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An Open Source Model for Teaching
Environments incorporating Wireless
Devices

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Abstract

Attempts have been made at bridging the digital divide in schools using desktop PC systems without much success. As a result many computer laboratories sit empty. There are many reasons for these failures. Often there are incompatibilities of software applications for the PC and its operating systems. In other cases non existent infrastructure such as networking support for the operations.. This paper describes a project aimed at achieving a more successful school educational environment by using students' mobile devices, desktop computer and open source applications. The project therefore, looks forward to a time when schools no longer have to purchase computers for their students but rather utilize mobile devices already owned by students. The paper presents results of an evaluation study on the interaction of students' mobile devices with course material and teachers using open source applications in a teaching environment. The pilot project was undertaken by Schoolnet in Namibia. The results presented show that although there were constraints on such devices the educational benefits far outweigh the physical limitations.

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Comments from my colleagues at the research laboratory (AIM lab - UCT) and several anonymous proof readers were tremendously helpful. Of course, all remaining mistakes are my responsibility.

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Chapter 1

Introduction

Various attempts to bridge the digital divide have been met with little success. Efforts to equip telecentres with desktop computers have had their misgivings. These centres remain unutilized. The reasons for the cases vary, but many would agree that resources necessary for success like networking, skills and maintenance to name but a few are of major concern[????????].

On the contrary the mobile computing arena offers unprecedented growth, a staggering growth rate of 65% in Africa. In South Africa, it is estimated that more than 50% of the populace own a cellular handset [?]. This trend is universal in most developing countries. The handset's power has been increasing steadily and in the future they are expected to have tremendous computing power. The ease of use and direct access to the desktop and internet is an invaluable asset that can be harnessed to bridge the digital divide, however, the desktop interface and feel is still intimidating to most new users in developing countries [?]. It still requires overcoming by new users which is not the case with mobile devices whose interface, look and feel is all too familiar. The solution offered here is thus to look forward to a time when schools and parents won't need to purchase desktop computers for their students. The mobile devices already owned by the students shall be sufficient. There is still a need to get ways of harnessing this power of mobile devices to unleash it's potential.

1.1 OSMS Model

This research presents a new Open Source Model for Schools (OSMS¹) that harnesses the power of the student's mobile devices. The model comprises in part PDAs, open source applications, students mobile devices and bluetooth technology. It has a great potential for providing students with a tool that can support learning in various contexts, e.g in field work to record and share data, in libraries and museums, and at home, in the classroom, as well as useful lifelong learning tools. The model allows access to learning resources anytime and anywhere and could enable students to make more effective use of time while away from home or school environment.

The research thus develops the model that incorporates teacher/student interaction with the desktop computers. It explores ways to incorporate open source applications on mobile devices to archive the above goals. The OSMS model enables interaction of course material using a desktop computer and wireless communication with the students' mobiles devices. The interaction involve various tasks like downloading lecture material, quizzes and interactions of students and teachers. For the success of such a model, both mobile devices and desktop computers need to have similar applications. In a current school computing environment, there are drawbacks as these systems lack ability to support the latest applications in the marketplace. Open source offers the ideal solution as its applications can be supported by both older systems and new mobile devices. Recently, the increasing functionality of mobile computing has led several authors to argue that palmtop computers could be usefully exploited as learning tools [?].

Studies investigating the potential use of mobile computers as learning tools have primarily been conducted within school settings. Waycott et al [?] speak of a 'paradigm shift' towards portable computing in education, likening it to the historic shift from reading as an activity that took place only in centres of learning to an activity that became an integral part of everyday life. There is great potential for palmtop computers to provide students with a tool that can support learning in various contexts. Mobile computers can be used, for example, in field work to record and share data, in libraries and museums, and at home, as well as in the classroom. They could also be used as lifelong learning tools. Such tools could accompany learners throughout their lives, and be used to input data and access information whenever the learner feels it is necessary. In this way, these

¹An Open Source Model for Teaching Environments that incorporates Wireless Devices

devices would become lifelong learning tools that release the learner from the situational constraints imposed by desktop computers. Similarly, portable computing technologies could be valuable for supporting open and distance education. Distance education students typically have to fit their self-managed learning activities around other tasks, such as work and family commitments. Providing access to learning resources anytime and anywhere, palmtop computers could enable students to make more effective use of time while away from the home or office environment[?]. The OSMS model presented in this research can be made available freely and promoted for use in developing countries.

The rest of this dissertation is arranged as follows;

Chapter 2 documents the background and literature review while Chapter 3 presents the educational model. Chapter 4 deals with the test environment that was used to evaluate the OSMS model. Chapter 5 deals with the evaluation of the research. Presented are the methodology that were taken to evaluate the OSMS model Results of the evaluation of the OSMS model along with the findings follow in Chapter 6 and finally Chapter 7 concludes the dissertation with a summary of interesting outcomes and discusses the way forward for future work.

Chapter 2

Background

2.1 Introduction

Educators constantly seek new channels, methods, and technologies to reach and intrigue students. The hope is to first capture their interest, then maximize their understanding and retention of the material, and finally encourage their own independent creative work. Throughout this process, they try to teach skills that can be applied in the real world. The breadth of the field and the variety of pedagogical approaches make this process very difficult. The OSMS model presented in this research and open source software (OSS) can serve as a channel, method, and technology for teaching and learning. OSMS has the potential to expand group work beyond the classroom to include much larger projects and more distributed learning. OSS can also be used to introduce students to a larger education community and to the practice of peer-review. OSMS can often provide free or lower-cost technology in the classroom, permitting the use of technology that the students might otherwise be unable to afford[?].

Everyday desktop computer users have mixed feelings when it comes to the use of open source software. Although stability and security are of importance to some, and others value freedom of choice, convenience and usability win the day. Users are only concerned about what they can do and how quickly and effectively it can be done. Until open source software becomes user friendly and intuitive enough to appeal to a mass audience, it will remain an ideal which many users find admirable, but are unwilling to adopt[?]. Although that may be the case, some open source applications such as OpenOffice.org (a Microsoft Office replacement) and Mozilla have made important advances in usability in

the last few years, and have become available to both Windows and Linux users[?]. "Open source" attempts to front the increased reliability that results from large communities of users being given access to source code (a benefit that relates to the Open Source dictum, with enough eyes, all bugs are shallow) while free software attempts to highlight how, in contemporary culture, software frequently structures how people act and communicate[?].

What of the future of open source? It could range anywhere from the inevitable future of the software field to its only good for operating systems, nothing more to it is in all probability a passing fad. Inevitable future or passing fad? No matter how one views it, the notion of open source software has certainly livened up the software scene[?].

Accordingly, the basic idea behind open source is simple: When users can read, redistribute, and modify the source code for a piece of software, the software evolves[?]. One set of issues concerns the use of open source software in teaching and the use of open source development models. Some basic questions that arise include "Should use of open source (and possible contributions to it) be the subject of classroom environment?" and "Should open source software be used?" [??]

In the OSMS model presented in this research, users are associated with varying geographic locations, and their mobility modelled together with the potential interactions as they access the wireless network during school time. However, rather than choosing user locations, speeds, and directions using random distributions, instead access and interaction patterns of students are used. The evolutionary network topology of OSMS is used to perform evaluation of the model in a realistic secondary school educational setting. On the contrary ad hoc routing models have been popular research topics for some time, and many models have been proposed and evaluated in the literature (e.g., [[????]]). Surprisingly, however, very few have been evaluated in realistic user settings [?] under realistic interaction models as is the case with the OSMS model. Recently, two efforts have evaluated ad hoc implementations in a small conference setting [?] and random synthetic outdoor environment [?], but neither explore the impact of interaction. As a result, little is known about the tradeoffs and applicability of expected interaction situations. Since groups of users with hand-held PDAs have often been used as a motivating setting for mobile networking, the OSMS model uses the same to perform evaluation of access and interaction patterns of students using their mobile devices and open source applications in an educational setting.

2.2 Literature Review

2.2.1 Open source software and education

Open source models and open source licensing.

The Open Source Initiatives definition of open source software is: "software that must be distributed under a license that guarantees the right to read, redistribute, modify, and use the software freely." [?]. The software goes through a type of natural evolution resulting in rapid development, increased reliability, and decreased cost. It is envisaged that the OSMS model presented in this research will go through a similar process. When marketing the "open source" approach, often the pragmatic properties of the open source code are relied upon. For instance, we may cite the software's reliability and high quality due to the peer review and rapid evolution of the source code [?]. The disparities lie in exactly who gets access to this source code, and why they have access to it.

Open source software can be released under a variety of different licenses. As of February 2002, the Open Source Initiative has approved 30 open source software licenses [?]. The GNU¹ (GNUs Not Unix) General Public License (GPL) is a very common open source license. This license assures any derived work of a GPL program will remain GPL, thus assuring the freedom for future users/developers to access, modify, and redistribute the source code. The OSMS model released under this license as in many other OSS models is copylefted. "Copylefted software is free software whose distribution terms do not let redistributors add any additional restrictions when they redistribute or modify the software." [?]. The Copyleft mechanism of the OSMS model provides incentive for developing and improving free software.

Regardless of a license, releasing OSMS model under an open source license allows others to find bugs, improve the algorithms, write documentation, or port the software to other hardware and software configurations.

Many groups have been established to develop and promote open source software as a viable technological solution for educational uses. By using open source software, schools can free themselves of licensing costs and put their (often scarce) resources to other uses. As one might expect, the focus is on Linux, and tools that work on Linux platforms. Red

¹GNU was founded by Richard Stallman and was the original focus of the Free Software Foundation (FSF)

Hat, a company best known for its commercial support of GNU/Linux, has developed the Open Source Now project. [15] Open Source Now is an advocacy group designed to advance the use of OSS in both education and public policy. For educators, they provide an introduction to OSS in education, a discussion list, and links to a wide variety of other OSS in education sites. Simple End User Linux - Education is a discussion list about all aspects of educational uses of Linux. [16] The site also provides a database of case studies, and links to current projects and a wide variety of software from astronomy to social studies. The OSMS model presented here allows a school to take advantage of outdated hardware they may already own, as well as save money by reducing the software licenses the schools must purchase. They claim to cut a lab's hardware and software costs by more than a third. OSMS model is not limited to low-cost computer labs in primary and secondary schools, but can also be actively used and developed by higher education institutions. Relying on the flexibility, low-cost, standards compliance, and stability of OSS to strengthen its credibility as an educational solution, it is possible to recognize the factors that inhibit its widespread acceptance. Today's schools are very Windows reliant, possibly due to historical vested interests, a steep learning curve, or masterful marketing.

Open source software and education

Open source software offers tremendous benefits to the education community. By using OSS, educators and students can develop (or further the development of existing) software that can be used and improved upon by an international community. This not only provides the student with a world-size laboratory and support staff, but also gives them experience in large-scale software collaboration and development. Distributed software collaboration has proven itself effective in the educational setting through the use of Internet-driven collaboration tools such as web pages and email lists [?]. These Internet-driven collaboration tools are the same as those that power open source development. Thus, we can look to the open source community to expose our students to large-scale distributed software development. By using the OSMS model, not only is the student participating in a large distributed software community, but is also interacting with large, real environment. Just as we look to conferences and journals for peer-review of our ideas, we can look to the open source community for the same type of scrutiny concerning the OSMS model presented in this research. By taking advantage of the open source development model we extend the methodology by which we learn, apply, and teach, to

include peer-review [?].

2.2.2 Mobile devices and Open Source Software in education

In this section, previous studies of wireless network user behavior are looked at and a discussion on the various mobility models that have been proposed and studied in the literature is presented. Note that related studies of 802.11 wireless networks typically use access point associations to track user interaction. In the OSMS model presented in the research, bluetooth technologies are employed.

Other studies have characterized wireless networks in different settings, large conference venues and corporate wireless LANs. [?] captured and analyzed a workload from a wireless LAN at the 2001 ACM SIGCOMM conference. Their goal was to characterize user behavior in this setting to facilitate the planning and deployment of wireless networks. Since the network was confined to a large auditorium for the conference, the interaction characteristics of the users were very limited. ? analyzed a corporate wireless LAN workload of 1366 users across 177 access points. Again, they collected data using SNMP² to periodically poll all access points involved. In their study, Balazinska and Castro compare their results with results from the previous studies to distinguish user behavior among the various user groups and identify factors which contribute to these differences. Finally, two recent studies investigated the performance of implementations of popular ad hoc routing models deployed 802.11 ad hoc networks. ? developed a distributed architecture for monitoring multi-hop mobile networks called DAMON, and used this architecture to monitor an ad hoc network at the 58th IETF meeting at the end of 2003. The study focused on the experience of using the AODV routing protocol in the network, however, and the number of users (seven) and trace duration (12 minutes) did not make mobility characterization interesting. ? compare the performance of four ad hoc routing algorithms in an outdoor deployment of 33 nodes. Nodes were stationary and therefore did not incorporate mobility into the algorithm evaluation, but they found that (1) the choice of algorithm had a significant impact on packet delivery, and (2) some algorithms that performed well indoors did not perform well outdoors, and vice versa. Numerous interaction models have been proposed for use in simulation and evaluation

²The simple network management protocol (SNMP) forms part of the internet protocol suite as defined by the Internet Engineering Task Force (IETF).

of ad hoc routing protocols. A recent survey presents a number of these models divided into entity and group mobility models [?]. The survey also presents simulation results from these models to emphasize the importance of properly choosing a mobility model for research simulations. They show that the choice of mobility model greatly impacts the performance of various ad hoc routing protocols. Perhaps the most widely used mobility model has been the random waypoint model [?]. In this model, each node begins a simulation stationary for pause time seconds, then randomly chooses a destination in the simulation space and moves to that location with a speed between speedmin and speedmax (chosen from a uniform distribution). Once a node reaches its destination, the process repeats. Aside from being far from realistic user behavior in most settings [?], random waypoint creates non-uniform [?] and fluctuating [?] node densities within the simulation area, as well as decreases the average nodal speed over time [??]. Recently, there have been a number of mobility models proposed as alternatives to the standard random waypoint model (e.g., [????????]). In general, the goal of these models is to increase the realism of random waypoint in particular settings. For example, ? propose a group mobility model called Reference Point Group Mobility (RPGM). RPGM calculates node velocity vectors as the sum of a group center velocity vector and a random motion vector for each node. Such a model could be used for group movement in disaster recovery where teams work and move together throughout a disaster area, or to model movement of convention attendees moving from room to room between project demonstrations. ? propose three movement models: conference, event coverage, and disaster area (a common theme, but with many differing models). New to these models was the incorporation of obstacles through which neither users nor radio signals could pass. ? proposes a mobility model with smooth, rather than sudden, changes in both velocity and direction. However, ? propose "Freeway" and "Manhattan" mobility models. These models restrict movement to paths defined prior to simulation. In addition, node movement depends upon the nodes previous velocity and the velocity of nearby nodes considered to be in the same. ? show that any mobility model in which speed and destination are chosen independently suffers from average speed decay. They propose a framework in which any given mobility model can be transformed to eliminate variations in average node speed as simulation time progresses. Finally, ? propose a mobility model that incorporates both obstacles and paths. Node movement is not only restricted to paths, but follows a shortest path

route to the nodes randomly chosen destination. In addition, node transmissions do not pass through obstacles. This framework was used to model student movement between buildings on a college campus. Each of the above mentioned works test various ad hoc protocols using their mobility models. Although protocol performance results vary from model to model, results indicate that a few key characteristics of the mobility models play major roles in the effectiveness of the ad hoc protocol under study.

Until now, these synthetic models have been the only means of specifying user movement and interaction testing. The OSMS model presented here in the research thus provides much needed data to complement, as well as validate, the varying models in use today.

2.2.3 Motivation for model

The main contribution of the OSMS model is the design and implementation of an educational model, an open source supporting infrastructure for educational environments access over very small devices. This work departs from other open source solution systems by proposing a different style of interaction, the educational model, that is more appropriate for very small devices than the desktop computer's setting model. The current design supports this existing model and also breaks new ground by combining characteristics of search engines, desktop web browsers, and content transducers.

2.2.4 Chapter conclusion

The use of open source software, and GNU/Linux in particular, is on the increase. Ranging in application from the embedded world to corporate infrastructure, open source software also gives educators a type of flexibility and intellectual freedom often absent from software. The OSMS model can serve as a channel, method, and technology to teach and learn. As a channel, OSMS model can expand teamwork past the classroom to include much larger projects and more distributed teams. As a method, OSMS model can be used to introduce our students to the larger community and to the practice of peer review. Finally, acting as a technology, OSMS model can provide free or lower-cost technology in the classroom that might otherwise be unable to afford. The students mobile devices used in this model and Palmtop computers, (also known as Personal Digital Assistants (PDAs)), are personal computing appliances, which can be carried around and

used anytime, anywhere. They can be used for a variety of functions: for example, to manage work or study schedules, to record and store data, and to access and disseminate information. In addition, the availability of e-book reading and editing software for most PDAs means they can also be used to read and interact with electronic text. Students or any user can now use hand held computers as electronic books. Recently, this increasing functionality of palmtop computers has led several authors to argue that palmtop computers could be usefully exploited as learning tools [?]. Studies investigating the potential use of palmtop computers as learning tools have primarily been conducted within school settings. Waycott et al[?] speak of a paradigm shift towards portable computing in education, likening it to the historic shift from reading as an activity that took place only in centres of learning to an activity that became an integral part of everyday life. There is great potential for palmtop computers to provide students with a tool that can support learning in various contexts. Palmtop computers can be used, for example, in field work to record and share data, in libraries and museums, and at home, as well as in the classroom. Palmtop computers could also be useful lifelong learning tools. Such tools could accompany learners throughout their lives, and be used to input data and access information whenever the learner feels it is necessary. In this way, portable devices would become lifelong learning tools that release the learner from situational constraints imposed by desktop computers. Similarly, portable computing technologies could be valuable for supporting open and distance education. Distance education students typically have to fit their self-managed learning activities around other tasks, such as work and family commitments. Providing access to learning resources anytime and anywhere, palmtop computers could enable students to make more effective use of time while away from the home or office environment[?].

Chapter 3

Educational Model

3.1 Introduction

In this chapter, a high level description of the Educational Model is given with all its major parts and the way these parts combine to make up the Model. Also described are the performance and techniques employed in providing distributed applications that use the system, with the extra functionality needed by those applications to enhance the interaction between different components of the Model. The chapter begins with an overview of the general scene in which the Model works and the other entities with which it interacts. First, section 3.1 provides an overview and a discussion of the educational model as such. Then section 3.2 looks at a set of simple but pure (i.e., free from implementation) considerations in an attempt to understand and illustrate the mechanisms involved in each of the models operations. Section 3.3 looks at a previous implementation of the model and section 3.4 sums it up. This chapter follows from chapter 1 where an introduction to the Educational Model was covered and chapter 2 where the background to the model was discussed.

The Open Source Model for Schools (OSMS) presented in this research investigates an open source alternative to the current existing desktop model available in schools and telecenters. It is a new development that uses open source application on students' mobile devices and existing school computer infrastructure. The current infrastructure in most schools, normally based on desktop computer generally having no network will be enhanced by incorporating a wireless environment (*bluetooth, 3G etc.*) An investigation of the functionality and interaction of these components will be documented together

with the overheads of implementation. The research also examines the functionality of applications running on PDA's. A list of possible functions and their implementation overheads are produced and implemented.

The remaining sections elaborate on the features highlighted in this scenario. The following sections describes in more detail the navigation model underlying the approach. The next sections describe how OSMS fits into the existing wireless and Internet infrastructures, followed by a presentation of the components that make up the architecture, and implementation details. The final section presents summary of the model.

3.2 Overview of the Educational model

3.2.1 Open Source Infrastructure for Very Small Devices

This section describes the Mobile infrastructure for utilizing existing educational content and services on wireless phones and other very small terminals. Very small devices typically with displays that normally show 3 to 20 lines of text on average, provide portability and other functionality while sacrificing usability. In order to provide access on such limited hardware, OSMS is implemented as a model that is more appropriate than the existing desktop computer model.

3.2.2 Open Source Educational Model

Today's "browser model" for accessing World Wide Web information evolved within the context of desktop computers with extensive user interfaces (displays, keyboards, pointing devices), considerable computing resources (CPU, storage, operating systems), and high bandwidth network connectivity. This model involves downloading and displaying HTML documents that include content (text, images, and user interface components) as well as links to other HTML and non-HTML documents (such as audio, video, Adobe PDF, and Microsoft Office files). The success of the browser model is due, in large part, to the characteristics of networked desktop computers. Large displays allow rich content to be presented in conjunction with embedded links without sacrificing user's ability to navigate the hyperlink structure. Full-sized keyboards and flexible pointing devices allow users to provide input to Web pages and plug-in applications without undue strain. Abundant

CPU, storage, and operating system resources allow complex plug-ins to be executed locally in order to display, manipulate, and output Web content in various ways. Finally, high-bandwidth network connectivity allows media rich content as well as sizeable plug-in applications to be quickly and easily downloaded to users' devices without compromising interactivity. In contrast, today's small Internet terminals possess characteristics much different from the devices driving the browser application model.

The HP PDA, one of the devices used in the test environment of the research during 2006, has a screen capable of displaying 9 lines of 24 characters. The HP PDA also includes a small number of auxiliary keys to turn power on and off, select and activate features in the display, and a wireless network connection. While some of these characteristics are improving over time, especially in the area of higher-resolution color graphic displays, it is unlikely that they will change substantially due to the portability trade-offs. The educational model integrates these aspects for accessing and using educational content. From the user point of view, the educational model embodies three steps:

1. The user makes a connection to the open source server using a PDA or mobile device via Bluetooth connection.
2. The user is presented with a list of sharable folders and other mobile devices and may decide to "do" something within the folder contents(step 3 below) or communicate with the visible devices.
3. The user is presented a list of items and upon selecting one, enters into the folder associated with that item.

Informally, this may be viewed as a "dig and do" model. Although the model appears simple, the realization raises design and implementation issues, especially in determining sensible labels for folder contents, dealing with "folder overload" from folders with huge numbers of subfolders, handling information that is not directly linked but rather embedded in pages, and creating a high-degree of "open system design" in the model. The design employs the notion of label "quality" so that during processing the user can compare various labels for the contents and select the required item. Nevertheless, even with the quality metric, the issue remains that the context of a folder informs the user.

Finally, the educational model offers an opportunity for open system design that is powerful and makes use of open source applications. Whereas the desktop browsers

associate a single viewer per MIME type, the model associates multiple folder lists and lets the user choose among them. In sum, the model allows users to exploit a more Desktop-like application model that enables them to perform large device tasks on smaller devices.

3.3 Usage Scenario

3.3.1 *The course and participants.*

An evaluation study was undertaken to understand the changes that occur when students use Hand held devices to read and interact with course materials. The study dealt on the teachers and students in their normal secondary school curricula. The course is primarily delivered online, making use of web resources and Open Source software. The subject matter involves evaluating the use of hand held devices and open source application to support teaching. Therefore, participants were encouraged to critique and evaluate their own experiences of using the model while undertaking the course. For this reason, the course offered a valuable forum in which to conduct this study. Participants were generally eager to try out a new medium for reading course materials and offered extensive feedback on their experience of using the Hand held device for reading. All 30 students enrolled in the course were supplied with PDAs towards the end of July 2006. However, it should be stressed that participation in the evaluation of PDAs was voluntary. The course is delivered country wide and so students are geographically dispersed and come from various cultural backgrounds. Participants were primarily novice PDA users, although there were some who had used PDAs in the past and some who currently owned a PDA or similar device.

3.3.2 *Teachers*

The following is a scenario of how one of the teachers participating in the evaluation used the model in his class. This was typical for most teachers evaluating the model.

Mr. Gaseb(name withheld), a secondary teacher in rural school setting wants to set quizzes to his students. He has two alternatives, either give hard copies of questions to his students or write them down on the classroom board. He decides instead to utilize the students mobile devices that are linked to the school computer. If he were back at the

lab, he would simply go to the school computer and format the quizzes. Instead, while in his house which is in the vicinity of the school compound and has bluetooth coverage, he pulls up his PDA and accesses the school's computer on his PDA's micro-browser. As shown below in Figure¹ 3.1 he sees the items he was looking for in the link preceded by a folder icon.



Figure 3.1: A Secondary school teacher using mobile device to interact with course material.

He places the contents from his folder to the shared folder that is accessible to the students. Gaseb can also interact with the students and he decides to answers their queries regarding past quizzes and other assignments. Because almost every small device is designed to select items from a list (e.g., phone numbers, contacts), the contents of the folders are displayed as lists. Therefore his interaction consists of scrolling the folder list up and down, "opening" a folder. Although Gaseb often finds it difficult to read a desktop web page on his Internet mobile phone, with a PDA he can comfortably navigate folders, especially when they follow a canonical layout, as do most folders in a computer. Moreover, he can flip back and forth between the folders.

¹Photo courtesy of SchoolNET Namibia

3.4 Data Flow and Architecture

Before presenting the OSMS's architecture, a description of how the system integrates into the existing wireless and an existing school computer infrastructures is presented. The packet flow through OSMS is shown in Figure 3.2. The system is designed to work with devices having an embedded microbrowser, such as cell phones and PDAs. Such microbrowsers are capable of accepting input from the user and displaying information. To make labels more understandable OSMS tightly integrates a "reading" view with each folder view so that users can expand and collapse the folders in the surrounding.

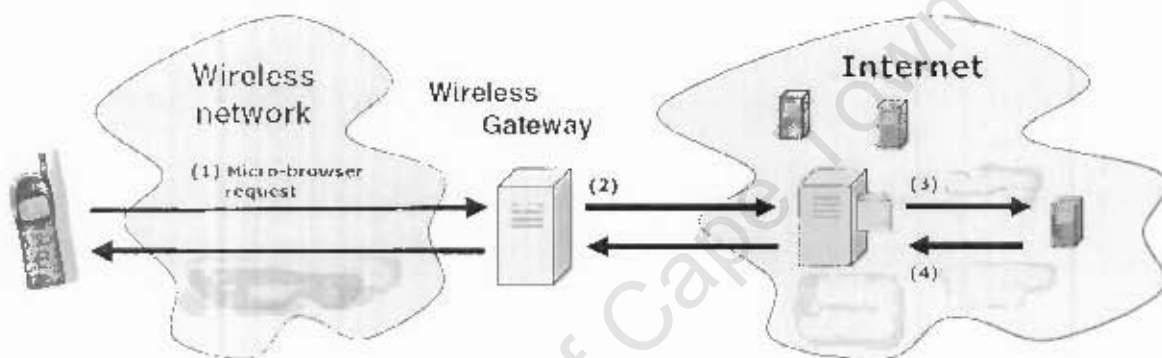


Figure 3.2: Wireless Internet Data Flow.

There are a number of microbrowsers available that employ various markup languages including HDML (Hand held Device Markup Language), WML (Wireless Markup Language), CHTML (Compact-HTML) or subsets of HTML. The OSMS framework works with all these markup languages.

- Microbrowsers communicate over an air-link network such as CDMA, CDPD, BLUETOOTH, GSM, SMS or TDMA to send requests to a wireless gateway (1). A cellular telephone carrier such as Vodacom, MTN, or Cell C commonly operates the air interface and it is transparent beyond the gateway.
- The gateway unpacks the data and forwards this information as HTTP requests to the Internet (2) as shown in Figure 3.3.

The Wireless Gateway usually performs other functions such as acting as a cookie proxy. (Other configurations that include private Wireless Gateways are also possible). When the OSMS server receives an HTTP request from the Wireless Gateway

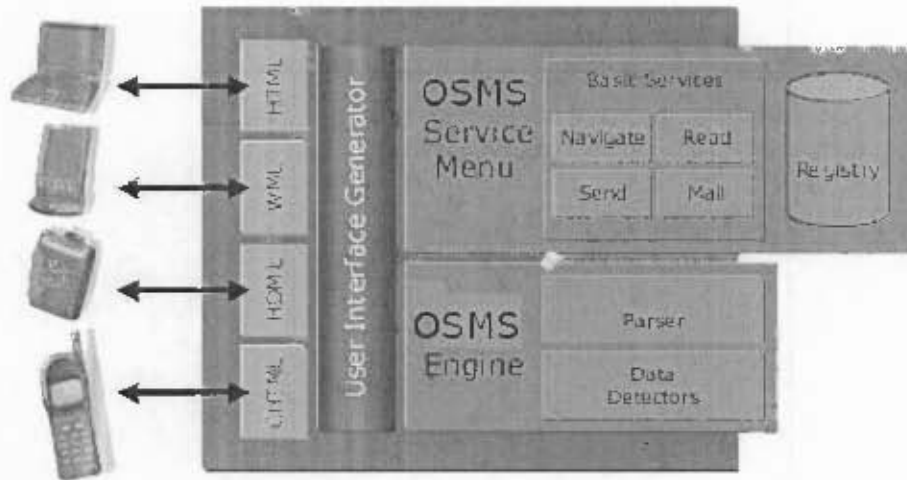


Figure 3.3: OSMS architecture. Heterogeneous small wireless devices connect to the OSMS model using an embedded microbrowsers via bluetooth.

it uses HTTP header information to identify the microbrowser and device capabilities.

- Incoming requests are either satisfied locally or a Web server is consulted (3 and 4).
- The OSMS server will respond to HTTP requests with service screens suitably formatted to device and browser characteristics in an appropriate markup language.
- The wireless gateway then forwards this information to the hand held devices where it is unpacked by the microbrowser and displayed.

This completes a single round-trip sequence between the microbrowser device and OSMS model. Generally this sequence occurs for each new page screen shown to the user, although to improve performance, devices are incorporating screen caches and are able to pre-load screens. Users direct their (micro) browser to OSMS folders, open a folder or mobile link and get the information they require.

3.4.1 Design Goals

The above scenario highlights some of the key aspects of the educational model framework. Providing access to information and services on very small devices having only a few lines of text (or images) introduces numerous challenges.

This design is reminiscent of both the early line-mode browsers, such as Lynx, as well as the familiar file selection dialogs. Figure 3.4 shows some characteristics of very small wireless devices. Wireless micro-browsers hook into the OSMS network-side infrastructure through a URL that manufactures native format (CHTML, HTML, WML, HDML) screens.

| Make Model | Network | Markup | Screen Size (HxW) | Dimensions (HxWxD) |
|-------------------|----------|----------------|-------------------------------|---------------------|
| Mitsubishi T250 | CDPD 1.1 | HDML WML | 80x96 pixels 10x23 chars | 200g 142x56x27mm |
| Mitsubishi D209i | TDMA | CHTML Color | 96x90 pixels 8x7 chars | 63g 125x40x15mm |
| NEC N209i | TDMA | CHTML Gray | 108x82 pixels 9x6 chars | 86g 90x46x19mm |
| NeoPoint NP1000 | CDMA PCS | HDML WML | 120x160 pixels 11x24 chars | 181g 140x54x25mm |
| Palm Pilot VII | | HTML Gray | 160x160 pixels | 190g 133x83x19mm |
| Qualcomm QCP-1960 | CDMA | HDML | 28x20 pixels 4x12 chars | 120g 157x53x17mm |
| RIM 950 | Mobitex | WML Gray | 132x65 pixels | 142g 63x89x23mm |
| Samsung SCH-3500 | CDMA | HDML WML | 96x52 pixels 4x12 chars | 154g 112x52x25mm |
| Sony CMD-Z5 | GSM | WML HTML | 96x72 pixels 4x17 chars | 82g 88x49x21mm |

Figure 3.4: Characteristics of some very small wireless devices.

In the OSMS design these challenges are approached through a number of high-level goals:

1. The OSMS model navigation capacity transforms the "fat" desktop web into a skeleton, more easily navigable form. Folders, documents, mail addresses, and other useful bits of information such as mobile devices connected in the vicinity are returned.
2. The OSMS navigation capacity makes it easy to dig into a site to uncover the contents needed.
3. After digging to some spot, users can do useful things by invoking a client-side or server-side service on the site.

- Web Navigation. Needed to make navigation on small devices faster and less disorienting, which led to culling the folder links from the content.
- Maximize program/data composibility. Emulated the desktop computer's ability to download content and perform many different operations on that content. The folder menu with its list display allows this flexibility of operation.
- Open Extensibility. Able to re-use existing web-based services as well as let users create their own connections. The mechanism for managing the underlying invocation and parameter passing to web based services based on user profile supports this.

3.5 Chapter summary

This chapter has described the Educational model thoroughly in an attempt to give the OSMS model background to the rest of the dissertation. An overview of the model was given to illustrate the way the model works and important aspects of the model were also covered.

Chapter 4

Test Environment

4.1 Introduction

The recent availability of mobile devices[Cellular and Personal Digital Assistants (PDAs)] makes it timely to consider whether these are useful tools for the teaching environment.

This chapter describes the test environment that was used to evaluate the OSMS model described in last chapter. This was done by students and teachers at SchoolNET¹ Namibia. The evaluation consisted of pre- and post-questionnaires, and follow-up interviews. In addition, participants discussed their experiences in an open forum. As wireless access proliferates, understanding user behavior and wireless network performance has become crucial as a basis for developing and evaluating new applications. The study, used the OSMS model by 31 secondary school students over a period of four months at SchoolNET Namibia. A key aspect of the study was the focus on hand-held PDA users with open source applications. The test environment had two goals. First, characterize the high-level mobility and access patterns of hand-held PDA users, and then compare these characteristics to the usage of a ordinary desktop model. Second, develop wireless network topology models for use in a school teaching environment. The evolutionary topology model represents connectivity among users solely based on open source application, bluetooth connection and PDAs. In this model, the network topology evolves over time as nodes and edges appear and disappear based upon user connections and discon-

¹SchoolNet Namibia is a non governmental founded in 2000 and offers innovative computer technologies and internet use to over 300 schools. It has pioneered the use of free and open source software solutions, creative commons licensed educational content(unique in Africa)

nections. Each PDA is connected via bluetooth to the server that houses the contents and open source applications.

4.1.1 Hand held devices as learning tools

Hand held devices (PDAs), are highly portable and are personal computing devices, which can be carried around and used 'anytime, anywhere'. They can be used for a variety of functions: for example, to manage work or study schedules, to record and store data, and to access and disseminate information. Researchers now speak of a 'paradigm shift' towards portable computing in education, likening it to the historic shift from reading as an activity that took place only in centres of learning to an activity that became an integral part of everyday life [?].

4.1.2 Using electronic text

The use of electronic text on computers is not new. With the advancement and proliferation of information technologies, including such resources as the Internet and online books, reading is no longer confined to the use of printed text.

With books, readers can sit anywhere, start reading immediately, change reading positions, and move easily from place to place. In contrast, desktop and laptop computers have many ergonomic constraints, with readers having limited control over the comfort of their reading environment. The portability issue, however, may no longer be relevant, given the increasing availability of hand held e-book devices and the addition of 'document-reader' software on palmtop computers such as PDAs. Such technologies aim to offer readers the benefits of accessing text electronically (e.g. storing several books on one device) while limiting the difficulties of reading text on a desktop computer.

4.1.3 Possibilities and constraints

The introduction of a new tool into an existing activity, such as reading, browsing, editing etc. will inevitably disrupt and change that activity in some way. This is generally referred to as the 'task-artefact cycle' whereby "an artifact suggests possibilities and introduces constraints that often radically redefine the task for which the artifact was originally developed." Thus, the task of the teaching would be redefined through the possibilities and

constraints imposed by the model [?]. The primary possibility introduced by our model, of course, portability and, consequently, the ability to have easy access to information stored electronically. The constraints are equally apparent: the portability and palmtop size of the PDA compromise other features such as screen size and text input mechanisms, which may limit the extent to which the tool could be usefully applied in a learning context.

A further constraint of using a hand held device is that it may be difficult to take notes on the same device. Given that hand held devices, along with e-book reading software, are becoming more widely available, it is important to consider what implications the possibilities and constraints introduced by these tools would have upon the activity of teaching purposes.

4.2 Model Methodology

In this section, we describe the procedure used to collect the data and our data analysis methods. We start by defining a few key terms used in the remainder of this section.

- *User*: A SchoolNET Namibia user, secondary school user, or a teacher equipped with a HP PDA which uploaded and/or downloaded data to the open source server during the 11-week study period.
- *HP Session*: A contiguous time period in which a user PDA is associated with a particular access point.
- *User Session*: A contiguous time period in which a user PDA is powered on and able to detect nearby access points. User sessions include their mobility among PDAs.

There were three development PDAs which uploaded data during the 11 week period.

4.2.1 Subjects

Data was collected from approximately 31 PDA users for an 11-week period between October, 2005 and August, 2006. The users were secondary school students and teachers using the laboratory facilities at SchoolNET Namibia. The student participants would normally use the facility due to its networking and internet connection. The teachers and SchoolNET personnel guide the students in their normal cause of usage of the facility.

The teachers participating in the study came from similar school environment and it was motivating when some of the student users met their school teachers at the facility.

Each of the students participating in the study came from many of the surrounding secondary schools. However, the participating schools had to be at secondary level and at least have a computer laboratory. Users were identified according to their registered wireless card MAC address, and the assumption was that there is a fixed one-to-one mapping between users and wireless cards. The mapping was anonymous; as there were no mapping of MAC address to user names. The laboratory had a bluetooth coverage in which students and teachers could access. The students participated inside and the surrounding vicinity of the SchoolNET office facility. The office facility covered approximately 120m x 110m square metres. The students mobile devices were logged to the server via the bluetooth connection. The above setting emulated a normal secondary school setting where eventually the model would be deployed.

4.2.2 Bluetooth connection

The OSMS server was connected to a USB bluetooth dongle that aided in communicating to the students mobile devices. The devices(HP PDAs) would then sensor and indicate any bluetooth enabled devices in their vicinity. Other mobile devices(most modern cellphones) that were bluetooth enabled would also sensor and register their presence with the OSMS server. The mobile devices would also sensor each other(irrespective of a server being near) and aide in communication. This was a very useful aspect especially if one device was out of range or off for sometime. When the device came back to life or was near a device whose range was near the server, documents and messages could be uploaded from the device near the server. This enabled students and teachers to see how many users are on the wireless network and hence communicate accordingly. This feature of was extensively used in the study by the teachers while interacting with the students, students while interacting with fellow students as well as course material.

4.3 School equipment

This section outlines the equipment used in the study, including the PDAs and software given to students. Students transferred the contents of the course material to the PDAs

using a standard Bluetooth connection to a server running open source applications.

4.3.1 Equipment

- Four PDAs
- SchoolNET laboratory equipped with ten Intel 80386Mhz and twenty Intel 80486Mhz Desktop computers. See Figure² 4.1.



Figure 4.1: Computer laboratory at SchoolNET Namibia.

- One Intel 80486 Server
- Open source applications, [TomCat, Open Office, Mozilla Browser, etc]
- USB Bluetooth device

4.4 Chapter summary

The OSMS model introduced both new possibilities and constraints to the course task, which changed the way students used the course materials. Notably, students and teachers liked the portability of the PDA which made it possible to have access to learning resources 'anytime, anywhere', of which many students found to be very beneficial. However, limitations, such as the small screen size of the PDA, awkward methods for entering

²Photo courtesy of SchoolNET Namibia

text, and navigational difficulties, meant that reading on the PDA was constrained. Nevertheless, there were some students who really valued the PDA for particular reasons, for example as an aid in the preparation of assignments, as a reference management tool, as a useful tool for composing messages on the move, or just as a tool that fitted in with their lifestyle. There were several other potential uses of our model as a learning tool that went beyond course materials. Detailed discussion is presented in later chapters of this dissertation.

University of Cape Town

Chapter 5

Evaluation

5.1 Introduction

The implementation of the OSMS's architecture system is based on Apache tomcat 5.0 engine running open source web server applications. The systems runs on a Pentium IV processor with 256 MB of memory connected to the Internet and communicates with PDA's via bluetooth. The server houses most of the work done in a normal classroom setting by a secondary school teacher. Heterogeneous small wireless devices connect to the OSMS model using embedded microbrowsers. The User Interface Generator converts all outgoing information into a form suitable for the device and browser. The users retrieves information from the server or fetches documents from other users connected via bluetooth. The remainder of this chapter is organized as follows. Section 5.2 discusses the aims of the evaluation. Section 5.3 describes the evaluation method. Section 5.4 describes the participants, experimental tasks and procedures. Section 5.5 describes the some brief observations and general comments. Full results and comments are presented in Chapter 6. Finally, Section 5.6 summarizes the evaluation and concludes the chapter.

5.2 Aim

As wireless access proliferates, understanding user behavior and wireless network performance has become crucial as a basis for developing and evaluating new applications. The evaluation study has two goals. First, to characterize the high-level mobility and access patterns of students' mobile devices, and then compare these characteristics to previous

workload studies focused on desktop users. Second, evaluate OSMS topology model for use in an educational setting. The OSMS topology model represents connectivity among users solely based on observed network proximity: an edge connects two nodes if two users can reasonably hear each other.

5.2.1 *Aim of the evaluation study*

The evaluation of students' use of PDAs¹ for interacting with course materials was to assess the possibilities and constraints introduced by the new model, and to examine how this new model impacts upon students' interaction strategies. The investigation therefore centred on the following questions:

- What are the benefits of using PDAs to interact with course materials?
- What are the limitations of using the students' mobile devices to read and interact with materials?
- How does the use of students' mobile devices change the way students read and interact with course materials?

5.2.2 The evaluation study

1. The course participants

An evaluation study was undertaken to understand the changes that occur when students use our model to interact with course materials in a teaching environment.

The study centred on the teachers and students in a normal secondary school setting and curricula. The subject matter involves evaluating the use of hand held devices and open source application to support teaching. Therefore, participants were encouraged to critique and evaluate their own experiences of using the OSMS model while undertaking their course. Participants were generally eager to try out a new medium for course materials and offered extensive feedback on their experiences. In all 40 students were enrolled in the class but only 31 participated. However, it should be stressed that participation in the evaluation was voluntary. The course

¹PDAs are taken in this instance as a representation of students mobile devices. It envisaged that future mobile handsets will have PDA like features, eg. bluetooth, 3G, high resolution, etc.

(mathematics grade 10) is delivered all over the country and so students are geographically dispersed and come from various cultural backgrounds. Participants were primarily novice mobile device users, although there were some who had used a PDA in the past but most owned or had used at least a mobile handset

2. Data Collection

Questionnaire responses were collated in an Calc(Open Office) spreadsheet. Responses to closed questions were graphed and percentages were used to identify the spread of responses. Open-ended questionnaire responses and interview transcripts were examined to ascertain students' perceptions of the benefits and limitations of using the OSMS model, and categorized accordingly. The most common limitations included small screen size, navigation difficulties, awkwardness of entering text, and the benefits included portability and the advantages of electronic text. Interview and questionnaire comments, and contributions to the online discussion conference, were also examined to determine how the PDA impacted upon students' strategies.

The expected limitations prior to the study were collected from the participants and are summarized below. More discussion on the responses and limitations are presented in Chapter 6.

3. Some limitations as observed by students

During discussions with the students as they answered the post questionnaires, they were encouraged to note any other issues that might have affected the study. The following are some summarized responses. Full responses are presented in later chapters of this dissertation.

Students received the PDA's during the final part of their term and thus they did not have sufficient time to learn to use the device. They were unable, therefore, to make full use of the PDA during the course. They would have preferred to receive the PDA at the beginning of the course when they could familiarize themselves with it and integrate it more effectively into their study activities. The timing of the post-questionnaire was also problematic. The use of questionnaires and interviews as the main evaluation methods could also be problematic due to the fact that both are self-report methods, and are therefore subject to potential bias.

4. Data collection questionnaires

Pre-questionnaires were administered before students received the PDAs. The purpose of conducting a pre-questionnaire was to determine students' preconceptions about the potential usefulness of PDAs, to ascertain the extent of students' past experience of using PDAs, and to find out the sort of strategies they used in the past. Open-ended questions asked students to specify how they believed the PDAs would or would not be useful to them. Post-questionnaires were administered at the end of the course, two months after the pre-questionnaires. The questions asked students what features of the Model they had used, whether they had found the PDA to be a useful tool for supporting their studies, what sort of strategies they adopted when using the PDA, and what the benefits and limitations were of using the PDA on course materials. It was not compulsory for students to respond to each questionnaire, and both questionnaires were distributed to the entire number of students. Consequently, not all students who responded to the pre-questionnaire also responded to the post-questionnaire, and some who responded to the post-questionnaire had not filled in the pre-questionnaire. This would make it difficult later to compare the two sets of responses.

5. Interviews

Interviews were conducted with 10 students, randomly selected from the entire number of students. Only a small sample of students could be interviewed due to time constraints. Nevertheless, the interviews elicited in-depth information about how the use of the OSMS model changed students' strategies, as well as gaining further understanding about the issues that impacted upon students' use.

6. Discussion Forum and computer conference

Students also participated in a discussion forum. Thirty one students contributed to the discussion on PDAs. Of these, twenty students were particularly active in the discussions and were responsible for over 80% of the messages. This group of active conference participants consisted of one student who already owned and used a PDA and two students who were novice users. In the discussions, the students shared their experiences of using the PDAs, offered each other advice about software and features to try, and helped each other with any technical difficulties they experienced. The

discussion forum therefore provided a useful means of capturing data about how some students used the OSMS model. The discussions were not mediated or directed by evaluators, (see Figure² 5.1). Evaluator participated in the conference only to answer specific queries or to make announcements about the study.

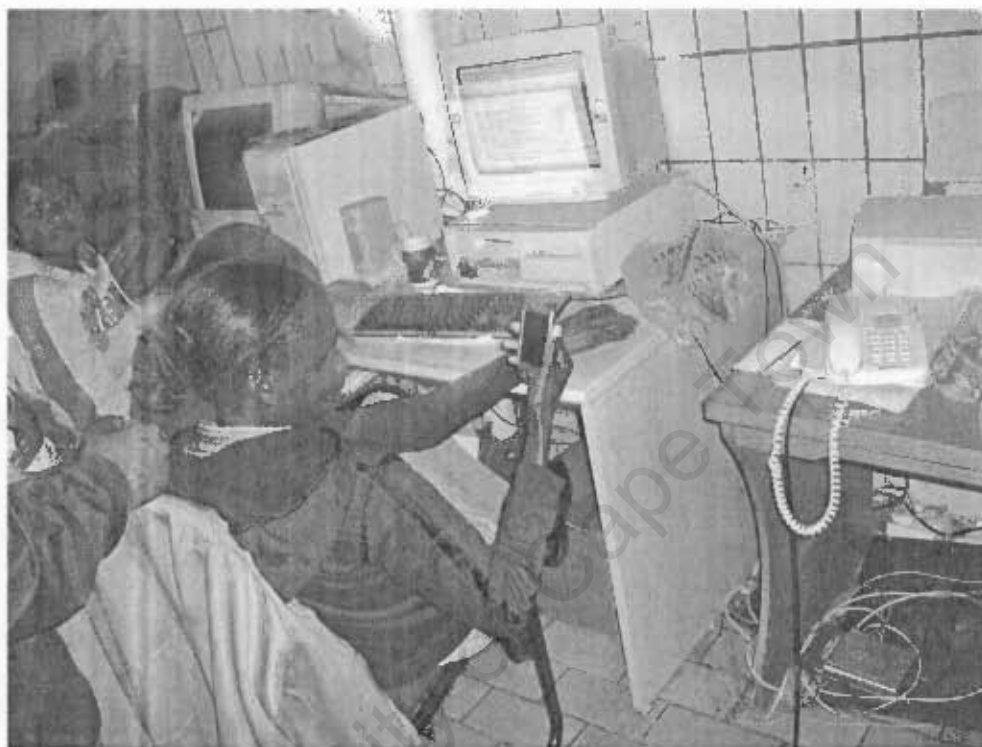


Figure 5.1: A Student participating (using PDA) in a quiz discussion forum; Evaluator and fellow student seen in the background.

5.3 Evaluation method

In this section, we characterize the mobility patterns of users of wireless hand-held PDAs in a secondary school environment using the OSMS model. The OSMS model utilizes a wireless network access via bluetooth connection by 31 secondary school students with HP PDAs. This was over the course of their second and third term (May-September 2006) at SchoolNET premises in Namibia. A key aspect is the focus on hand-held PDA users. The OSMS model's network topology evolves over time as nodes and edges appear and disappear based upon user connections and disconnections. The OSMS model is used to perform the evaluation study. The section also outlines the equipment used in the study.

²Photo courtesy of SchoolNET Namibia

including the PDAs and software given to students, and describes the methods used to collect data and to evaluate the model

5.3.1 Equipment

Students were supplied with 4 HP PDAs. The HP model was chosen because it is a relatively affordable model that offers all of the features common to most PDAs, such as note-taking facilities, an address book, calendar and to-do list, as well as options for email and Internet access. It also has a sufficient memory for storing a large amount of electronic text. The HP PDAs are widely available and there is a variety of third party software and open source software that can be used with this platform, enabling students to explore the potential use of PDAs beyond reading course materials. The HP PDA has a touch-sensitive screen and screen icons are manipulated by using a pen stylus or finger to tap on the screen. Text can be entered by tapping letters on an onscreen keyboard, or by using the Graffiti handwriting recognition software. This involves learning the specific Graffiti alphabet characters and writing these on the screen with the stylus. The computer then converts the handwriting to type. The size of the HP PDA is 3.01 W x 0.65 D x 4.71" H with a 3.5" viewable size, 16-bit color transfective and it weighs about 125 g with batteries installed. It operates on two AAA batteries which could last for up to two months.

5.3.2 Document reader software

Open office suite with available document editor and viewer, was used to present course materials on the OSMS model. This was chosen because it is a flexible program that can be used for a variety of purposes, including recording notes, editing documents and reading text. The document viewer mode enables users to read the text in a variety of ways, for example, by using the scroll bar on the side of the screen or the buttons at the bottom of the device, by dragging the stylus along the screen, or by using the 'teleprompter' facility which moves the text automatically, one line at a time. In addition, the software has search facilities, such as 'Find' which seeks out instances of the specified word, and 'Go to paragraph' which allows users to jump to a particular paragraph. The software was supplied to teachers on a CDROM. Teachers transferred the contents of the CDROM to their desktop computers. Figure 5.2 shows how writer software looked on the desktop

computer.

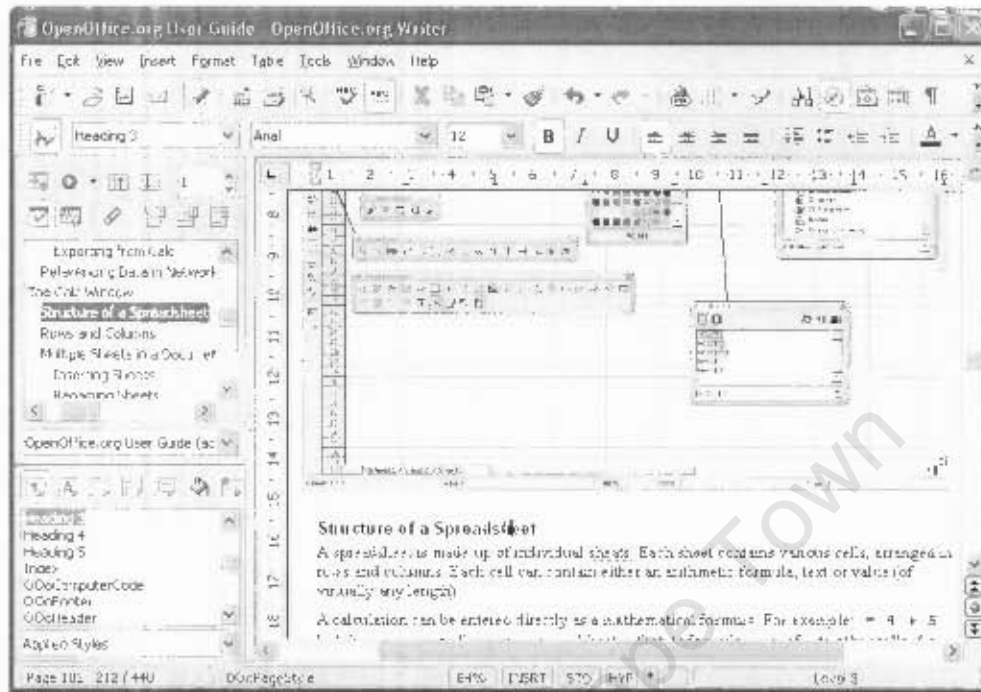


Figure 5.2: Open Office Writer word processor.

The Writer software (open source wordprocessor) used had everything expected from a modern, fully equipped word processor or desktop publisher. The following are some reasons why Writer was chosen as an text editor software for the OSMS model.

- It's simple enough for a quick memo, powerful enough to create complete books with contents, diagrams, indexes, etc. The Wizards takes all the hassle out of producing standard documents such as letters, faxes, agendas, minutes, or carrying out more complex tasks such as mail merges and you can create your own templates.
- Styles and Formatting puts the power of style sheets into the hands of every user. It Traps typing mistakes on the fly with the AutoCorrect dictionary, which can check your spelling as you type.
- Reduce typing effort with AutoComplete, which suggests common words and phrases to complete what you are typing. AutoFormat takes care of the formatting as you write, leaving you free to concentrate on your message.
- Text frames and linking give you the power to tackle desktop publishing tasks for newsletters, flyers, etc. laid out exactly the way you want them to be. Increase

the usefulness of your long, complex documents by generating a table of contents or indexing terms, bibliographical references, illustrations, tables, and other objects.

- Email your documents - Writer offers direct connection to email software. Make your documents freely available with WRITER's HTML export to the web, or publish in Portable Document Format (.pdf) to guarantee that what you write is what your reader sees.
- Save your documents in OpenDocument format, the new international standard for office documents. This XML based format means you're not tied in to WRITER. You can access your documents from any OpenDocument compliant software. WRITER can of course read all your old Microsoft Word documents, or save your work in Microsoft Word format for sending to people who are still locked into Microsoft products.

5.3.3 Course materials

Three sections of the provided course materials were accessed through the OSMS model. These sections made up nearly half of the secondary school curricula for the year. In the normal course presentation the sections are supplied on A4 size paper. During the study, students had access to the hard copy of course materials and the electronic version via bluetooth from the OSMS server. Use of the PDA to read course materials was voluntary. The electronic version of the course materials was stored in the OSMS server. The documents were not reformatted for presentation on the PDA. It should also be pointed out that the materials supplied were entirely text-based, so as to cater for some students mobile devices that lack support on presentation of graphical displays or images. Students downloaded the documents via bluetooth to their PDAs. The course materials could then be viewed on the PDA. Figure³ 5.3 below shows the settings for course material entry on the server. The PDA was used for preparing students assignments. To the right of the computer (not visible in the picture) are the paper notes.

Teachers received the manufacturer manuals that were supplied with the HP PDA, as well as an online manual for the Writer software. In addition, the teachers were provided with further instructions about how to install the software and hints about using the PDA

³Photo courtesy of SchoolNET Namibia



Figure 5 3: A Teachers PDA is next to the desktop computer.

to interact with the course material. These included tips such as how to highlight the text by making it bold or underlining it, how to write notes, and how to operate the different document viewer modes.

5.4 Chapter summary

The evaluation of the OSMS model was conducted in the afternoons at the SchoolNET Namibia laboratory facility. Students from various schools normally visit the centre, an initiative by SchoolNET Namibia to avail computing facilities to the community. In the study, data was collected from participants (both teachers and students) on the use of the OSMS model. The target use on the school curriculum was grade ten mathematics and the aim was to find the benefits, limitations and changes that occurred while utilizing the OSMS model. Expectations of the users before the evaluation was noted to compare the results at a later stage after evaluating the OSMS model.

Chapter 6

Results and Discussion

6.1 Results

6.1.1 Introduction

This section reports the results obtained in the OSMS model evaluation study. Students and teachers' opinions about the benefits and limitations of using the OSMS model and PDAs for interacting with course materials are reported, as are the strategies that teachers used with paper and computer-based materials, and the impact that the model had upon these strategies. Comments from the survey/interviews and conference discussions provide illustration and further clarification of the issues that emerged from the questionnaire responses. In addition, data from these sources revealed further uses that students and teachers made, and hoped to make, of the OSMS model as a learning tool in a teaching environment.

6.1.2 Results on the expectations about using the PDA's

Thirty one students responded to the pre-questionnaire. Of these, one said that they had used a PDA in the past. Students were asked to indicate how useful they believed the PDA would be useful for course materials. Most respondents (27) said they believed the PDA would be somewhat useful. Twenty students believed the PDA would be very useful, and three said they felt it would be not at all useful. The one student who had previously used a PDA had mixed expectations about their potential usefulness. This respondent gave the following reason for that expectation:

“ I have not tried it yet, but think the screen size will be too small. This will make scan reading really difficult. But anything that reduces the amount of stuff I carry around when I am commuting would be worth a go”.

This comment was not atypical. Thus, it appears that students had mixed expectations about how useful the PDA would be. They were concerned about possible limitations, such as the small screen size and potential difficulties highlighting text on the PDA. However, they were also positive about anticipated benefits, such as being able to interact with course material using mobile devices.

- Expected limitations

Small screen size. The primary limitation that students anticipated was that the PDA screen would be too small and difficult to read from.

- Expected benefits

Portability/Mobility. The most common potential advantage identified was that the PDA would make it easier for students to carry around reading materials and interact with teachers whilst on the move.

Evaluation of the Model as a tool for interacting with course material

- Usefulness

Twenty six students responded to the post-questionnaire.

- Ease of use

Students were asked to indicate how easy or difficult they found the model to be. Twenty six students answered this question.

- Students were asked why they felt it was easy or difficult.

6.1.3 Results on the Expected limitations

Small screen size.

The primary limitation that users anticipated was that the PDA screen would be too small and difficult to read from. This is unsurprising, given that small screen size is one of the general limitations of mobile devices that may off-set the advantages of having a

lightweight, portable device. Users expected the text to be small and were concerned about problems of eyestrain. Past experience of reading text from a computer screen also contributed to expectations of difficulties.

Navigation

Students were also concerned that insufficient clues about the information space of the reading material would make it difficult to find information quickly and browse through the text, as they would when they use a familiar paper-based document:

“I frequently know exactly where to find something I have read and want to return to, because I can picture in my head exactly where it is on the page. I won't be able to do that with scrolling text.”

Thus, it was evident that the tactile qualities associated with book reading are essential.

Highlighting and annotating text.

Another anticipated limitation was the potential difficulty of highlighting and annotating text on the PDA, as compared with highlighting and annotating text on paper. Users were concerned that such interaction strategies would be difficult to undertake when using the PDA.

6.1.4 Results on the expected benefits of the OSMS model

Portability/Mobility.

The most common potential advantage identified was that the PDA would make it easier for students to carry around reading materials whilst on the move and communicate with peers and teachers. The issue of portability was considered important to users, many of whom had to travel long distances to access computer facilities. Users found the paper-based course materials to be heavy and cumbersome, and so the anticipation of being able to carry the documents in a portable lightweight device was appealing.

Recording notes.

Students also saw potential benefits in using the PDA to record and store notes electronically. They felt that having a portable device which could be used to record electronic notes would support their learning activities, enabling them to summarize course materials more effectively and keep their notes better organized.

6.2 Evaluation of the OSMS as a tool for interacting with course material

Usefulness

Thirty-one users responded to the post-questionnaire. When asked how useful they found the PDA for reading course materials, eight students (25%) said they found it not useful, fifteen students (48%) found it somewhat useful and six students (19%) found it very useful, as shown in Figure 6.1. Two students did not answer this question. Students were also asked how useful the PDA was overall, that is, for general tasks in addition to reading course materials. In response to this question, five students (16%) said they found the PDA to be not useful, 12 (39%) said it was somewhat useful and 13 (42%) said it was very useful. One student did not answer this question. When using the PDA as a general tool, students utilized functions such as the diary (18 students), teacher communication (21 students), communication with peers (19 students), notes or memo pad (24 students) and calculator (13 students). Therefore, the PDA was a useful time and information management tool and some students took advantage of these facilities.

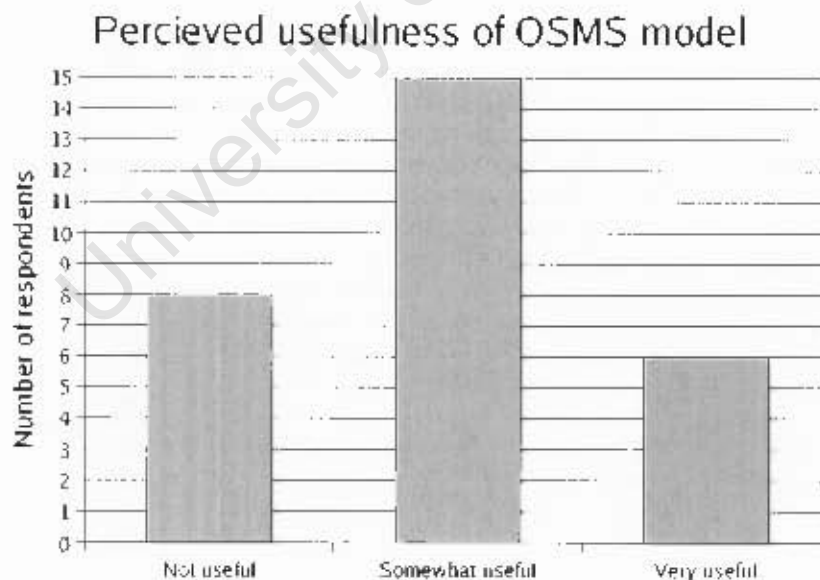


Figure 6.1: Perceived usefulness of OSMS for interacting with course materials, as determined by post-questionnaire responses.

6.2.1 Ease of use of the OSMS model

Students were asked to indicate how easy or difficult they found it to read course materials on the PDA. Thirty-one students answered this question, and nearly half of respondents (49%) said they found it either very difficult (eight students) or somewhat difficult (seven students). Seven students said it was neither easy nor difficult, five students said it was rather easy and four students said it was very easy. Students were asked why they felt it was easy or difficult to read course materials on the PDA. Reasons given included difficulties reading from a small screen with small text size, the awkwardness of having to scroll through the text, difficulties skim-reading and navigating through the text, and the inability to annotate and highlight text in the same way as one would annotate or highlight text on paper. These issues are elaborated further in 6.2.2 and 6.2.3 sections.

6.2.2 Limitations of using the OSMS model for reading

Responses to the open-ended questions in the post-questionnaire, as well as comments made in the interviews and discussion conference, revealed that, as they had anticipated, students as well as teachers did experience constraints when using the PDA for interacting with course materials. The main limitations identified were the small screen size of the PDA, navigation difficulties, and the awkwardness of entering text on the PDA.

Small screen size.

The small screen size of the device was considered a severe limitation. Only a small amount of text could be viewed at any one time and this meant students found it difficult to scan through the text and gain an overview of the document. Reading text on the small screen was slower than on paper, and students had to concentrate on each individual line of text. Users found that they had to change their reading strategies in order to allow for the small screen size:

"Only being able to see a small amount of text at any one time, you have to adopt a different reading strategy. With text on paper I can scan read some way ahead this is not possible with the PDA." "Reading is not a linear process confined to decoding the individual words in sequence, you need to be able to refer quickly to other parts of a text. etc., all of which is impossible on a screen this size."

Navigation difficulties.

Navigating through documents was difficult on the PDA, and users compared it unfavourably with flicking back and forth between pages in a paper document. Some students found visual clues, such as headings, difficult to see on the small screen of the PDA, and this contributed to navigational difficulties:

"(It was) more difficult to navigate around the text ... I mean, obviously Im comparing it with hard copy ... Its just that, scrolling through the screens its difficult to pick up headings and things like that."

One interviewee suggested navigation may have been easier if there had been hyperlinks between sections of the document:

"I did find it difficult, because you have all the headings at the beginning, which is very good, but they are not hot-linked. So I couldnt jump to those sections and just take a look and then jump back again."

Some users said they felt lost within the documents. They found it difficult to know their location within the document space, due to few contextual clues such as page numbers. They felt that more information about their location within the document space would have been beneficial:

"I know it has a little bar on the side to say how youve progressed through the reading, but Id still like something a little bit more . . . I've seen one somewhere on some computer screen that has percentages how far youve got through the reading. I think something a little bit more obvious like that would be more helpful. I sort of like to know where I am in the reading."

Awkwardness of entering text.

In general, users found the methods for entering text on the PDA to be slow and awkward. Typing on a full-size keyboard or writing on paper was deemed to be much faster and superior. A fold-out keyboard can be purchased for PDAs, but users were not supplied with this accessory. Typing out letters on the PDAs small onscreen keyboard was slow and error-prone. There was recognition that the speed and accuracy of entering text may improve with practice. One interviewee said that previous experience of using a PDA had made it easier for her to use the model.

6.2.3 Benefits of using the OSMS model for reading

Despite the limitations, many students found there were benefits of using the OSMS model to interact with course materials. Most students countered their dislike for the limitations of the mobile device with an appreciation for the advantages of being able to carry the course materials around in a small, lightweight device, make contacts with their peers or teachers any time. A majority of students were primarily positive in their evaluation of the OSMS model: for these students, the portability and the fact that the device enabled them to have access to electronic versions of the course materials outweighed the limitations. Four students actually said they preferred reading course materials on the PDA to reading them on paper. Reasons varied, but common were portability and compactness (as opposed to reading from a bulky textbook), navigation on the online material as opposed to carrying a number notebooks or textbook. Other reasons were more aesthetic, like the mobile devices were 'trendy' and students could feel satisfaction while impressing their peers. Although rather surprising reasons, it shows how the culture of mobile devices has penetrated into the students lifestyles.

Portability.

When asked what was the main benefit of using the OSMS model, 22 questionnaire respondents referred to the portability and of the device and accessibility of the course material and teachers. The PDA was very lightweight, small and easy to carry around, therefore allowing easy access to course materials. As one respondent put it, the PDA meant the course materials were handy anytime anyplace. The PDA enabled students to read course materials in various situations, even while they were carrying out other activities. For example, one interviewee said he used the PDA on the way to school. Another teacher interviewee used the PDA to get feedback from students while in meetings when the topic being discussed was not relevant to her. The PDA was an unobtrusive and neat device. This enabled students to fit their study time more effectively around other activities: "It was so much easier to do the work, you could do it everywhere and that was an enormous advantage." Students also took advantage of the portability of the PDA to aid the process of revision, using it to re-read course materials when away from the library or school environment. As one interviewee teacher said, she used the PDA to prepare her lessons while going about other day-to-day activities:

"It helped me prepare notes I was reading because I would read a couple of

sentences and have it near me, whatever I was doing. if I was doing something else as well, you know, practical kind of house stuff."

Another student said that she felt the PDA provided the opportunity to review and build on what she had learned from reading the same materials on paper: "Having the choice between paper and PDA-meant that I felt like I could process more of the course materials, and consolidate my understanding of it: reading in one domain reinforced reading in the other domain." Students therefore used the PDA in conjunction with the printed materials. Having the course materials on the PDA gave students the opportunity to read those texts in situations in which it would have been difficult or inappropriate to read the A4 size printed materials. The PDA therefore became an extension of the printed materials, providing more opportunities for students to read and review the course materials.

Electronic text.

A majority of students found that having the course materials in electronic format was beneficial. They took advantage of this by cutting and pasting sections of the text to aid the process of revision. In addition, some teachers recorded electronic notes, which they then transferred to the desktop computer to incorporate into more extensive documents: 'Note taking was easy and I could download notes to computer instead of having to copy type them up,' observed one teacher. Again, portability was considered an important issue. Being able to record notes electronically while away from the home or school enabled one interviewee teacher to make more effective use of time.

6.2.4 Users reading and note-taking habits

In the pre-questionnaire, users were asked about their interaction with course materials on the OSMS model, in peer discussion messaging, and in the set books used on the course. The post-questionnaire asked about their use of the printed study material, which contained the texts that were made available on the PDA (via bluetooth to the server); the results comparing students use of the printed study material with the PDA materials are described in sections below.

Strategies for reading print and peer conference messaging.

Users note-taking habits were also explored. Paper is the most popular medium for note-taking. Nearly everyone takes notes on a separate piece of paper when reading text

books: over half do this sometimes and two-fifths frequently. Over half of the students take notes on paper when reading course material from the server. A very popular activity is highlighting or underlining text in the text books (half do it frequently, a quarter sometimes). Writing notes in the actual books is considerably less popular, although the majority still do this at least sometimes. Electronic note-taking is less popular. When reading information from the OSMS server and in peer messaging, students mostly do not type notes on their mobile devices, though a minority do so sometimes. However, they are reasonably likely to type notes when reading from their set books for the course, with a substantial number (nearly half) reporting that they do this sometimes. Finally, students were asked about their bookmarking habits and noting the location of important information. When reading text books, half of the students fold the corners of the pages of the text book.

Strategies for reading print and PDA materials

The post-questionnaire results showed that using the PDA for reading changed the way students interacted with the learning materials, particularly with respect to the strategies they used for taking notes on the materials and highlighting the text. This section describes how such reading strategies were different when students read course materials on the PDA, compared with using the print-based version of the materials.

Taking notes.

Figure 6.2 represents the post-questionnaire responses that reveal the note-taking strategies students used when reading course materials on paper and on the PDA. The figure shows the percentage of respondents who answered never, sometimes and frequently to each question. Response rates to each question represented in Figure 6.2 varied. Nevertheless, it is apparent that students were more likely to take notes, in various forms, when using the paper version of the course materials. Some students, however, did take notes while reading course materials on the PDA. In addition, some students took notes on the PDA while reading the paper version of the course materials, as shown in panel (e) of Figure 6.2. Those teachers who did persevere with taking notes on the PDA devised strategies in order to overcome some of the difficulties associated with entering text on the PDA. For example, teacher ignored errors and took abbreviated notes, then transferred the notes recorded on the PDA to the desktop computer where they could be developed into more extensive documents:

“The key thing was to get the notes down. If the odd character was wrong it was more time-consuming to go back and correct it than it would be just to sort it out when youve got it on the main machine.”

Marking up text.

Figure 6.3 shows the post-questionnaire responses that reveal tendencies to highlight, embolden or underline text when reading course materials on paper and the PDA. Again, users were more likely to highlight and underline text when using the paper version of the course materials. Nevertheless, there was a small minority who attempted to embolden and underline text on the PDA. One questionnaire respondent preferred to mark up text on the PDA, because it was neater:

“It was easy to mark things up - this really paid dividends if I printed material out later. much neater than highlighter, pen, etc.”

Further uses of mobile devices as learning tools

The interview and discussion comments also revealed that users were keen to explore further ways in which PDAs could be used to support learning activities beyond interacting with course materials. For example, one teacher who already owned a PDA described how they had used the tool to support different aspects of lesson preparation.

Discussions about current and future uses of PDAs revealed an awareness of the potential for increasing functionality by using other devices in conjunction with the PDA. Discussions centered around the use of mobile phones for transferring data, such as emails and text messages, and there was also mention of the possibilities offered by connecting digital cameras to computers: Sharp have designed tiny cameras about the size of a tiny, single, lego brick and half the depth, which could be embedded into the PDA and used for video conferencing.

The future seems to lie with PDAs that are compatible with phones to allow access to the internet and/or video conferencing. These comments suggest further possible ways in which PDAs might support learning activities, and reveal that some students were keen to explore other potential uses of PDAs as learning tools.

Note-taking with print-based course material

Note-taking with PDA on course material

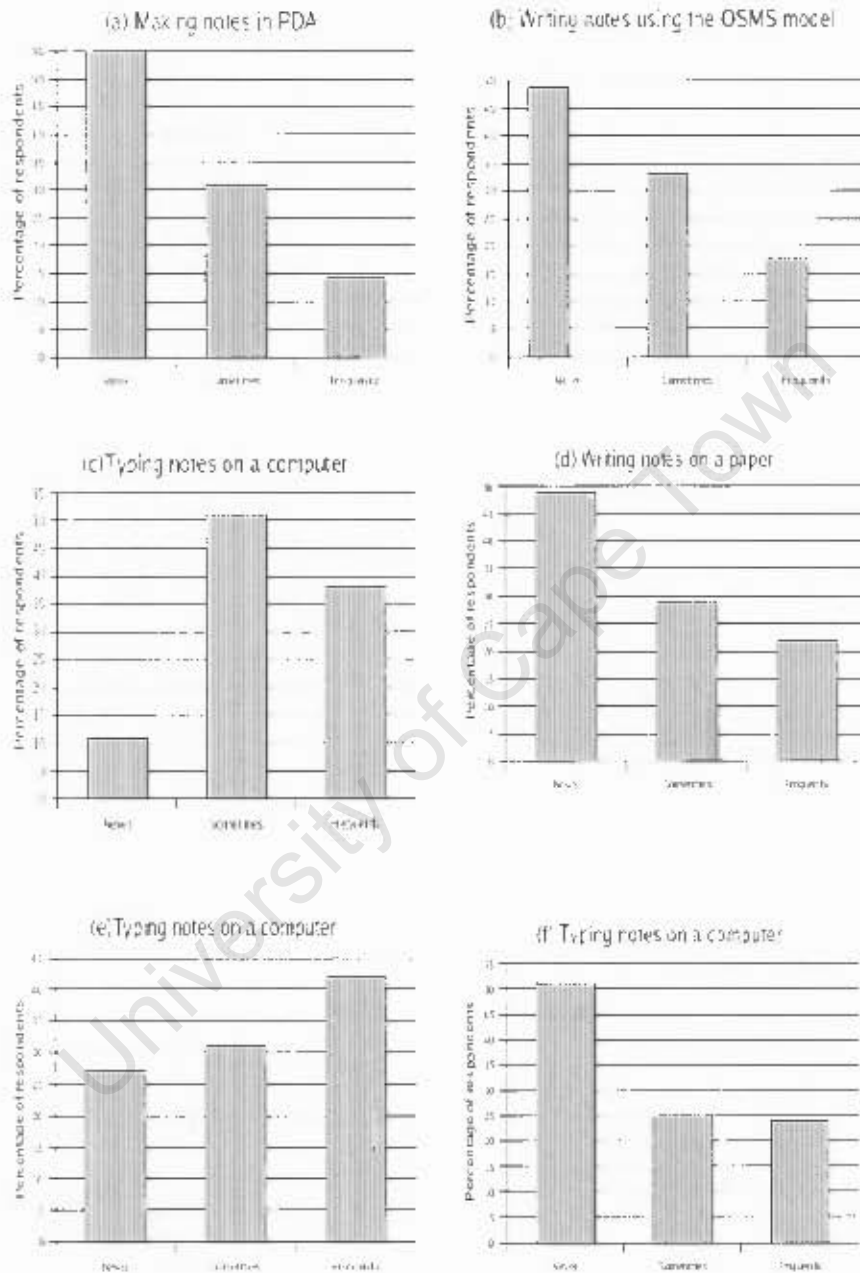


Figure 6.2: Note-taking strategies when using print-based and PDA course materials. Panels a, c & e refer to use of the printed Study Guide. Panels b, d, & f refer to use of the course material sections on the PDA (% of respondents, not students).

Marking up printed course material

Marking up using the OSMS model

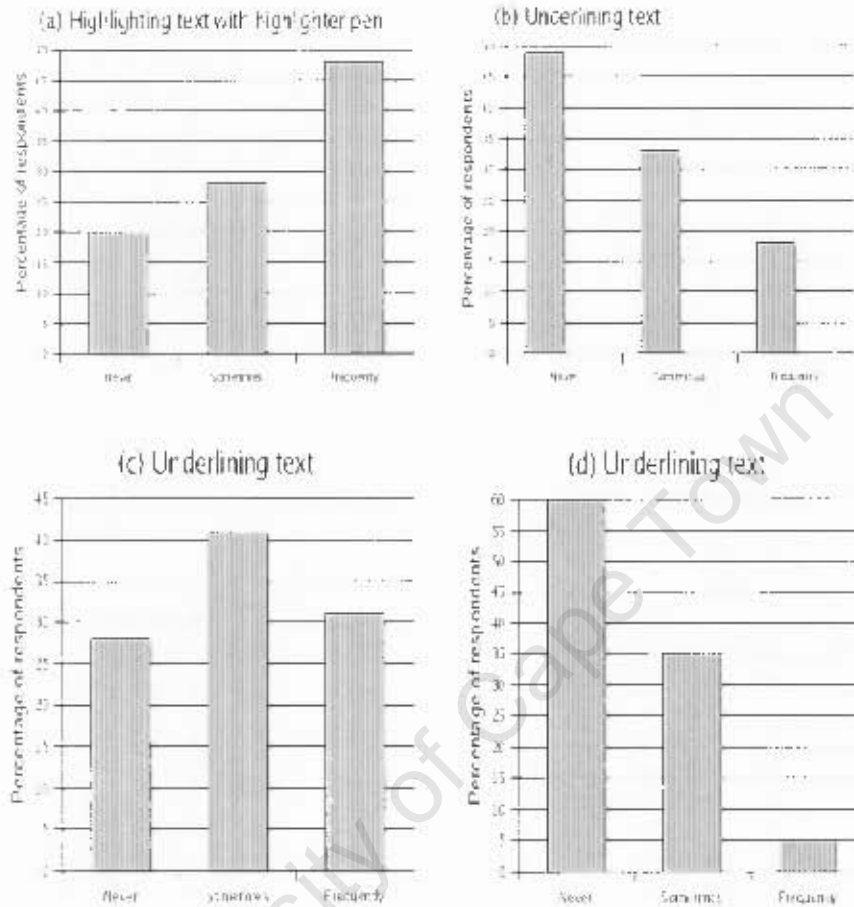


Figure 6.3: Marking up print and PDA course materials. **a** & **c** refer to use of the printed Study Guide; **(b)** & **(d)** refer to use of the course material guide sections on the PDA.

6.3 Discussion of findings

The research revealed benefits and limitations of students' use of Open Source application and their mobile devices for interacting with course materials. While the portability of the device was generally welcome, and some students took advantage of having access to the electronic format of the course materials, limitations such as the small screen size, navigation difficulties, and slow and error-prone methods for entering text, made it difficult to read documents. In addition, use of the PDA changed the way students interacted with the course material. They were less likely to take notes and highlight text when using the PDA, compared with the strategies they employed when reading print-

based materials. In the following section, the findings are discussed with reference to the way the new model changed the way users interacted with the course material.

How the PDA changed the interaction with course material

As ? suggest, the possibilities and constraints introduced by a new tool do change the task that the tool is used to support. This study showed that the use of a PDA for interacting with course materials changed the way users interacted with course material (tasks), by giving users new possibilities, such as anytime, anywhere access to learning resources, and introducing constraints such as small screen size.

Students

With the PDA, students could carry course materials in a small, lightweight and unobtrusive device, which was more portable than the A4-size print version of the course materials. Using the PDA, users could interact with course materials while engaged in other activities or during short periods of time which would otherwise be wasted, such as while travelling to school or waiting for a class. This meant that reading course materials did not have to be confined to the laboratory or classroom contexts, and it was not so important to set aside study time. However, despite positive feedback from students about the benefits of having the course materials on a mobile device, some students found it difficult to read text on the PDA. The limited display area on the PDA meant that only a few lines of text could be viewed at any time. This made it difficult to scan through the text, and required a more concentrated line-by-line reading strategy. In addition, the ease with which students could flick through paper documents was missing on the PDA. These students noted they found it difficult to move back and forth between sections, and they were unable to easily assess their location within the document space. This contributed to feelings of being lost in the reading materials and to an inability to gain an overview of the documents. Students liked the affordances of paper: for example, being able to flick through the document and skip ahead to see how long a section was.

This finding is similar to the results of past research that have compared reading from paper with reading from a computer screen [?] and [?]. The contextual clues that are available when reading printed documents, such as paper size and document weight, are missing with electronic text. Therefore, it is important for electronic documents to contain other contextual clues, along with more flexible navigational tools such as hyperlinks connecting sections of text. A further constraint of the PDA was the difficult

means of entering text and lack of aids to move through text. This is one of the general usability problems of the present generation of mobile devices and is another consequence of their small size and portability [?].

Students generally found it difficult to use the onscreen keyboard on the PDA. They found these text-input mechanisms to be much slower and less accurate than writing on paper or typing on a computer. Consequently, students were less likely to take notes while reading on the PDA, compared to reading on paper. In any case, the note-taking findings from the pre-questionnaires indicate that students mostly write notes on paper (separate to the paper they are reading from), that they like to highlight or underline printed text. Students do not appear to have developed the habit of making notes electronically when working with electronic text. This may partly explain some of their reluctance to make notes on the PDA. In addition, students tended to use both the printed version of the materials and the PDA, depending on the context in which they were studying. Therefore, they may have reserved note-taking and highlighting strategies for when they were using the printed materials, and used the PDA solely for reading the documents. It may have been difficult to take notes in the circumstances in which students were using the PDA (e.g. while travelling), whereas reading the printed materials in a home or classroom environment would have been more conducive to note-taking. Students therefore used the PDA in conjunction with other tools, suggesting that PDAs are not e-books that replace the need for printed course materials. Instead they are used to support and extend other technologies and resources and can replace desktop computers to help bridge the digital divide.

Teachers

Most teachers did take notes on the PDA. They found it beneficial to be able to take notes in electronic format at any time, wherever they happened to be. They devised strategies to overcome limitations of the PDA, using abbreviated notes, which they transferred to the desktop server computer to be incorporated into more extensive documents.

6.3.1 Limitations of the research

The mobile device used in this study is one of the lower-end models, chosen partly because of its relative affordability given the financial resources that were available for this research. Screen quality on the mobile devices is not as good as that available on more

expensive mobile devices. While the provision of a more expensive mobile devices was not an option for this evaluation study, future mobile devices are expected to possess features specific for reading electronic text. However, at the beginning of this study, such devices were not widely available. Indeed, the results of this study showed that users did use the OSMS model as a general tool for supporting time and information management. For example, they used such facilities as the diary, feedback, to-do list and the notes applications. When rating how useful the mobile devices were as a general tool, the majority of questionnaire respondents (77%) said that it was somewhat or very useful.

Students received the PDAs midway in their school term and many interviewees commented that they did not have sufficient time to learn to use the device. Interview comments suggested that students felt they needed more time to become familiar with all of the features and functions of the device. They were unable, therefore, to make full use of the PDA during the course. They would have preferred to receive the PDA at the beginning of the course when they could familiarise themselves with it and integrate it more effectively into their study activities. The timing of the post-questionnaire was also problematic. By the end of the study there were 41 students enrolled in the course. However, only 31 students responded to the post-questionnaire. This raises issues about the possible reasons that 10 students did not respond to the post-questionnaire. It may be that these students had rejected the PDA outright, or they had attempted to use it but found it too difficult. In this case, the findings would have indicated a more positive evaluation of students use of the PDAs than was actually the case. Another possible explanation is that some students may have made a conscious decision not to use the PDA because of time pressures at that stage in the course: in that case, their non-response does not imply a negative attitude or experience. However, the response rate may also have been adversely affected by the fact that the questionnaire was not administered until two months before end of their course. Students would therefore not have felt obligated to take part in the questionnaire. It can only be speculated, however, on the reasons for some of the poor response and how the findings might have been different if all students had taken part in the questionnaire. In any case, the findings showed mixed views about the value of using the OSMS model to interact with course materials and the assumption is that these responses are representative of the range of responses that might have otherwise been received.

The use of questionnaires and interviews as the main evaluation methods could also be problematic due to the fact that both are self-report methods, and are therefore subject to potential bias. That is, students may have provided responses they believed the evaluators wished to hear, rather than a totally honest account of their perceptions. However, given the mixture of positive and negative assessments, this seems unlikely. The study may also have been affected by the subject topic of the study: 'An Open Source Model for Teaching Environments' that incorporates wireless devices. It may be that users on this study were more receptive to using a new technical tool than other students from a less technology exposed area. Therefore, students who took part in this study may have been more enthusiastic about the possibilities of using a PDA and sought to evaluate it more positively than others. It would be helpful, therefore, to conduct further evaluations of PDAs using students from areas with less technology exposure. However, it must be said that an advantage of using students from latter areas is that they were generally very aware of how they used technology to support their studies and so were articulate in their evaluation of the OSMS model as a tool for teaching environments.

6.3.2 Implications for future use of PDAs as learning tools

The course materials used in this study were not reformatted specifically for presentation on the OSMS server. Instead, they were presented in their original document format. Findings from this study suggest that in future it may be advantageous to reformat the documents with more salient contextual clues about the readers location within the document and more flexible navigational tools, such as hyperlinks, to allow students to move with ease back and forth within the documents. Furthermore, this study looked at the use of textbased documents. The open source application software on mobile devices did not support the presentation of graphics. Therefore, further investigation could be made to determine whether it is feasible to view graphics on mobile devices and other small screen devices. The findings showed that users did appreciate having access to learning resources while on the move. It is important to note, however, that the OSMS model did not necessarily replace the paper copy of the course materials. Instead, the PDA used in the OSMS model was used in addition to the printed documents and was used in conjunction with other tools. For example, some teachers liked being able to record and store electronic notes on a portable device, which could then be easily transferred to the

desktop computer for further work. Therefore, the possibility of using PDAs to support learning in this way should be further explored. However, it is important to consider the limitations imposed by the device, such as small screen size and poor screen quality.

This study also showed that there are several ways that the OSMS model could be used to support learning activities beyond reading course materials. Most users found the OSMS to be useful as a general tool. In particular, many students saw advantages in using the PDA as a communication tool. Comments made in the peer conference discussion revealed that some users used their PDA in conjunction with mobile telephones (bluetooth enabled) to send and receive emails when they were away from their computer. They also downloaded and composed messages on the PDA. In addition, several students used the PDA to access Internet resources. The potential for OSMS model to be used as learning tools extends beyond the ability to interact with course material. As mobile devices evolve (e.g. 3G, better resolutions, etc) and become more widely available, it may be possible to further explore such potential uses, particularly for supporting communication aspects of learning activities, such as the use of webbased computer conferencing in distance education. A comparison of the pre and post questionnaire can generate further study that would compare hypothesis (not done in this study) and come up with reflections on the changes that can occur.

6.3.3 Chapter summary

The chapter presented and discussed the results of the evaluation study of the OSMS model in an education setting. Expectations about the benefits and limitations were collected prior to the evaluation of the model for comparative purposes. The results on usefulness, ease of use and actual limitation and other benefits of the OSMS evaluation model were discussed in-depth.

Chapter 7

Conclusion

Attempts to equip school computer laboratories and telecenters with desktop computers by various stake holders have produced less than desired results. Some of the reasons to the impasse are due to the incompatibilities of software applications for the PC and its operating systems. Lack of infrastructure like networking to support the operations and computer skills to manage the resources are other reasons. The current computer hardware (normally donated refurbished machines) have limited capacity to support current software applications. The list is endless. This research is an attempt at achieving a more successful environment by using students' mobile devices, desktop computer and open source applications. The research therefore, looks forward to a time when schools no longer have to purchase computers for their students but rather utilize mobile devices already owned by students.

This research presented results of an evaluation study on the interaction of students' mobile devices with course material and teachers using open source applications in a teaching environment. In particular, the portability of the model made it possible for students to interact with course material and teachers as well as having access to learning resources anytime, anywhere, which many students found to be very beneficial. The study introduced new possibilities and constraints. Students mobile devices availed access 'anywhere, anytime', aided in preparation of assignments, made neater notes, acted as reference tools and communicating tools. The students were able to compose and upload/download material on the move. The mobile devices were also fitting with the students lifestyles and familiarity with the technology will not be an issue. Though there are constraints on such devices (small screen size/navigation/entering text), the benefits

far outweigh the limitations.

This chapter presents the final conclusions that emerged from the research. A summary of the contributions of the thesis is presented and discussion on possibilities for future work in this research area.

7.1 Summary of Contribution

This section summarises the research contributions. The research addressed three main issues:

1. Development of locally relevant open source applications that use students mobile devices for rural areas in developing countries to bridge the digital divide.
2. Use of open source applications and students mobile devices in a teaching environment to develop and test an educational model built in a bottom up approach.
3. To derive comments on how students mobile devices, open source applications and a network desktop computer setting could complement each other in a school environment.

In order to develop a locally relevant open source software application for a rural setting in Africa, the normal software development life cycle was augmented. It was found that many schools with donated equipment lacked the networking infrastructure, skills to operate the laboratories and train users. Moreover, this approach tended to cater for only a few number of students since an average laboratory capacity rarely exceeds 40 students in a sitting session. In other words, usually, as computer sessions would only run in specific times in the afternoons and many of these sessions are not incorporated in a regular school curricula. This approach can not work in rural areas if we wish to address real school community needs. Instead, a new approach is paramount, based on accessibility if we are to bridge the digital divide and meet the requirements of a target school community.

To address these deficiencies and to adapt the existing infrastructure, a pre-implementation survey was done on anticipated usage of the educational model. Students mobile devices, PDAs and open source applications were used to develop an educational model (OSMS). OSMS model provided the steps needed to create an enabling environment that overcomes

most of the physical limitations present at schools and telecenters. It described the overall process used to for a target school community and a framework to discover a problem area and provide a solution. A survey questionnaire was used to give guidelines on the techniques used to ensure that the model prototype developed addressed user needs. These included discussion groups, paper prototyping amongst others.

Additionally, sound software engineering principles were used for model development and guidelines to ensure best practice were followed throughout the model testing. In particular, was essential to ensure not to neglect any aspect of the model testing project that could affect its success. Examples of such factors include the fact that training was crucial to help participants use the prototypes developed and also sustainability issues for which SchoolNET Namibia was lobbied. With all these methodologies and guides in mind, a cyclical approach was composed for developing the model in rural and under serviced areas in Namibia. This enabled a loose process to be followed to develop a model prototype and work with a rural school community by adding a research aspect to the model development life cycle.

In addition, idea of a teacher to manage the implementation of the OSMS was crucial in a school environment. The teacher helps facilitate interaction within a school community. Using the teacher in the evaluation of the OSMS model, it was possible to utilize prior relationships between people to gain trust and build rapport in one's own relationship with the school community. The teacher also sometimes monitored the models' progress in the field and sometimes helped set up adhoc meetings with participants. Another use of the teacher, was to help penetrate cultural barriers between the researcher and school community participants. Having someone from a similar culture or who speaks the local language, helped researcher pick up on cultural nuances and community feelings which would have otherwise passed unnoticed. For a particular OSMS model testing, there can be several teachers serving different purposes. The tasks described above can be divided and relegated to the teachers. This would normally be the case if the participants are many and surpass a normal class setting. Various group testing would then be undertaken under supervision of the teachers. This framework was used to develop and test the model in a teaching environment from schools in Namibia. The OSMS model solution for teaching environments allows interaction of students with the teachers and teaching material using open source applications via bluetooth. It is novel in that it was the first use

of students' mobile devices over a wireless network in Namibia, South Africa and probably the rest of Africa. OSMS was also innovative in that it made use of bluetooth presence to allow participants to determine if their contacts were available for interaction. From our activity logs and interviews, it is evident that OSMS was the preferred solution for student interaction and was seen as an improvement over the previous desktop computer model. In particular, question asking and peer tutoring was seen as useful by both the teachers and student participants. This confirms that the OSMS model approach not only allowed development of a locally relevant open source application for Namibia but also enabled the lives of all the school participants to be enriched.

Finally, we found that computer networking facilities in Namibia and South Africa have a long way to go before they open up real opportunities for bridging the digital divide. In particular, arguments for OSMS are presented as a solution for providing computing in isolated regions. It is also suggested that these areas have minimal fee payment by cellular networks so that students could get access to cyberspace from their mobiles. More importantly, this would also allow students to use whatever mobile devices they have.

7.2 Future Work

There is scope for future work in this field of research. Firstly, the OSMS educational model could be further refined for rural and isolated areas other than the Namibia or South Africa. This approach could also be used in other sites in developing countries with similar conditions to test how well it performs elsewhere.

Secondly, the OSMS prototype could be improved and tested in other environments similar to the Namibia. Revisions that were suggested by participants but which were not implemented during the model testing due to time constraints could be introduced. For an example, limitations, such as the small screen size of the mobile devices, awkward methods for entering text, and navigational difficulties, meant that using the device was constrained. Fewer students took notes and highlighted text on the PDA than they did with printed materials. The small screen size of the PDA required a more concentrated reading strategy and made it difficult to scan-read the text. Students therefore found it difficult to read on the PDA and it was generally considered to be inferior to reading on

paper. The OSMS model could thus be adapted for students mobile devices that support newer and upcoming wireless technologies like 3G. Short Message Service (SMS) features could be included to inform participants when a OSMS user requests services or wishes to interact with peers. Another additional feature would be implementing video conferencing with a proper quality of service and high image quality. The study also showed that there are several potential uses of PDAs as learning tools beyond reading course materials. In particular, students suggested that they would have liked to be able to use the PDA as a communication tool, particularly for supporting activities such as online conferencing while at home or away from the bluetooth coverage. It would be valuable, therefore, for further studies to investigate the potential benefits and limitations of using PDAs for these learning activities.

Furthermore, OSMS could be expanded to facilitate communication between multiple groups within a school and across schools. At each site, either one teacher (head of department) could be solely responsible for OSMS or a number of teachers in a department people could do the work alternatively. Internet connectivity could also be provided via 3G to link up international sites. Another area for future work would be to see how OSMS server that is connected to the internet can be altered now that VoIP is legal. An analysis of this change could be performed to see if VoIP and use of students mobile devices is a viable model in rural areas. The scope for changing the OSMS prototype is therefore endless but all suggestions and changes should always be centred in school needs. At the time of writing, plans were being formulated to implement the OSMS model to another school in the rural northern parts of Namibia where the bulk of the country's population is situated with similar conditions. Many of the suggestions made here can be tested at these new sites.

In all, the OSMS model helped comment on both the ways open source applications and students mobile devices can be used in teaching environments for rural areas and to develop applications that are beneficial to the educational sector of a developing country. The results also showed that the model introduced both new possibilities and constraints to the environment, which changed the way students and teacher interacted with the course materials. Nevertheless, there were some students who really valued the PDA for particular reasons, for example as an aid in the preparation of assignments, as a means to neater notes, as a reference management tool, as a useful tool for composing conference

messages on the move, or just as a tool that fitted in with their lifestyle. These students may have been more tolerant of the PDAs shortcomings as a reading device. It would be interesting to investigate the relative value of different functions of the PDA to individuals and groups in learning contexts. Although the results have limited generalizability because of the small number of model testing participants, it is believed that they are transferable to any other school or situations with similar conditions and circumstances.

University of Cape Town

List of Abbreviations

3G: Third-generation technology in the context of mobile phone standards

ACM: Association for Computing Machinery

AIM Lab: Advanced Information Management Laboratory

CDMA/PCS: Code division multiple access/Personal Communication Services

CDMA: Code division multiple access

CDPD: Cellular Digital Packet Data

CDROM: Compact Disc read-only memory

CHTML: Compact-HTML

GPL: General Public Licence

GSM: Global System for Mobile communication

HDML: Handheld Device Markup Language

HP: Hewlett-Packard Company

HTML: Hypertext Markup Language

HTTP: Hypertext Transfer Protocol

IETF: Internet Engineering Task Force

LAN: Local Area Network

OpenOffice.org: Multiplatform and multilingual office suite and an open-source project.

OSMS: Open Source Model for Teaching environments

OSS: Open Source Software

PDA: Personal Digital Assistant

RPGM: Reference Point Group Mobility

SIGCOMM: Special Interest Group on Data Communication

SNMP: Simple Network Management Protocol

TDMA: Time division multiple access

UCT: University of Cape Town

USB: Universal Serial Bus

VoIP: Voice over Internet Protocol

WML: Wireless Markup Language

XML: Extensible Markup Language

Questionnaire

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Appendix B - RESEARCH QUESTIONNAIRE

An Open Source Model for teaching environment (OSMS Model)

This survey aims at collecting information which will be used in evaluating ways of making it possible for small business enterprises to take part in conducting electronic commerce. The research is part of an evaluation study on the interaction of students' mobile devices with course material and teachers using open source applications in a teaching environment done by James Mutuku currently doing an MSc in Computer Science at University of Cape Town in South Africa. To ensure confidentiality, general trends in adoption, use or intention to use electronic commerce would be discussed and not individual responses.

Although express permission has been granted by the SchoolNet Namibia management to take photos (and use them for publication of the survey) of the sessions, only willing participants shall be photographed. You may opt not to appear in any or all of the photo sessions.

Your participation on this questionnaire is greatly appreciated and voluntary, you are free to stop answering the questionnaire at any point should you feel so.

Thanking you for your anticipated cooperation.
James Mutuku

PART A.

A1. Secondary school location (e.g. Windhoek central, Katutura, etc.)

.....

A2. Computer facilities present at your secondary school:

.....

.....

| (Please circle your choice) | 1 | 2 | 3 |
|-------------------------------------------------------------------------------------------------------|------|--------------|-------------|
| A3. Where do you use computers from? | Home | At my school | Other place |
| A4. Do you have a computer(s) in your school? | Yes | No | Don't know |
| A5. Do you have a network connection at your school? | Yes | No | Don't know |
| A6. If you answered No to question A5 above, where do you use the internet from? | Home | Post office | Other |
| A7. Do you know what a PDA? | Yes | No | Not sure |

A8. IF the answer to question A7 is **YES**, what do you understand by a PDA?

.....

PART B.

B1. Network and Computer usage:

Which of the following suits your usage of computers?

(Please Circle all that apply)

| | Yes | No |
|--------------------------------|-----|----|
| A) Browsing for information | 1 | 2 |
| B) Communicating with peers | 1 | 2 |
| C) Communicating with teachers | 1 | 2 |
| D) Doing homework –typing | 1 | 2 |
| E) Reading documents-e books | 1 | 2 |
| F) Web-based learning | 1 | 2 |
| G) Downloading software | 1 | 2 |

| | Yes | No |
|--------------------------------|-----|----|
| I) Listening to music | 1 | 2 |
| J) News | 1 | 2 |
| K) Playing games | 1 | 2 |
| L) Surfing the web | 1 | 2 |
| M) Taking courses | 1 | 2 |
| N) Chartroom/discussion groups | 1 | 2 |
| O) Other (Specify) | 1 | 2 |

B2. Pre-Questionnaire on expectations of using the OSMS model**(Please Circle your choice)**

| B2. Please indicate how you believe the PDA would be useful for interaction | Very useful | Somewhat useful | Not useful |
|------------------------------------------------------------------------------------|-------------|-----------------|------------|
| A. Interaction with course material | 1 | 2 | 3 |
| B. Interaction with fellow students | 1 | 2 | 3 |
| C. Interaction with teachers | 1 | 2 | 3 |

PART C.**C1. Post-Questionnaire on use of using the OSMS Model**

On a scale of 1 (**Very useful**) to 3 (**Not useful**) indicate the extent to which you agree or disagree with the following points.

| Scale | Very useful (VU) | Somewhat useful (SU) | Not useful (NU) |
|-------|---------------------------|-------------------------------|--------------------------|
| | 1 | 2 | 3 |

C1. USEFULNESS**(Please circle your choice)**

| Usefulness of model at school | VU | SU | NU |
|--------------------------------------------------------------|-----------|-----------|-----------|
| A) How useful was the PDA in reading course material? | 1 | 2 | 3 |
| B) How was the overall use of the PDA (other general tasks)? | 1 | 2 | 3 |
| C) How was the PDA's communication with the teacher? | 1 | 2 | 3 |
| D) How was the PDA's use for notes or memo pad? | 1 | 2 | 3 |
| E) How was the PDA's communication with fellow students? | 1 | 2 | 3 |
| F) How was the PDA's use as a diary? | 1 | 2 | 3 |
| G) How was the PDA's use as a calculator? | 1 | 2 | 3 |

C2. EASE OF USE**(Please circle your choice)**

| How easy it was for you to use OSMS Model? | VU | SU | NU |
|---------------------------------------------------|-----------|-----------|-----------|
| A) Reading course material on the PDA? | 1 | 2 | 3 |
| B) Screen size of the PDA? | 1 | 2 | 3 |
| C) Navigation on the PDA? | 1 | 2 | 3 |

C3. LIMITATIONS**(Please circle your choice)**

| Indicate the limitations while using the model for reading | VU | SU | NU |
|-------------------------------------------------------------------|-----------|-----------|-----------|
| A) Screen size | 1 | 2 | 3 |
| B) Navigation | 1 | 2 | 3 |
| C) Entering text | 1 | 2 | 3 |

C4. BENEFITS**(Please circle your choice)**

| Indicate the benefits while using the model for reading | VU | SU | NU |
|----------------------------------------------------------------|-----------|-----------|-----------|
| A) Portability | 1 | 2 | 3 |
| B) Electronic text | 1 | 2 | 3 |
| C) Recording notes | 1 | 2 | 3 |

C5. CONFIDENCE (SELF-EFFICACY)**(Please circle your choice)**

| Indicate your level of confidence in using the OSMS model | VU | SU | NU |
|----------------------------------------------------------------------------------------------------|-----------|-----------|-----------|
| A) I could use OSMS even if there was no one around to help | 1 | 2 | 3 |
| B) I feel confident understanding features relating to the OSMS model | 1 | 2 | 3 |
| C) I feel confident browsing the world wide web without any assistance while using the OSMS model. | 1 | 2 | 3 |

C6. INFLUENCE (SUBJECTIVE NORM)

(Please circle your choice)

| Influences on EC usage | VU | SU | NU |
|-----------------------------------------------------------------------------|----|----|----|
| A) People who influence me may influence my decision to use the OSMS model. | 1 | 2 | 3 |
| B) I would use OSMS model if my peers use it. | 1 | 2 | 3 |
| C) I would use OSMS model if my teacher requires me to use it. | 1 | 2 | 3 |

C7. DIFFICULTIES

(Please circle your choice)

| Computer facilities availability | VU | SU | NU |
|---------------------------------------------------------------------------|----|----|----|
| A) My school has a computer laboratory readily available for use. | 1 | 2 | 3 |
| B) I have all the computer facilities I need to use at home. | 1 | 2 | 3 |
| C) Our school has put all in place internet for our use in the laboratory | 1 | 2 | 3 |

C10. INTENTION FOR FUTURE USE of the OSMS model

(Please circle your choice)

| Your future intention to use OSMS model | VU | SU | NU |
|----------------------------------------------------------------------|----|----|----|
| A) I intend to use the OSMS model more in the future. | 1 | 2 | 3 |
| B) If it is available, I intend to use the OSMS model in the future. | 1 | 2 | 3 |
| C) I have been frustrated while using the OSMS model. | 1 | 2 | 3 |

D1. Post-Questionnaire on user reading and note taking habits

(Please Circle your choice)

| Strategies for reading print and PDA material | Never | Sometimes | Frequently |
|-----------------------------------------------|-------|-----------|------------|
| A) Making notes on a PDA | 1 | 2 | 3 |
| B) Typing notes on a computer | 1 | 2 | 3 |
| C) Writing notes on a paper | 1 | 2 | 3 |
| D) Marking up text on PDA | 1 | 2 | 3 |
| E) Highlighting with pen on printed material | 1 | 2 | 3 |
| F) Underlining text using PDA | 1 | 2 | 3 |

Part E

Please circle your choice in E1 to E6 below.

E1. Gender: (1) Male (2) Female**E2. Age:** (1) 16-25 (2) 26-35 (3) 36-45 (4) 46-55 (5) over 55**E3. Years of Work Experience at secondary school level** (*Applicable to teachers only*)

(1) Less than 2 years (2) 2-5 years (3) 6-10 years (4) Over 10 years

E4. Highest Level of Formal Education (*Applicable to teachers only*)

(1) Diploma (3) Degree (4) Post Graduate (5) Other (Specify)

E5. Current Position at work (*Applicable to teachers only*)

(1) Teacher, (2) Head of Department, (3) Headmaster, (4) Headmistress, (5) Other

(Specify).....

E6. Any other comments you would like to contribute to help us have a better working of the OSMS model?

.....

.....

Thank you for participating in this survey – Good day.