** : This function allows connection to the MySQL database.
- **mysql_select_db()** : This function selects the specified database.
- **mysql_query()** : This is a query function that allows the retrieval and editing of information stored in the database.
- **mysql_result()** : This function returns the contents of one cell from a MySQL result set.
- **mysql_numrows()** : This function returns the number of rows in a result set.
- **mysql_close()** : This function closes a MySQL connection.

4.2.2 User Interface Implementation

One of our goals is to design a system which can be easily maintained and is flexible for future growth. We achieved this by implementing the Smarty Templating engine, which separates presentation from the logic aspects of our application resulting in clean and easily maintainable code. Smarty generates web content by the placement of special Smarty tags within a document. These tags are processed and substituted with other code and are enclosed by template delimiters. Smarty template files can contain JavaScript and html code and have the *.tpl.html extension in addition to being stored in a folder called templates within the root directory of the application. Each time the program runs the template pages are cached for faster access if the page is requested in the future. To use Smarty with PHP, one needs to load Smarty classes using the “require once” directive to specify the location of the smarty classes.

```
1 <? php
2 require_once(SMARTY_DIR . 'Smarty.class.php');
3 ?>
4
```

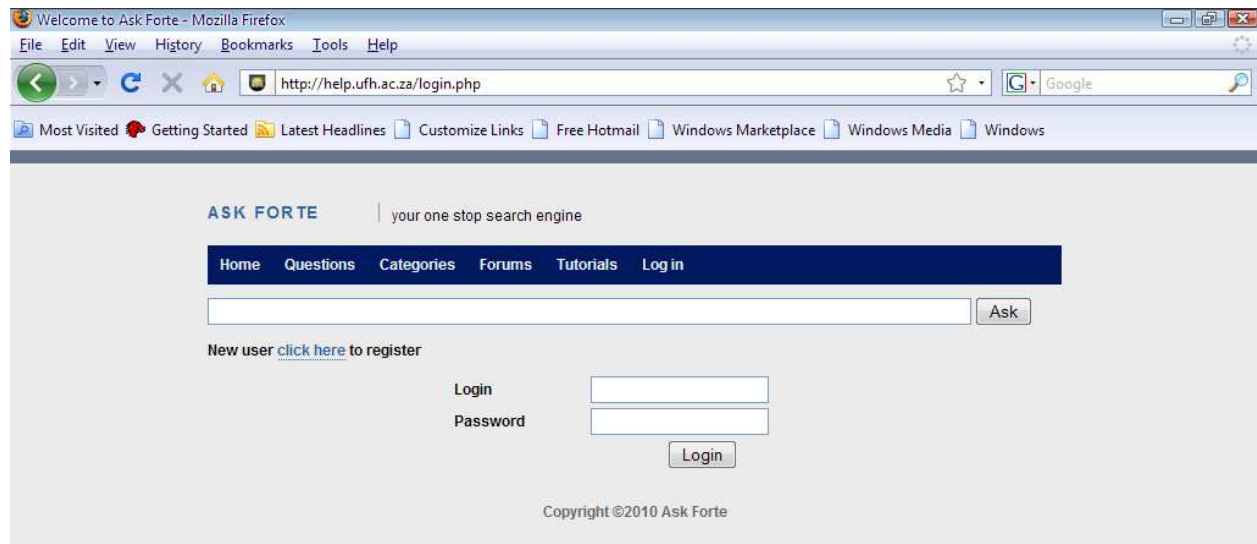
For smarty to work the smarty object needs to be initialised using the following code below:

```
1 <? php
2 $smarty = new Smarty();
3 ?>
```

Smart templates are included in a php page using the display function

```
1 <? php
2 $smarty->display('filename.tpl.html')
3 ?>
```

Usage Example: Use of Smarty in implementing the login page



To render the login page above, we use the login.php page which calls the login.tpl.html, mainheader.tpl.html, lang_auth.php, validate-form.php, footer.tpl.html, index_auth.php scripts.

login.php

```
1 <?php
2 // call smarty classes
3
4 require_once (SMARTY_DIR . 'Smarty.class.php');
5
6 //initialize news smarty object
7 $smarty = new Smarty;
8 // validate user session
9 require_once('index_auth.php');
10 // display main header
11 $smarty->display('mainheader.tpl.html');
12 // call the language pack chosen by user
13 require_once('lang_auth.php');
14 // validate username and login
15 require_once('validate-form.php');
16 //display footer
17 $smarty->display('login.tpl.html');
18 ?>
```

4.2.3 Security Implementation

Security is one of the main considerations of the system. The application has to be secure at all levels of architecture with particular attention being paid to the data in case of unauthorized attacks which can compromise data quality. This section discusses the implementation of the application with regard to issues around security.

Web Server security

Web server software vulnerabilities have the most disastrous effects; a malicious user can gain access to the operating system, potentially compromising the whole network. It is important that the Apache web server process runs under a unique user ID, which must not be used by any other operating system processes.

The web application or website files and scripts should always be on a separate partition or drive to that of the operating system, logs and any other system files. There is no need monitor and audit the server by frequently checking the network service log files for strange log entries. All the logs present in a web server should ideally be stored in a segregated area. Administrators should avoid simple, easy-to-guess passwords, particularly for privileged administrator accounts. Unnecessary accounts (such as guest) should be eliminated. Passwords should be changed frequently and enabled for sensitive areas and administration functions. There is a need to install all Apache web server updates, disable unnecessary web server modules and limit server functionality to web technologies which are going to be used.

To make server connections faster and more convenient, both individual users and server administrators store their user account passwords in their per-user configuration files. However, the passwords are stored in plain-text within the file and can easily be read. Therefore, it is important to ensure that configuration files such as (*auth_database_connect.php* and *open_database.php*) are not viewable by other users of the system, and are stored in non-public locations.

Database security

Since our application is data dependent, securing our data is a critical factor. The priority when installing MySQL is to assign a password to the MySQL root account which is empty by default.

Since the MySQL relational database supports multiple databases, multiple user accounts need to be created for access rather than depend on the root account. There also exists the need to disable wildcards in the grant tables with the role based authentication limited to the database our application is using for security reasons. This is because a hacker could use a single compromised account to gain access to other parts of the system.

Port 3306 should be blocked to prevent attacks by allowing the application to access the database using localhost as the hostname. Another area that often gets lost in the layers of security is the critical area of database backup and recovery. Data back-ups should be regular and should be stored offsite in case of system failure.

Application Security

Basic access authentication is used to allow a user to gain access to the system through the web browser, by providing credentials in the form of a user name and password. The first step is to register the user by collecting personal information which is to be stored in a database. Since the input data will be stored in a database the values received from the form should be sanitized to prevent SQL injections. Input data is also validated against redundancy and integrity. For example, no form should be submitted blank, no two users will have the same username or email address, and email addresses should have the correct syntax. To strengthen security, the user's password is encrypted as a 32-character hexadecimal number using the MD5 (**Message-Digest algorithm 5**) function provided by PHP. If all the details provided by the user are valid, they are stored in the members' database table and email notification containing the access details is sent to the new user.

Usage Example: (Verifying system login credentials)

```
1 <?php
2 // User authentication
3 require_once('auth_database_connect.php');
4 //Connect to mysql server
5 require_once('open_database.php');
6 //Create query to open the members table for password verification
7 $qry="SELECT * FROM members WHERE login='$login' AND passwd='".md5($_POST['password'])."'";
8 $result=mysql_query($qry);
9 if($result) {
10     if(mysql_num_rows($result) == 1) {
11         if($result) {
12             session_regenerate_id();
13             $member = mysql_fetch_assoc($result);
14             $_SESSION['SESS_EMAIL'] = $member['email'];
15             $_SESSION['SESS_MEMBER_ID'] = $member['member_id'];
16             $_SESSION['SESS_PASSWORD'] = $member['passwd'];
17             $_SESSION['SESS_FIRST_NAME'] = $member['firstname'];
18             $_SESSION['SESS_LOGIN_NAME'] = $member['login'];
19             $_SESSION['SESS_LAST_NAME'] = $member['lastname'];
20             $_SESSION['SESS_LAST_LOGIN'] = $member['datetime'];
21             $_SESSION['SESS_USER_TYPE'] = $member['user_rights'];
22             session_write_close();
23             header("location: member_index.php");
24             exit();
25         }
26     }else {
27         $errmsg_arr[] = 'Password and Username not matching';
28         $_SESSION['ERRMSG_ARR'] = $errmsg_arr;
29         session_write_close();
30         header("location: login.php");
31         exit();
32     }
33 }else {
34     //Close connection
35     mysql_close();
36 }?>
```

Sessions

Our system requires users to be registered to benefit from the system's full functionality. This then brings the need to identify users each time they log on to the system. A PHP session solves this problem by allowing one to store user information on the server for later use during the session. However, this session information is temporary and it is deleted as soon as the user has logged off. Sessions in our application are useful in cases where users respond to or ask questions and their user details are automatically attached with their contributions towards future tracking. It means users do not have to type their personal information each time they contribute knowledge to the system since the system will automatically store their credentials

from the database in a session each time they log on to the system. Sessions work by creating a unique identification (UID) number for each visitor and storing variables based on this ID. This helps to prevent two users' data from getting confused with one another when visiting the same webpage.

Starting a PHP Session

The code snippet below is placed within the very top of a PHP code to start up a PHP session.

```
1  <?php
2  session_start ();
3
4  ?>
```

To begin storing user information in a PHP session, there is a need to first start the session. The code must be placed at the beginning of code, before any HTML or text is sent.

Storing a Session Variable

To store user credentials that are stored in a database in a session, we use the `$_SESSION` associative array. This is where one both store and retrieve session data and eliminates the need to query the database each time we need to collect the user's personal information during a session.

PHP Code:

```
1
2 ?php
3 //Create query to check if the username and password are valid
4 qry="SELECT * FROM members WHERE login='$login' AND passwd='".md5($_POST['password'])."'";
5 $result=mysql_query($qry);
6 //Check whether the query was successful or not
7 if($result) {
8     if(mysql_num_rows($result) == 1) {
9         if($result) {
10             //if the query was successful the user details in the database are passed on and stored
11             //as session variables to be used during the session
12             session_regenerate_id();
13             $member = mysql_fetch_assoc($result);
14             $_SESSION['SESS_EMAIL'] = $member['email'];
15             $_SESSION['SESS_MEMBER_ID'] = $member['member_id'];
16             $_SESSION['SESS_PASSWORD'] = $member['passwd'];
17             $_SESSION['SESS_FIRST_NAME'] = $member['firstname'];
18             $_SESSION['SESS_LOGIN_NAME'] = $member['login'];
19             $_SESSION['SESS_LAST_NAME'] = $member['lastname'];
20             $_SESSION['SESS_LAST_LOGIN'] = $member['datetime'];
21             $_SESSION['SESS_USER_TYPE'] = $member['user_rights'];
22             session_write_close();
23 }
```

The piece of code above will register the user's session with the server, allow you to start saving user information and assign a UID (unique identification number) for that user's session.

Session Authentication

When one logs in, system creates a variable and store it in a session, to be used until the user logs off , or if the user remains inactive for a specified period of time. However, before the system can use a session variable it is has to check if the session variable for a particular user already exists to avoid users from logging in with the same credentials simultaneously. This is also useful when checking if the session is still active, for example, if a user leaves his session active without logging out and another user tries to use it. To eliminate the fraudulent use of a user's session, each and every page has a session authentication and timeout code to automatically log out the user if no activity is taking place.

The code below explains the scenario described above.

PHP Code:

```
1 <?php
2
3 if(!isset($_SESSION['SESS_MEMBER_ID']) || (trim($_SESSION['SESS_MEMBER_ID']) == '')) {
4 //If the session is not set, the session is set as visitor and the user is redirected to the main page
5     $_SESSION['SESS_FIRST_NAME']="Visitor";
6     header("location: index.php");
7 }
8 // If the session is set the user details are gathered from the session variables
9 {
10     $user= $_SESSION['SESS_FIRST_NAME'];
11 }
12 ?>
```

Cleaning and destroying a session

A session can end in two ways; either when a user has logged out or when it automatically expires after a session exceeds the time limit set in the php.ini file.

PHP Code:

```
1 <?php
2 /Unset the variables stored in session
3     Unset ($_SESSION['SESS_MEMBER_ID']);
4     unset($_SESSION['SESS_FIRST_NAME']);
5     unset($_SESSION['SESS_LAST_NAME']);
6     unset($_SESSION['SESS_LAST_LOGIN']);
7     unset($_SESSION['SESS_LOGIN_NAME']);
8     unset($_SESSION['LANGUAGE']);
9 ?>
```

One can also destroy the session entirely by calling the *session_destroy* function.

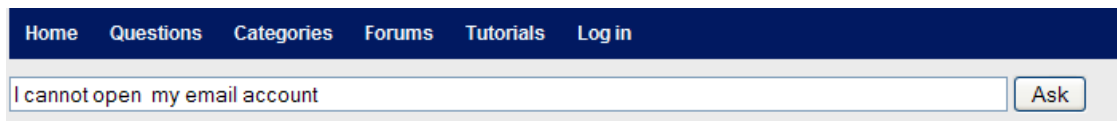
PHP Code:

```
1 <?php
2 session_destroy();
3 ?>
```

4.3 Implementation of System Components

Our system is made up of five main components which are linked together to facilitate the sharing of information. The components under discussion here are Search Engine, Knowledgebase, Language packages and Issue Tracking. The following screenshots help to illustrate how these components were implemented with reference to relevant PHP code, where necessary.

4.3.1 Search engine



The screenshot displays a web interface for a search engine. At the top, there is a dark blue navigation bar with white text links: Home, Questions, Categories, Forums, Tutorials, and Log in. Below this bar is a light gray search area. It contains a text input field with the placeholder text "I cannot open my email account" and a blue button labeled "Ask" to its right.

From the above stated screenshot, the problem solving process is either initiated by the user through the use of the ASK functionality. Normally, the starting point of problem solving is through asking, and our system offers this functionality prompting users to type details of the problems they are facing. Following the above stated screenshot, where the user cannot open an email account, clicking the **Ask** button will prompt the system to search the case library first to check if the problem has been experienced before. Individual words are the determinants in the separation of cases or problems as they are weighted as a way of ranking and associating them with a particular problem or solution. If the keywords of the search phrase matches previously solved cases the system returns a list of results ranked according to best match. The users can then select the results and check if they are helpful.

PHP code snippet for the search functionality [search.php]

```
56 // Define the number of results per page
57 $pagenum_results = 10;
58
59 // Figure out the limit for the query based
60 $from = (($pagenum * $pagenum_results) - $pagenum_results);
61
62 //trims the whitespace before and after the searched terms
63 //replaces all of the extra white spacing with single spacing
64 $search = preg_replace('/\s+/', ' ', $search);
65
66 $search_words = explode(" ", $search); //and now we break the spaces between words
67
68 //list of stop words
69 $CommonWords = array('a', 'as', 'any', 'all', 'am', 'an', 'and', 'are', 'at',
70                      'b', 'be', 'but', 'by',
71                      'c', 'can',
72                      'd', 'did', 'does', 'do',
73                      'e', 'each', 'else', 'even', 'ever',
74                      'f', 'for', 'from',
75                      'g', 'go', 'get');
76
77 foreach ($search_words as $word) {
78     if (!in_array($word, $CommonWords) && (trim($word) != '')) {
79         $searchWords[] = $word;
80     } else {
81         $junkWords[] = $word;
82     }
83 }
84 if(!$search){
85     $found=0;
86     echo "Search variable not entered";
87 }
88 else{
89
90     //Make the query possible
91     echo "Your results containing search term(s):      ".<b>" . $search. "</b>";
92     $conta = count($search_words); //how many words are there to search?
93     $found=0;
94     $notfound=0;
95
96     // Figure out the limit for the query
97
98     $from = (($pagenum * $pagenum_results) - $pagenum_results);
99
100
101     //search for each individual word
102     for ($i = 0; $i < $conta; $i++) {
103         //ok, now search for each word separately:
104         if (strlen($search_words[$i])>3){
105             $result = mysql_query("SELECT * FROM $tbl_name WHERE a_answer LIKE '%$search_words[$i]%'");
106
107             $num_rows = mysql_num_rows($result);
108         }
109         if($num_rows){
110             while($iRow=mysql_fetch_array($result))
111                 //the tables to be printed out:
112             {
113                 $question=$iRow["question"];
114                 $answer_id=$iRow["answer_id"];
115                 $rating=$iRow["rating"];
116
117                 $found+=1;
118                 //print 'em out:
119                 ?>
```

4.3.2 Knowledgebase

Knowledge is represented in various forms in our system. User Forums and Tutorials are the primary source of knowledge in the system. Newly asked questions are automatically posted to the forums for discussion, with tutorials being listed under the tutorials section after approval from administrators.

User forums

User forums allow registered users to exchange information about open issues which need solutions. User forums can be accessed directly or automatically if the user fails to find a solution during the search process. For instance, when a search does not yield relevant results, the asked question will automatically appear in the forums and on the main page under recently asked questions as an open topic where registered users can contribute to the topic.

Home Questions Forums Tutorials Manage Log Out Your Login name is:fred					
					search
Topic_Id	Topic	Views	Replies	Date	
1	I cannot view video objects using Internet Explorer browser	6	0	19/09/10 03:19:32 PM	
2	I cannot open my email account	4	0	19/09/10 02:45:25 PM	
3	Does Google voice recognise Xhosa language	4	1	16/08/10 01:10:21 PM	
4	How do i insert a cover page for my document	3	0	13/05/10 12:47:05 PM	
5	How can i edit my pictures	52	2	13/05/10 12:24:45 PM	
					Create New Topic
1 2 Next					

PHP code snippet for displaying forum topics [contribute.php]

```

15 // Connect to server and select database.
16 mysql_connect("$host", "$username", "$password")or die("cannot connect");
17 mysql_select_db("$db_name")or die("cannot select DB");
18
19 if(!isset($_GET['cont_page'])){
20     $max_results = 5;
21
22     // Figure out the limit for the resource query
23     $from = (($cont_page * $max_results) - $max_results);
24
25     $result = mysql_query("SELECT * FROM $tbl_name ORDER BY datetime DESC LIMIT $from, $max_results");
26     $smarty->display('contribute_headings.tpl.html');
27 }
28
29 <?php
30 while($rows=mysql_fetch_array($result)){ // Start looping table row
31     <?
32     <tr>
33     <td bgcolor="#FFFFFF"><?php echo $number++; <?></td>
34     <td bgcolor="#FFFFFF"><a href="view_topic.php?id=<?php echo $rows['id']; <?>">
35     <?php echo $rows['topic']; <?></a><BR></td>
36     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['view']; <?></td>
37     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['reply']; <?></td>
38     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['datetime']; <?></td>
39     </tr>
40     <tr>
41     <td colspan="5" align="right" bgcolor="#E6E6E6"><a href="create_topic.php"><strong>
42     <?php $smarty->display('new_topic.tpl.html');
43     <?></strong> </a></td>
44     </tr>
45     </table>
46     <?php

```

Under the forums, if a topic is clicked it is listed showing its author, the topic, category, replies and the author's rating. Replies can be posted as either text or as PDF files in the form of tutorials. Users can give a rating to the solutions posted to the question, with the best solutions being posted to the front page as best answers. If a solution gets a higher rating from the user, it is automatically closed and is stored as a legacy case for future use.

Home Questions Forums Tutorials Manage Log Out Your Login name is:fred			
			search
Topic	Started By	Category	
How can i edit my pictures	Username:matwayi ☆☆☆☆☆ User Rating: 0% Datetime:13/05/10 12:24:45 PM	Hardware	
Post Reply		Post Article	
Answer	Posted By	Answer Rating	
Try Adobe Photoshop	Username:edim ☆☆☆☆☆ User Rating: 0% Datetime:13/05/10 12:31:14 PM	★★★★★ Rating: 90% 1 Rate It	
Comment on this answer			
Answer	Posted By	Answer Rating	
You can use Macromedia Fireworks it easy to use	Username:fred ★★★★★ User Rating: 80% Datetime:13/05/10 12:25:32 PM	★★★★★ Rating: 60% 1 Rate It	
Comment on this answer			

The following code snippet corresponds to the above stated screenshot.

PHP code snippet for forum topic [view_topic.php]

```
56 <?php
57 require_once('lang_auth.php');
58 $smarty->display('view_topic_headings.tpl.html'); ??
59 <tr>
60 <td align="left" bgcolor="#FFFFFF" > <?php echo $rows['topic']; ?></td>
61 <td align="left" bgcolor="#FFFFFF"><?php echo $rows['detail'];
62 $users=$rows['name']; ?></td>
63 <td align="center" bgcolor="#FFFFFF"><?php echo nl2br ('Username:'. $users. "\n". '<span class="rating">
64 
65 User Rating: '. $rater_stars_txt. '</span> ');?></td>
66 <td align="left" bgcolor="#FFFFFF"><?php echo $rows['datetime']; ?></td>
67 </tr>
68 <tr>
69 <td colspan="4" align="right" bgcolor="#E6E6E6"><a href="answer.php?id=<?php echo $i_d; ?>" >
70 <strong><?php $smarty->display('reply.tpl.html'); ?></strong> </a></td>
71
72 </tr>
73 </table>
```

Tutorials

Tutorials in our application are files that have been uploaded to assist users in resolving certain queries. They can be in the form of audio, text or video files which users can download. Anyone can post tutorials, however, only system administrators have the authority to approve whether the content posted is suitable for display. Tutorials are either posted when replying to an open issue or by the system administrators. The following example explains the file upload process.

Upload files

File Summary

Category

Please select a pdf file to upload

Topic_Id	Topic	Downloads	FileSize	Date Posted
----------	-------	-----------	----------	-------------

PHP code snippet for forum topic [upload.php]

```
35 //Check that we have a file
36 if ((!empty($_FILES["uploaded_file"])) && ($_FILES["uploaded_file"]["error"] == 0)) {
37     //Check if the file is JPEG image and it's size is less than 350Kb
38     $filename = basename($_FILES["uploaded_file"]["name"]);
39     $ext = substr($filename, strrpos($filename, '.') + 1);
40     if (($ext == "pdf") && ($_FILES["uploaded_file"]["size"] < 209715200)) {
41         //Determine the path to which we want to save this file
42         $newname = dirname(__FILE__).'/upload/'.$filename;
43         //Check if the file with the same name is already exists on the server
44         if (!file_exists($newname)) {
45             //Attempt to move the uploaded file to it's new place
46             if (move_uploaded_file($_FILES["uploaded_file"]["tmp_name"], $newname)) {
47                 echo "It's done! The file has been saved as: ".$newname;
48             } else {
49                 echo "Error: A problem occurred during file upload!";
50             }
51         } else {
52             echo "Error: File ".$_FILES["uploaded_file"]["name"]." already exists";
53         }
54     } else {
55         echo "Error: Only .pdf files under 350Kb are accepted for upload";
56     }
57 } else {
58     echo "Error: No file uploaded";
```

The screenshot displayed hereafter shows how the uploaded files are listed. The listing of uploaded tutorials shows the number of downloads, the file size and the date posted.

Home Questions Forums Tutorials Manage Log Out Your Login name is:fred				
				search
Topic_Id	Topic	Downloads	File Size	Date Posted
1	How to create bubbles with photoshop brushes	5	216kb	13/05/10 12:37:35 PM
2	PHP References: How They Work, and When to Use Them	3	18kb	09/12/10 07:17:59 PM
3	How to Build a XML Driven Quiz Application in Flash	3	100kb	09/12/10 07:13:56 PM

PHP code snippet for forum topic [tutorials.php]

```
43 while($rows=mysql_fetch_array($result)){ // Start looping table row
44     ?>
45     <tr>
46     <td bgcolor="#FFFFFF"><?php echo $number+=1;
47     $filename=$rows['filename'];
48     ?></td>
49     <td bgcolor="#FFFFFF"><a href="file_view.php?id=<?php echo $filename;?>
50     "TITLE="Click here to download this file"
51     <?php echo $rows['question']; ?></a><BR></td>
52     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['view']; ?></td>
53     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['size']; ?></td>
54     <td align="center" bgcolor="#FFFFFF"><?php echo $rows['a_datetime']; ?></td>
55     </tr>
56     <tr>
57     <td colspan="5" align="right" bgcolor="#E6E6E6"><strong></strong> </a></td>
58     </tr>
59     </table>
```

4.3.3 Language Packs

Our system is multilingual, allowing the user to switch the navigation bar and other important labels on the user interface. The system is restricted to two languages at the moment with the ability to easily add new language packs. User content, such as cases, could not be translated at this moment. The screenshot displayed hereafter shows what the interface looks like when Xhosa is selected.

[Home](#) [Umbuzo](#) [Iqumrhu lengxoxo](#) [Incwadi](#) [Ukulawula](#) [Phuma](#) [Igama Lakho ngufred](#)

Xhosa

Select

There is 1 visitor online

Imiphendulo igrand

Inombolo yeumbuzo	Umbuzo	Uhlulu	Umlinganekiso
1	How can i edit my pictures	Hardware	★★★★★ Rating: 90%

Imibuzo intsha

inani yenxgoko	Ngxoko	Iboniwe	Imiphendulo	Xghesha
1	How do i check the weather forecast for Eastern Cape	17	2	05/05/10 11:28:30 AM

The language packs are stored in the global configurations folder, *conf* in the application's root folder as shown hereafter.

 english.conf	4 KB	CONF File
 xhosa.conf	4 KB	CONF File
 .htaccess	1 KB	HTACCESS File
 database_connect.php	1 KB	PHP Script

The following code snippet below shows how the language was integrated into our application.

[init_language.php]

```
16 <form method="post" action="language.php">
17
18 <div align="right">
19     <?php
20         $sql5="SELECT * FROM $tbl_name5 ";
21         $result = mysql_query ($sql5);
22         echo "<select name=language value='language'>language</option>";
23         // printing the list box select command
24
25     while($nt=mysql_fetch_array($result)){//Array or records stored in $nt
26         echo "<option value=$nt[language]>$nt[language]</option>";
27         /* Option values are added by looping through the array */
28     }
29     echo "</select>";// Closing of list box
30     ?>
31
32     <input type="submit" name="button" id="button" value="Select">
33 </div>
34 </form>
```

4.3.4 Issue Tracking

[Home](#) [Issue Manager](#) [My Posts](#) [Submit Articles](#) [Approve Articles](#) [Log Out](#) Your Login name is:fred

Issue Management

Category Id	Category	Articles Posted	Open Issues	Closed Issues	Tutorials
1	Software	0	0	0	0
2	Other	1	1	0	0
3	Hardware	8	6	1	1

You dont have Issues Assigned to you

Administration of the issues is done by experts who have the authority to assign open issues, approve uploaded articles. However, any registered user can view his/her posts and change profile credentials. This section shows how issue tracking was implemented.

[Home](#) [Issue Manager](#) [My Posts](#) [Submit Articles](#) [Approve Articles](#) [Log Out](#) Your Login name is:fred

Topic	Category	Assign to an Expert
Does Google voice recognise Xhosa language	Hardware	Jim Assign Expert

[Post Reply](#)

The above named open issue can be assigned to an expert, in this case Jim. The user who asked the question is sent an automatic email notifying him/her that their problem is being attended to. The expert also receives a notification about a new issue which needs his attention.

```

42  $to = $expert_email;
43  $subject = "Issue assignment";
44  $msg = "A new issue has been assigned to you!";
45  $headers = "From: admin@siyakhula.com \n Reply-To: admin@siyakhula.com";
46  $config = "-stfu@noob.com";
47  mail("$to", "$subject", "$msg", "$headers", "$config");
48
49  $to = $posted_by_email;
50  $subject = "Issue assignment";
51  $msg = "Your issue has been assigned to an expert";
52  $headers = "From: admin@siyakhula.com \n Reply-To: admin@siyakhula.com";
53  $config = "-stfu@noob.com";
54  mail("$to", "$subject", "$msg", "$headers", "$config");

```

As soon as that issue has been fixed the user receives an email from the expert with information on how the issue was resolved.

4.4 Conclusion

In this chapter we presented the implementation details of our system. Open source technologies were used for implementation as building blocks of the system. We looked at how the key components were implemented and integrated into the knowledge base. The next chapter shows how the system was tested and the related results collected from the target end users of the system.

5 Chapter 5: Systems Testing and Results

5.1 Introduction

This study examines the technical sustenance of the Siyakhula Living Lab by offering users the ability to collaborate in fixing routine technical problems. This chapter makes reference to the functional requirements specified in the systems design chapter as a benchmark for testing the overall success of our system. The chapter concludes with a summary of the findings.

5.2 Review of Functional Requirements

The system should allow users to ask questions, contribute towards discussions, rate solutions and trace open issues with minimal help from experts. We expect users to seamlessly share and expand knowledge, with the help of this system, as a way of promoting technical sustenance.

5.3 Test Plan

Our hypothesis is that collaborative knowledge sharing helps to achieve a level of technical sustainability of the Siyakhula Living Lab by encouraging users to assist each other in resolving routine technical problems. To examine our hypothesis we conducted a survey of 20 computer users at Ngwane School, in Dwesa, in the Eastern Cape, South Africa. Survey participants were recruited from a selection of computer users within the community during a period of one week in November 2010.

Our study was conducted amongst a sample of 20 participants with an age group ranging from 15 to 50 years. The study group included community dwellers, school children and teachers with levels of education that ranged from uneducated to teacher training certified. Initial encounters showed that most users relied more heavily on experts for technical assistance since most of them had low computer literacy skills. 50% of the respondents were unemployed youths between the ages of 18 and 30 hoping to make use of the Siyakhula Living Lab to connect with friends and family as well as using the internet to search for jobs. 30% of the respondents were teenagers of school going age and 20% of the respondents were over 30years of age, mainly teachers and a handful of community elders.

Survey Respondends

■ <18 years ■ 18-30 years ■ 30> years

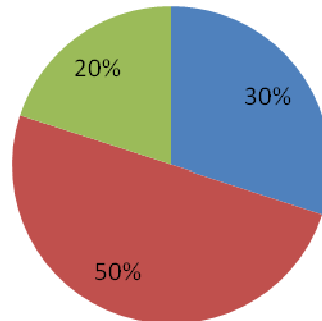


Chart 1: Survey Respondents

We grouped our testing into two phases, Functional and Usability testing. In functional testing we assessed whether the system meets the functional requirements specified in the Design Chapter, whilst the usability testing assessed the overall presentation of the system.

5.3.1 Functional Testing

Test cases for our Functional testing were grouped as follows:

1. Collaborative knowledge sharing
2. Issue Tracking
3. Case-based Reasoning
4. Tutorials

Collaborative knowledge sharing

To test for collaborative knowledge sharing we created a new question to check if respondents can collaborate until a solution has been found. In this test scenario we created a question which most of our respondents were familiar with. The following screenshots help to describe this test case.

SIYAKHULA
HELPDESK

your collaborative knowledge sharing space

Home
Questions
Forums
Tutorials
Manage
Log Out
Your Login name is:fred

Enter Details of your Issue/Topic

Topic :

Detail :

Software

Copyright ©2010 Ask Forte

The above stated screenshot shows how one can post a new question. In this scenario, we created the question “*How do I type a CV using the computer*”. The Question is automatically listed in the forums for users to collaborate as shown by the next screenshot below.

SIYAKHULA
HELPDESK

your collaborative knowledge sharing space

HomeQuestionsForumsTutorialsManageLog OutYour Login name is:fred

search

Topic_Id	Topic	Views	Replies	Date
1	How do I type a CV using the computer	0	0	20/12/10 04:50:46 PM
2	I cannot view video objects using Internet Explorer browser	6	0	19/09/10 03:19:32 PM
3	I cannot open my email account	22	0	19/09/10 02:45:25 PM
4	Does Google voice recognise Xhosa language	9	1	16/08/10 01:10:21 PM
5	How do i insert a cover page for my document	3	0	13/05/10 12:47:05 PM

Create New Topic

12Next

The following screenshot shows a registered user responding to the asked question.

SIYAKHULA HELPDESK | your collaborative knowledge sharing space

Home Questions Forums Tutorials Manage Log Out Your Login name is:fred

Topic Detail

How do I type a CV using the computer

Category : Software Started By : fred Email : webmaster@ufh.ac.za
Date Posted : 20/12/10 04:50:46 PM

Contribute to this Issue

Make sure that the computer is switched on and log in.After logging in go to Applications and the Open office on the main menu to Open Office and start typing.I hope this helps

The response by this a user is listed together with the question to allow other users to further contribute until the best solution is found as shown in the next screenshot below.

SIYAKHULA HELPDESK | your collaborative knowledge sharing space

Home Questions Forums Tutorials Manage Log Out Your Login name is:fred

Topic	Started By	Category
How do I type a CV using the computer	Username:fred ★★★★☆ User Rating: 80% Datetime:16/08/10 01:10:21 PM	Software

[Post Reply](#) ← A user can post a different reply → A user can post a an article to reply this question [Post Article](#)

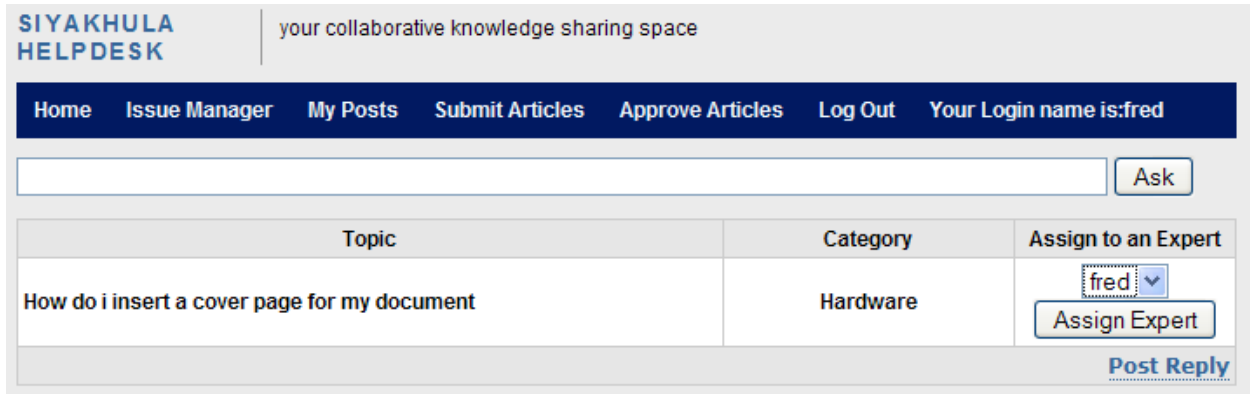
Answer	Posted By	Answer Rating
Make sure that the computer is switched on and log in.After logging in go to Applications and the Open office on the main menu to Open Office and start typing.I hope this helps	Username:Unathi ★★★★★ User Rating: 0% Datetime:16/08/10 01:10:53 PM	☆☆☆☆☆ Rating: % 1 Rate It

A user can rate this solution A user can comment on this solution

1

Issue Tracking

A test case for issue tracking takes place in situations where a posted question proves to be complex for users, resulting in the need for expert intervention. The process is either triggered by the system automatically or manually by system administrators. Automatic issue tracking is triggered when an issue is not fixed within three days. Issue assignment is then done by the administrators as shown by the following screenshot below.



The screenshot displays the SIYAKHULA HELPDESK interface. At the top, there is a header with the logo and the tagline "your collaborative knowledge sharing space". Below this is a navigation bar with links: Home, Issue Manager, My Posts, Submit Articles, Approve Articles, Log Out, and Your Login name is:fred. A search bar with an "Ask" button is positioned above a table. The table has three columns: Topic, Category, and Assign to an Expert. The first row shows the topic "How do i insert a cover page for my document" and the category "Hardware". In the "Assign to an Expert" column, the name "fred" is selected from a dropdown menu, and there is an "Assign Expert" button. A "Post Reply" link is located at the bottom right of the table.

Topic	Category	Assign to an Expert
How do i insert a cover page for my document	Hardware	fred Assign Expert

When the administrator has assigned the issue the user who posted the question is sent an email containing the issue id, the expert fixing the issue, and the status of the issue. As soon as the issue is fixed the user receives another email containing the solution to that problem.

Case-based Reasoning

A test case for case-based reasoning takes place when users type in a problem in the search bar to look for a possible solution in the knowledge base. In this test case we want to check if previously solved solutions can be used to solve present problems. This test scenario is dependent on the number of cases in the case base. The knowledge base with the common problems faced by users had to be populated during our regular field trips to the study site. We then asked users to search for solutions to problems which they had faced before to see if the system helps to formulate the problem to suggest the best solution.

Tutorials

The test case for tutorials was to check if users were able to upload tutorials as solutions to open problems as well as using uploaded tutorials to solve their own problems.

5.3.2 Usability testing

Usability testing for our system was assessed by considering the user's overall perception of the entire system. There are no test cases for this type of testing, with respondents being asked about the usefulness of the systems function and features as well as the overall design of the system. To conduct our usability testing we used the System Usability Scale (SUS), which is a simple, ten-item scale giving a global view of subjective assessments of usability. SUS addresses different aspects of the user's reaction to the website as a whole which makes it a reliable measure of user experience. Initial training was done so that users have an idea of how the system works in addition to assisting them in understanding the questionnaire. In order to get reliable results in our study a minimum of 15 users was necessary for the testing. The system was tested according to its four main components: issue tracking, tutorials, discussion forums and search functionality with the users completing the Questionnaire in Appendix A to assess those system components. The Questionnaire in Appendix A has a total of 12 questions, with 4 questions for each of the three major metrics listed hereafter.

The following list of metrics are used on our usability tests:

1. Effectiveness

- Ability to ask, answer and rate questions
- Ability to reuse past cases to solve future problems
- Ability to trace open problems/issues
- Ability to use tutorials to solve problems.

2. Efficiency

- Time to learn how to use the system
- Availability of help or documentation use
- Ability to quickly recover from mistakes
- Ability to use the navigation bar with ease

3. Satisfaction

- Rating scale for usefulness of the help desk system.
- Rating scale for satisfaction with functions and features
- Rating scale for satisfaction with the overall design of the system
- Ability of the system to replace the need for the physical presence of experts.

All 12 questions of the Questionnaire were to be rated by the user on a scale of 1 to 10, with 1 being the least favourable and 10 being the most favourable result. In order to have a clear understanding of our respondents, the questionnaire requires the user to fill in his/her personal details with regard to employment, level of education, age, and computer literacy levels. This is useful as respondents were categorised into two groups according to computer literacy levels when results were analysed.

5.4 Results attained

We divided our users into two groups: novice and experienced, depending on their literacy levels. The novice group consisted primarily of users over the age of 30 with those below 30 being more experienced. The graph below shows the literacy levels of the 20 respondents. Users with computer usage experience spanning more than a year were regarded as experienced while those with less than a year were regarded as novices. In our test sample, 8 users had used the computer for less than a year with 12 of the respondents being more experienced as they had used the computer for a period over a year.

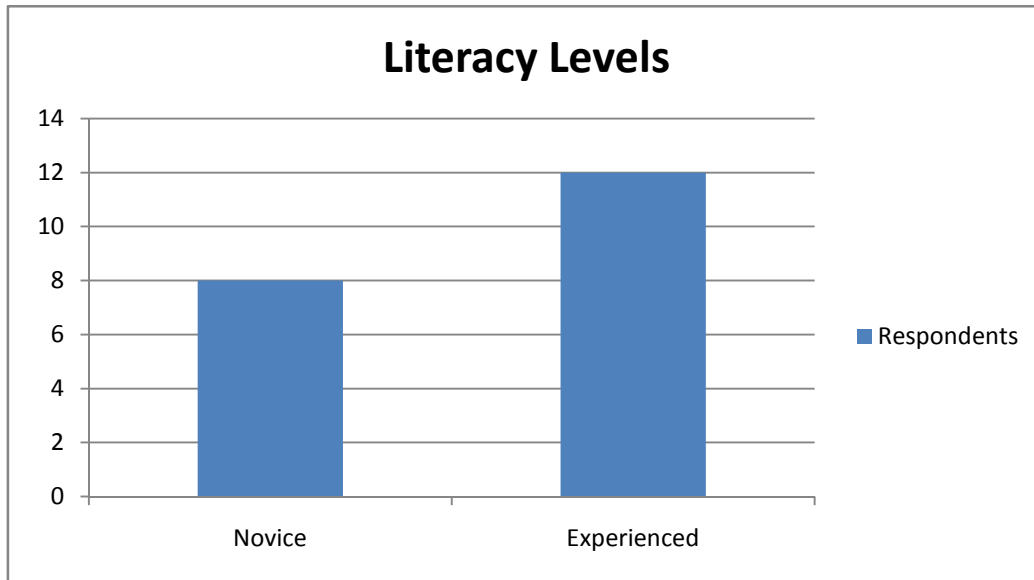


Chart 2: Computer Literacy Levels

Table 1 shows a sample of the results of our usability testing, based on the level of computer literacy of the respondents.

Metric	Novice Users	Experienced Users	All users
Efficiency	40%	70%	55%
Satisfaction	45%	80%	63%
Effectiveness	50%	60%	55%
Overall	45%	70%	58%

Table 1: Questionnaire results table

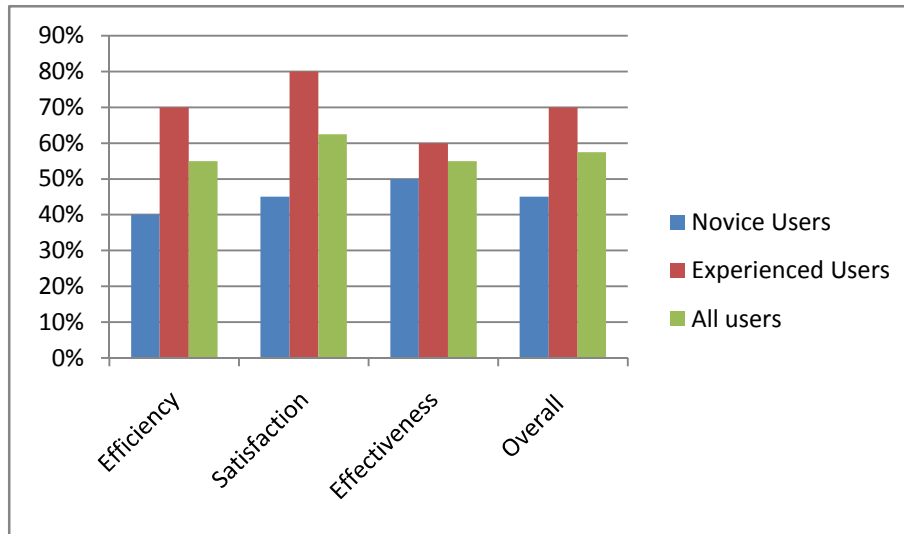


Chart 3: Questionnaire results

The graphs in Chart 3 show the response collected from the participants of the test. Experienced users were happy with the level of user control and freedom as they were able to complete the tasks of asking, answering and rating questions and solutions using the system as evident from the 60% recorded for the systems efficiency. Novice users recorded a low efficiency rate of 50% due to the fact that most members of this group were still learning how to use computers. Unlike the experienced users who understood that content is dependent on user participation over time, novice users' expectations were high since they expected all their problems to match solutions in the case base. The overall efficiency rate for both user groups is 55%, a positive trait which we expect to raise with increased computer literacy levels over time.

The overall satisfaction level for all users is set at 63% with all users satisfied with the look and feel of the web based help desk system. Experienced users were comfortable with the functionality and features which the system provides and were optimistic that the system would be more useful over time as they collectively build the knowledge base, based on their experiences. However, inexperienced users were not prepared to work without the constant visits by experts which placed their group satisfaction level at 45%.

Experienced users found the system effective with a rating of 60%, and were comfortable with the time spent to complete a task using the system. They found the training useful in helping them understand how the system works. However, they were not impressed with the frequent message boxes that would appear to notify the user when they clicked buttons, a feature which novice users liked. Novice users were not happy with the time spent on learning how to use the new system and were unable to carry out tasks in a timely fashion which resulted in their perception of the effectiveness of the system being set at 50%. They were confident that, over time, they would be comfortable with the system.

5.5 Statistical Analysis of Results

In this section we are going to analyse independent variables from our data sample with respect to the knowledge sharing. The independent variables under consideration for a correlation analysis are age, level of education (LOD) and computer literacy levels (CL). Our initial hypothesis states that the use of a knowledge management system such as our helpdesk will promote knowledge sharing within the community and in turn help to foster collaborative problem solving as a technical sustainability approach. In order to test this hypothesis we performed a chi-square test for the existence of an association between use of a knowledge management system and knowledge sharing within the Siyakhula Living Lab. The tests following hereafter were done on our dataset using the SAS statistical software with the assistance from the Statistics Department at the University of Fort Hare.

Correlations

Notes

Output Created		28-Mar-2011 15:07:13
Comments		
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.032
	Elapsed Time	00:00:00.359

[DataSet1]

Correlations			
		Age	KS
Age	Pearson Correlation	1	-.829
	Sig. (2-tailed)		.001
	N	20	20
KS	Pearson Correlation	-.829	1
	Sig. (2-tailed)	.001	
	N	20	20

Figure 20: Correlations between Age and Knowledge Sharing

We found a strong negative correlation of $-.829$. The relationship between age and knowledge sharing (KS) is strong because the correlation value is above 0.5. The direction is negative meaning the two measured variables are moving in the opposite direction. This strong negative correlation is justified by the fact that as age increases knowledge sharing decreases. This is evident from our sample population where younger community members were more willing to share information since they spend more time using computers as compared to older people.

Correlations

		LOE	KS
LOE	Pearson Correlation	1	.634
	Sig. (2-tailed)		.002
	N	20	20
KS	Pearson Correlation	.634	1
	Sig. (2-tailed)	.002	
	N	20	20

Figure 21 : Correlations between Level of Education and Knowledge Sharing

We found a strong positive correlation of .634 between the level of education and knowledge sharing. The correlation value of these variables is above 0.5, thus making the correlation strong. These two variables are directly proportional thereby making the correlation positive. This can be justified from the observation amongst community members especially high school children and teachers since they shared more as compared to uneducated members of the community.

Correlations

		CL	KS
CL	Pearson Correlation	1	.719
	Sig. (2-tailed)		.331
	N	20	20
KS	Pearson Correlation	.719	1
	Sig. (2-tailed)	.331	
	N	20	20

Figure 22: Correlations between Computer Literacy Levels and knowledge sharing

We found a strong positive correlation of .719 between the computer literacy levels and knowledge sharing. The positive correlation positive can be attributed to the fact that as people get confident with using computers their literacy levels increase and they are likely to try out new things resulting in the seeking of new knowledge which can be aided by knowledge sharing. We noted that users with low literacy levels preferred to share the use of a computer with a more experienced member meaning that sharing of knowledge would remain in the experienced users since the inexperienced users would not contribute their experiences to the knowledge management system.

Hereafter, follows the chi-square test to ascertain existence of an association between use of a knowledge management system and knowledge sharing within the Siyakhula Living Lab. We selected a sample of questions and categorized them under knowledge sharing (Q1) and use of a knowledge management system (Q2). For each of these categories are 6 questions which we took from our questionnaire results according to their relevance to each of the two variables. Below is the generated cross tabulation report of the Chi-square Test.

Cross Tabulation Report

Page/Date/Time 1 3/28/2011 2:55:30 PM

Database

Chi-Square Contribution Section

	Q1						
Q2	1	2	3	4	5	56	Total
1	0.36	0.45	0.09	0.67	0.67	0.67	3.58
2	1.01	0.90	1.20	0.40	0.40	0.40	4.71
3	0.27	0.05	0.15	0.05	0.05	0.05	0.67
5	0.60	0.05	4.82	0.05	0.05	0.05	5.67
6	0.60	0.05	4.82	0.05	0.05	0.05	5.67

Total	2.84	1.50	11.08	1.22	1.22	1.22	20.30
--------------	------	------	-------	------	------	------	-------

The number of rows with at least one missing value is 0

Q1		
Q2	67	Total
1	0.67	3.58
2	0.40	4.71
3	0.05	0.67
5	0.05	5.67
6	0.05	5.67
Total	1.22	20.30

The number of rows with at least one missing value is 0

Chi-Square Statistics Section

Chi-Square	20.300926	
Degrees of Freedom	24	
Probability Level	0.0079541	Reject H0

WARNING: At least one cell had an expected value less than 5.

Chi-Square Test

We performed a chi-square test to establish the association between use of a knowledge management system and knowledge sharing.

Our null hypothesis denoted as **H₀**: There is no association between use of computers and KS and **H₁** denotes that there is an association between use of a knowledge management system and knowledge sharing.

After performing some cross tabulations between Q1 and Q2 we got the Chi-Square Test results shown depicted in the Chi-Square Statistics Section above.

We found a chi-square value of 20.3 under 24 degrees of freedom. This gave us a p-value of 0.0079755. Since the **Probability Level** value is less than 0.05 it meant that we reject the null hypothesis **H₀**.

Rejecting **H₀** means that we accept **H₁** and conclude that there is an association between use of a knowledge management system and knowledge sharing.

5.6 Conclusion

The usability test results for all users considering all three metrics remains above average at 58%. This is an above average figure showing that users are generally comfortable with using the system for knowledge sharing, however statistical analysis done on the data showed how other characteristics contribute to the level of knowledge sharing. Using the chi-square test, we found that an association exists between the use of a knowledge management system and knowledge sharing. Using the correlation statistical analysis we established that variables such as age, level of computer literacy and level of education are correlated to knowledge sharing. Statistical analysis results supports the notion that the more experienced the users are, the more they feel comfortable in using the system to collaboratively assist each other in routine technical problems. Thus, users with high computer literacy levels are bound to share more since they are prone to face new problems due to their frequent usage of the computer. Younger people tend to share more than older people due to the more time they spend using computers. The level of education has a significant effect as noted by the low levels of sharing trends by people with low education in particular at an older age.

6 Chapter 6: Conclusion & Future Work

6.1 Introduction

This chapter provides a roundup of the thesis with respect to the achievements, limitations faced, lessons learnt as well as prospects for future work.

6.2 Achievements

The overall development of our system was successful as evident from the testing phase results. We managed to combine discussion forums, search engine, tutorials and issue tracking into one system sharing a common knowledge base. This gave users some flexibility by allowing them to choose their preferred point of entry when looking for solutions to commonly faced problems. Through normalization of the database tables and case-based reasoning problem solving concepts we were able to resolve double posting, a common problem in help desk systems where the same problem is posted more than once by constantly checking the legacy case base for matching problems and associated solutions each time a user posts a problem. Our system can be readily deployed in any environment with possible adjustments, in particular the language packages and stop words to suit that particular environment.

6.3 Addressing the research objectives

Technical sustainability is best achieved through collaborative participation as evident from the users' willingness to assist each other in solving problems. However, ensuring technical sustainability of ICT projects in rural areas is dependent on the level of computer literacy amongst end users. Higher computer literacy levels allow users to try new things, hence there exists a need to provide sufficient training for the end users so that they can be comfortable with using computers on their own.

Survey results reveal that most users preferred physical contact as a way of assisting each other however problems would arise if the Lab has a few users which would result in some users wanting to leave. A problem as such resulted in users realizing the need for them to collaborate

online by messaging each other problems and solutions which they could refer to at a future date, rather than being unable to continue working when the people they rely on are not there.

Sharing took on different forms; for instance, many respondents preferred to come to the Lab together with friends or family while using separate machines. Others preferred to work in groups on the same machine leveraging differential levels of expertise. Some of the respondents were comfortable with coming to the Lab on their own without the need to share the use of a computer. After being introduced to the system users felt the need to have personalized access to the knowledge base by logging in to the system each time they are in the Siyakhula Living Lab.

Users reported that, through using the system, they could have access to all the problems and solutions which other users encountered which was impossible through word of mouth knowledge sharing. 60% of the respondents from the sample studied reported gaining knowledge and learning from other users through using the system. 40% were not yet comfortable with the system due to their inability to contribute to the system because of their low literacy levels. They thus preferred to use the system as a group alongside other experienced users. Most respondents felt a connection with the system since they could easily change from English to their home language, Xhosa.

6.4 Limitations

The following list of limitations were experienced and had to be address when developing the Siyakhula Help and Support System.

6.4.1 Low literacy levels

Due to the location of our study a lot of assumptions had to be made with regard to the design of the system due to the low literacy levels of the users. The system was designed to cater for users with basic as well as advanced computer skills by stressing simplicity in the overall look of the system. Users were able to use the system training as a pre-requisite so as to have an idea of how it can help them to resolve hardware and software related problems which they face on a daily basis.

6.4.2 Lack of skilled personnel

Apart from its low literacy levels, the society views skilled personnel in our study area as the teachers at each of the four schools. However, most of these teachers were also exposed to ICTs at the same time as some members of the community. This resulted in frequent visits to our study area to train the teachers and users so that they achieve a certain level of literacy in order to be able to train other community users.

6.4.3 Lack of accountability

Members of the community with low literacy levels did not feel that they were the rightful owners of the Siyakhula Living Lab. This resulted in a lack of accountability in cases where members face some problems since they were shy to report their mistakes. This results in the need for a platform where users can share their experiences.

6.4.4 Underutilization of resources

ICT opens windows of opportunity in the form of limitless services accessible through the internet. However, lack of sharing of knowledge and mistakes confined users to services which they were confident in using. This resulted in the ICT platform being underutilized instead of adding value to their social lives.

6.5 Future work

Responses from users highlighted the need to integrate SMS functionality for issue tracking and receiving SMS notifications on their phones without the need to walk to the Siyakhula Living Lab to check the status of their issues. The voice to text feature when responding to problems would be useful in the future, as it would encourage elderly users to use the web based help and support system with ease.

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Appendix A: Questionnaire

Objective : To evaluate the Help desk system so that the result of the test can be evaluated based on users' responses.

Instruction : Please complete the following short survey.

Remark : The information which you have provided will be strictly confidential.

Name:.....**Age:**.....

Testing Centre:.....**Date:**.....

Level of Education:.....**Occupation:**.....

Please fill in the questionnaire below: The Questions are rated on a scale of 1-10 (1 being the least favourable response with 10 being the most favourable)

Questions	1	2	3	4	5	6	7	8	9	10
1. Ability to ask, answer and rate questions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Ability to trace open problems/issues	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Ability to reuse past cases to solve future problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Ability to use tutorials to solve problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. The information (such as online help, on-screen messages, and other documentation) provided with this system is clear	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Whenever I make a mistake using the system, I recover easily and quickly	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. I was able to navigate to all links according to my needs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. It was easy to learn how to use the system	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. I find the system useful in understanding how to use computers effectively	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. I am pleased with the features and functions offered by the system	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. I am satisfied with the overall design of the system.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

12. I think the system can replace the need for experts to be around each time I use the computer

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Questions concerning overall issues & problems, comments and recommendations for the proposed Help desk system:

1. Were there any issues or problems faced in this test?

Yes ☐ No ☐

2. If yes, please specify the issues or problems.

3. Besides the features found in the proposed Help desk system, were there any other features found in the similar systems that can be implemented in the proposed Help desk system?

Yes ☐ No ☐

4. If yes, please specify the features that can be implemented in the proposed Help desk system.

5. Please specify other aspects, comments or recommendations for the proposed Help desk system.

Do you have any comments on this questionnaire? If yes, please specify. Your opinion is very important to me.

Appendix B: System installation and setup

System Requirements

Software	Min Requirement	Recommended	Latest Options
PHP	4.3.10	4.4.7	5.x series
MySQL	3.23.x or above		5.x series
Apache	1.3 or above		2.2 series
IIS	6	7	7.5

Figure 23: System resources

The help desk application can be deployed on any operating system which runs Apache. The application will work on Apache 1.3 or Apache 2.x hosted on UNIX/Linux, OS X, or Windows. The default database server for this application is MySQL. PHP 4.3.x. version or higher is compatible with this application. All modern browsers that support CSS and JavaScript can render the application. However, minor variations in appearance maybe experienced since web browsers have varying levels of compliance with Internet standards such as cascading style sheets. Below is a list of browsers that are compatible with this application:

- Internet Explorer
- Firefox
- Opera
- Safari
- Camino Google Chrome

Server hardware requirements such as availability, hardware reliability and durability should be high since the application must run for long periods without interruption. Faster, higher-capacity hard drives, and uninterruptible power supplies will help to ensure the server's ability to continue functioning in the event of a power failure.

Installation

The following installation steps work for any web server running Smarty, PHP and MySQL.

Step 1: Make sure you have at least 1GB free disk space to allow tutorial uploads.

Step 2: Download the Siyakhula folder to the root folder of your system. Within the Siyakhula folder there is the *config* sub-folder which contains the htaccess file, database access credentials, language configuration files and sql file for the application's database. Overall, the application folder has ten sub-folders and fifty-two PHP scripts.

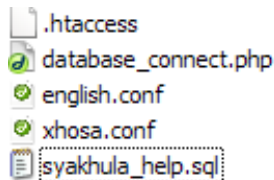


Figure 24: Config folder

Step 3: You have to change the user credentials for database access to suit your database server settings.

Step 4: Import the database's *siyakhula_help* sql dump file into your MySQL relational database system.

Step 5: Grant server write permission to the *templates_c* and *upload* folders.

Step 6: Now go to your new application through the web browser,
<http://www.example.com/siyakhula/index.php> in our example.

Appendix C: User manual

Our application has two user manuals for different types of users depending on their roles. We have both normal users and experts who are the administrators of the system.

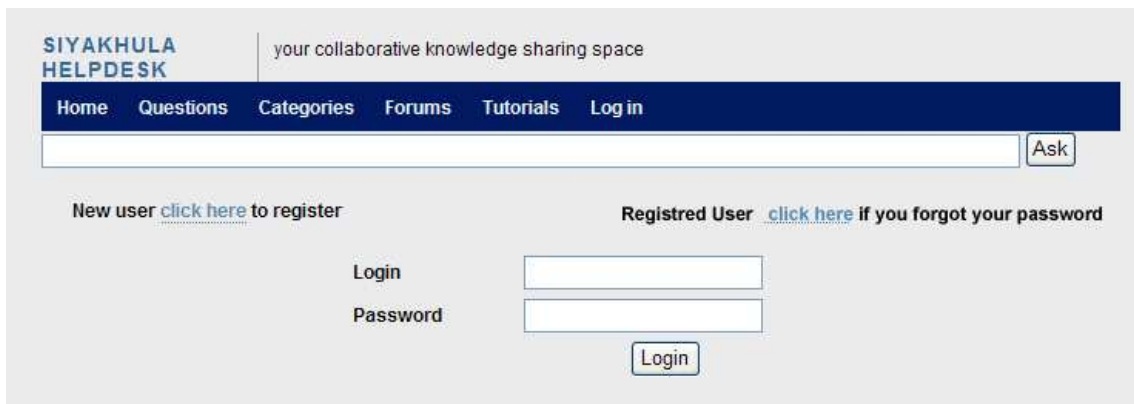
Normal Users:

Registered users can view legacy cases, ask and answer questions. The manual will focus on the following tasks:

- User Login
- Main Menu

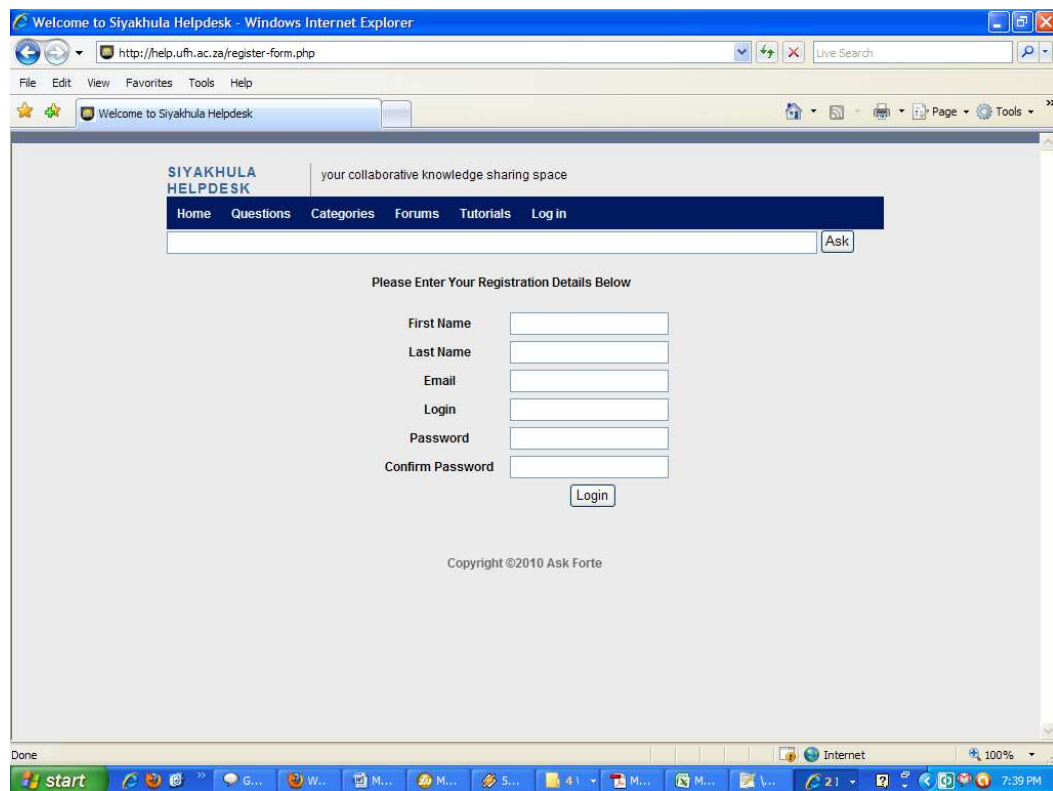
User Login

A registered user will have to click on Login on the main menu to enter credentials for system access. If a registered user forgot their password they need to click on the password recovery link on the left panel.



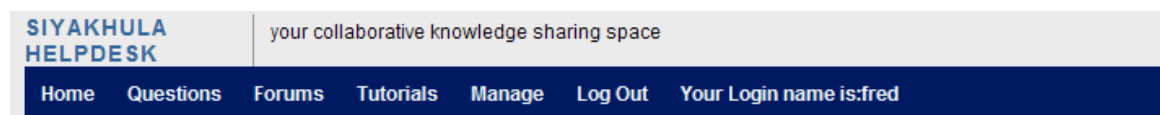
The screenshot shows the SIYAKHULA HELPDESK login interface. At the top, the logo 'SIYAKHULA HELPDESK' is displayed next to the tagline 'your collaborative knowledge sharing space'. Below this is a dark blue navigation bar with links: Home, Questions, Categories, Forums, Tutorials, and Log in. Under the navigation bar is a search bar with an 'Ask' button. The main content area has two links: 'New user [click here](#) to register' and 'Registered User [click here](#) if you forgot your password'. Below these links is a login form with labels 'Login' and 'Password' next to two input fields. A 'Login' button is positioned below the password field.

For a new user to register, they need to click on the new user registration link. User details for registration are the user's first name, surname, login name, password and a valid email address which they are also going to use for issue tracking and password recovery.



A new user will automatically be logged in on condition that the registration details that are provided are valid.

Index Page



The main menu on the index page has four menu parts which users can access, namely: categories, forums, tutorials and manage. Full access is limited to logged in users. The Questions tab gives the user access to all the cases listed according to their categories. It shows the number of closed issues, open issues and tutorials. The Forums link directs the user to the discussion forum where they can answer, comment and rate solutions. The tutorials tab lists the tutorials in the knowledge base. A user can update their profile by clicking on their name in the main panel. In this case, if the user clicks on Fred, he can change his profile details. Just below the main menu there is a search bar allowing users to post questions. The manage tab allows users to view

all the posts which they started and their contribution to other users' posts as shown by the screenshot below.

Topics which you started				
Topic_Id	Topic	Views	Replies	Date
1	I cannot view video objects using Internet Explorer browser	6	0	19/09/10 03:19:32 PM
1				
Your Contribution to Issues posted by other users				
Topic_Id	Topic	Views	Replies	Date
1	Try to replace the power supply unit			16/08/10 01:10:53 PM
2	You can use Macromedia Fireworks it easy to use			13/05/10 12:25:32 PM

Best Answers & Recently Asked Questions

Best Answers			
FAQ_No	Question	Category	Rating
1	How can i edit my pictures	Hardware	★★★★★ Rating: 90%

Below the search bar there is the best answers section which lists the top five solutions with the most favourable rating from other users as shown above. Just below that there is the recently asked questions section which lists the latest open questions which need solutions.

Recently Asked				
Topic_Id	Topic	Views	Replies	Date
1	How do i check the weather forecast for Eastern Cape	17	2	05/05/10 11:28:30 AM
2	Am looking for job application websites	6	0	05/05/10 11:28:57 AM

Administrators:

System administrators have advanced features on their main menu. They can manage issues, view their posts, submit and approve tutorials. In this manual we are going to demonstrate how posted articles are approved.

Approve articles

To save disk space, the system is restricted to files of less than 2MB. If a user uploads an article it has to undergo a review process by the experts before it can be displayed for all users to see.

SIYAKHULA
HELPDESK

your collaborative knowledge sharing space

Home
Issue Manager
My Posts
Submit Articles
Approve Articles
Log Out
Your Login name is:fred

File No	Title	FileSize	Date Uploaded	Approval Status
1	How to create bubbles with photoshop brushes	216kb	13/05/10 12:37:35 PM	Pending
				Approve Change Status
File No	Title	FileSize	Date Uploaded	Approval Status
2	PHP References: How They Work, and When to Use Them	18kb	09/12/10 07:17:59 PM	Pending
				Approve Change Status

If the experts are satisfied with the content of the article they can change the status of the article to approve so that it can be available for all users.