ASHESI UNIVERSITY COLLEGE

DESIGNING AND IMPLEMENTING A RURAL ICT CENTER

By

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I hereby declare that this dissertation is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

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I hereby declare that the preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of dissertation laid down by Ashesi University College

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Abstract

This report details the findings of an applied project to design and implement a sustainable Information and Communications Technology center in the rural community of Berekuso. The project was intended to address the challenges of providing the community with access to quality education.

The project design was divided into three key areas which include the establishment of the physical hardware infrastructure, the hosting of a digital library equipped with relevant educational content, and ICT literacy and training services.

The implementation of the project consisted of two phases, the first of which is the initial setup phase and has been fully implemented. The second phase involves long-term support and is yet to be implemented. This report is concerned primarily with the first phase, although some recommendations have been made concerning the implementation of the second phase and beyond.

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Chapter 1: Introduction

1.1 Introduction and Background to the Project

Berekuso is a small town on the outskirts of the Accra Metropolitan Area, with a population of approximately 4000. Despite its proximity to the capital city of Ghana and Ashesi University College, which boasts state-of-the-art educational facilities, the state of education in Berekuso is in dire need of reform. Children in these schools do not have access to basic educational resources such as textbooks, which places them at a steep disadvantage with students living in urban areas. The vast majority of graduates of the public Junior High School (JHS) are unable to gain admission into senior high schools (SHS). This state of affairs limits their prospects of economic advancement and entrenches the cycle of poverty in this community.

The United Nations' Millennium Development Goals (MDGs) on education are about providing universal access to quality education and eliminating gender inequality. Yet despite significant amounts of money being spent on education in Ghana each year, most people living in rural areas are deprived of educational resources and infrastructure. The relatively high levels of primary school enrollment obscure the problems of low quality education in many schools in remote rural communities. This indicates that the current approach to educational service delivery in Ghana is not very effective, and calls for a new model of educational service delivery which maximizes the utility of national resources in the field of education.

Information and Communications Technologies (ICT) are increasingly being viewed as effective tools to aid in the democratization of information resources. This is because they provide a cheaper alternative to distribution of information. In addition, the changing nature of the global technological environment means that ICT skills are becoming vital to gainful employment in many industries. It therefore stands to reason that ICT must become a central feature of Ghanaian educational institutions. However, the cost of implementing ICT solutions varies greatly depending on the kind of approach taken. Possible solutions range from high-end technology utilising the latest hardware and software to low-end solutions such as radio and television education programmes.

This project is an attempt to examine and test a model for addressing challenges relating to the provision of educational resources in the community of Berekuso. This involves the design, implementation, and testing of a publicly accessible ICT center within the community which will provide access to educational resources and training services. Several similar ICT initiatives have been implemented in many parts of the developing world, with variable rates of success. One reason for this is the top-down approach commonly used by governmental institutions, charities, and NGOs which results in institutions that are economically, socially, or technologically unsustainable.

This project operates within the framework of sustainable design to ensure the development of a solution which effectively addresses the challenges unique to rural communities in general and Berekuso in particular. Three key sustainability criteria serve as the overall guidelines for the design process, namely, economic, social, and environmental sustainability. This necessitates the bottom-up approach of engaging in dialogue with the target community to understand their unique needs and circumstances in order to develop a solution which is tailored to the context of their local environment.

While this project is limited to the town of Berekuso, this approach may also serve as a broad model for the future implementation of similar initiatives which may be adapted to different rural communities across the nation according to the unique parameters of each local context. This report identifies the key variables which have played a role in determining the design of this project as well as the practical constraints of the implementation process, and suggests alternative approaches to those employed in this project which may be relevant to implementing this solution in different socio-economic contexts.

1.2 Objectives

- The first and primary objective is to design and implement a facility which will provide community members with access to ICT hardware. This is the central bottleneck of such projects due to the prohibitive cost of physical hardware and the required software. On its own, this center will provide the community members to gain familiarity with access to ICT technology, but also serves as the platform for the implementation of the remaining objectives.

- The second objective is to equip this facility with an electronic library containing digital educational content and information resources that will provide community members with a wide range of educational resources in order to supplement the shortage of such resources. Appropriate content will include materials relevant to the curriculum of the students as well as a wide variety of general educational content relevant to people of all ages.

- The third objective is enable the provision of teaching and training services to members of the community to aid in their learning. This includes the training of teaching staff and generation of awareness among the local community to the available services.

Underlying all of these objectives is the goal of long-term sustainability, without which the facility is likely to become obsolete and ineffectual. Each of these objectives has been pursued within the constraints of sustainable design principles, which have been narrowed down to the following three factors:

  - **Economic**: The center must be economically viable. This implies that it must be able to generate enough revenue through its operations to support ongoing maintenance and other recurrent costs.

- **Social**: The project must encourage the local community to engage with the facility and empower them to hold a stake in the project.
- **Environmental**: The total environmental impact of the project should be minimal. This influences the choice of hardware configuration and overall system architecture.

1.3 Outline of Dissertation

The current chapter provides a general overview of the project and context in which it is situated.

Chapter 2 provides a description of the various design methods used during the initial stages of the project. The four main stages of the design process are listed and explained, including the impact of each process on the development of the final solution. A number of potential scenarios are explored and analysed in terms of the challenges presented in each scenario and how the solution is expected address them.

Chapter 3 describes the process of implementing the solution developed during the design process. This includes the budgeting and financial considerations involved during the implementation. The technologies and tools used during the implementation of this project are outlined, and the software which serves as the platform for the project is also described.

Chapter 4 describes the results of the tests conducted during and after the implementation of the solution. Performance testing was conducted primarily by the project team, with some user testing conducted by staff and students of Fidelity Basic School.

Chapter 5 outlines the general findings from this process and includes recommendations.

Chapter 2: Design

2.4 Design Methods

Particular emphasis was placed on the project design in order to maximize the long-term sustainability of the solution. The core principles of sustainable design were central to the shaping of the design process, which was structured into five stages: research, ideation, prototyping and testing, and refinement of the solution. This chapter outlines each stage of the design process and the resulting influence on the final proposed solution.

Research

The research stage involved a review of the literature on current approaches to the design and implementation of similar initiatives in different parts of the world. This assisted in shaping the overall approach of the project, taking into account the various recommendations of institutions that have already attempted similar projects in various parts of the developing world such as Malaysia, Bangladesh, and Uganda. This was necessary to place the project within the context of ongoing international efforts in a similar direction.

The research stage also involved interacting with the target community in order to gain an understanding of the local context of the problem, an analysis of the environment, and special considerations to take into account. The key findings of this stage helped form the guidelines for the remainder of the design process and identify issues which were critical to ensuring long-term sustainability.

Problem Definition

This involved the synthesis of findings from the research stage in order to isolate the central issues to address concerning the challenges of education in Berekuso and consequently to identify the central objectives of the project. This process assisted in identifying the physical hardware infrastructure, informational resources, and community training and support services as the key areas of focus. This arose directly from the findings of the research stage which indicated lack of financial resources to implement ICT solutions, poor management of public schools, and low awareness of the importance of education among community members as the major factors hindering access to quality of education in Berekuso.

Ideation

A wide range of possible solutions were explored during this phase, each of which was evaluated based on how well it met the objectives of the project compared to the other alternatives. The final alternative approaches which were identified are listed below, each of which has the additional option of using either completely new or slightly refurbished computing equipment:

Hardware and Software Infrastructure:

- A commercially based standalone desktop computing architecture such as Windows or Apple

- A commercially-based distributed computing software and hardware (N-computing)
- An open-source standalone desktop computing architecture based on the Linux operating system
- An open-source-based distributed computing architecture (Linux Terminal Server Project(LTSP) and the Raspberry Pi)

Prototyping and Testing

Preliminary testing was conducted on each of the above candidate solutions for the physical hardware during the design process before the final architecture was eventually selected. This involved the installation and testing of complete systems where possible and partial configurations where complete access to the equipment was not possible.

After preliminary research and testing, the available alternatives were listed and compared in order to determine which met the goals of the project most effectively. The financial figures used for the comparison were obtained through interviews with institutions that had implemented configurations of a similar scale to the project.

The table below lists the comparative advantages of each of the alternatives which were identified:

	Standalone (Commercial)	Standalone (Open-source)	Distributed (N-Computing)	Distributed (LTSP)
Setup Cost	High (GHS15,000 – GHS20,000)	Intermediate (GHS8,000 – GHS15,000)	Intermediate (GHS8,000 – GHS15,000)	Low (GHS5,000 – GHS10,000)
Ease of Use	High	Intermediate	High	Intermediate
Scalability	Low	Low	High	High
Cost of Maintenance	High	Low	Intermediate	Low
Energy footprint	High	High	Low	Low
Technical Support	Full	OS-dependent	Full	OS-dependent

Table 1: Comparative Advantages of Various Computing Architectures

Refined Solution

Based on the overall analysis of the available alternatives, the open-source LTSP architecture was selected as the proposed solution. The Raspberry Pi was selected as the primary thin-client to use in the installation. The Raspberry Pi is a low-cost miniature computing device designed to be portable and used for a wide variety of applications. Additionally, the LTSP network is capable of converting older generation desktop computers into higher-performance diskless thin clients. The overall versatility, efficiency, and scalability of the LTSP setup are what ultimately made it the most likely solution to meet the objectives of the project in the most sustainable manner.

2.5 Functional and Non-functional Requirements

The functional requirements listed below represent the minimum level of features required to satisfy the project objectives optimally. Although it is possible to conceive of a complete setup that does not meet all the functional requirements, they may not be adequately suited for the purposes of the project. The non-functional requirements listed relate to additional features that will significantly increase the utility of the facility. Although they are not required for basic functionality some of the features are essential to issues of sustainability and user experience.

Hardware Infrastructure

Functional Requirements:

- The computer center must be equipped with at least 10 fully functional user terminals in order to allow more people in the community to have access to the services.
- The facility must utilize a distributed architecture to permit centralized system administration and efficient use of energy and processing resources.
- The computer center must be equipped with Internet access to provide access to the worldwide web
- The facility must have a backup power supply in case of electricity outages

Non-functional Requirements:

- The total cost of the setup must be kept as low as possible but enough to achieve all the project objectives (i.e. GHS10,000 or less)
- The cost of maintenance and upgrades of hardware and software in the facility must be kept to a minimum to ensure long-term sustainability (i.e. GHS500 monthly or less)
- The total environmental footprint of the project must be kept as low as possible. This necessitates the use of hardware infrastructure which consumes as little energy as possible.
- The system must be easy to setup and administer
- The software must provide accessibility features for people with physical impairments
- The infrastructure must be scalable to efficiently accommodate future expansion
- Some level of technical support must be available

Digital Content Library

Functional Requirements:

- The center must provide access to electronic K-12 educational content and resources relevant to the national curriculum (Maths, Science, Business, etc.)
- The center must also provide access to content of general educational value which is suitable for a wide range of users

(Encyclopedia, fiction, and non-fiction literary collections)

- The center must provide local hosting of content which may be accessed at any time, without regard to state of Internet connectivity.

Non-functional Requirements:

- User-friendly software interface which takes into account the various classes of users
- Clarity of content structure in order to facilitate easy navigation of content
- Ease of system management and updates

Community Services

General Requirements:

- Free basic ICT literacy program which will provide users with an introduction to computing technology
- ICT technical support services
- Accessibility to all members of the community
- Commercial ICT training programs for people who need these skills to improve their employment prospects and aid in capacity-building

2.6 Scenarios

This center is intended to be accessible by all members of the Berekuso community, several of whom have expressed interest in improving their ICT literacy skills. Several possible scenarios were taken into consideration during the design process. Certainly, not all possible scenarios have been accounted for, but those listed below represent the most likely situations to encounter during the operation of the facility.

Teaching Sessions

Students at Fidelity Basic School will have access to the lab for practical exercises in ICT. They will be expected to apply their lessons from the classroom on the computer terminals. The average class size at Fidelity is approximately 20 students.

There are two possible approaches to hosting classes in the computer center. Given that there will initially only be 12 machines in the facility, a class size of more than 12 pupils may be divided into two or more groups that will be scheduled to access the lab at different periods, allowing for a 1:1 ratio between students and machines.

However, if this is not possible due to scheduling constraints, it is also feasible to allow students to use the machines in pairs. Class sizes above 22 will have to be divided to avoid overcrowding. In particular, the lower classes are more suitable for sharing machines, while the older classes must initially be given priority access as they will likely need to acquire ICT skills for the purposes of examination sooner than the younger students.

Training Sessions

Training sessions involve the general members of the community. The typical training session will have a ratio of 1:1 users per terminal. These will be conducted on selected weekdays and once a week on weekends. In case the number of students exceeds the number of terminals, access will be based on a first-come first-serve basis. Users will be encouraged but not required to share terminals in such a situation as in the classroom scenario.

Unstructured Access

In addition to organized teaching and training sessions, the facility will be available for independent access to general members of the community for usage when no other activities have been scheduled. Users will have access to local content and limited Internet access for an unstructured and self-directed learning experience. The system administrator will nevertheless be on hand to provide assistance with any issues the user might have relating to the system. Just as in the case of the training sessions, access to terminals will be given out on a first-come first-serve basis, and sharing of terminals encouraged but not required.

Technical Problems

In case of minor technical challenges, the resident system administrator will be required to resolve the technical issues. If the administrator is incapable of solving the issue, technical support may be obtained from the project coordination team for the duration of the second phase of the project. By the end of this period it is expected that the resident administrator will have enough technical understanding of the system to address any minor issues. In case of major issues, volunteer support is available in several online communities dedicated to supporting users of the LTSP and Linux software. In the case of complete system failure, members of the project coordination team will be available for long-term support to reconfigure and restore the system to full functionality.

Power Outages

Power outages are a relatively frequent phenomenon in Berekuso. Currently, an Uninterruptible Power Supply (UPS) unit is the main source of protection for the central server and switch from data loss in case of sudden power outages. This will allow the administrator enough time to perform a clean shutdown of the system to avoid significant data loss or hardware failure. Although the other machines in the network do not have this feature, because all their data is stored on the central server, there are less chances of data loss. However, they are still susceptible to hardware damage and as such need to be upgraded to UPS support as soon as the funds are available.

2.7 Use Case

Considering the case of a student attending Fidelity Basic School as the typical user, we can expect the usage of the service to follow a typical pattern:

- The average student user will first receive ICT lectures in a classroom setting from a schoolteacher.
- They student will then be scheduled into a teaching session where he/she will have a chance to practice lessons learned in class
- The student may ask for help or assistance from the administrator in charge of the lessons
- The student will log into his/her KA Lite account using a unique username and password when required by the instructor to watch educational videos or exercises
- After school, the student may return to use the facility for unstructured and self-directed learning based on the available locally hosted content

Chapter 3: Implementation

3.1 Local Partnerships

Collaboration with the local community has been a critical factor in the implementation of this project. The site for the center was provided by Fidelity Basic School, a privately-operated primary and junior high school in Berekuso. Mr. Michael Ayi, the principal of the school is a community leader who has dedicated much of his life to providing an alternative to the public schools and raising awareness within the community about the importance of educating their children. Parent-teacher meetings at the school usually feature invited guests from industry and academia who lecture the attendees on issues relating to education.

Mr. Ayi expressed great interest in supporting this project, both financially and in kind, by providing a room within the school to set up the center as well as making contributions towards various costs involved in furnishing the facility. He has also given support to the idea of opening up the facility to the community free of charge, and is committed to establishing commercial training services to community members who are interested in building their ICT skills. This collaboration was critical to reducing the overall cost of the project as well as providing an avenue for engagement within the local community.

As a result of the location, the facility will primarily serve the students of Fidelity Basic School during regular school session (8am to 3pm) but will be freely accessible to all members of the community outside of these hours.

3.5 Finance and Budgeting

This implementation of this project required the soliciting of funds to purchase the necessary computing equipment. A proposal for funding was drawn up and sent to a number of institutions, which resulted in the acquisition of a GHS3000 grant from Ecobank Ghana Ltd, which served as the primary source of funding for the project. The remainder of the funds was raised personally by the members of the project team.

The figure below illustrates the initial estimated budget for the first phase of the project which was included in the proposal for funding.

A. Initial Setup Costs

Item(s)	Qty	Unit Cost(GHS)	Total Cost (GHS)
Raspberry Pi Model B, 8GB SD Card, Case & Power Supply	15	150.00	2,250.00
LCD Monitor, USB Keyboard and Mouse	15	180.00	2,700.00
Server PC	1	600.00	600.00
Uninterruptible Power Supply (UPS) Backup	4	150.00	600.00
External Hard Drive	1	200.00	200.00
Ethernet Switch	1	250.00	250.00
Building furnishing	1	1,500.00	1,500.00
Broadband Internet installation	1	1,200.00	1,200.00
		Total	**9,300.00**
			(USD) 4,043.48

Figure 1: Proposed Budget for the Project

The actual expenditure eventually came down to approximately GHS5000, about half of the estimate, which is partly a reflection of the constraints of the actual funding received. It must also be noted that the broadband Internet feature could not be implemented for this reason. However, this feature may be added at any time in the future when the funds become available. In the meantime, a cellular USB modem will provide Internet access. This will only be able to provide minimal bandwidth to facility, but this can still be used to provide valuable teaching and training services, particularly when accessing sites with predominantly text-based content, such as the online version of Wikipedia.

3.6 Technology and Tools Used

Raspberry Pi

The central technology used in the implementation of the computer was the Raspberry Pi, which served as the primary computing unit of the thin-client terminals. The Raspberry Pi is equipped with a 700MHz ARM11 processor and 256MB of RAM. On its own, the Pi is not a powerful computer and has difficulty running software that is only moderately processor - or memory-intensive. However when connected to an LTSP server, the performance of the Raspberry Pi is significantly boosted due to the sharing of resources with the server computer.

One drawback of using the Raspberry Pi as a thin client is that its motherboard only provides the option of using HMDI output or RCA output, both of which are standard interfaces for televisions and not VGA-input monitors, which are the most common computer screens on the local market. In order to connect the Raspberry Pi to a standard VGA-input monitor, it requires an HDMI-to-VGA adapter or HDMI-to-DVI adapter, which only increases the cost of the Raspberry Pi as a computing unit. However, the total cost is still competitive when compared to other computing solutions on the market.

Additionally the low power consumption of the Pi makes it the most energy-efficient computing device among the existing alternatives.

LTSP Server

The computer used for the central LTSP sever was a Dell Optiplex 755 tower desktop which came equipped with a Core 2 Duo 2.2GHz 64bit Dual Core processor, Gigabit LAN Ethernet card and 1GB RAM. The RAM was subsequently upgraded to a total of 5GB to suit the needs of the LTSP service, with additional capacity for expansion.

Network Switch

In order to meet the requirements for seamless communications between the client terminals and the server, a Gigabit Ethernet switch was required to serve as the networking interface.

Legacy Computers

Fidelity Basic School has existing computer equipment, although they had never been put to significant use prior to this project. The machines in the school are refurbished pre-Pentium IV processors operating on as little as 256 MB RAM. Of the six machines already in the school, four were incorporated into the LTSP network. Their performance as standalone computers is little better than the Raspberry Pi on its own. As a result they equally stood to benefit from gaining additional resources of the LTSP server. Adding them to the LTSP network was a straight-forward process. The machines simply needed to have their BIOS configured to boot first from their PXE cards which were connected via Ethernet to the server. Most legacy computers produced within the past ten years have this functionality built in.

The use of legacy computers is one possible avenue for the expansion of the facility, as they are easily available and extremely affordable. The drawback of these machines however is their size and power consumption relative to smaller devices such as the Pi and N-computing clients. Using the Raspberry Pis in conjunction with these older machines is the best situation.

Peripheral Hardware

The client terminals were equipped with standard input and output devices, which included monitors, keyboards, optical mice, headphones for audio output.

Building Furnishing

The room was furnished with a wooden shelf desks and three wooden benches with back support. The desks support the terminal screens and input devices while the benches allow a minimum of twelve seated at four per bench or a maximum of twenty-four if younger students are seated in pairs.

The table below provides a full list of the hardware inventory of the ICT center:

ITEM	**QUANTITY**
Dell Optiplex 755 PC	1
Raspberry Pi Model B + 8GB SD card	10
17-inch Dell Monitors	8
Gigabit Switch	1
UPS Device	1
Network Router	1
300m CAT5e Ethernet Cabling	1
USB Keyboard	8
USB Optical Mouse	8
HDMI-to-VGA Adapter	8
Headphones	12
Extension Boards	6
Desk shelves	1
Wooden benches	3

Table 2: Hardware Inventory of the Berekuso ICT Center

3.7 Platform

Operating System

The Edubuntu Linux operating system serves as the central platform of the system architecture. Edubuntu is a branch of the main Ubuntu Linux distribution which is managed by Canonical Ltd. in the United Kingdom. The version of Edubuntu used in this project is 12.04.1 LTS. Canonical provides commercial support for all stable Edubuntu releases, which are labeled LTS to indicate that they are committed to providing long-term support.

As its name suggests, Edubuntu was developed primarily for use in the classroom settings by educators and school personnel, or for home users who wish to have a dedicated computer system for the education of younger family members. The standard installation contains hundreds of free software packages, such as GBrainy, which provides games designed to improve brain function in areas such as memory, arithmetic, and logic. Other software include Gcompris, an educational suite filled with dozens of games designed for pre-school children, and Epoptes, a software which manages the thin-client terminals, giving the system administrator remote access , control, and surveillance of each terminal to ensure that the system is not abused by wayward users.

Linux Terminal Server Project (LTSP)

The LTSP software package provides a platform for distributed computing using virtually any computer into a diskless or fat client terminal. Client terminals share the CPU and memory resources of the server computer, which allows for the use of low-end computers such as the Raspberry Pi and older machines which have difficulty running modern software.

Thin-clients boot their operating and file systems over the local network using the PXE function of their network cards. Since their file systems are stored on the server they do not require hard disks. This greatly reduces the energy used by these clients as well as the heat which is consequently generated from running a room full of desktop computers.

Fat or thick clients are machines which are configured to take a higher burden of the computing and memory load than thin clients. Fat clients are typically machines that have relatively high onboard computing resources but can still benefit from being connected to a central LTSP server. This project uses thin clients exclusively, but once the server has been implemented, adding new clients is as simple as plugging a machine into the local network via an Ethernet card.

BerryTerminal

The Raspberry Pi is technically not a diskless client because it requires an SD card for the initial boot process before the network boot can be initiated. BerryTerminal is an open-source operating system that was developed for the Raspberry Pi specifically to be used in connecting to

LTSP networks. The BerryTerminal development group provides a disk image file which can be written onto the SD card to boot Raspberry Pi.

The figure below illustrates the network topology of the ICT center:

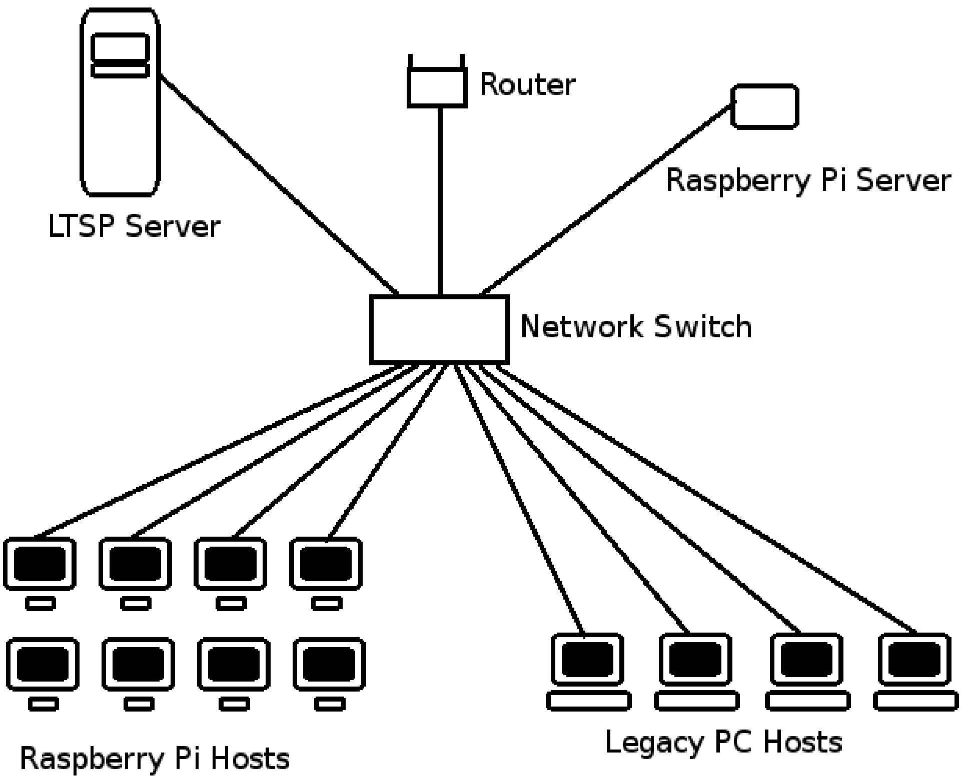

Figure 2: Network Diagram of the ICT Center

Chapter 4: Test and Result

Several tests were conducted throughout the design and implementation process as well as on the final setup of the system architecture. The project successfully achieved the majority of its functional and non-functional requirements. The table below lists the features which were successfully implemented and those which were not, primarily due to financial concerns.

Hardware Performance

The Raspberry Pis showed significant increase in performance after connecting to the LTSP server as compared to standalone performance. Services over the local network were accessible from each of the terminals with very little latency. This confirms the results from preliminary testing which indicated that the Raspberry Pi/LTSP server configuration is power efficient yet still effective at handling basic graphics. However, the system displays lagging on heavy applications and occasionally cannot launch such applications. However, most of these applications graphics editing and 3D games are not among the requirements of the center.

The figure below is a photograph of the physical layout of the center in its current state:


Figure 3: Physical Layout of the ICT Center

Ease of Use of Content

The user experience provided by the LTSP setup is seamless and well integrated. Client terminals were preloaded with general purpose user accounts while teachers at Fidelity Basic School were able to access unique staff accounts for the preparation of lesson notes and teaching materials. The figure below is a screenshot of the landing page that greets users when they launch the Mozilla Firefox browser from any terminal.

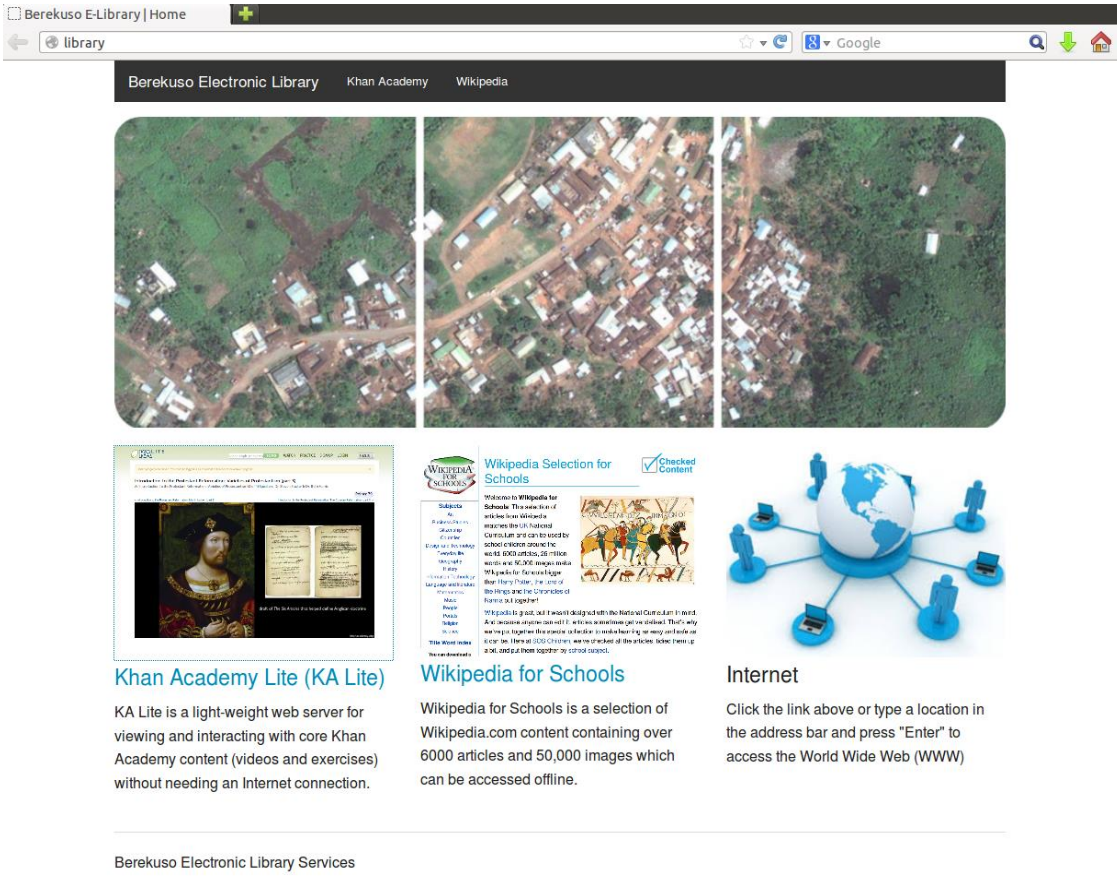

Figure 4: Landing Page of Terminal Browser

Below the Google Maps satellite image of Berekuso are three image grids which provide links and descriptions of the resources available on the network. The first link takes users to the KA Lite homepage, and the second links to the Wikipedia for Schools web archive. This page employs a simple but effective user interface designed to orient new users within the system and provide them with a clear outline of the available content.

Chapter 5: Conclusions and Recommendations

The initial results of this project suggest that ICTs present a viable approach to addressing educational challenges in Berekuso. The project was successfully executed and despite financial constraints was able to almost all of its objectives. This indicates that given additional funding, the project objectives could have been achieved in their entirety. The deployment of this project has not been without challenges, which have served to illuminate several key issues relating to the design and imlpementation of rural ICT centers. Despite the limitations of the scope of this project, it is possible to infer that other rural communities around the country can greatly benefit from similar initiatives. However, before this process may be replicated in rural communities around the country, there are a number of factors to take into consideration.

Implementing this project in Berekuso has been a relatively simple process due to its proximity to Accra. Most of the equipment used in the setup were purchased in Accra and transported to the project site. This presents a significant obstacle for remote communites which can be several hours' journey from major cities and commercial areas. Setting up such initiatives in remote rural areas will require significant planning and coordination to mitigate such costs. However, this also means that rural areas close to Accra and other major cities are ideal locations to initiate such projects due to relatively low logistical costs.

Additionally, the location of the center within a private institution may ultimately limit the accessibility of the center to the general community. Despite the efforts to reach out to the community in the initial phase of this project, it is always possible for private management to divert the center away from its initial objectives over time. This issue may be addressed by appointing an independent institution to manage the center, ensuring that it always reains committed to the goal of improving education for the entire community and not only a privileged minority.

Even though it is possible for the project to have a wider impact when placed in a public institution, such as the public school in Berekuso, concerns relating to poor management of these schools must also be addressed. This will require significant effort from the national government to reform the administrative systems within the Ghana Educational Service. In the meantime, outsourcing the management of the ICT center to a private institution may be the best option. Such an institution should ideally be a non-profit entity which places the mission of the center above all other concerns, and provide the necessary organizatinoal framework to ensure sustainability over the long term.

Further research into alternative hardware configurations is required to determine the optimal setup. Particularly, devices that might provide higher processing power than the Raspberry Pi at a similar price range can be investigated. Alternative sources of power such as solar panels can help to supplement the supply of power whenever the electricity grid fails. This will serve to keep the facility accessible at all times while improving the environmental impact of the center, by avoiding the use of petrol or diesel-powered generators.

Finally, comprehensive user testing will be required in order to determine how best meet the needs of individual learners from all sections of the community. This will be necessary to identify the various obstacles to learning faced by different types of users in their interaction with the software and harware systems, and identify means to optimize the user experience. Ultimately, it will help to maximize the impact of the center on each of its users and create a highly effective learning environment for the

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