Web-based M-Learning System for Ad-hoc learning of Mathematical Concepts amongst first year students at the University of Namibia

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Abstract

In the last decade, there has been an increase in the number of web-enabled mobile devices, offering a new platform that can be targeted for the development of learning applications. Worldwide, developers have taken initiatives in developing mobile learning (M-learning) systems to provide students with access to learning materials regardless of time and location. The purpose of this study was to investigate whether it is viable for first year students enrolled at the University of Namibia (UNAM) to use mobile phones for ad-hoc learning of mathematical concepts. A system, EnjoyMath, aiming to assist students in preparing for tests, examinations, review contents and reinforce knowledge acquired during traditional classroom interactions was designed and implemented. The EnjoyMath system was designed and implemented through the use of the Human Centred Design (HCD) methodology. Two revolutions of the four-step process of the HCD cycle were completed in this study. Due to the distance between UNAM and Rhodes University (where the researcher was based), the researcher could not always work in close relation with the UNAM students. Students from the Extended Study Unit (ESU) at Rhodes University were therefore selected in the first iteration of the project due to their proximity to the researcher and their similar demographics to the first year UNAM students, while the UNAM students were targeted in the second iteration of the study. This thesis presents the outcome of the two pre-intervention studies of the first-year students' perceptions about M-learning conducted at Rhodes University and UNAM. The results of the pre-intervention studies showed that the students are enthusiastic about using an M-learning system, because it would allow them to put in more time to practice their skills whenever and wherever they are. Moreover, the thesis presents the different stages undertaken to develop the EnjoyMath system using Open Source Software (PHP and MySQL). The results of a user study (post-intervention) conducted with participants at UNAM, ascertained the participants' perception of the usability of the EnjoyMath system and are also presented in this thesis. The EnjoyMath system was perceived by the participants to be "passable"; hence an M-learning system could be used to compliment an E-learning system at UNAM.

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Glossary of Abbreviations

BL	Blended Learning
B.SC	Bachelor of Science
E-learning	Electronic learning
ESU	Extended Study Unit
HCD	Human Centred Design
LMS	Learning Management System
MB	Megabyte
M-learning	Mobile learning
MTC	Mobile Telecommunications Limited
ICT	Information and Communication Technology
PDA	Personal Digital Assistants
PoN	Polytechnic of Namibia
SMS	Short Message Service
SUS	System Usability Scale
UNAM	University of Namibia
VCR	Virtual Classroom

Chapter 1. Introduction

1.1 Introduction

Information Communication Technologies (ICTs) have advanced significantly over time, proving to be powerful drivers that can enhance living conditions and opportunities around the globe (Global Information Technology, n.d.). This in turn has led to numerous investigations regarding how ICTs could be utilised in multiple disciplines including that of Education. To date, access to the Internet in educational environments has increased, supported by less expensive devices such as low-end computers and mobile phones. The advancement in technology in education globally provides access to information through the use of Electronic learning (E-learning) systems. E-learning systems have been used in education for the past few decades, enabling students to access information and content pertaining to the courses they are studying outside of the formal classroom environment. Although computers have been the common device used for accessing information in educational environments, mobile phones are in greater abundance than computers (Bhatia, Bhavnani, Chiu, Janakiram, &Silarszky, 2008;Brown, 2005;Markett, Sánchez, Tangney, & Weber, 2006). Currently, there are more than 84 million mobile phones with Internet capabilities in Africa (Fripp, 2011). Furthermore, seven out of ten mobile phones are predicted to be Internet-enabled by 2014 in Africa (Fripp, 2011). As a result, researchers are investigating and initiating methods pertaining to how mobile phones could be used in education even though still in its infancy (Motiwalla, 2007).

Although ICTs have advanced globally, countries such as Namibia are faced with the challenge of access to ICT infrastructure. There are a limited number of landlines, and a general lack of electricity and bandwidth in Namibia (Gomez, 2009), making it difficult to utilise ICT infrastructure (Alemneh& Hastings, 2006). However, mobile network coverage is accessible by most people in Namibia regardless of their socio-economic level. Namibia has 65% mobile network coverage (Gomez, 2009) and the mobile penetration amongst the Namibian population is high. The Mobile Telecommunications Limited (MTC), which is the biggest mobile phone provider in the country, ended the year 2010 with a total number of 1.53 million active SIM-cards subscribers (International Telecommunication Union, 2011) (although the number of unique subscribers is unknown). As such, a significant number of individuals can connect to the Internet via mobile phones (Gomez, 2009). Given that the Namibian total population is around two million citizens, this is a significant level of mobile phone penetration. The proliferation of mobile phones and access to mobile phone networks in Namibia provide a platform to support people accessing information for a number of endeavours including educational purposes. To address the problem of limited computing resources in Namibia and especially in educational settings, mobile phones could be used to compliment computers in education.

1.2 Motivation

Every year, students from different educational backgrounds enrol at the University of Namibia (UNAM). Some students enter the university with a psychological block (caused by the myth that Mathematics is difficult (Jason, 2009) towards Mathematics, which they developed at a young age, while some students enter the university with a poor academic background, especially in Mathematics(Academics without Borders, Canada, 2011). As a result, many students experience difficulties in understanding Mathematics at the tertiary level due to a lack of understanding of the prerequisites taught at the primary and secondary levels (Jason, 2009). One of the biggest challenges faced by tertiary institutes in Namibia is the poor quality of Mathematics and science education at primary and secondary school levels (Haufiku, 2009). Studies could therefore be undertaken at either primary, secondary, or tertiary level investigating the use of mobile phones for Mathematics or science education. To limit the scope of the work in this thesis, we have chosen to focus on Mathematics education at tertiary level for the following reasons: proximity to primary researcher; limited access to mobile devices in primary and secondary schools (Shinovene, 2013); and near-ubiquitous access to mobile devices at tertiary level. Mobile phones are not prohibited on the UNAM campus and are widely distributed amongst the student body. Students also have experience using mobile phones as some students have used mobile phones from a young age. Mobile phones could therefore be used to enable students to extend learning to outside the classrooms, as students seem to require an alternative way of learning to compliment traditional learning taking place at UNAM.

1.3 Problem Statement

Mathematics is a compulsory module for all first year students who wish to major in a subject offered by Faculty of Science at UNAM (UNAM, n.d.). Students from other faculties who wish to major in a subject offered by the Faculty of Science also have to fulfil these requirements (UNAM, n.d.). In 2011, UNAM experienced a 75% failure rate in the Mathematics courses (Academics without Borders, Canada, 2011). Although the university has an E-learning system, there are limited computer lab facilities on campus, limiting student access. Apart from the limited computing resources, use of the E-learning system at UNAM is also limited by the fact that some first year students enrol at UNAM without any background in basic computer literacy. For example, students from poor communities are only likely to access computers at school. According to Gomez(2009), out of 854 Namibian households surveyed, only 51 had access to the Internet. At UNAM, students from such backgrounds attend computer literacy classes either in the first or second semester of their first year (UNAM, n.d.). Some students who choose to do computer literacy in semester two might have difficulties using a computer in semester one because of their poor computer literacy levels. As a result, their academic progress might be hindered. This scenario has a negative effect on the use of the E-learning system by most of these previously disadvantage students at UNAM. Although there is a Wi-Fi network on the UNAM main campus (E-learning Africa, 2012), not all students have laptops that can access the wireless network and unfortunately the wireless network is not always available. As mentioned in Section1.1 , computer and Internet access is limited in Namibia; however, mobile phone penetration in Namibia is significant and as such could be used to enhance students' educational opportunities. By looking at the Namibian mobile phone penetration rate, mobile phones could be the most effective tools in reaching the underserved. Suitable mobile applications could be developed and used in such subjects as Mathematics at a tertiary level. As such an informal and lightweight, M-learning system, catering for lower end mobile phones that are Wireless Application Protocol (WAP) enabled, was proposed and developed for ad-hoc learning of mathematical concepts for first-year students at UNAM.

1.4 Research Objectives

This project aims to investigate the use of mobile phones for the ad-hoc learning of mathematical concepts for first-year students at UNAM. In so doing, the following sub-objectives were investigated:

- Assess students' perceptions of the use of ICTs (mobile phones and computers) in education;
- Investigate whether an M-learning system that caters for different mobile phone types could be developed;
- Investigate whether the created M-learning system could be used to provide students with Mathematics learning materials regardless of time and location;
- Establish if students are enthusiastic to use the developed M-learning system; and
- Suggest ways of developing an M-learning system that could be used to compliment traditional learning.

1.5 Research questions

The main research question posed during the course of this research study was:

- How could an M-learning system be developed and implemented to provide first-year mathematics students at UNAM with learning materials regardless of time and location?

To better answer the main research question, the following sub-questions were posed:

- What are the levels of access to and use of computers among UNAM first-year students?
- What are the levels of access to and use of mobile phones among UNAM first-year students?
- What are the challenges and benefits of the use of mobile phones among UNAM first-year students?
- Is it possible to implement an M-learning system, complimenting the E-learning system at UNAM?
- What technologies should be used to develop an M-learning system that is usable by most first-year students?
- What are the students' perceptions of the usability of the developed system?

1.6 Scope of Research

This research project targets first-year students enrolled for Mathematics at UNAM. First-year mathematics students were chosen because of the poor Mathematics background of some first year students at UNAM and mobile phones were chosen due to the rapid increase in the number of mobile phones (as compare to computers)among first year students that it made sense to use mobile phones as the medium to interact with the students. Although the study could be applicable to other universities, the performance analysis of this project was conducted among the first-year students enrolled for basic mathematics on "slow mode" at UNAM. While basic mathematics was chosen as the subject area in which to field trial an M-learning system (for the various reasons discussed throughout this chapter), the developed system could also be used for other subjects across the university.

1.7 Thesis Organisation

The thesis is organised into five chapters. Chapter 1 provides an overview of the thesis; the problem statement that led to the commencement of this thesis and the scope of this research are presented.

In Chapter 2, a literature review is presented and the different types of ICTs used in education are discussed. Different modes of E-learning, case studies, and technologies used to implement M-learning systems are also discussed in this chapter. Furthermore, sampling techniques and evaluation methods used in M-learning studies are presented. In addition, Chapter 2 investigates mobile phones in Human Computer Interaction (HCI) and the challenges encountered when developing mobile applications. Lastly, the Human Centred Design (HCD) methodology is presented.

Chapter 3 presents the design and implementation of the M-learning system titled EnjoyMath. The survey methods and instruments used in this thesis are also discussed in Chapter 3. Results obtained from the survey conducted amongst the Extended Study Unit (ESU) students in the first iteration of the HCD methodology, ascertaining students' perceptions around M-learning, are presented. Furthermore, tools and technologies used to design and implement the EnjoyMath system are discussed.

Chapter 4 presents results of the pre-intervention user study aiming to ascertain the UNAM first-year students' perception around M-learning. Furthermore, the results of the post-intervention user study conducted amongst the first-year students at UNAM, aiming to ascertain the usability of the EnjoyMath system, are also presented. Finally, Chapter 4 discusses and analyses the overall results of the two user studies (UNAM and ESU students) conducted.

Lastly, Chapter 5 concludes the thesis, assessing the initial research questions posed in Chapter 1. Chapter 5 also presents possible future work, providing suggestions regarding how the developed M-learning system could be enhanced and how a detailed view of the students' perceptions around M-learning at the tertiary level could be acquired.

Chapter 2. **Related Work**

2.1 Introduction

Lack of computers, together with the proliferation and affordability of mobile phones, has spurred substantial investigation in the field of M-learning, to compliment E-learning. In this chapter the use of ICTs in education is discussed. The chapter then introduces ICT technologies used in education and different E-learning modes. The chapter proceeds to discuss some of the technologies and case studies of M-learning in education. Lastly, HCI issues pertaining to mobile phones and a brief summary of the chapter are presented.

2.2 Information and Communication Technologies in Education

Information has become more accessible over the last few decades due to the significant advances in technology. This in turn has contributed to the growing number of approaches of delivering information to people in different geographical areas. This makes it easier to expand access to education and thus, hopefully, enabling developing countries to raise their quality of education (Tinio, 2003). ICT tools used to transmit and access information in education include, but are not limited to, radio, television, computers, mobile technologies, web-based technologies; and electronic learning platforms (Lwoga, Sanga, &Sife, 2007). Radio and TV are among the oldest ICTs used to broadcast information for the purposes of education and are still in use.

Broadcasting of educational information via radio and TV occurs in three general modes: direct class teaching (recorded programmes substituting teachers), school broadcasting (broadcasting information that is not taught in class in order to compliment learning), and general educational programming for communities (national and international stations providing general and informal educational opportunities) (Tinio, 2003). In Namibia, for example, One Africa Television and Namibia Broadcasting Corporation (NBC) broadcast educational videos weekly, focusing on grade 10 and grade 12 courses offered by the Namibian College of Open Learning (NAMCOL), an educational institution that provides learning opportunities for adults and out-of-school youth (NAMCOL, n.d.).

Broadcasting educational programmes benefits not only students studying in different modes (part-time, full-time and distance) but also the public at large. Due to the growing demands of industry performance, the knowledge economy, and global and local development, ICT is not something new to the Namibian education discourse. For instance, tertiary institutes such as UNAM and the Polytechnic of

Namibia (PoN) are already using E-learning systems to supplement conventional learning (UNAM, n.d.; Polytechnic of Namibia, n.d.). Conventional learning alone is inadequate to meet current global and local demands, especially due to the high demand for education.

Universities are required to upgrade their curriculum in order to meet local and global demands. Lecturers and students are expected to cover a significant amount of learning materials in a short period of time. As a result, some students tend to memorize instead of thinking, analysing, innovating and contributing to the on-going discourse. This has a negative effect on the quality of the educational outcome of the students, especially for practical courses, as students do not apply practical knowledge and therefore complete their studies unaware of how things work in the real world ,(Dona A. Vassall-Fall, 2008;Kinzie, Kuh, Schuh, & Whitt, 2010).

The introduction of E-learning has brought a dramatic shift in the nature and focus of education, as E-learning systems can complement conventional learning by providing learning environments outside the classroom to cover materials that could not be covered in class, while supporting interaction amongst students (as some students tend to work in isolation). In addition, introverted students are provided with a chance to interact with other students and the lecturer via E-learning systems.

E-learning includes a wide set of applications and processes such as web-based learning and virtual classrooms (VCR) (Derouin, Fritzsche, & Salas, 2005). Web-based learning is often referred to as "online learning or e-learning because it includes online course content" (Contillon, Jollie, &McKimm, 2003, p.4) while avirtual classroom is referred to as an online learning environment which can be web-based, accessible via a portal or software-based, requiring a downloadable executable file(Rouse, 2010). Different universities employ different E-learning methods depending on the pedagogic need of the institution, the students enrolled for E-learning courses, and the ICT infrastructures available at the university. For example, some universities employ virtual classrooms (VCRs) while others employ web-based learning to compliment traditional face-to-face learning. Web-based learning can be in the form of pure online distance learning (course material, assessment and support delivered online with no face-to-face courses), or it can simply be a replication of printed course materials online to support what is essentially a traditional face-to-face course (Cantillon, Jollie, &McKimm, n.d.).

Web-based learning is useful for self-assessment (i.e. multiple-choice questions) making it a convenient way for students to submit assignments from remote sites and hence more suitable for distance students (Cantillon et al., n.d.). Web-based learning eases the way of assessing a large number of students. Lectures do not need tutors to mark (only applicable if the system does the marking). Students get their feedback on time, sometimes shortly after submitting their assignment. In addition, web-based marking can be more fair and reliable than lectures and tutors because lectures' and tutors' assessments are mostly based on subjective judgement (Ma & Zhou, 2000). Although web-based learning environments are useful in enhancing student learning, they are also limited. Certain courses are more complex and need more attention, especially courses that are more practical-based and discuss concepts that require further explanation. Web-based assessment cannot be used for open-ended questions, e.g. explanatory questions. As a result of these shortcomings of web-based learning, VCR is employed at some universities.

VCR learning is learning that happens over the Internet in a virtual environment. In the field of computer science, the term 'virtual' refers to something whose existence is simulated using software rather than actually existing in hardware or some other physical form (Hiltz, 1994). Hiltz(1994) defines the VCR environment as a teaching and learning environment located within a computer-mediated communication system. An example of the difference between a VCR environment and a traditional classroom environment is in the activities used. In the VCR environment, activities are mediated by computer software rather than face to face interaction (Hiltz, 1994).

VCR has the means of improving access to information by not limiting students to courses and programs offered in their geographical localities, and giving all students equal opportunities to participate in the classroom (Hiltz, 1994). Despite the above-mentioned advantages of VCR, only a few institutes offer courses in VCR environments. Delivering courses in VCR environments in developing countries might be challenging due to technical issues in training educators and access to quality infrastructure such as fast Internet access. For reasons mentioned previously, web-based learning systems are more suitable for use in developing countries.

Unfortunately, web-based learning cannot fully be utilized by all as some students do not have computers, or those with computers do not have access to the Internet. However, mobile devices have become pervasive and there has been advancement in the mobile technology. The advancement in mobile hardware and communication, the evolution of mobile devices' functionalities and the near ubiquitous availability of wireless networks (Ebibi, Fetaji, &Fetaji, 2010) has led to the introduction of mobile devices in education (M-learning) (Motiwalla, 2007, &Muyinda, 2007). The improvements in mobile hardware have strengthened mobile devices' capabilities in terms of computing power, memory storage, and network capabilities (Ebibi et al., 2010). As a result, some mobile devices are capable of performing computational functions which, in the past, could be performed only by desktop computers and servers.

2.3 E-learning in Education

There has been an increase in the demand for higher education over the last few decades, with a forecast of 120 million students to be enrolled in tertiary institutions worldwide by 2020 (Daniel, 2009). The forecast is expected to pass 130 million if part-time students are included (Daniel, 2009). "As the world is entering a knowledge-based internet-driven economy, a college degree becomes a necessity for any individual who wants to be competitive and successful, regardless of his or her age, gender, or race" (Alexander, Perreault, Waldman, & Zhao, 2003,p.1). Therefore, universities and colleges are expected to accommodate the growing numbers of students. Many universities and colleges have responded to the high demand of education by integrating new technologies in order to make provision for individualized, student-centred learning (Alexander et al., 2003). Universities thus employed Blended Learning (BL) to compliment traditional learning. Reay, Rooney, Sands, Ward, LaBranche and Young in (Bonk & Graham, 2004)defined BL as a system that enables instructors to combine online and face-to-face instruction.Universities such as UNAM uses BL as it has an online portal, allowing registered students to view their results and download course materials online regardless of their physical location (UNAM, 2013).Integrating ICTs in education could promote access to education among under-privileged and marginalized communities. This could be achieved by using online education programs to reach out to people who cannot attend traditional school environments (Glass, Vrasidas, &Zembylas, 2009).

For a successful implementation of ICTs in education, ICT resources capable of supporting an E-learning environment should be available. For instance, if ICT resources have to be used in marginalized communities, the training institute (university) should have stable ICT infrastructure, and the same applies to the marginalized community. This is especially challenging in developing countries where ICT resources are limited. Limited ICT resources are considered to constrain the growth of education, especially in developing countries (Glass et al., 2009). The uses of ICTs have the potential to lead to the acquisition of knowledge and information, therefore leading to modernization (Glass et al., 2009). In addition, the introduction of ICTs in education can contribute to schools being more productive and efficient in terms of teaching and learning, thereby potentially improving students' skills and better preparing them for the work force (Glass et al., 2009).

Today's work force is expected to be highly educated by continually improving their skills and upgrading their knowledge to acquire new skills (Hrastinski, 2008). This is usually achieved by enrolling for short and degree courses at universities. Most universities around the world have responded positively by offering courses on a part-time and distance basis to accommodate the working force who cannot enrol for full-time classes. Yet part-time classes and distance learning is still not flexible enough for some students.

There has been a marked increase in the creation of open educational resources after the introduction of open-source technologies in education. This has resulted in a reduction in software costs incurred by universities. As a result, universities have employed open educational resources to offer E-learning facilities. Clark and Mayer (2011) defined E-learning as instructions delivered on a digital device, such as a computer or mobile device that is intended to support learning. As illustrated in Figure 2.1, learning in an E-learning environment can be conducted either via the network or on a standalone device. In both cases, the student can either take a content approach (providing content itself or access to available content) or a communication approach (providing communication facilities or access thereto) (Brown, 2003).

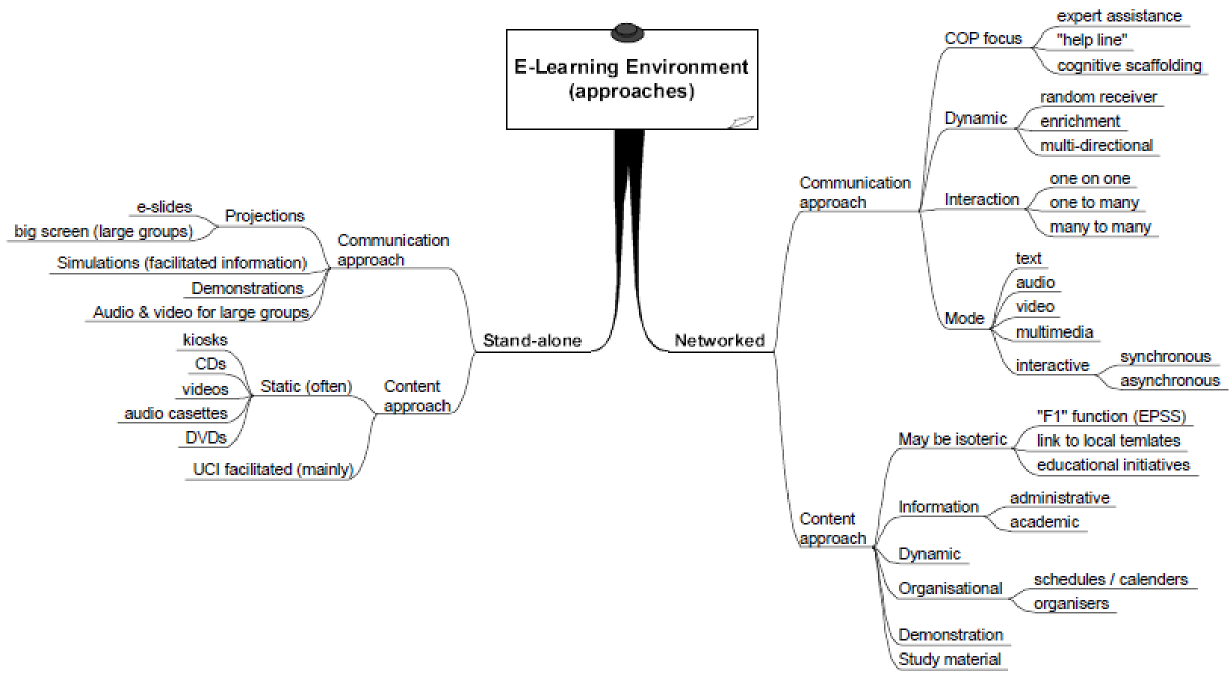


Figure 2.1: E-learning environment approaches, as depicted in (Brown, 2003)

E-learning occurs in four modes: Database E-learning, Online support, Asynchronous E-learning and Synchronous E-learning (Adrian, n.d.). Universities either use the E-learning methods separately or combine them to support learning. Database E-learning happens when the user browses through different topics in a database, searching for a specific answer or an explanation to various questions. Online support involves different users interacting either via a chat room, forum, email, bulletin boards, or instant messaging applications (Adrian, n.d.). Furthermore, users are provided with more specific answers in their sessions as compared to database E-learning (Adrian, n.d.). Online E-learning and database E-learning can be allied and used at the same time to form what is known as asynchronous E-learning (Adrian, n.d.). Hrastinski (2008) defines asynchronous E-learning as a method of E-learning that is facilitated by media such as e-mail and discussion boards in order to support work retention amongst learners even when participants cannot be online at the same time. Asynchronous E-learning is the opposite of synchronous E-learning. In synchronous E-learning, the learning happens live; synchronous E-learning is more like traditional learning except that it happens in a virtual environment. Synchronous and Asynchronous modes of E-learning are discussed in greater detail in Section2.3.1 .

2.3.1 Synchronous E-learning and Asynchronous E-learning

The limited number of lecturers and the high growth in student intake at tertiary institutions has motivated the use of E-learning. Advances in technology and increasing bandwidth capabilities have led to the deployment of synchronous E-learning (Hrastinski, 2008) at some institutions. Synchronous E-learning allows students and lecturers to log into the E-learning environment at a specific time (typically the same time) and interact in a similar manner to traditional classroom interactions. In synchronous E-learning, students can raise their electronic hands, view a common blackboard and interact with each other and the lecturer in the virtual environment (Adrian, n.d.).

Synchronous E-learning is mostly used in cases where students cannot physically attend full time classes, thereby removing physical barriers to attendance (Hrastinski, 2008). Massive Open Online Courses (MOOCs) have been the recent development in E-learning, aiming to provide access to education for students who cannot physically attend full time classes and it has evolved rapidly (Daniel, 2012). MOOCs are online systems where participants use open knowledge distribution repositories like the web. In a MOOC, participants provide interactive forums where knowledge is shared, providing positive or negative feedback(Abajian et al., 2011).In order to employ MOOCs in education, access to the Internet is required. MOOCs could fall in the category of synchronous E-learning or Asynchronous E-learning, depending on the Internet connectivity. With synchronous E-learning, Internet connectivity is a priority;

otherwise MOOCs will not be conducted effectively. Alternatively, asynchronous E-learning could be employed in cases of intermittent Internet connectivity. As noted in Section2.3 , asynchronous E-learning is an E-learning method that can be carried out at the learner's own pace. The learner and the instructor do not have to be logged into the E-learning environment at the same time.

Until recently, asynchronous E-learning has been commonly practised in universities because learners have full control of the content. The learner controls the time and space to access the learning content (Adrian, n.d.). Although asynchronous E-learning has been mostly accessed in higher education institutions using computers, investigations into using mobile technologies have been on-going, especially in developing countries where Internet connectivity is poor, and where mobile phones are plentiful (Dearden&Traxler, 2005;Tsunke, 2012).

2.4 M-learning in Education

Advancements in technology have led to the evolution of E-learning, as Distance learning came to rely more on technology (Cherian & Williams, 2008). Tertiary institutions have been using computers to facilitate E-learning for the last few decades. However, the pervasiveness of mobile devices has led to on-going research exploring the use of mobile devices in education. There have been on-going debates regarding whether M-learning will enhance learning experiences (T. W. Chan et al., 2003;Massy, 2002). These debates have attracted many researchers worldwide, but to date there is no universal definition of M-learning (Eteokleous&Laouris, 2005). Several researchers define and conceptualize M-learning differently in terms of devices, technology, the mobility of learning and the learners, and the learners' experience with mobile devices (Eteokleous&Laouris, 2005;Kukulska-Hulme& Shield, 2008). These definitions of M-learning all incorporate a common thread which is "the use of mobile technologies to facilitate the transfer and acquisition of knowledge, the learning process" (Eteokleous&Laouris, 2005) cited in (Caudill, 2007,p. 3) . Caudill(2007) summarized the advantages of M-learning as "being the advantages of access" (Caudill, 2007,p. 4) meaning that students can access learning materials anytime and anywhere.

It is increasingly important for everyone to have access to technology because it has the potential to reduce "inequality by lowering the barriers to information allowing people of all backgrounds to improve their human capital, expand their social networks, search for and find jobs, have better access to health information and otherwise improve their opportunities and enhance their life chances" (Hargittai,2003,p. 3). Information could be made available if technologies catering for low income groups are introduced into society and thus reduce the Digital Divide. The Digital Divide is a phrase used to indicate the gap between people who have and those who do not have access to technology (Glass et al., 2009). To bridge the Digital Divide, access to information is required. This could be achieved by introducing the use of mobile phones at tertiary institutions, as almost every student is likely to have access to a mobile phone. Mobile phones could compliment computers at institutions where computers are limited.

2.4.1 M-learning Case Studies

Significant research has been done in the field of M-learning, where different mechanisms have been used to prototype and implement M-learning systems depending on the learners' needs and available resources. Most of these efforts were centred on text-based systems that allowed student-to-student and student-to-lecturer communication using short messaging service (SMS). For example, (Markett et al., 2006) designed two interfaces for in-class and outside class interaction. This was done in order to facilitate students' learning. Other approaches explored for M-learning include the use of quizzes where questions are randomly generated from a server (Arumugam, Bhatia, &Putohit, n.d.) while other approaches used games (Ardito et al., 2008).

Mobile applications have been developed to support learning in various curricular areas and at different educational levels. For example, (Foad, Ibrahim, Izzriq, Mahamad, &Taib, 2008) developed Mobile Math, an M-learning system, using Open Source Software, for primary school learners. It allows students to use quizzes to learn, and the students' progress and performance are tracked by mobile graphs. Open Source software is software "in which the source code is available for the general public to use or modify from its original design, free of charge, such as PHP and MySQL" (Foad et al., 2008,p. 1). The Mobile Math system was developed for two environments: the web browser on personal computers and the micro browser on mobile devices. This application was developed by adapting server side scripting concepts using XHTML, WML, PHP and MySQL.

MOBI, a web-based application, was developed in South Africa to assist secondary school- going learners (grade 8-9) in Mathematics, using a MySQL database & PHP on the server side and Java Micro Edition (JavaME/J2ME) and/or a mobile browser on the client side (Liebenberg &Matthee, 2007). Newnhamand Parsons (2006) also developed a web-based application that used a lightweight XML over the HTTP communication protocol and a JavaME smart client. JavaME was used on the client side, while J2ME polish was used at the interface for a better display view of the system. Servlets were used on the server side and the MySQL database was used for storing content in the backend. Hibernate was used for mapping the server-side model to the database (Newnham& Parsons, 2006).

At the tertiary level, the University of Pretoria (UP) launched a UP mobile application at the beginning of 2012. This application allows students to access learning materials via their mobile phones and it is available on iOS®, Android™, BlackBerry® and Internet-enabled phones (Tsunke, 2012). Researchers in education also developed learning management systems (LMS). A LMS is “a software application for the administration, documentation, tracking, and reporting of training programs, classroom and online events, e-learning programs and training content”(Latitudelearning, 2013, p.3). Ronchetti and Trifonova (2003) developed a learning management system (LMS) offering interoperability between an E-Learning Management System (E-LMS) and a M-Learning Management System (M-LMS). Interoperability between the E-LMS and an M-LMS was achieved by developing a “mobile adapter” that “sits on top of the traditional E-learning system and provides adaptation of the existing e-services, like user identification, authorization, distribution of didactic material, gathering of data related to user-system interaction etc” (Ronchetti&Trifonova, 2003,p. 3).

There are six M-learning emerging categories as listed below (Traxler, 2009a):

- Technology-driven mobile learning. In this category, the technology is introduced into the classroom to show feasibility.
- Portable e-learning. In this category, devices are used to replicate conventional e-learning. This may include making material and learning environments already accessible on desktop computers available on mobile devices.
- Connected classroom learning. In this category, mobiles are used in classroom settings and perhaps interact with other classroom technologies (e.g. iClickers).
- Informal, personalized, situated mobile learning. In this category, mobile technology is used to enable location-aware delivery of educational experiences outside the classroom setting.
- Mobile training/performance support. In this category, technology is used to improve the productivity and efficiency of people working in a mobile environment.
- Remote/rural/development learning. In this category, technologies are used to address an infrastructure gap where traditional e-learning technologies would fail (e.g. lack of wired infrastructure for electricity or internet).

As noted by (Traxler, 2009b), M-learning is still in its infancy and pioneers in M-learning are busy developing methods of using mobile technologies to enhance learning. Woodill(2011) categorised LMSs into five categories with regard to their use as M-learning systems: LMSs not ready for mobile learning; LMSs graphically redesigned for mobile devices; mobile extensions ("plugins") for existing LMSs; stand-alone, self-sufficient M-LMSs; and innovative M-LMSs that use some of the new affordances of mobile devices such as location or cloud computing. Woodill(2011) further noted that none of the M-LMSs meet Level IV (innovative M-LMSs). The next section discusses technologies used to develop M-learning systems.

2.4.2 Technologies used to develop M-learning systems

Many M-learning case studies and projects have been initiated and implemented in education using multiple mobile technologies(Cavus& Ibrahim, 2009;Ivanov &Momchedjikov, 2009). These technologies depend on the project type and the mobile devices available for use by the targeted community. Identifying the mobile technology for use prior to the introduction of an M-learning project is imperative in order to develop a system accessible to most students. For example, introducing a web-based M-learning system will not be helpful if students cannot access the Internet via their mobile phones (Caudill, 2007). Table 2.1shows an overview of popular widget frameworks, and Table 2.2shows an overview of the main mobile phone platforms. As illustrated in Table 2.1 and Table 2.2, different platforms support different programming languages. Thus, the programming languages used in every project to develop mobile applications depend on the targeted users' mobile phone platforms, specifically their operating systems.

Some mobile phone operating systems allow developers to develop native applications (e.g. the Android and Symbian platforms) while others do not unless a relationship is established with the vendors (e.g. Nokia Series 40 and Sony Ericsson) (Enough software, 2001). Native applications are developed specifically for the targeted platform when the project's objective is to create an optimum experience for the users (Hiltz, 1994). This benefits users with mobile phones that have limited computing capabilities, and this approach works if all users have mobile phones with the same computing capabilities, which is rarely the case unless users are provided with mobile phones or if multiple versions of the same application were created, one for each of the available user platforms.

On the other hand, if the project objective is to simply utilize portability of the content, a web application could be the best option (Hiltz, 1994). However, special attention should be given to the content layout and the browser type. For instance, accessing websites using mobile phones with browsers that do not support scripting languages limits users from accessing information on those websites, especially websites with many graphics. Graphics can have large file sizes, take longer to load or not load at all. Using mobile phones to access applications specifically developed for desktop computers has a direct effect on the application. Some mobile phones will display part of the application's content, while others will not display the content at all. Displaying part of the content forces users to scroll frequently (horizontally or vertically) for every page accessed, or forces users to zoom in to view the content. This could be avoided by either developing a mobile version of the application or by developing plug-ins for mobile phones.

Table 2.1: An overview of popular widget frameworks (Enough software, 2001,p. 9)

Environment	Language(s)	Remarks
Symbian Web Runtime (WRT) Widgets	XML, HTML, CSS, JavaScript	Standard web technology- based widgets, with a proprietary packaging standard. JavaScript APIs offer high degree of access to platform features. www.forum.nokia.com/Develop/Web
WAC/JIL	XML, HTML, CSS, JavaScript	A joint initiative by Vodafone China Mobile and other companies are pushing the W3C widget standard. www.jil.org
Samsung	XML, HTML, CSS, JavaScript	innovator.samsungmobile.com
Series 40 web apps	XML, HTML, CSS, JavaScript	Web apps for the proxy- based Ovi Browser enabling UI manipulation on a device through JavaScript. W3C packaging standard used. www.forum.nokia.com/webapp
PhoneGap	HTML, CSS, JavaScript	Cross- platform widget platform. www.phonegap.com
Sony Ericsson WebSDK	HTML, CSS, JavaScript	Based on PhoneGap developer.sonyericsson.com
Blackberry	HTML, CSS, JavaScript	na.blackberry.com/eng/developers

Table 2.2: An overview of the main mobile phone platforms (Enough software, 2001,p. 5)

Platform	Language(s)	Remarks
Android	Java, C, C++	Open Source OS (based on Linux), developer.andriod.com
Bada	C, C++	Samsung's mobile platform running on Linux or RealTime OS, developer.bada.com
Blackberry	Java, Web Apps	Java, Web Apps and Java ME compatible, extensions enable tighter integration, na.blackbery.com/eng/developers
IOS	Objective- C, C++	Requires Apple Developer Account, developer.apple.com/Iphone
MeeGo	QT, C, C++, others	Intel and Nokia guided open source OS (based on Linux), meego.com/developer
Symbian	C, C++, Java, QT, Web Apps, others	OS built from the ground up for mobile devices, www.forum.nokia.com/symbian
WebOS	HTML, CSS, JavaSCRIPT, C	Supports widget style programming (based on Linux), developer.palm.com
Windows Mobile	C#, C	.Net CF or Windows Mobile API, most devices ship with JavaME compatible JVM, developer.windowsmobile.com
Windows Phone	C#, VB.NET	Silverlight, XNA frameworks, create.msdn.com

2.4.3 Architectures used to develop M-learning applications

This section presents architectures used to design M-learning applications. These architectures were based on an analysis of different types of user and device mobility (Gruhn&Köhler, 2006). According to

Gruhn andKöhler (2006), four types of architectures, differentiated by the dependency of the mobile application client on the central server, can be distinguished when developing mobile phone applications. These vary from complete offline architecture (no communication between the mobile application and the central server), offline architecture (the mobile application is synchronized occasionally with a central server), a hybrid architecture (the mobile application communicates online with a central server if the network is available, otherwise no communication between the mobile application and the central server takes place until later when the network is available) and the always online architecture (exclusive communication between the central server and the mobile application) (Gruhn&Köhler, 2006).

These approaches each have their own weaknesses and strengths. With completely offline architectures, users always work offline. The advantages are: availability of full user interface design capabilities, no network connections are needed, no environmental constraints when using the application, no costs and no performance problems. The disadvantages of this application include: no interaction among the users over the internet and, regular development and deployment of components for updating the application is required (Gruhn&Köhler, 2006). Offline architecture incorporates the advantages and disadvantages of the completely offline architecture. However, with offline architecture, the data on the client are often synchronized with the central server, although users always work off line. This approach requires a synchronize mechanism to transfer data stored at the client and to resolve possible conflicts with the central server. In addition, the users influence the synchronization interval and there is no assurance of the data and component integrity (Gruhn&Köhler, 2006).

The strength of always online architectures lies in the fact that low-end devices are catered for as the applications run on the server. Running the application from the server removes the need for sophisticated devices (Motiwalla, 2007). Mobile applications developed using this approach are developed once and run on different mobile platforms (cross-platform development). This approach involves a client, a server and sometimes a database. It uses technologies such as HTML, CSS and JavaScript (Hiltz, 1994)on the client side, scripting languages such as PHP on the server side and databases such as MySQL and Oracle for data storage. The weakness of always online architectures lies in the fact that a mobile network should always be available. In addition, the user interface design of the browser base application is limited and the central server is expected to meet requirements regarding its operational and performance availability, as there is simultaneous communication between many clients and the central server (Gruhn&Köhler, 2006).

The hybrid architectures combine the offline and online architecture; hence incorporate all the advantages and disadvantages of the two. With hybrid architecture, users can either work online or offline depending on the availability of the network. The disadvantage of this approach includes administration effort as additional components need to be developed for updating and handling sessions. An updating mechanism responsible for transferring data stored at the client and resolving possible conflicts with the server-side database also needs to be developed (Gruhn&Köhler, 2006).

2.5 Mobile phones in Human Computer Interaction (HCI)

2.5.1 Introduction

Human Computer Interaction (HCI), also referred to as Man-Machine Interaction or Computer Human Interaction, is a multidisciplinary area where various academic (Booth, 1989) disciplines such as computer science, psychology and sociology are combined in order to better understand the relationships between users, computer systems and applications (Love, 2005). HCI has borrowed research methods and system evaluation techniques from psychology (e.g. the use of questionnaire design techniques), while it uses software tools from computer science to develop interfaces allowing users to interact with systems. It also uses methods and techniques adapted from sociology to design and evaluate mobile devices and applications (e.g. observational studies, ethnography) (Love, 2005). To better understand the relationship between users and the proposed system as stated earlier in this section, users' requirements and information regarding the development of the system should be acquired. The next section discusses the users' and organisations' requirements in the mobile HCI field.

2.5.2 User and Organisation requirements

Identifying the relationship between target users and the proposed system (Szekely, 1995) is imperative in the HCI field. This is achieved by gathering information from users. This is essential in order to avoid developing products that do not meet the intended users' needs. When developing products, certain characteristics need to be considered. In HCI the emphasis is on the users, thus it is vital to identify individual characteristics that could have a significant impact on users' perceptions towards using mobile phone applications and services. Examples of individual characteristics include spatial ability, personality and memory.

Spatial ability is referred to as “the extent to which individuals can deal with spatial relations and the visualisation of spatial tasks” (Love, 2005,p. 15). Spatial ability consists of sub-factors which are: spatial relations (ability to solve mental rotation problems quickly), spatial orientations (ability of the individual to walk in an environment without bumping into other people) and visualisation (ability to visualise the tasks one is currently undertaking) (Love, 2005). Spatial ability has an effect on the user’s performance in using mobile phones and if not considered, the system might confuse low spatial ability users. For example, accessing a system (e.g. tourist information guide) where users have to go four levels down the hierarchy might be confusing as users might find it hard to navigate back to the first level (Love, 2005). A study conducted by Stanney and Salvendy in Love (2005) found that low spatial ability users find it “difficult to construct visual mental models of the system they are interacting with, thus leading to poor task performance” (Love, 2005,p. 17). Vicente and Williges(1988) also found that there is a difference in task performance between high and low spatial ability users. Low ability users are slow at performing tasks in comparison with high spatial ability users. It is therefore important to develop mobile applications that accommodate users with both low and high spatial ability.

An individual’s ability to successfully use a mobile device or application could also be affected by a system which is too exhaustive with information. An exhaustive system could affect a user’s working memory. Working memory, also known as short term memory, has a limited capacity and holds information for a short time before it decays (Love, 2005). When designing a mobile application, excessive information presented to users should be avoided. A speech-based mobile phone service is a good example, where limited information should be presented to the user to avoid placing great demand on the user’s working memory (Love, 2005). Developers should therefore reduce the complexity of information presented in a mobile application.

Personality is another characteristic that could have a significant impact on users’ perceptions towards using mobile phone applications and services (Love, 2005). According to Atkinson, Atkinson and Hilgard, (cited in Love, 2005,p. 18), personality “describes the characteristic patterns of behaviour and modes of thinking that determine an individual’s adjustment to the environment”. For example, in a voice application scenario, the voice chosen for a mobile service should convey a proper image because it determines the “uptake and continuing use for that system” (Love, 2005,p. 20). Introverted people behave differently from extroverted people, thus having an extrovert voice for the system might dissuade some users from using the system. Therefore, system usability should be considered upon completion of the system as this could have a significant impact on users' perceptions towards mobile phone applications and services.

Usability is "the effectiveness, efficiency and satisfaction with which specific users achieve specified goals in particular environments"(Marja& Matt, n.d., p.1). System usability refers to a system that allows users with different capabilities to perform tasks properly, and people of average abilities and experience should be able to use the system without getting frustrated (Albert &Tullis, 2010). Hackosand Nielsen (1993) associated usability with five attributes, namely, learnability, efficiency, memorability, low error rate or easy error recovery, and satisfaction. For the success of any new computer system or computer based-service, it is imperative to determine the usability of the system, as usability is recognised as a vital determining factor in the success of any system (Cherian & Williams, 2008).

Different methodologies leading to an implementation of a usable system are followed in the HCI field. The HCD methodology is an example of a HCI methodology, enabling developers and designers to obtain a usable product. The HCD methodology is adopted during the system development phase (Carvalho, 2001), and consists of four steps. These steps are part of an iterative design, as shown in Figure 2.2. Steps undertaken throughout the HCD methodology are detailed below:

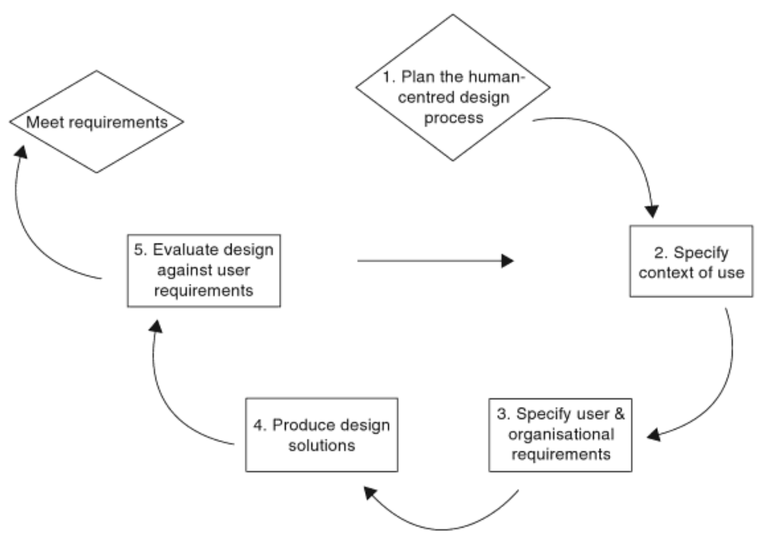


Figure 2.2: Human-Centred Design Activities (ISO 13407) (Love, 2005)

1. Plan the human-centred process

   Planning the human-centred process allows the design and development team to identify the objectives of the study. This involves planning the steps to be followed throughout the project.

Any initial design concepts of the anticipated software are drawn before the project commences. This involves drawing the overall workflow of the system. Users' interaction with the system and the tasks to be performed by the target users and the system are identified in the workflow (Carvalho, 2001). Once the tasks are identified, technical details are also specified. These include hardware to be used during the study, and environmental constraints such as the environment in which the users' will be using the system (Carvalho, 2001).

2. Understand and specify the context of use

   This stage provides the design team with the background information for use in the design and evaluation stage of the project (Love, 2005). Context of use refers to the particular context in which the system or developed product will be used (Carvalho, 2001). Describing the usability of products or systems in reference to the context in which they will be used is imperative, as products developed will be used by different users in different environments (Maguire, 2001b). The environments (physical and social) from where or in which the targeted users intend to operate the system are identified, specified and understood before the project starts (Love, 2005). Moreover, users' and systems' tasks, and equipment to be used in the project, are also identified. This is important as the designed product can be modified by the designers to suit the real-world usage. Evaluation methods to be used throughout the project life cycle are also specified in this stage (Love, 2005).

3. Specify user and organisational requirements

   This is the most crucial part in software development, as the success of the system depends on how well the requirements have been identified (Maguire, 2001a). The design team gathers characteristics of the targeted users, functionalities that the system needs to support and the scenarios where the system will be used. A detailed guide of the relationship between the users and the system (how the users will interact with the system) is obtained during this stage. This is achieved by means of interviews (interviewing the target group(s)), brainstorming (designers discuss ideas regarding how to go about designing the system) or card sorting (allow participants to present their mental model of the proposed system)(Love, 2005).

4. Produce designs and prototypes

   Designers use different prototype techniques to express their ideas as quickly as possible (Jones & Marsden, 2006). Prototypes are based on feedback obtained from users by means of a gathering technique, for example, interviews or the designers' ideas obtained during brain storming. Users' feedback obtained from the prototype system is then used to iteratively develop better prototypes. Through prototyping, designers discover system faults and can rectify them inexpensively and easily (Love, 2005).

5. Evaluate design against users requirements
   Designers evaluate designs throughout the system development process by employing prototypes (Carvalho, 2001). This is vital as the users' needs and abilities are put in the forefront of the designing team's concerns. This is achieved by conducting a system evaluation with target users as early as possible (Jones & Marsden, 2006), and then conducting another system evaluation after the system is complete to ensure that the users' requirements are met (Love, 2005).

2.5.3 Design and prototypes

During the first iteration of a system's testing phase, target users are required to perform tasks such as undoing operations, interrupting operations and responding to all possible inputs (Szekely, 1995). Allowing users to perform those tasks on the actual software system is expensive and difficult, especially if those tasks are to be performed on a variety of devices (Szekely, 1995). The wide variety of devices available in the market makes it difficult for HCI designers and developers to support all the target users. Variance across handsets includes screen size, input technique, battery power, storage capacity, connectivity supported by the device and operating system (Ebibi et al., 2010;Kukulska-Hulme&Traxler, 2005).

Since testing with the actual device is expensive and time consuming, the testing process can be hastened by using prototypes. Prototyping is a cheap way of collecting information to guide the construction of software products (Szekely, 1995). Through prototyping, the designed interface of the product is tested and revised prior to coding. Moreover, ideas about the products are promoted, modified, rejected and refined prior to coding (Jones & Marsden, 2006;Szekely, 1995).

There are two ways of developing prototypes: by using low fidelity prototypes (not resembling the final product or artifact), or high fidelity prototypes (resembling the final product or artifact) (Landay, Takayama, & Walker, 2002). Low fidelity prototypes are employed in the early stages of the project, while high fidelity prototypes are introduced as the project progresses (Landay et al., 2002). The prototype's capabilities employed are described either by using 'horizontal prototypes' or 'vertical prototypes'. This is chosen depending on the message the designers want to convey to the target users or team members. Horizontal prototypes involve modelling the outer shell of the entire system e.g. windows, dialogue boxes, menus, screens, reports and batch processes, with little or no processing behind them (Jones & Marsden, 2006; Soegaard, 2010). This prototype is appropriate to use when designers want to convey the system's abilities, because it demonstrates relationships across the system, thereby explaining the functions of the system to the target users (Jones & Marsden, 2006). Correspondingly, vertical prototypes involve modelling a few features of the system that are almost implemented: a "walking skeleton" (Soegaard, 2010). The vertical prototype is more appropriate for use as a proof-of-concept. This prototype is applied when a complex feature of the system needs to be explained in detail (Jones & Marsden, 2006).

Interface designers use different prototyping tools (e.g. paper and pencil tools and facade tools), ranging from easy to complicated, to acquire different kinds of information from the team members and target users (Szekely, 1995). Paper and pencil tools allow designers to draw objects resembling the final application on paper (Szekely, 1995). This is one of the easiest tools used to prototype software because it allows designers to extend the prototype anytime, and encourages team work as all the designers can draw and discuss ideas at the same time (Szekely, 1995). However, it is also limited as it captures only the view of the interface, and the interface is not executable.

Facade tools are another prototyping tool that allow designers to construct screens that resemble and behave like the screen of the real application, allowing users to specify the input behaviour, but there is no code in the background (Szekely, 1995). Flowella, Fluid and Proto (Fluid, n.d.;Nokia, n.d.;Proto, 2013) are examples of facade tools used by mobile designers to prototype mobile applications rapidly. These tools enable usability to be tested and the design to be refined prior to coding, using screen mock-ups such as images and pencil sketches (Nokia, n.d.). Upon completion of the interface design, images are imported into the prototyping tools and exported to multiple devices such as Nokia devices, iPhone and Android phones. Facade tools retain the benefits of paper and pencil, while adding the ability to describe the behaviour and to execute the prototype. This results in very reliable feedback from end users as they get an impression of interacting with the real application (Szekely, 1995).

HCI designers also face challenges designing for mobility, namely, designing for a widespread user population, designing for limited input/output facilities, designing for (incomplete and varying) context information and designing for users multitasking at levels unfamiliar to most desktop users (Cranshaw, David, &Ryu, 2006;Dunlop & Brewster, 2002). Aspects of mobility should be addressed both technically and contextually (Cranshaw et al., 2006). Furthermore, certain aspects such as content used, navigating through and between pages, consistency throughout the application and flexibility should be considered during the mobile application design phase (Ahmad, Ahmad, &Hashim, 2011). Most importantly, systems designed should be ‘user friendly’. Designing a ‘user friendly’ system reduces performance errors, reduces training and support of the system, increases productivity and improves acceptability of software (Carvalho, 2001). Most systems designed that are ‘user friendly’ are evaluated iteratively until the users’ and the systems’ requirements obtained during the requirements phase are met. In the next section, system evaluation will be discussed, and the methods used to evaluate systems in HCI will be outlined.

2.5.4 Evaluation

System usability is based on the users’ experience with the system being evaluated. The effectiveness and the successfulness of applications are achieved through devising and implementing usability evaluation methods (Ebibi et al., 2010). Systems are evaluated using different types of evaluators, different numbers of users, different types of data and different evaluation approaches. System evaluation is obtained either by observing the users while they are using the system or by collecting information by means of questionnaires focusing on the users’ perceptions of the evaluated system. Usability questionnaires used during the evaluation stage can either be created from scratch or questionnaires designed by experts can be used (Jones & Marsden, 2006;Love, 2005). Table 2.3shows some of the existing usability questionnaires. These questionnaires are adapted depending on the usability aspects of the software being measured.

Table 2.3: Different existing usability questionnaires (Love, 2005;Szekely, 1995)

Instrument	Purpose	Sample size	Number of questions
System Usability Scale(SUS)	Measure perception of usability and is technology independent.	At least 12 users.	10 item questionnaire (odd-numbered items worded positively and even-numbered items worded negatively) on a 5 or 7 point scale (strongly agree->strongly disagree).

Software Usability Measurement Inventory(SUMI)	Provides a valid and reliable method for the comparison of (competing) products and different versions of the same product, as well as providing diagnostic information for future developments.	Minimum of 10 users recommended	50 item questionnaire devices in accordance with psychometric practice

Several usability evaluation methods exist (Choong, Lin, &Salvendy, 1997);Daniel, 2009), and some are summarised in Table 2.4 and Table 2.5. Some usability evaluation methods involve users (e.g. Usability Testing) while others do not involve users (e.g. heuristic method) (Choong et al., 1997;Jones & Marsden, 2006;Love, 2005).

Table 2.4: Different usability evaluation methods (users involved) (Choong et al., 1997)

Users involved

Method Name	Definition	Advantages	Disadvantages
Usability Testing	Based on the principle of trailing prototypes and capturing data about the system and user performance that can be analysed.	• Identify serious problems • Identify recurring problems • Avoid low-priority problems • Some degree of objectivity	• Require expertise • High cost • Need large number of users • Easy to miss consistency problems
Thinking-aloud approach or protocol analysis	Participants are asked to think aloud while they are using the system that is being evaluated.	• Pinpoints user misconceptions • Low cost	• Unnatural to users • Hard for expert users
Formal modelling	Research aims at developing theories pertaining to the interaction of humans with the interfaces in order to structure more objective techniques for the evaluation process.	• Quantitative analysis • Provide unexpected insight • Some degree of objectivity	• Extremely complex • Require expertise • Tend to focus on one dimension

Table 2.5: Different usability evaluation methods (users not involved) (Choong et al., 1997)

Users not involved

Method Name	Definition	Advantages	Disadvantages
Heuristic evaluation	The design is checked against good design rules-of-thumb, and an expert-based review where someone who has lots of experience in designing mobile interactions uses their knowledge of what works to identify weaknesses in the design.	• Identify many problems • Identify more serious problems • Low cost • Predict further evaluation needs	• Require expertise • Require several evaluators • Some degree of subjectivity • Time consuming (Fripp, 2011)
Guidelines/checklists	Companies have their own guideline or checklist used by the designer to design the user interfaces.	• Identify general problems • Identify recurring problems • Can be used by non-specialists • Applicable at all design stage	• Easy to miss some severe problems • Might be misapplied • Difficult to follow

2.6 Summary

This chapter discussed the different E-learning and M-learning modes where different ways used to broadcast educational information were outlined. Advantages and disadvantages of different E-learning and M-learning modes were stated and different cases where these modes should be applied were identified. From this chapter, it could be seen that M-learning is simply a small branch of E-learning. Otherwise stated, M-learning is E-learning where mobile devices are used instead of computers. Some case studies ranging from primary to tertiary level were also presented in this chapter. Chapter 2 also discussed technologies used to implement M-learning systems and different platforms used to develop mobile phone applications. Furthermore, the chapter considered the different tools used to prototype mobile applications. Different evaluation methods used to evaluate systems, usability questionnaires used in usability surveys and the individual characteristics that might affect the participants' perception on the use of M-learning projects were also discussed. The chapter also discussed mobile HCI, focusing on human characteristics to consider when developing an M-learning system. Next, the chapter outlined the HCD methodology, where different steps of the HCD methodology were discussed. Finally, the chapter discussed benefits and needs of user valuations, presenting various usability evaluation methods. The next chapter presents steps undertaken to design and implement the M-learning system, where the HCD methodology will be discussed as applied in this study.

Chapter 3. **Design and Implementation**

3.1 Introduction

The aim of software developers is to develop systems that meet technical, functional and user requirements (Maguire, 2001b). Often, developed systems perform well when tested in laboratory conditions yet these systems do not guarantee optimal performance in the real world. As a result, users find these systems difficult to learn and complicated to operate (Maguire, 2001b). Systems should therefore be tested with real users. This could be achieved by employing methodologies that guide the development process of the product or system. Those methodologies should involve users from the design phase in order to incorporate users' feedback into the system development process (Love, 2005;Maguire, 2001a). This ensures that the systems developed are usable in the real world and users are satisfied with the systems' performance.

This chapter presents the steps undertaken to design and implement the system, titled EnjoyMath, through the use of the HCD methodology. These steps show how the design and implementation of EnjoyMath was drawn from a number of sources in the literature, results presented from interviews conducted with participants (director, lecturer and first year students enrolled for Mathematics) from the Extended studies unit (ESU) at Rhodes University and participants (Head of Department, lecturers, tutors and first year students) from the Mathematics Department at the UNAM.

3.2 HCD Methodology

The HCD methodology, as stated in Section2.5.2 , is composed of five essential activities, of which four are repeated throughout the project life cycle until a certain objective is achieved (see Figure 3.1) (Maguire, 2001b). In these activities, the relationship between the developed system and the target users is identified to incorporate users' feedback into the system development process, hence achieving a usable system(Greenhouse, n.d.;Maguire, 2001a) . Two revolutions of the four-step process of the HCD cycle, as is depicted in Figure 3.1, have been completed during this study. The first iteration of the study involved staff (the Director, lecturer in mathematics) and first-year mathematics students from the ESU at Rhodes University, while the second iteration of the study involved staff (the Head of Department, lecturer, tutors) and first-year students from the mathematics Department at UNAM.

EnjoyMath was initially developed for UNAM students as a poor performance in Mathematics was identified at the university (as described in Section1.2). Addressing this problem is therefore imperative because all the science subjects are underpinned by Mathematics(Ball, n.d.). Due to the distance between UNAM and Rhodes University (where the researcher was based), the researcher could not often work in close relation with the UNAM students. As a result, students from the ESU were selected in the first iteration due to their proximity to the researcher. In addition, students from the ESU share similar demographics such as age, level of education and parental employment status with some first-year students at UNAM. The remainder of this chapter discusses each step of the HCD cycle as applied in this study.

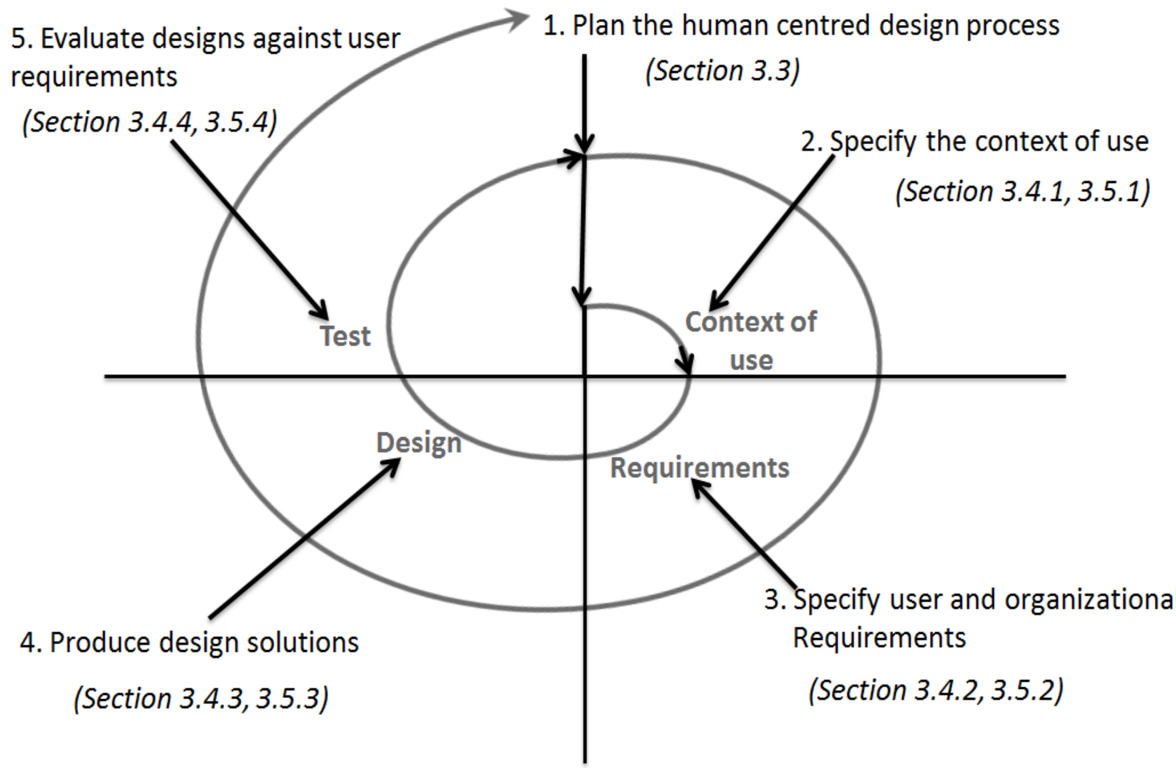


Figure 3.1: The HCD cycle adopted in this study completed two revolutions of the four-step process

3.3 Initial planning

The first phase of the HCD cycle involved planning the steps to be followed throughout the life cycle of the project. Ethics approval was obtained from Rhodes University (Approval number CS12-04). First-year students, tutors and the lecturer from the mathematics Department at UNAM and the Director, mathematics lecturer and the students from the ESU at Rhodes University were identified as the population of interest (participants) for this study. It was decided that interviews and questionnaires were to be used to collect data in order to inform and obtain data from the participants regarding their requirements for such a system. A convenience sampling method was used for sampling the participants. Convenience sampling is a technique in which participants in a study are selected based on their convenient proximity, willingness to respond and accessibility to the researcher (Forzano&Gravetter, 2011). The initial design of the system was drawn from a number of sources in the literature, and interviews conducted with the participants from the ESU at Rhodes University. Thereafter, the second iteration began. The design of the prototype in the second iteration was drawn from the first iteration, interviews conducted with Mathematics tutors, basic mathematics lecturer and students enrolled for basic mathematics on “slow mode” at UNAM. Lastly, participants from UNAM were selected to test and evaluate the developed system.

3.4 Iteration one: ESU

The first iteration involved the staff and first-year students from the ESU at Rhodes University. The ESU is a unit that provides an alternative access route to students from disadvantaged educational backgrounds who show the potential to succeed in studies at Rhodes University (Rhodes University, n.d.). The study began briefly with an email informing the Director of the ESU about the proposed research study. An interview was conducted with the math teacher and Director of the ESU. The main agenda of the meeting was to inform them about the proposed research study, to understand the course requirements and to ascertain the perceptions of the staff regarding the use of an M-learning system for mathematical concepts. This assisted in providing insight into the students’ background and determining the mutual background between the students from UNAM and the students from the ESU. In addition, it also helped in identifying the context of use (Section3.4.1). At the same time, permission was sought from the staff at the ESU to conduct a survey with the mathematics students within the ESU.

The survey was conducted with the ESU students by means of a questionnaire (Section3.4.2). Based on the survey and the research findings reported in related literature, a prototype was developed using a prototyping tool called Flowella (Section3.4.4). After the implementation stage, the prototype was then presented to the lecturer in mathematics from the ESU, the Director of the ESU, and randomly selected first-year mathematics students in the ESU (Section3.4.5). The feedback from the initial evaluation was used to inform the design of the system in the second iteration.

3.4.1 Context of use

Students’ educational background and the potential environments where the system might be accessed by the users were identified during the meeting held with the staff from the ESU. The interviews conducted with the staff revealed that most students from the ESU were from rural or peri-urban areas in South Africa where electricity and landlines are limited. However, these students have access to the mobile phone networks.

Moreover, a number of sources in the literature, typically M-learning projects conducted in developing countries, were surveyed to ascertain the environments in which students typically accessed M-learning systems. Research in developing countries, for example Liebenberg andMatthee (2007), found that students used their mobile phone to access M-learning systems when waiting for the taxi, at home, on campus during free hours, etc.(Brown, 2003). Thus, the application was developed for access in those environments.

Another factor identified in this phase was the device that the participants would use to access the mathematical content throughout the project. One of the project objectives was to provide students with access to learning materials regardless of time and location. The EnjoyMath system was therefore designed for two types of users, namely the micro browsers on mobile phones to be used by students, and a web browser on personal computers to be used by the administrators (tutors and lecturers).

Utilising students' own mobile phones avoided the need for providing training as users are already relatively familiar with the workings of their personal mobile phones (Dyson, Lawrence, Litchfield, &Zmijewska, 2007). On the other hand, making the system accessible via computer was found to be more suitable for lecturers and tutors because they have access to computers in their offices and the limited features of mobile phones might dissuade them from using the system, especially when having to add complex mathematical content.

3.4.2 Requirements

The characteristics of the targeted users, functionalities that the system needs to support and a detailed guideline of the relationship between the users and the system (how the users will interact with the system) were identified in this stage. The ESU students were interviewed by means of a questionnaire. Survey results, detailing their specific user requirements, are presented in Sections 3.4.2.1 -3.4.2.5 .

3.4.2.1 *ESU Sample*

Data were collected in July and August 2011 amongst first-year students in the age group 18-49 (18-25=96% and over 40=4%) at the ESU at Rhodes University, where 30 students were asked to complete the questionnaire used in this portion of the study (an example of which can be seen in Appendix A). Of the 30 ESU students, 29 completed the questionnaire. Participants were informed of the purpose of the research study prior to distribution of the questionnaires. The participants were also informed that participating in the study was voluntary and confidential. A consent form (an example of which can also be seen in Appendix C) was signed by the participants before answering the questionnaires.

3.4.2.2 *ESU Questionnaire*

The questionnaire aimed at ascertaining the students' perceptions of M-learning systems to determine whether an M-learning system would be beneficial for first-year students. A questionnaire, consisting of a consent form and 15 questions (closed and open-ended questions), was used in this part of the study. The questionnaire concentrated on the students' use of mobile phones; ascertaining the capabilities of the students' mobile phones; students' experience using mobile phones; factors influencing the students' use of the Internet on their mobile phones, and the students' perceptions of M-learning systems.

3.4.2.3 *ESU Survey results*

Results from the ESU survey showed that all participants owned a mobile phone and 93% of the participants had more than three years' experience using mobile phones. It was also found that the remaining 7% of the participants had used a mobile phone for a year or two. It could therefore be assumed that the students did not require training to use mobile phones. It was also assumed that students could spend more time focusing on learning the subject matter (namely Mathematics) rather than learning how to use the device. Moreover, 79% of the participants claimed to use their mobile phones to access the Internet. Those students who did not have Internet access at home could thus use their mobile phones to access the Internet. The survey confirmed the importance of integrating mobile technology into the learning and teaching environment, as the results revealed that 78% of the students were enthusiastic about using an M-learning system if present. However, some students stated that Internet data was expensive and might affect the use of the system. It was found that the least amount of money that students spent on Internet data per month was R2-00 and the highest amount of money was R30-00. Due to the high price of data, one requirement of the system was to consider minimizing data utilization.

3.4.2.4 *ESU Students' mobile phones capabilities*

In the survey conducted among the ESU students, students were asked to write down the make and model of their mobile phone and the capabilities of the phones were later determined by the researcher. Thereafter, the programming language used to develop the prototype M-learning system was chosen, based on the common programming language that the students' mobile phones could support. Figure 3.2shows the capabilities of the students' mobile phones.

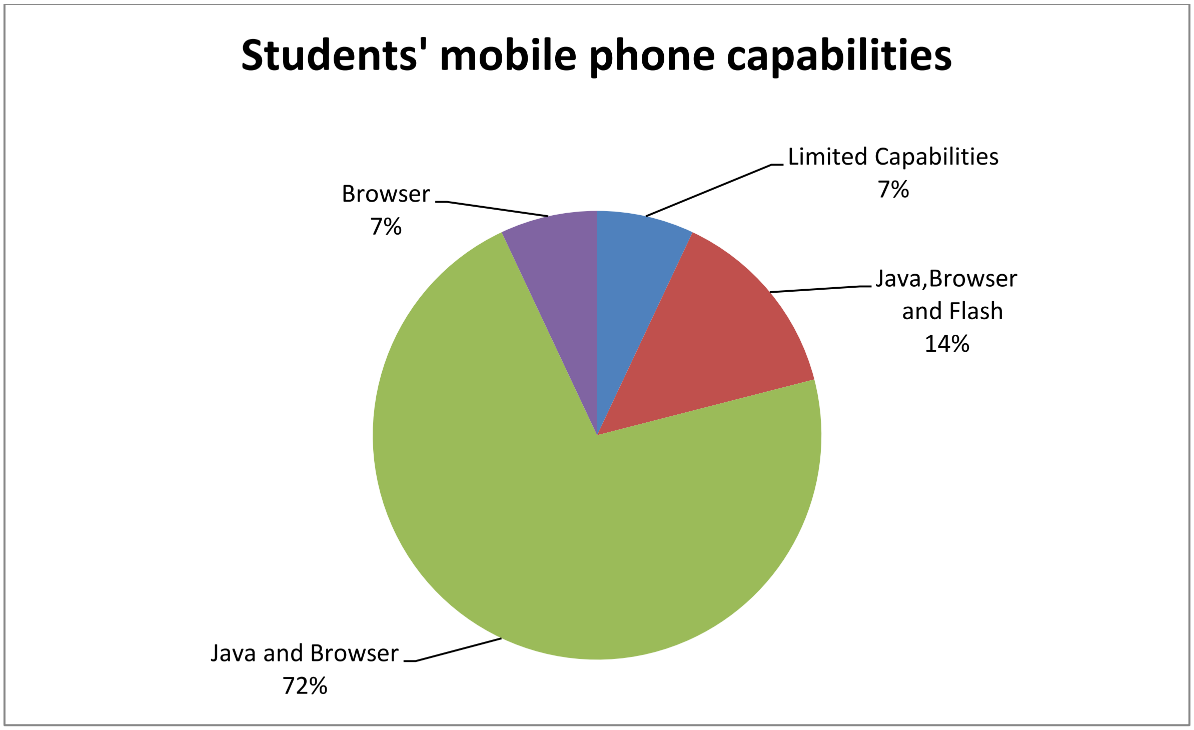


Figure 3.2: ESU students' mobile phone capabilities

As illustrated in Figure 3.2, 7% of the students' mobile phones were Internet enabled only, 72% of the students' mobile phones were Java and Internet enabled, 14% of the students' mobile phones were Java, Flash and Internet enabled, and lastly, 7% of the mobile phones had limited capabilities (neither Java, Flash nor Internet enabled). Of the identified students' mobile phone capabilities, it was found that 93% of the students' mobile phones were Internet-enabled. Hence developing a web-based M-learning system would cater for the majority of the students at the ESU. The UNAM students' mobile phone capabilities were also explored, and will be discussed in Chapter 4.

3.4.2.5 *Participants' comments and suggestions*

The staff of the ESU were enthusiastic about the envisaged system and were looking forward to the completion of the system. The ESU Director suggested that the tutors upload the content on the system, and that the system should allow tutors to view the students' performance. Moreover, 34% of the students suggested Mathematics, among other subjects, should be incorporated into an M-learning system, while 48% suggested that all the courses for which they were enrolled should be incorporated in the application, and 18% suggested different subjects for incorporation into the system. Students from the ESU who had never used their phones to access the Internet were excited to learn that they had web-enabled mobile phones and were looking forward to using the system.

Although 86% of the participants from the ESU were enthusiastic about the system, 14% of the participants from the ESU were worried about the small features of the mobile phones (e.g. screen size and small keyboard) and disliked the idea, stating that they enjoyed studying Mathematics using pen and paper and that the M-learning system would make them lazy as they wouldn't practice enough. Furthermore, of the 14%, two participants had laptops and they disliked the idea, stating that they would prefer using their laptops as they felt more comfortable using their laptops rather than using their mobile phones.

3.4.3 Features and the basic system flow of EnjoyMath

Feedback from the interviews conducted with the Director and the lecturer in mathematics at ESU, together with results from the survey conducted with the students from the ESU and features from existing systems noted in the literature were aligned to design the EnjoyMath system. These features are shown in Figure 3.3, and a basic flow control of the system is shown in Figure 3.4.

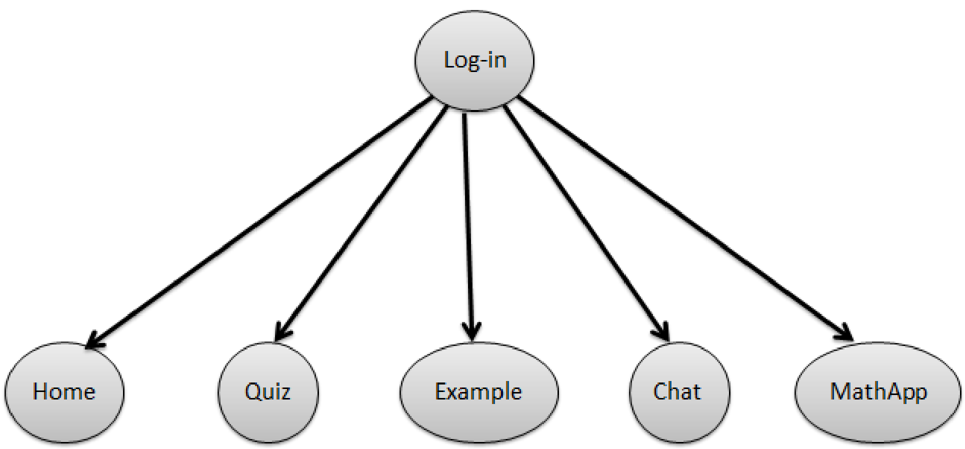


Figure 3.3: Features of the EnjoyMath system during the first iteration

The features of the EnjoyMath system, in the first iteration, were:

- Home – to inform users of the latest events. For example, reminding the users about an upcoming test or assignment's due date;
- Quiz – the quiz features were adapted from the system developed in (Arumugam et al., n.d.);
- Example – to present examples of mathematical concepts. "The Example feature was based on the fact that studying examples of mathematical problems was a successful method of learning Mathematics" (Kalloo& Mohan, 2012,p. 11);

- Chat room – the chat room allows students to chat with anyone currently logged into the system via their mobile phones (Liebenberg &Matthee, 2007); and
- MathApp – allows students to perform calculations using the system (Yarushamy, n.d.).

The user must register in order to gain access to the system. After the user successfully logs in, the user is presented with the main menu. From the main menu, the user is presented with six options: Home, Example, Quiz, Chat, MathApp and logout (see Figure 3.4).

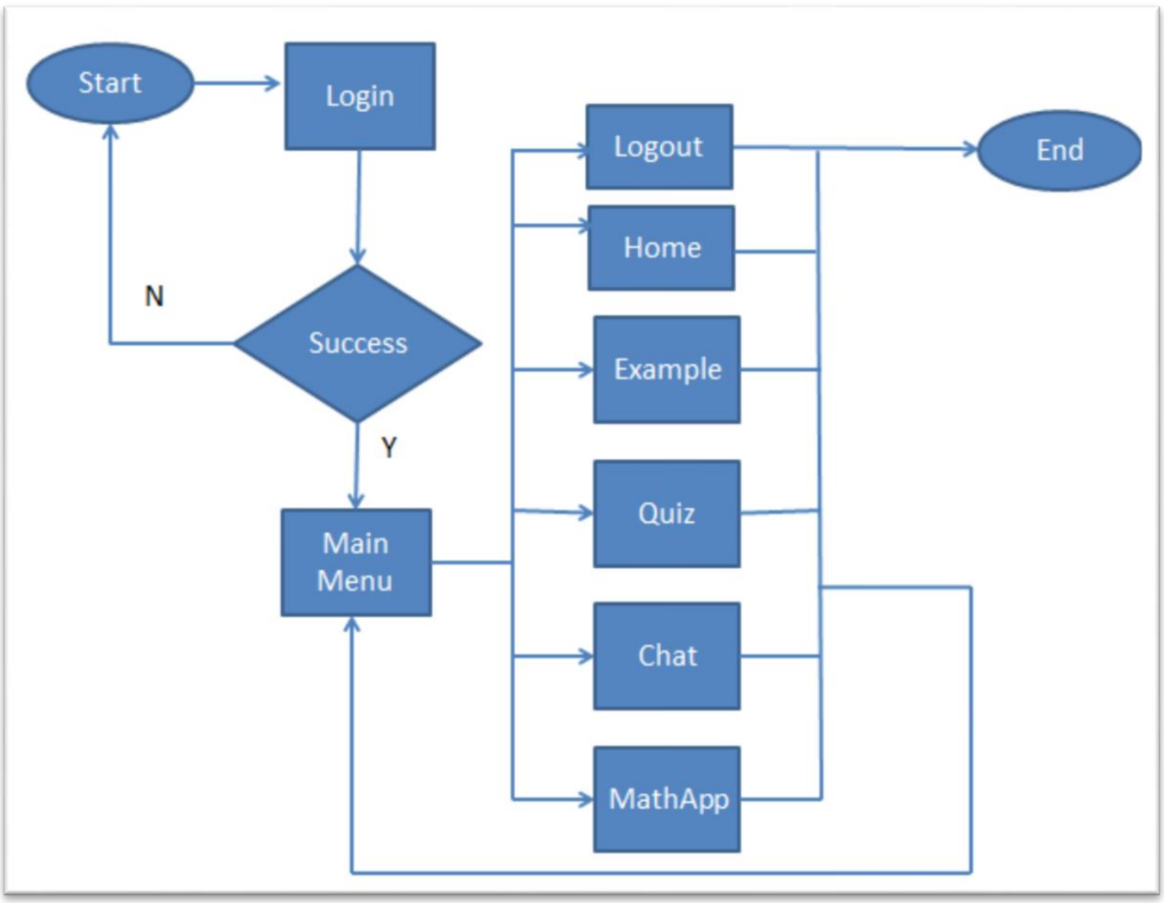


Figure 3.4: Basic System Flow of the EnjoyMath system

3.4.4 Design

Different designing tools exist and are used depending on the designing stage and the objective of the project. In the first iteration of the project, the horizontal prototype system was designed using Flowella. The horizontal prototype was developed to clarify the scope and requirements of the project with the target audience. After the prototype had been designed, the images were imported into Flowella. The prototype was then exported to flash lite and presented to the first-year participants, Director and mathematics lecturer from ESU on a Nokia N97 (examples illustrated in Figures 3.5-3.7). The horizontal prototype was presented on a Nokia N97 as this was the phone distributed amongst the participants for their feedback. With Flowella, every application is designed specifically to suit the screen size of a specific phone. For instance, a prototype designed to be run on a Nokia N97 cannot be deployed on a Nokia N95. In addition, Flowella was design for the prototype to be tested on Nokia devices only. The main drawback of Flowella is that it could be deployed only on the specific phone that the application was designed for (Nokia, n.d.), although a series of Nokia phones (e.g Nokia 5800, Nokia N95 etc.) (Nokia, n.d.) can run applications developed using Flowella.

Due to the variety of mobile phones available among the participants, designing deferent applications serving the same purpose would have been time consuming and was not necessary because I had chosen to implement a web-based application instead which is accessible to all web enabled phones.

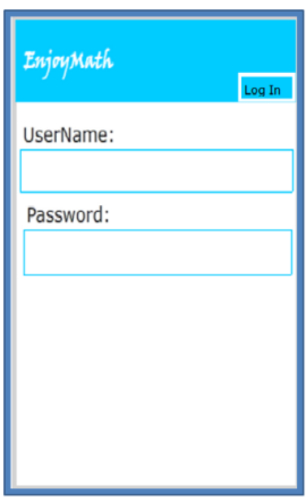


Figure 3.5: EnjoyMath Login Screen

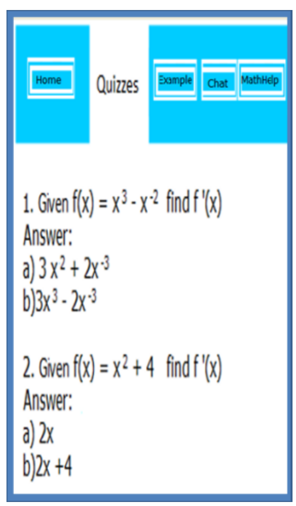


Figure 3.6: Example of Quiz screen

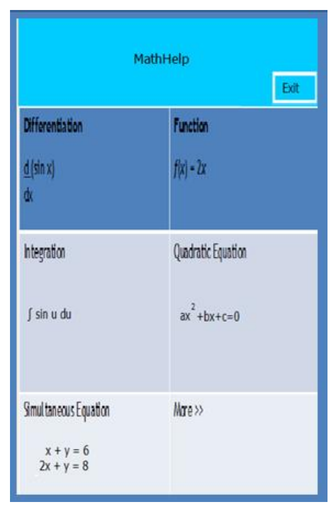


Figure 3.7: MathApp Screen

Figure 3.5shows the user login interface of the system. When the user logs onto the system, the home page is presented. This allows the user to decide on the activity they wish to undertake. The user can answer a quiz (example in Figure 3.6), view more examples, chat to other students or the administrator and lastly, the student can enter values to solve Mathematics problems as illustrated in Figure 3.7. The calculation menu allows the student to choose the topic in order to be assisted with calculations.

3.4.5 Testing

The developed prototype was presented to the target users (specified below) for evaluation at this stage. This is important as system faults were identified and users were assessed as to whether they could use the prototype successfully (Carvalho, 2001). This horizontal prototype was presented to the staff of the ESU and to randomly selected first-year mathematics students at ESU. The system was evaluated in order to enhance the user interface design and to ensure that the participants had a clear understanding of the anticipated M-learning system. The feedback was incorporated into phase two of the system development and changes were made to the prototype wherever necessary before coding.

Based on feedback from the users, a few additional features were added to the EnjoyMath system and are listed below:

- Granting tutors administration privilege. This allows users with administrative privileges to create and delete examples, quizzes and to update the home page instead of a programmer hard-coding pages.
- Develop a dynamic system that allows different subjects, topics and quizzes to be incorporated as needed.
- Allow the student to choose the number of examples to be displayed depending on the size of the student’s mobile phone screen in order to better accommodate small screen sizes and make it easier for students to work with their mobile phones.
- Allow the system to mark the quizzes that students take and provide feedback when they answer incorrectly. Feedback should take the form of providing the incorrect answer they chose, together with the correct answer without specifying which number in the options they were, in order to discourage students from memorizing the correct options.
- Add a report menu to the administrator’s view, allowing administrators to view the students’ progress. This is vital during revision as tutors can then emphasize topics where the students’ performance was poor.

3.5 Iteration Two: UNAM

The second iteration involved staff (Mathematics tutors, the basic mathematics lecturer and the head of the mathematics Department) and first-year students enrolled for basic mathematics on “slow mode” at UNAM. “Slow mode” refers to students who did not achieve 50% in their first basic mathematics test. These students are enrolled for basic mathematics for the whole year instead of a semester. The study began briefly with an email informing the Head of the mathematics Department at UNAM about the proposed study (an example of which can be seen in Appendix B). Permission was sought to conduct interviews with the Mathematics tutors, basic mathematics lecturer and the first-year mathematics students at UNAM. After permission was obtained from the mathematics Head of Department, interviews were conducted with the specified staff at UNAM.

From the interviews, the context of use was identified (Section3.5.1), and permission to conduct interviews with the first-year students enrolled for basic mathematics on "slow mode" at UNAM was sought from the basic mathematics lecturer. After permission was obtained, a survey was conducted with students enrolled for basic mathematics on "slow mode" by means of a questionnaire (Section3.5.2). The design of the system in the second iteration was taken from three sources: the first iteration conducted with the ESU staff and students, the feedback from the survey conducted with first-year students enrolled for basic mathematics on "slow mode", and the interviews conducted with Mathematics tutors and the basic mathematics lecturer at UNAM (Section3.5.3). A web-based system using PHP, JavaScript and MySQL was then developed and implemented. Lastly, the system was evaluated (Section3.5.4) among tutors and students by means of a questionnaire, the results of which are presented in Chapter 4.

3.5.1 Context of use

In the second iteration of the study, the context of use was identified during the interviews conducted with the staff from UNAM. During the interviews, tutors suggested that the system might be more beneficial to students studying basic mathematics on "slow mode", as opposed to the first year pre-calculus mathematics students that the system was originally envisaged for, because "slow mode" was introduced for students who need greater attention in Mathematics. Contextual factors such as students' educational background and possible environments where the users might intend to use the system were identified during the interviews. These factors were aligned with factors identified in the first iteration. Similarities such as the availability of mobile phones among the ESU and the UNAM were also identified.

3.5.2 Requirements

In the second iteration of the HCD methodology, interviews were conducted with the first year students enrolled for basic mathematics on "slow mode" and basic mathematics staff at UNAM. These interviews aimed at ascertaining the use of ICTs in education (both mobile phones and computers). Since the problem of a high mathematics failure rate was identified at UNAM, more questions were added to the questionnaire used in the survey originally conducted amongst the ESU students. Instead of only focusing on the use of mobile phones, the uses of computers by first year students at UNAM were also ascertained. This was done to determine the students' computer skills knowledge and to ascertain whether the students are familiar with ICTs in education. The prototype developed in the first iteration was presented to the participants on a Nokia N97 for comments and suggestions.

After the interviews with the tutors and the basic mathematics lecturer, the system's calculation menu (MathApp) was modified. Instead of developing a mathematics application allowing students to solve mathematics problems (as initially planned and shown in Figure 3.7), links to existing free mathematics application were provided. The links to the applications were chosen based on the students' mobile phone capabilities, ensuring that the applications downloaded could be used by the participants. This was done as the lecturer who was to teach basic mathematics for the second semester resigned. Thus lecturer at the time that the study was conducted was new to the subject and thus needed more time to prepare for the course, such as compiling his own notes. As a result the lecturer was not able to provide the mathematics content necessary for the system. Data were collected among the students during the first hour of the practical session by means of questionnaires. The UNAM sample and the questionnaire used to collect data among the first year students enrolled for Mathematics on "slow mode" are discussed in the subsequent sections.

3.5.2.1 *UNAM Sample*

Data were collected in August 2012 from 101 first year students in the age group of 15-35 years (15-20=78%, 21-25=17%, 26-30=1% and 31-35=4%). Participants were asked to complete the questionnaire and were informed about the purpose of the research study prior to the distribution of questionnaires. Participants were also informed that participating in the study was voluntary and confidential. A consent form (an example of which can be seen in Appendix C) was signed by the participants before answering the questionnaire.

3.5.2.2 *UNAM Questionnaire*

The questionnaire consisted of two sections and a consent form. The first section of the questionnaire concentrated on the students' use of mobile phones and consisted of ten questions. The second section of the questionnaire concentrated on the students' use of computers and consisted of 11 questions (an example of which can be seen in Appendix D). The questionnaire was used to ascertain the capabilities of the students' mobile phones, students' use of mobile phones, students' use of computers and students' perceptions of M-learning systems. In addition, the semester in which the students registered for computer literacy, the place where the students first used computers and the students' awareness of the E-learning system at UNAM was also ascertained. At the end of the first series of the survey, students who wished to participate in the follow-up survey (the user evaluation of M-learning system) of the M-learning study were asked to give their contact details.

3.5.3 Design

At this stage, the system design focused on the users' primary actions. The mobile phone screen sizes and the battery power were considered during the design phase. The content of the mobile website was arranged according to the limited screen size on most mobile phones. Unnecessary navigations and over-use of JavaScript, CSS and flash elements (e.g. images) were also avoided in order to minimize data usage and conserve costs to the student users (Enough software, 2001). A UML 2.0 diagram (Figure 3.8) was used to illustrate the flow of control of the EnjoyMath system. The users first registered in order to gain access to the system. After registration, users could log into the system using their email addresses and their passwords. Thereafter, the user's credentials were checked. If these were correct and the user was a student, the student interface was presented; otherwise the administrator interface was presented. The user's privileges differed depending on whether the user was granted student or administrator rights. Once either the student or administrator interface was loaded, all the components could be used repeatedly until the browser's window was closed or until the user logged out of the system.

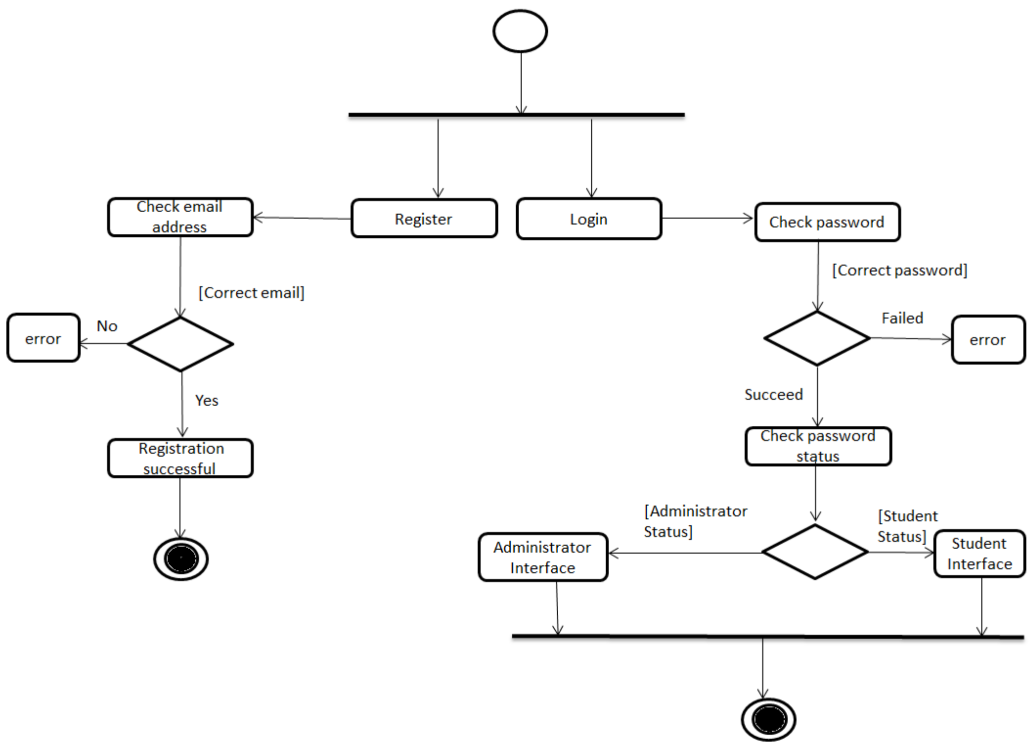


Figure 3.8: EnjoyMath UML activity diagram

3.5.3.1 *Technologies used to develop the system*

The implementation of this system was based on the results from the first iteration and the results from the study conducted with the participants from UNAM (which are discussed in Chapter 4). It was concluded that the system would be web based and would be accessible via the micro browsers on mobile phones or web browsers on personal computers. The development tools chosen should therefore develop a system accessible both on desktop computers and mobile phones. The EnjoyMath architecture is shown in Figure 3.9.

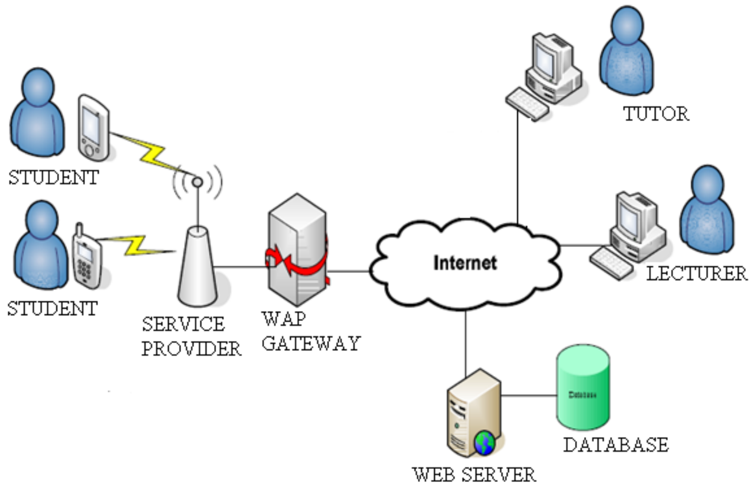


Figure 3.9: EnjoyMath architecture

HTML, JavaScript (supported by Ajax and jQuery), PHP and a MySQL database were used to implement the system. HTML, Ajax and jQuery were used on the client side, while PHP was used on the server side and a MySQL database was used for data storage. Special attention was given to the interfaces displayed in order to fit the display of the system on the screen of the device being used to access the system. The technologies used to implement the system are discussed further in the subsequent sections.

3.5.3.2 *Asynchronous JavaScript and XML (Ajax)*

Ajax allows web applications to send and receive asynchronous data from the server without interfering with the display and the behaviour of the whole page (W3schools, n.d.). Otherwise stated, Ajax allows web applications to load a requested portion of the page instead of loading the whole page. In this project, JavaScript was used to access the Document Object Method (DOM) in order to display information and to allow users to interact with the information presented via the interface. Moreover, XMLHttpRequest was used to send direct HTTP requests to the web server from the web browser. The web server's responses were then loaded back into the JavaScript and sent back directly to the web browser. This allowed for a quicker response from the server and therefore information requested from the server was loaded more quickly on the end devices.

3.5.3.3 *PHP and MySQL*

PHP statements were used to process data to and from the server in order to create the desired outputs. A connection file consisting of the hostname, username and password of the MySQL database was written in PHP. This file was used to create a connection to the MySQL database used in this project. The connection file was included in all the files where a database connection was required. When a connection to the database failed, an error was displayed, otherwise the user would be connected to the database successfully.

3.5.3.4 *HTML forms*

HTML forms were used to take in data from the system users. A form consisted of input boxes allowing the user to enter data and submit buttons allowing the user to submit the data entered. HTML forms were used on the client side of the application, together with JavaScript for the mobile client. HTML forms were also used together with Ajax on the desktop client side to provide interaction between the user and the system. In the subsequent sections the system interfaces are discussed.

3.5.3.5 *Registration interface*

The registration interface consists of five input boxes and a “register me” submit button. The input boxes take in the user’s name, surname, password, confirm password and E-mail address while the “register me” submit button sends the user’s information to the server. The user’s information is stored in a MYSQL database and the information is used for authentication when the user logs into the system.

3.5.3.6 *The Forgot password interface*

The Forgot password interface consists of a text box and a “Retrieve Password” submit button. The text box takes in the user’s email address and the “Retrieve Password” button responds to the key click by submitting the user’s email address to the server. After the user’s email address is entered, the system sends the user’s password to the user’s email address.

3.5.3.7 *Login interface*

The login interface consists of two input boxes, two links and a “login” submit button. The input boxes take in the user’s password and the user’s email address, while the two links allow the user to request a new password and to register. The “login” button is responsible for submitting the user’s credentials to the server. If the credentials entered do not match a set of credentials in the MYSQL database, an error message is displayed on the interface, otherwise access is given to the user and the user is presented with the appropriate user interface. The credentials entered determine whether the user will be presented with the administrator interface or the student interface.

3.5.3.8 *The Administrator menu Interface*

The administrator interface is the administrator’s view of the system and offers complete control of the system. The administrator, as stated earlier, is responsible for uploading content on the system. The CLEditor which is a WYSIWYG (“What you see is what you get”) HTML editor was integrated into the system allowing the administrator to edit the content on the website. The CLEditor is a jQuery plugin and was chosen because it is lightweight, full featured, cross browser, extendible and open source (Landowski, 2011).

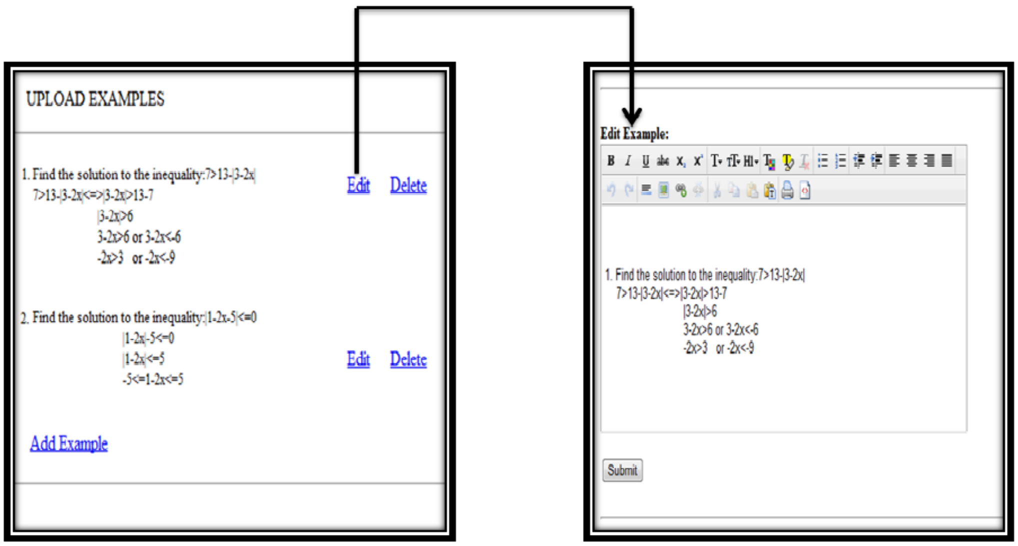


Figure 3.10: WYSIWYG examples

As illustrated in Figure 3.10, the system allows the administrator to add, edit and delete examples. The administrator is also responsible for uploading topics, questions and answers on the system. In other words, different quizzes under the same topic can be created as illustrated in Figure 3.11and Figure 3.12. Figure 3.11depicts how the administrator is able to upload topics and Figure 3.12displays how the administrator is able to upload questions.

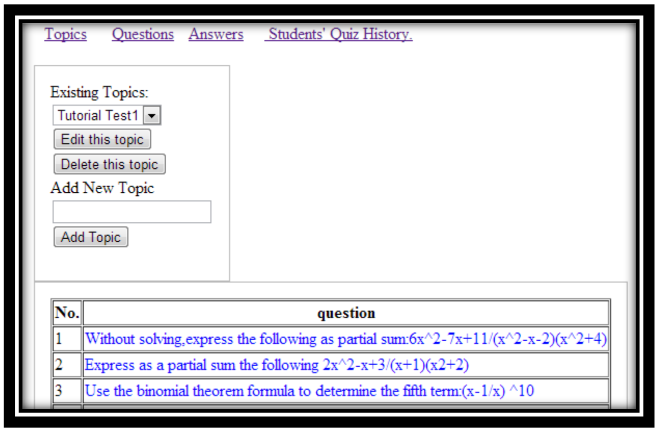


Figure 3.11: Load topics

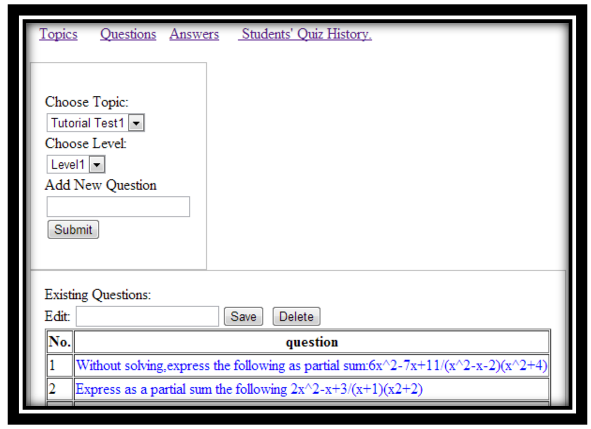


Figure 3.12: Load questions

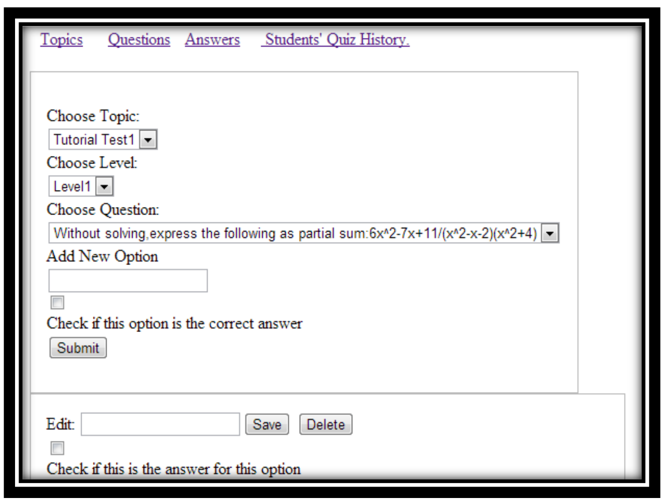


Figure 3.13: Add Answer interface

The Add Answer interface (Figure 3.13) allows the administrator to upload different answers for different questions for different topics on the system. The answers are entered in the option input box and a check box for ticking the correct option is used to mark the correct answer. The add answer interface comprises of three drop down menus allowing the administrator to choose the topic and the level in order to enter the answer for the topic, level and question chosen. The interface also consists of a submit button for submitting the options (answers) entered. Ajax was used on the client side to upload the tables on the administrator interface. Ajax was used as it allows a portion of the page to be uploaded without loading the whole page, thus conserving the amount of data to be sent over the network.

3.5.3.9 *Student Interface*

The Student menu consists of five links, allowing the student to navigate between the different pages. The student navigates between the pages depending on the functionality the student wants to access at a specific time. The menu interface is found on all the interfaces allowing easy navigation. The menu presented to the administrator differs from the menu presented to the students, in that students do not have access to the admin page.

3.5.3.10 *Home Interface*

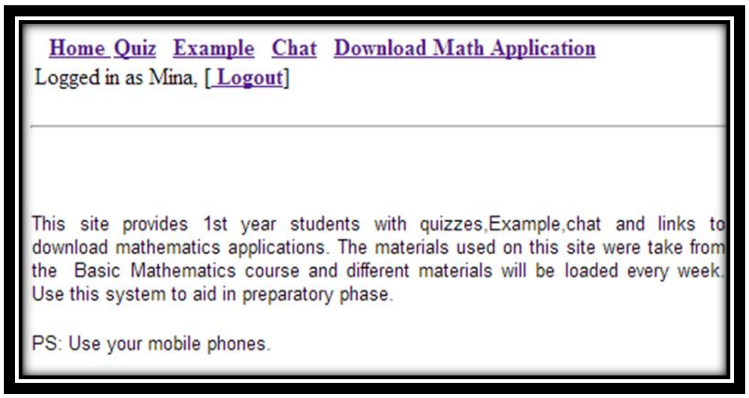


Figure 3.14: Home interface

The Home interface (Figure 3.14) is the first interface presented to the user when the user logs into the system. Information on this interface is uploaded by the administrator. Information on this interface informs the students of any upcoming events as stated earlier. The screen shot was taken when the system was being introduced to the students at UNAM. Thus the home page interface at this time was informing the students about the objectives of the study.

3.5.3.11 *Quiz Interface*

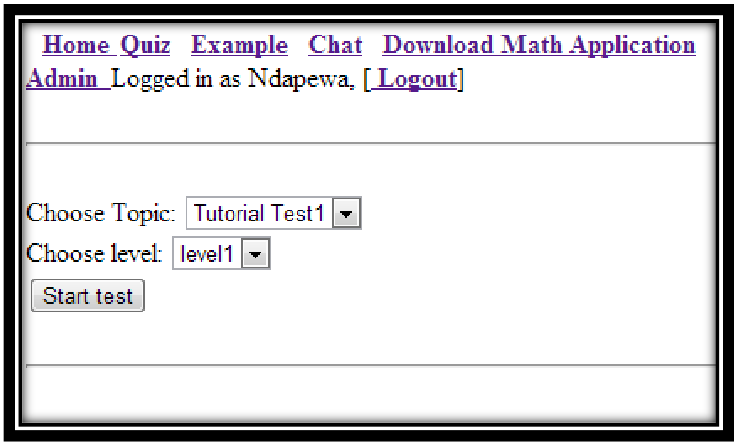


Figure 3.15: Quiz interface

The Quiz interface (Figure 3.15) allows the student to take a quiz on the system. When the quiz is submitted, the system marks the quiz and provides feedback to the student as illustrated in Figure 3.17. A drop down menu was used in the quiz interface to allow ease of use since the system targets mainly mobile phones with screen size limitations. The drop down menu allows the user to select options instead of entering values. Using drop down menus reduces the amount of typing (Enough software, 2001), hence making it easier for mobile phone users. The use of drop down menus will also allow users to spend less time learning how to enter and search for Mathematics symbols; hence minimising time spent learning how to use the system and allowing the students to concentrate on learning mathematical concepts.

Multiple choice questions (Figure 3.16) were used to prevent users from having to enter data using their mobile phone's keyboard, as some mobile phone keyboards are very small and have limited functionality (Enough software, 2001) or do not support Mathematics symbols. As stated in Section2.5 , different users have different personalities therefore searching for mathematical signs might frustrate and irritate some users hence dissuading them from using the system (Maguire, 2001b).

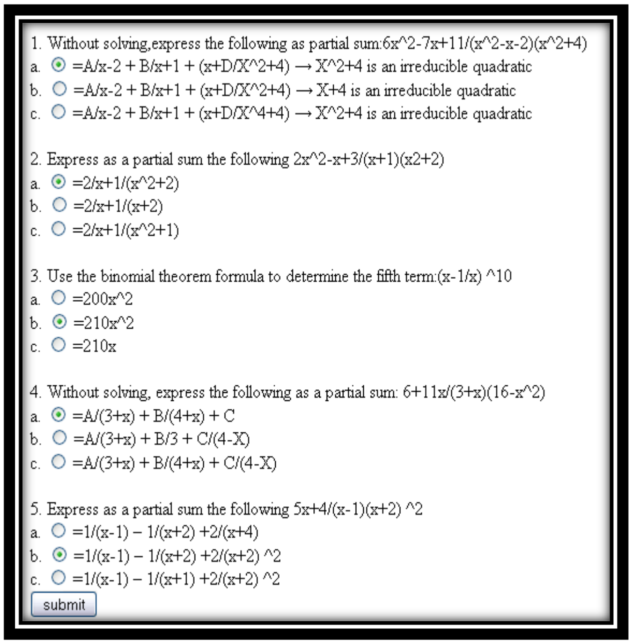


Figure 3.16: Take quiz interface

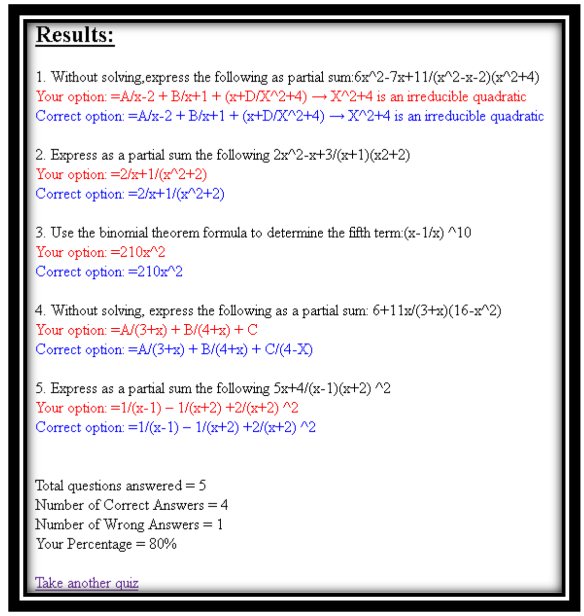


Figure 3.17: Quiz feedback

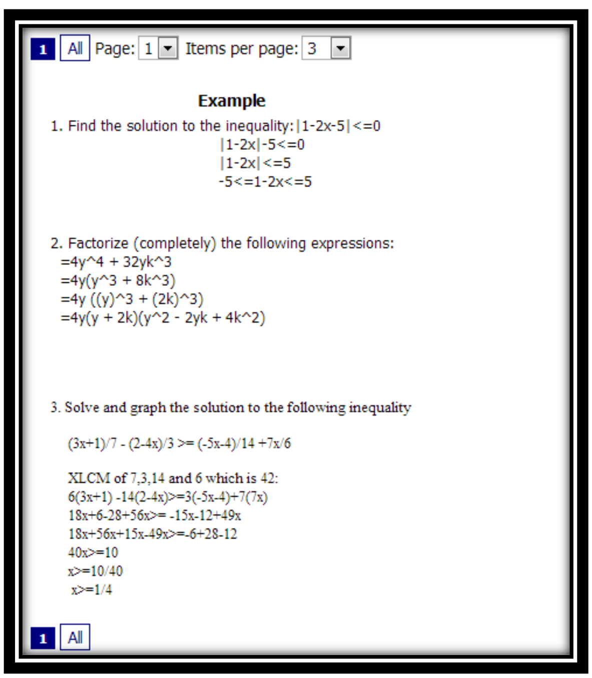


Figure 3.18: Example interface

The Example interface (Figure 3.18) provides students with examples of the available content for learning. Students are provided with an option of choosing the number of examples to load at a time.

Students can load three or more examples at once, depending on the mobile phone screen size. This was done to minimize the number of examples displayed in order to minimize the need for scrolling and achieved via the paginator class (Jason, 2009).

3.5.3.12 *Chat Room Interface*

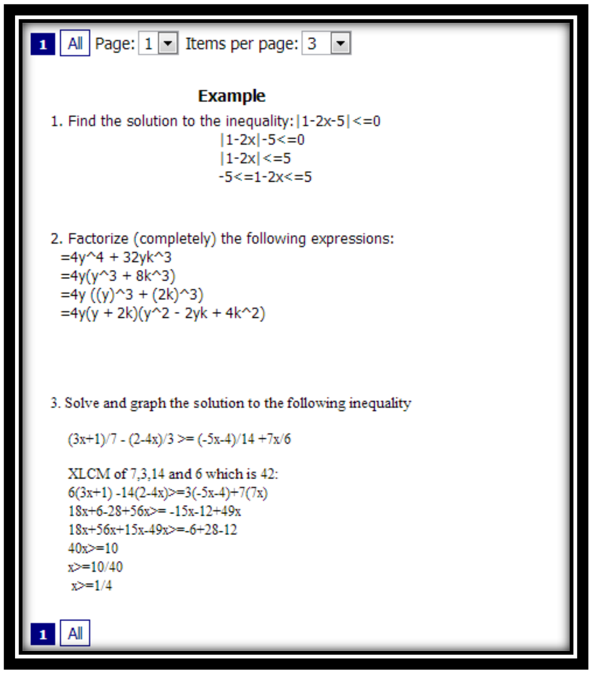


Figure 3.19: Chat Room interface

The Chat room (Figure 3.19) comprises a main chat room allowing students to chat to other students or to the administrators. Although the advanced chat room functionality that allowed students to create new private chat groups was initially developed, this functionality was eventually removed because it resulted in chat room loading issues on some phones such as Nokia x3 and HTC wildfire. Certain mobile phones, like that of the HTC wildfire, have limited internal memory and can therefore only run few applications simultaneously. In order to run additional or more memory intensive applications an additional memory card is required.

3.5.3.13 *Download Math applications Interface*

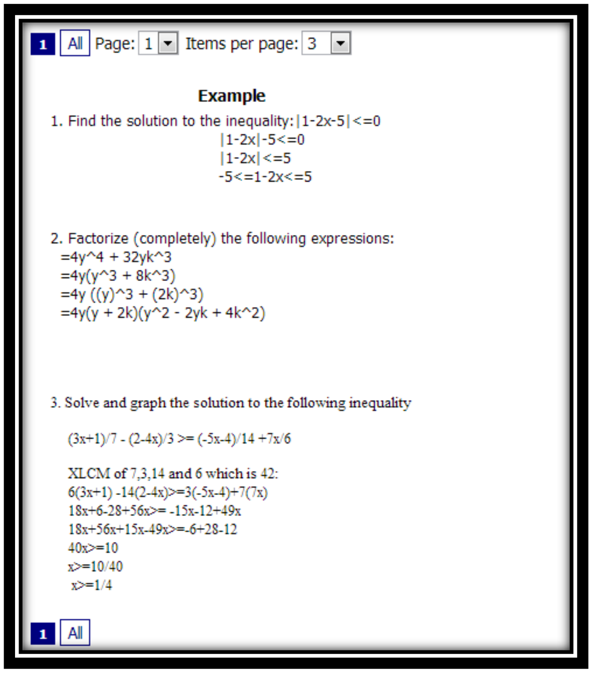


Figure 3.20: Download Math Applications interface

The Download Math Applications interface (Figure 3.20) comprises a number of webpage links allowing students to download free existing mathematics applications. The mathematics applications provided on this page are native applications running on phones that support Java. The free applications provided were chosen based on the programming language in which they were developed and the students' mobile phone capabilities identified in the study conducted with the students from UNAM. This was done in order to provide links to applications accessible to the majority of the students' mobile phones.

3.5.4 Testing

The prototype M-learning system, EnjoyMath, was evaluated in October 2012, with first-year students studying basic mathematics on "slow-mode" and the mathematics tutors at UNAM. The participants were informed that participating in the evaluation study was voluntary and confidential. A short message service (SMS) text message was sent to the students' mobile phones who had expressed an interest in taking part in the evaluation portion of the survey at UNAM, informing students about the second series of the study. The SMS sought permission to conduct the survey with the students and informing them about the second series of the study. In the SMS, students were asked to reply if they wished to participate in the study and asked to state the time that suited them in order to complete the questionnaire.

Alternatively, tutors were contacted in person and appointments to conduct the survey were sought. After obtaining the time slots that suited the participants, each participant was met individually. The participants were informed about the purpose of the survey prior to the distribution of the questionnaires. Four tutors and 19 students participated in the evaluation study. Two questionnaires were used in this stage. Instead of creating a questionnaire from scratch, the System Usability Scale (SUS) (Sauro, 2011) questionnaire (an example of which can be seen in Appendix E) was adapted in this survey and additional questions were added to the questionnaire.

The SUS questionnaire used in this survey consisted of two pages ascertaining the usability of the system, students' mobile phone models and students' suggestions and comments on the system. Lewis and Sauro(2009) suggested a modification to the SUS questionnaire. The word "Awkward" was used instead of "cumbersome" because the word "cumbersome" confused users in previous studies.

Questionnaires were distributed to the participants based on whether the participants used the system or not. Participants were asked whether they used the system before the questionnaire was distributed. Of the 23 participants, 18 used the system and were asked to complete the SUS questionnaire. Five participants who did not use the system although initially sounded enthusiastic about the proposed M-learning system volunteered to complete the second questionnaire (an example of which can also be seen in Appendix F). The second questionnaire ascertained why they did not use the system. The questionnaires were collected upon completion and the results of both questionnaires are also presented in Chapter 4.

3.6 Summary

This chapter discussed the steps undertaken to design and implement the EnjoyMath system. The chapter showed how the HCD methodology was applied to obtain the necessary information that led to the implementation of the EnjoyMath system. The sampling technique and sampling method used to gather information from the participants (ESU and UNAM) in this study were also discussed. The chapter has highlighted how the EnjoyMath system was designed based on the literature reviews and the results obtained from the survey conducted amongst the participants at ESU. Steps used to design the prototype in the first iteration of the study were detailed. The technologies used to develop the EnjoyMath system in the second iteration were also discussed and reasons for those technologies being selected were presented in this chapter. The next chapter presents the evaluation phase of the EnjoyMath system. The modified SUS questionnaire was used to gather results in the evaluation study.

Results obtained from the evaluation study conducted amongst the UNAM participants will be presented in chapter 4.

Chapter 4. User Study

4.1 Introduction

The HCD methodology used in this study included two testing phases. The results from the first testing phase - the flash prototype presented to the mathematics students in the ESU at Rhodes University - were presented in chapter 3 and the results from the second testing phase - the web-application conducted with the basic mathematics students and tutors at UNAM - are presented in this chapter. The latter involved two separate testing phases with target users at UNAM in order to ascertain whether the users' requirements were met and whether the intended users could use the developed system with ease (Carvalho, 2001). This helped in exposing the system's faults and allowed the system's functionalities to be enhanced.

This chapter begins by presenting the results of the pre-intervention study conducted with first-year basic mathematics students enrolled for "slow mode" at UNAM. Thereafter, results from the post-intervention study conducted with the mathematics tutors and the first-year basic mathematics students enrolled in "slow mode" at UNAM are presented, showing the users' evaluation of the M-learning system, EnjoyMath. The chapter then analyses the findings presented in Chapters 3 and Chapters 4, discussing the lessons learned and the potential value of an M-learning system in supporting the ad-hoc learning of mathematical concepts for university students. Finally, the chapter concludes with a summary.

4.2 Pre-intervention study

The pre-intervention study aimed at ascertaining the students' perception of the use of ICTs in education (specifically mobile phones and computers). Students who participated (n=101) in the study were presented with a questionnaire (see Appendix D) and the mathematics lecturer and the tutors were interviewed before the EnjoyMath system was implemented at UNAM, ascertaining the users' requirements of the system. Results obtained from this study were compared to the results of the study conducted among the ESU students, ensuring that necessary changes were made before the final implementation of EnjoyMath was made available on the UNAM campus. In the subsequent sections the results obtained from the study conducted with the selected group of participants from UNAM will be discussed.

4.2.1 Usage of Mobile phone

This section of the pre-intervention questionnaire concentrated on the participants' usage of mobile phones. Participants were asked to select their age group and also asked whether they owned a mobile phone. The survey found that most participants (78%) were in the age group of 15-20 years old and the smallest number of participants (1%) was in the age group of 26-30 years old. In addition, 17% of the participants were in the age group of 21-25 years old, and 4% of the participants were in the age group of 31-35 years old.

It was also found that all participants owned mobile phones and 6% of the participants had more than one mobile phone. Participants were asked to write down the make and model of their mobile phones in order for the mobile phone capabilities to be determined. Determining the participants' mobile phones' capabilities was important in this study as the programming language decided upon in the first iteration would be reconsidered if the majority of the participants' mobile phones in the second iteration did not support the proposed programming language. The mobile phones' capabilities were then determined by the researcher. It was found that 5% of the participants owned Blackberry phones, 53% of the participants owned Nokia phones; 35% of the participants owned Samsung phones and 7% of the participants owned either a Sony Ericsson, LG, Huawei or MTC mobile phone. Although all participants stated the make of their mobile phones, only 59% of the participants provided the model of their mobile phones, hence participants' mobile phones capabilities could only be calculated from the information provided, by those participants who provided their mobile phone model and make, as shown in Figure 4.1.

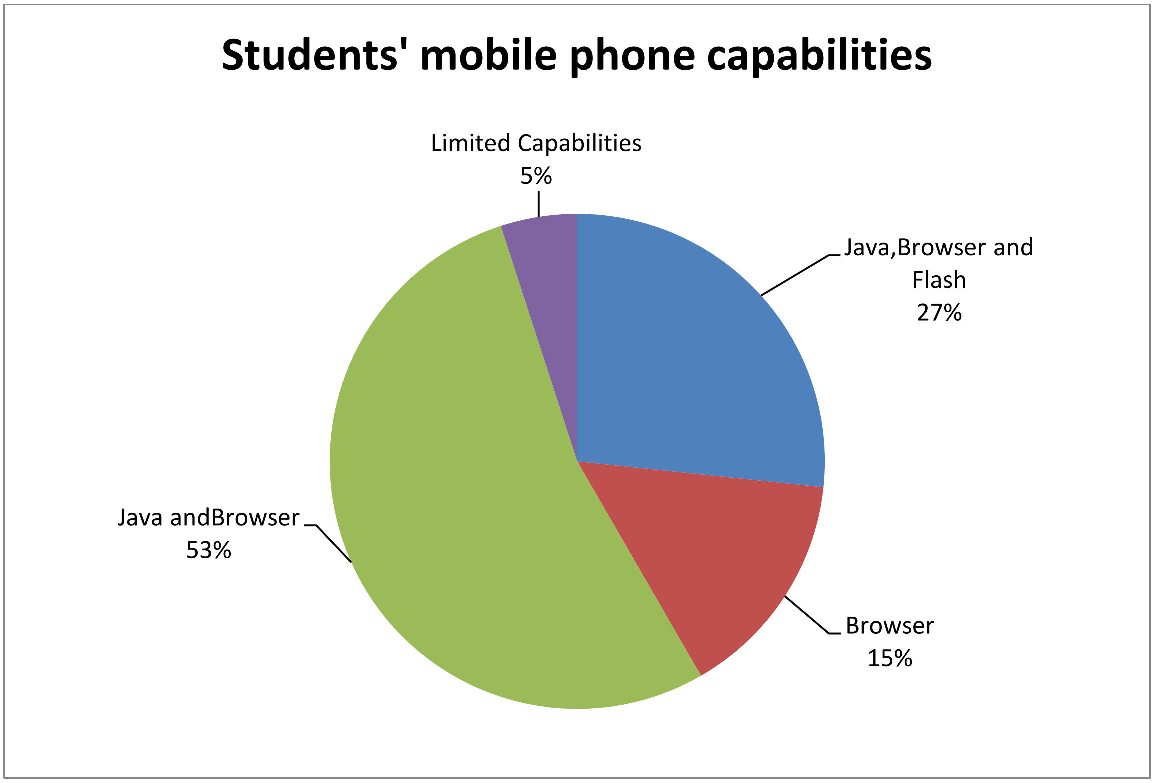


Figure 4.1: UNAM Students' mobile phone capabilities

It was found that 15% of the participants' mobile phones were Internet-enabled only, 53% of the participants' mobile phones were Java and Internet-enabled, 27% of the participants' mobile phones were Java, Flash and Internet-enabled, and lastly, 5% of the mobile phones had limited capabilities (neither Java, Flash nor Internet-enabled). Thus, of the identified participants' mobile phone capabilities, it was found that 95% of the participants' mobile phones were at least Internet-enabled.

After determining the participants' mobile phones capabilities, it was necessary to determine whether the participants were accustomed to accessing the Internet using their mobile phones and whether the majority of the participants were able to use the web based system as decided in the first iteration (at ESU) of the study. Participants were asked to state how often they used their mobile phones to access the Internet, and the amount of time they spent accessing the Internet using their mobile phones. The results of how often participants used their mobile phones to access the Internet is shown in Figure 4.2.

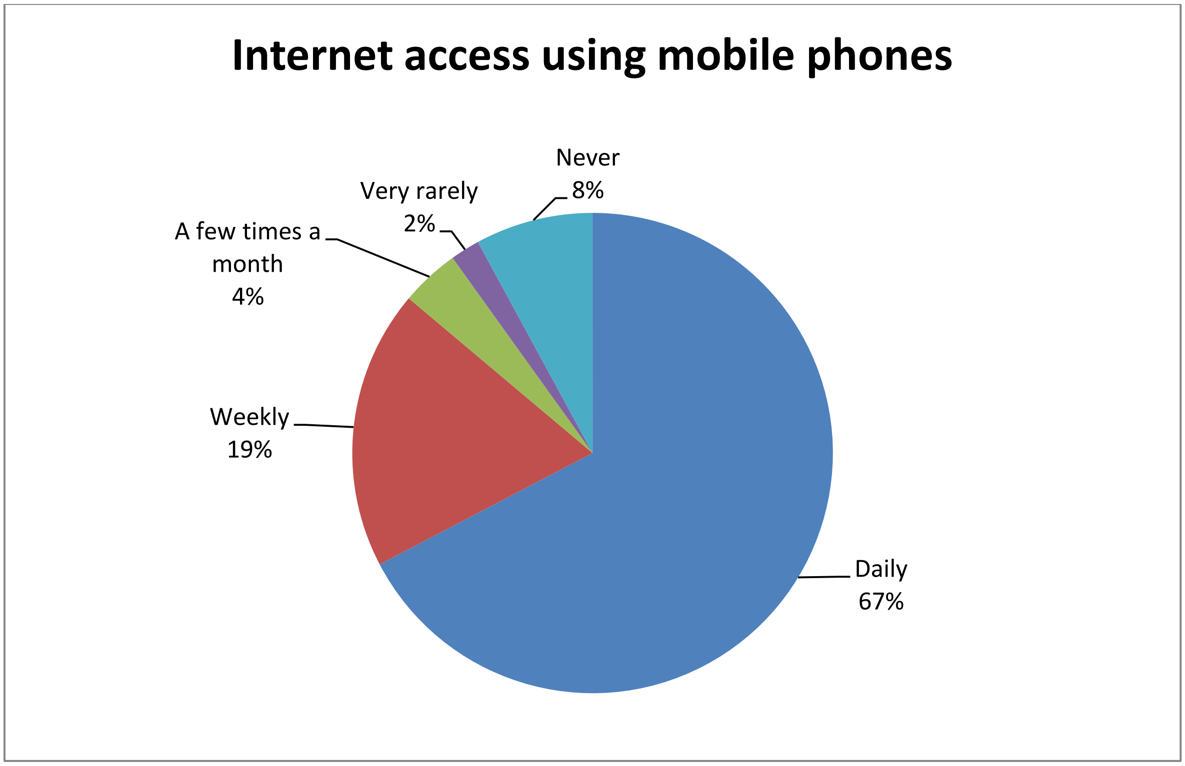


Figure 4.2: Amount of time spent by first year students in basic mathematics at UNAM accessing the Internet

It was found that 67% of the participants accessed the Internet using their mobile phones daily, 19% of the participants accessed the Internet using their mobile phones weekly, 4% of the participants accessed the Internet using their mobile phones a few times a month, 2% of the participants accessed the Internet using their mobile phones very rarely and 8% of the participants never connected to the Internet using their mobile phones.

The results of Internet usage via mobile phones among the participants supported the development of a web based M-learning system as 92% of the participants already used their mobile phones to access the Internet at some stage or another. Of the 92% of the participants who accessed the Internet using their mobile phones, different wireless communication protocols were used to connect to the Internet, as illustrated in Figure 4.3. It was found that the biggest sub-group of the participants (34%) used3G technology to connect to the Internet.

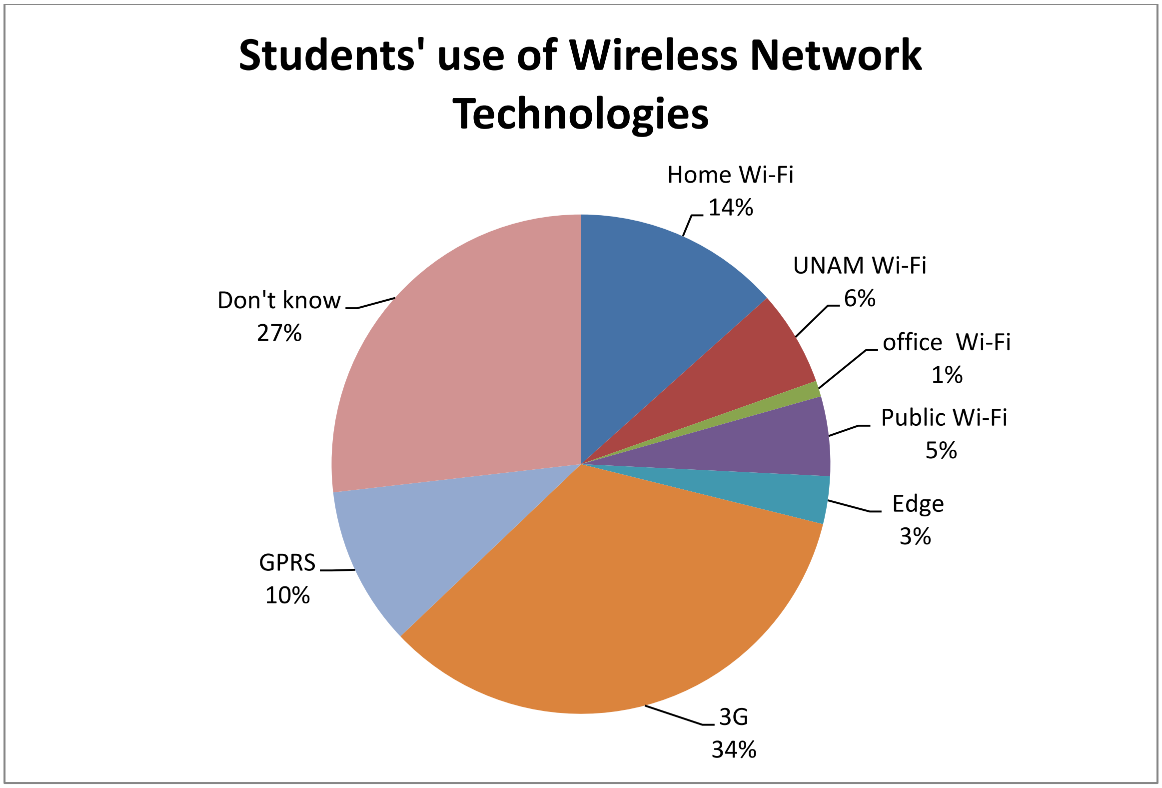


Figure 4.3: Various wireless network technologies used to connect to the Internet using mobile phones by first year students in basic mathematics at UNAM

To determine the physical environment from which the mobile web application would be operated, it was necessary to ascertain the physical environment from which the participants accessed the Internet in the 6 months prior to commencement of the study. Participants were asked where they were when accessing the Internet via their mobile phones over the 6 months prior to the commencement of the study. Of 101, 90 participants answered this question. It was found that 38% of the participants who answered accessed the Internet using their mobile phones while at home, 29% of the participants accessed the Internet using their mobile phones while on UNAM campus, 11% of the participants accessed the Internet using their mobile phones while travelling, and 22% of the participants accessed the Internet using their mobile phones wherever they were as long as they could access the Internet.

Participants were also asked to state factors that prevented them from accessing the Internet using their mobile phones. Of 101, 93 participants answered this question. Most of those answering this question (72%) stated that it was too expensive to browse the Internet using their mobile phones, 12% of the participants claimed that they did not have web-enabled phones, 6% of the participants stated that they did not know how to connect to the Internet using their mobile phones, 1% of the participants found it difficult to access the Internet using a mobile phone and 9% of the participants specified the following factors: inconsistent network coverage (network problems), limited availability of the UNAM Wi-Fi network around campus, busy daily schedules, very slow Internet connections on participants' mobile phones and mobile phones in poor condition.

Participants were asked to select the number of years they had owned mobile phones, and to state the number of years they had used them, whether their own mobile phone or someone else's. Only one participant omitted to answer this question. It was found that 48% of the participants who answered this question had their own mobile phones for 0-5 years. Although this category included zero years, the participants also indicated that they all had their own mobile phones, so this can be interpreted as less than 5 years. It was also found that 42% of the participants had their own mobile phones for 6-10 years and 10% of the participants had their own mobile phones for over ten years.

In terms of the number of years that participants had been making use of mobile phones it was found that 34% of those who answered had 1-5 years of experience using mobile phones, 50% had 6-10 years of experience using mobile phones and 16% had over ten years of experience using mobile phones. Three participants (n=98) omitted to answer this question. From these results, we could see that students enrolled for the basic mathematics on "slow-mode" course at UNAM were accustomed to using mobile devices, thus training participants to use mobile phones to access the M-learning system was deemed unnecessary. Participants could then focus on learning the course content instead of learning how to use the device.

Participants were also asked to state the amount of money they spent on data per week. Results are shown in Figure 4.4. Of the 93% who answered, 4% did not specify the amount of money they spent on data per week. The least amount of money (11%) participants spent on data per week was N$1-5 (Namibian Dollars), and the highest amount of money (14%) participants spent on data per week was above N$30-00. It was also found that the biggest sub-group of the participants (21%) spent around N$6-10 per week, while 11% of the participants did not know how much they spent on data per week.

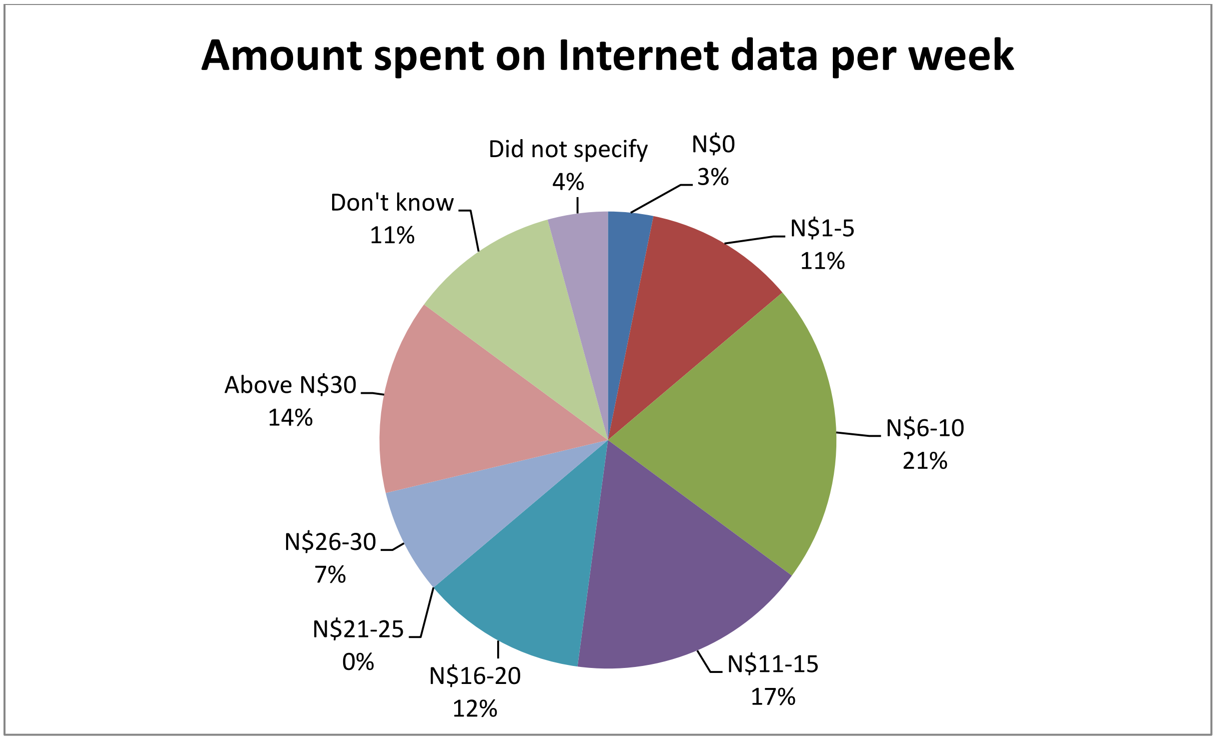


Figure 4.4: Amount of Namibian dollars spent on Internet data per week by first- year basic mathematics students at UNAM

In Namibia, there are two mobile telecommunication operators: Mobile Telecommunication Company (MTC) and CellOne. Each company's data price differs depending on the amount of data purchased. The cheapest data bundle at both mobile companies can be purchased for N$30-00. The cost of one megabyte (out of bundle rate) at MTC is N$0.46 (MTC, n.d.) and N$0.60 at CellOne (LEO, n.d.). The out of bundle rate was used because only 14% of the participants spent above N$30-00 per week and the rest of the participants indicated that they spent less than N$30-00 per week. The amount of Namibian dollars spent by the participants was converted into Internet data, as shown in Table 4.1.

Table 4.1: Out of bundle data spent by the participants

	CellOne	MTC
N$5-N$10	8.35MB-16.7MB	10.85MB-21.7MB
N$11-N$15	18.37MB-25.05MB	23.87MB-32.55MB
N$16-N$20	26.72MB-33.4MB	34.7MB-43.4MB
N$21-N$25	35.07MB-41.75MB	45.57MB-54.25MB
N$26-N$30	43.42MB-50.1MB	56.45MB-65.1MB

Depending on the network used by the participants, it was found that the lowest amount of Internet data spent by participants per week was between 8.35MB-16.7MB at CellOne and 10.85MB-21.7MB at

MTC, while the highest amount of Internet data spent by participants per week was 43.42MB-50.1MB at CellOne and 56.45MB-65.1 MB at MTC.

4.2.2 Usage of Computers

This section of the pre-intervention questionnaire concentrated on the participants' usage of computers. It was found that 64% of the participants owned their own computer, and 91% used computers prior to commencing their university studies. Participants were asked to state where they used computers for the first time. Of the 95 who answered, it was found that 37% used computers for the first time at home, 23% used computers for the first time in primary school, 25% used computers for the first time in secondary school, 13% used computers for the first time at university and 2% used computers for the first time at work.

Participants were also asked whether they used the university's computers. Of the 99 participants who answered, 92% used the university's computers. Of the 92% who used university computers, it was found that 18% used computers from the computer laboratories, 42% used computers from the library, 36% used computers both from the computer labs and the library, and 4% used computers everywhere around campus.

At UNAM, students who do not meet the computer skill requirements of the university must enrol for computer literacy either in the first or second semester of their first year. Of the 101 participants, two participants did not indicate when they registered for computer literacy; neither did they indicate whether they were exempted from the course. Of the 99 who answered this question, 72% registered for computer literacy in the first semester, 16% registered for computer literacy in the second semester and 12% were exempted from the computer literacy course.

Participants were also asked to estimate the amount of time they spent using the university's computers. Results are shown in Figure 4.5. Of 101 participants, 93 answered this question. It was found that most (53%) used the university's computers for less than an hour on various week days, and the fewest (5%) used computers for more than 5 hours on various week days.

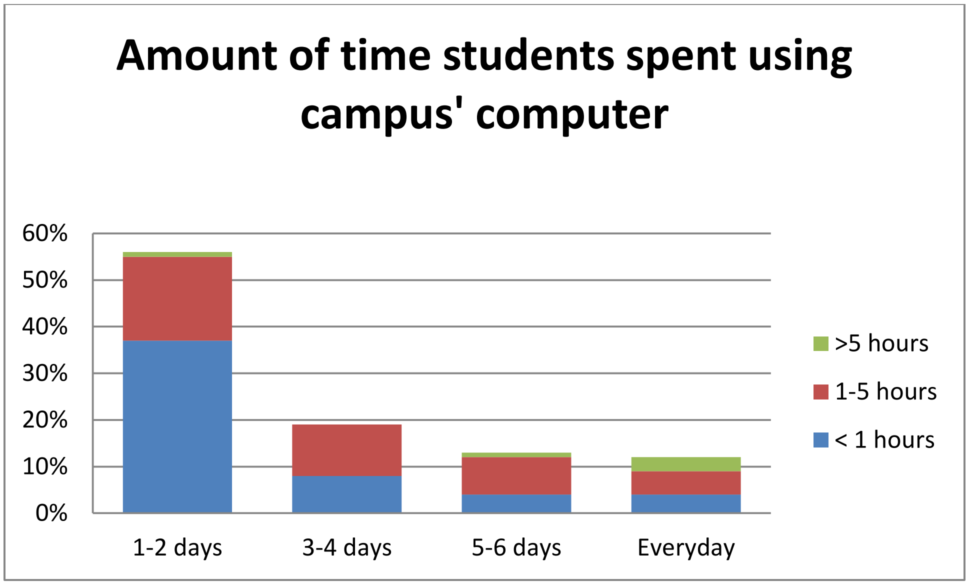


Figure 4.5: The amount of time students spent using the computers available on UNAM campus

As shown in Figure 4.5, it was found that 37% of the participants used computers for 1-2 days per week for less than an hour, 8% used computers for 3-4 days per week for less than an hour, 4% used computers for 5-6 days per week for less than an hour, and 4% used computers every day of the week for less than an hour. It was also found that 18% of the participants used computers for 1-2 days per week for 1-5 hour per day, 11% used computers 3-4 days per week 1-5 hour per day, 8% used computers for 5-6 days per week for 1-5 an hour per day, and 5% used computers every day for 1-5 hours per day. It was also found that 1% used computers for 1-2 days per week for more than 5 hours, 1% used computers 5-6 days per week for more than 5 hours per days and 3% used computers every day for more than five hours.

Participants were also asked whether they were aware of the UNAM E-learning system. Of 101 students, 5 omitted to answer this question. It was found that 68% of those who answered had not used the UNAM E-learning system. Those participants (68%) were asked to state whether they were aware of the UNAM E-learning system, and 39% answered the question. Of the 39% it was found that 29% were not aware of the E-learning system. A follow up was done to clarify these surprising results and it appears that the students confused or did not understand the term E-learning, as the UNAM E-learning system is referred to as the UNAM portal. Of the participants (32%) who did use the UNAM E-learning system, they were asked the amount of time they spent using the UNAM E-learning system. It was found that most (55%) who used the E-learning system used it for less than an hour for 1-2 days per week, and the least (5%) of the participants used the E-learning system for less than an hour 5- 6 days per week day.

Participants were also asked whether they used the UNAM wireless network with their personal computers. Of 101 participants, it was found that 54% used the UNAM wireless network. Of those, the biggest sub-group (35%) used the UNAM wireless Internet for less than an hour for 1-2 days per week, and the least number of participants (2%) used the UNAM wireless Internet for less than an hour 5- 6 days per week day.

One of the project's objectives was to ascertain whether it is possible to implement an M-learning system, complimenting the E-learning system at UNAM. To achieve this, participants were asked whether they would use an M-learning system if it was available for all the courses they were taking. Of 101 participants, 94 answered the question, and 90% of those stated that they would use the M-learning system if it was available. Participants were then asked to state which courses they wished to have incorporated into the M-learning system (72% of the 101 participants answered this question). Figure 4.6lists the courses that the participants suggested to be incorporated into the EnjoyMath system.

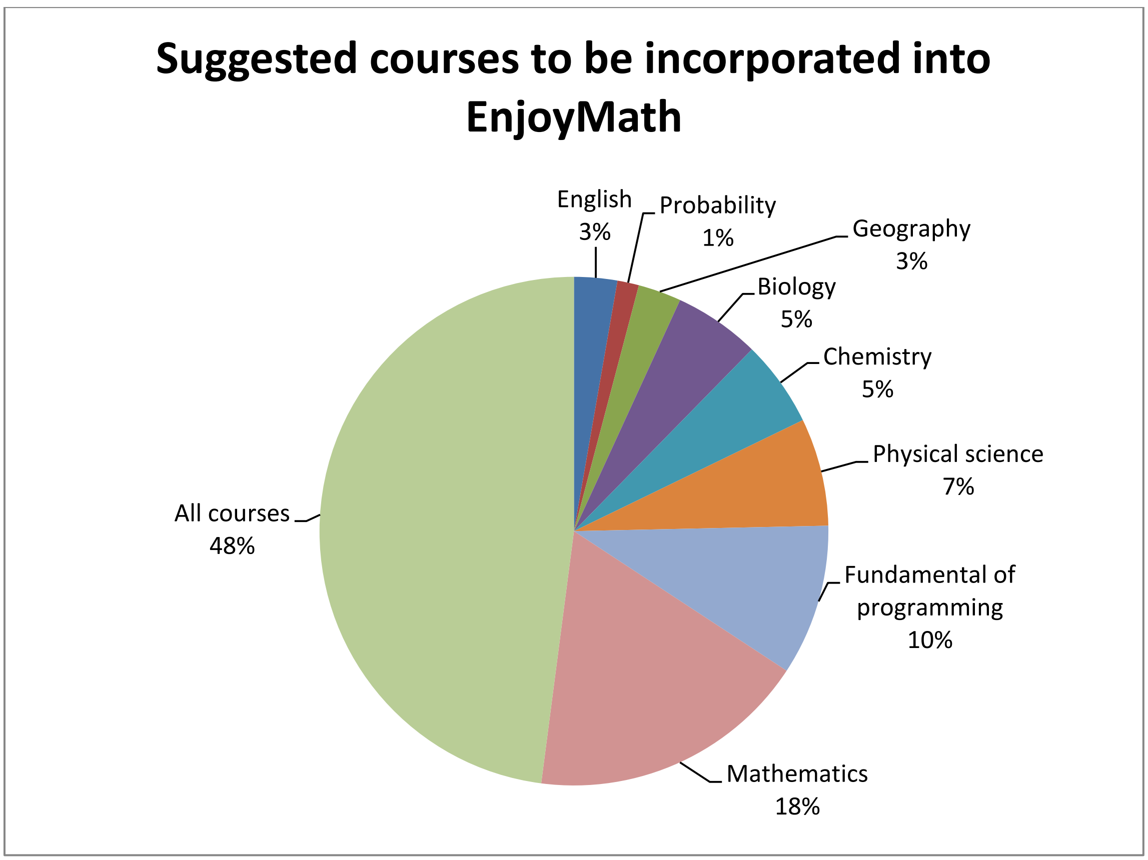


Figure 4.6: Courses that the participants suggested to be incorporated into the M-learning system

The biggest sub-group of the (48%) participants who answered suggested that the M-learning system should incorporate all courses offered at UNAM. This was followed by the suggestion of Mathematics, which was suggested by 18% of the participants. In addition, 10% suggested fundamentals of programming, 7% suggested Physical Science, 5% suggested Chemistry, 5% suggested Biology and 3% suggested both Geography and English to be incorporated into the M-learning system. Probability was the least (1%) suggested of the courses to be incorporated into the M-learning system.

In addition to the subjects suggested by the participants for incorporation into the M-learning system, participants also stated the courses they did not want to have incorporated into the M-learning system. Only 33% of the 72% of participants who answered the previous question indicated the subjects they did not wish to be incorporated into the M-learning system. The biggest sub-group of participants (29%) listed Mathematics. Figure 4.7shows the courses that should not be incorporated into the M-learning system, as suggested by the participants.

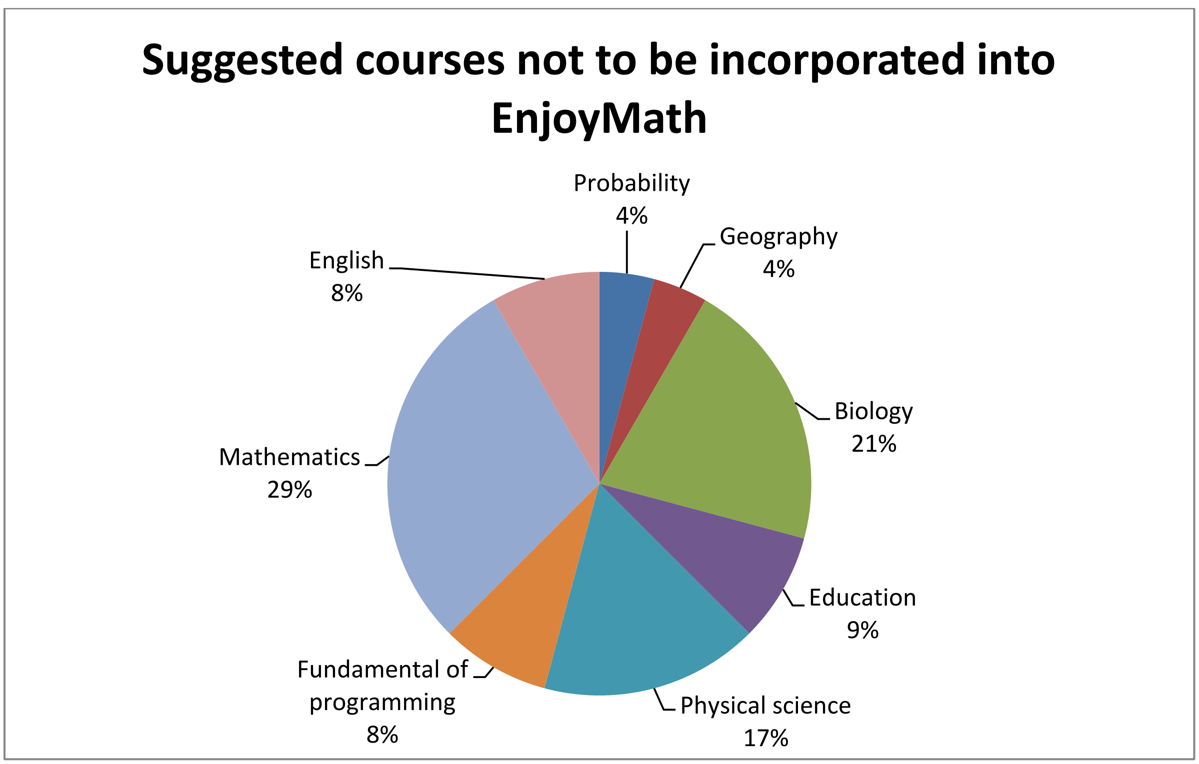


Figure 4.7: Courses that the participants suggested should not be included for integration into the M-learning system

Participants were then asked to write down reasons why certain subjects should or should not be incorporated into the M-learning system. One of the participants was quoted saying: "*Mathematics is a practical course and needs further explanation; I think M-learning will work more for theoretical courses* *such as biology*". This statement was contradicted by another student who said: "*I would like Mathematics to be incorporated into the M-learning system as it have numbers and subjects like biology has too much theory. Hence, it will be very difficult to read those theories on a mobile phone screen*".

Participants (10%) who stated that they would not use the M-learning system provided reasons such as mobile phones' small features (e.g. screen sizes, keyboards) and lack of advanced computing capabilities on mobile phones. One of the participants was quoted saying: "*mobile phones screens are small and barely big enough to scroll readable text, secondly, phones don't allow follow in-depth academic activities such as reading, drawing for visual art and deep calculations for maths*". Lastly, participants were asked to give their contact details if they wished to participate in the second series (evaluation study) of the study, and 78% agreed to participate in the second series of the study.

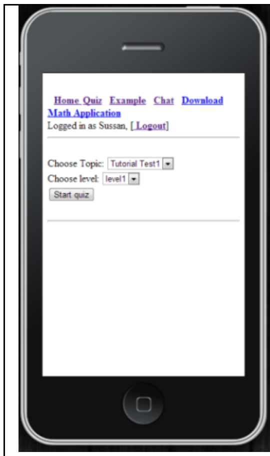
4.3 Post-intervention study

The results obtained in the post-intervention study are discussed in this section. The post-intervention study aimed at ascertaining the mobile phones used by the participants to access the EnjoyMath system and the perceived ease-of-use (users' satisfaction) of the system. In addition, factors that prevented the participants from accessing the EnjoyMath system were investigated. Although 78% of the UNAM students who participated in the pre-intervention study stated that they would participate in the post-intervention study, only 29% of the 78% actually participated when the post intervention study commenced.

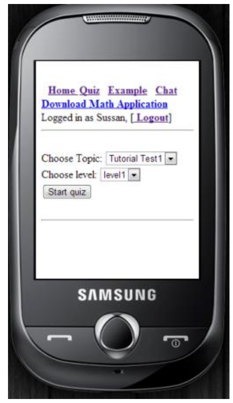
4.3.1 Participants' mobile phone models

To ascertain the mobile phones used to access the EnjoyMath system, participants were asked to state the make and model of the mobile phones they used to access the M-learning system. This was important to know in order to improve on the user interface in case the participants had problems accessing or viewing the EnjoyMath system. Of the 23 participants, only 14 listed the mobile phones they used to access the M-learning system. This was because the four tutors used desktop computers to access the system and the five other participants did not use the system. Participants used different mobile phones, with screen sizes ranging from 240x320 to 320x480. Table 4.2shows the M-learning system displayed on the smallest and the biggest mobile phone screen sizes used to access the system.

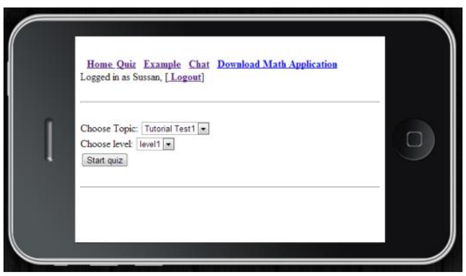
Table 4.2: Enjoy Math's Quiz interface displayed on different Screen Sizes



a) Screen Size: 320x480



b) Screen Size: 240x320



c) Screen Size: 480x320

d) Screen Size: 320x240

4.3.2 System usability

One of the factors ascertained during the post-intervention study was the usability of the system. As stated earlier, usability of the system measures the perceived ease-of-use (ascertaining whether the designed system was: learnable, efficient, memorable, had a low error rate or easily recovered from errors, and was satisfying (Hackos& Nielsen, 1993)). As stated in Chapter 3, the SUS questionnaire was used to measure the overall performance of the system. For a detailed description of the SUS questionnaire, refer to Section2.5.4 The SUS questionnaire was adopted as it was identified to be a quick way of measuring the overall usability of a system (Lewis &Sauro, 2009). Statements in the SUS questionnaire cover aspects such as the need for support, training and complexity of use (Chan et al., 2011). Moreover, the SUS questionnaire was found to be the best at revealing the usability of a system compared to other usability questionnaires in previous research studies investigated in the literature (Tullis& Stetson, 2004).

Participants were asked to complete the SUS questionnaire, which consists of Likert scale type questions with five options ranging from strongly disagree to strongly agree (1=strongly disagree, 2= disagree 3=neutral, 4=agree and 5=strongly agree). The mean and the standard deviation of each statement were calculated and are shown in **Error! Reference source not found.**. Statement 1 ("I think that I would like to use this system frequently.") received the highest mean of all responses with a mean score of 4.56. A mean of 4.56, which is nearly 5, implies that on average, the participants strongly agreed that they would use the EnjoyMath system frequently. In contrast, statement 2 ("I found the system unnecessarily complex.") received the lowest mean with a score of 1.44. A mean of 1.44 implies that on average, participants strongly disagree that the EnjoyMath was unnecessarily complex.

Table 4.4: SUS statements and the mean and standard deviation

SUS statement	Mean	Standard deviation
1. I think that I would like to use this system frequently.	4.56	0.70
2. I found the system unnecessarily complex.	1.44	0.86
3. I thought the system was easy to use.	4.11	0.96
4. I think that I would need the support of a technical person to be able to use this system.	2.39	1.61
5. I found the various functions in this system were well integrated.	4.11	1.08
6. I thought there was too much inconsistency in this system.	1.83	0.79
7. I would imagine that most people would learn to use this system very quickly.	4.11	1.23
8. I found the system very Awkward to use.	2.56	1.65
9. I felt very confident using the system.	4.33	0.69
10. I needed to learn a lot of things before I could get going with this system	2.61	1.58

Data derived from the questionnaire were grouped and are shown in Figure 4.8. It can be seen that the participants tended to strongly agreed with positively worded items and strongly disagreed with negatively worded items. Based on these results, it can be inferred that the participants were satisfied with the developed M-learning system.

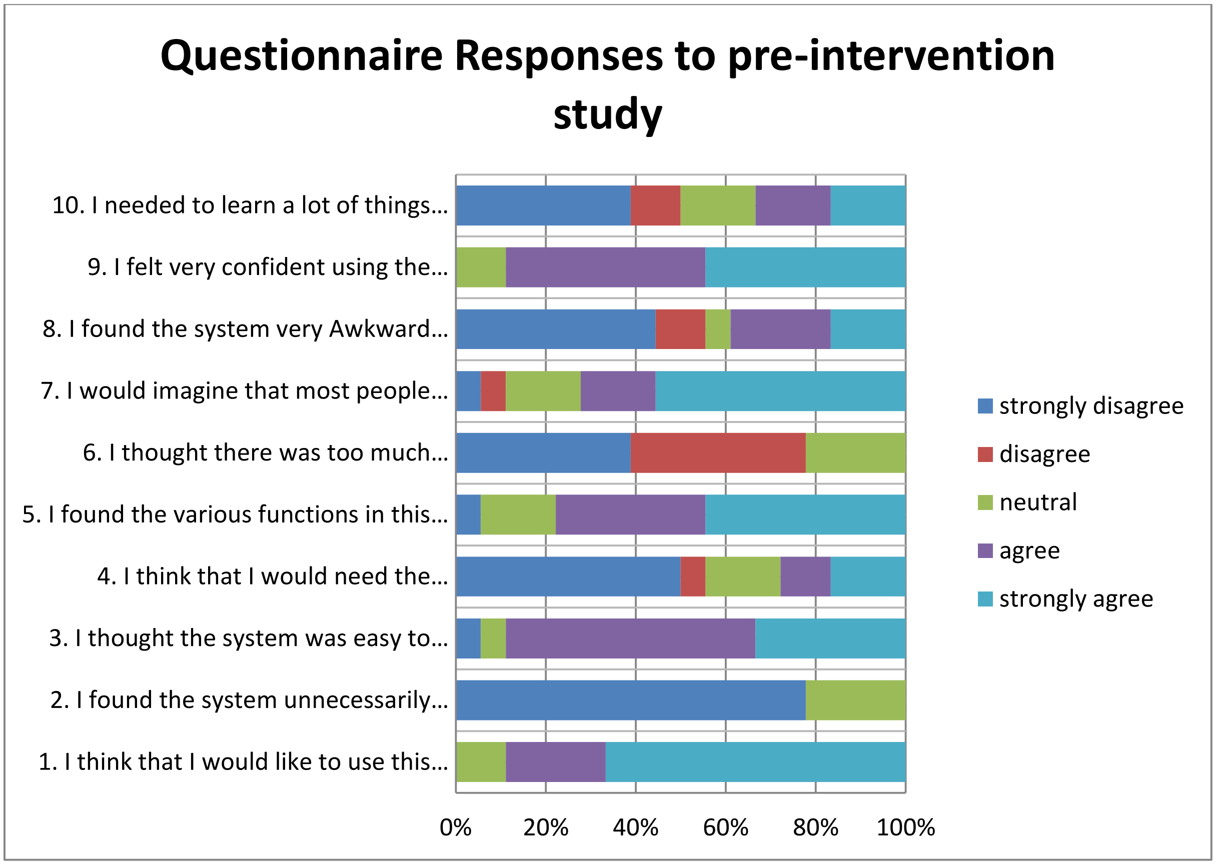


Figure 4.8: Mean of the responses from the post intervention study

The SUS scores of the participants were calculated and can be found in Appendix G. The SUS score of the participants were then used to calculate the mean SUS score. The mean SUS score was used to conclude whether the EnjoyMath system was usable or not. As recommended by Lewis and Sauro(2009) all questions omitted by the participants were given three points because 3 is the neutral point Brooke(personal communication, November 14, 2012). This was done to avoid discarding participants' data that had completed most of the SUS items (Brooke, 1996). Brooke(1996, p. 5) stated that "All items should be checked". Thereafter, the marked numbers on each SUS questionnaire were entered into a Microsoft Excel spread sheet to calculate the average SUS score. The score of each statement was obtained by subtracting one from the scale position (scale positon-1) for even-numbered questions (negatively worded items) and subtracting the scale position from 5 (5-scale position) for odd-numbered questions (positively worded items) (Brooke, 1996). The SUS score of each participant was then obtained by multiplying the sum of the statement score contribution by 2.5 (Brooke, 1996). The effect of the 2.5 multiplier is to get a scale ranging from 0 to 100 rather than 0 to 40 Brooke(personal communication, November 14, 2012; Eteokleous&Laouris, 2005). From a psychometric perspective, any action that simply adds a fixed amount to a variable or multiplies it by a fixed amount will result in a value that correlates perfectly with the original value Brooke(personal communication, November 14, 2012;James (personal communication, December 10, 2012) .

For clarity, the steps involved in calculating the SUS score of the first two participants are shown below. The numbers substituted in the formula can be seen in Appendix G.

SUS score of Participant 1:

=((5-1)+(5-1)+(4-1)+(5-1)+(4-1)+(5-1)+(5-1)+(5-5)+(5-1)+(5-1))*2.5

=85

SUS score of Participant 2:

=((5-1)+(5-1)+(4-1)+(5-3)+(4-1)+(5-1)+(3-1)+(5-4)+(4-1)+(5-3))*2.5

=70

Little literature on the SUS mean score’s sufficiency has been published (Smichaels, 2012). However, Bangor, Kortum and Miller (Bangor, Kortum, & Miller, 2008) conducted a comprehensive analysis on products that used the SUS questionnaire. This study provided details on what constituted an acceptable SUS mean score and found that a product with a SUS mean score of less than 50 is considered to be cause for significant concern and is judged to be unacceptable. In addition, a product with a SUS mean score between 50 and 70 is considered to be a candidate for scrutiny and should be improved. A product with a SUS mean score above 70 is considered passable and a true superior product should score better than 90. The method used to interpret the average mean SUS score in this study was adopted from (Bangor et al., 2008).

Figure 4.9shows the SUS score of the participants. It was found that seven participants had a SUS score below 75 and eleven participants had a SUS score of 75 or above. The minimum SUS score of the participants was 55 and the maximum SUS score of the participants was 95. The overall mean SUS score for all participants was 76, indicating that the EnjoyMath system was generally perceived by the participants to be passable.

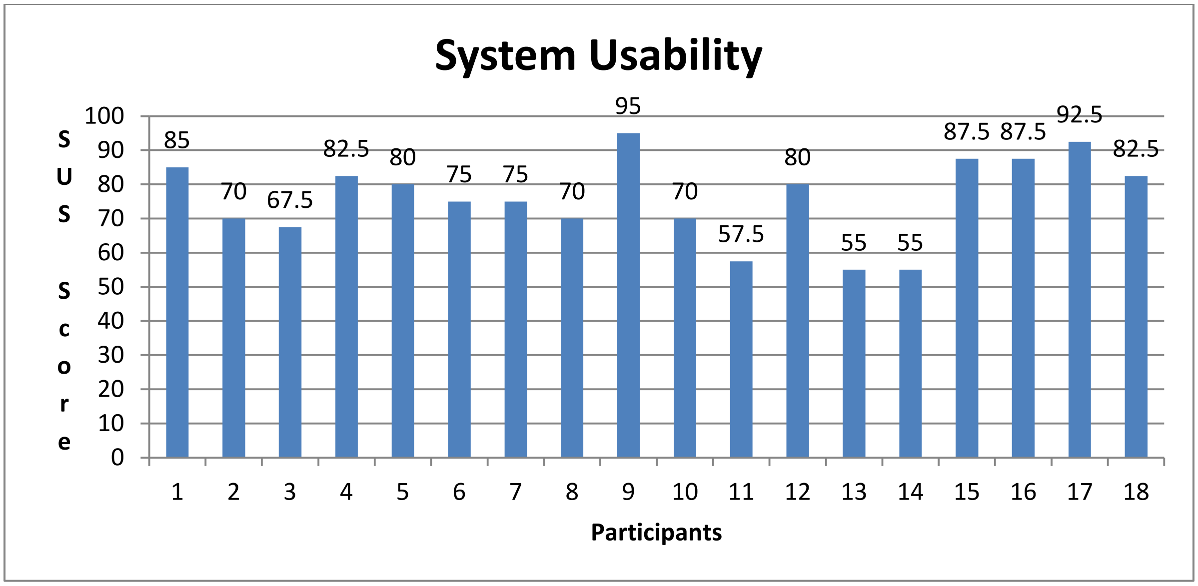


Figure 4.9: Participants' SUS score

4.3.3 Comments and suggestions

Participants were asked to comment and give suggestions about the EnjoyMath system. Four students found the system to be reliable and very easy to learn. One of the students was quoted saying: "*one can learn a lot from the M-learning system. The system is a quick method of learning and reliable and very easy to use*". Three students suggested more subjects be incorporated into the M-learning system. One student suggested an incorporation of learning materials from all the science modules, while another student suggested an incorporation of all the courses offered at UNAM. Moreover, one student suggested that past examination papers should be uploaded on the system and the system should allow students with web-enabled mobile phones to download documents using their mobile phones. Upgrading the system by adding more features and introducing the system to different universities was also suggested by one student. One of the students stated that the system might be helpful to students in developing countries especially during unfavourable conditions such as power failures.

Although the system was found to be passable with an average SUS score of 76, two students stated that the system was difficult to use. One of the participants was quoted saying "*every student should be given training detailing the steps on how to successfully use the M-learning system instead of explaining how to use the system and not demonstrating how the system is used*". Furthermore, one of the students stated that students enrolled for Mathematics should be taught how to use computers in detail before using the M-learning system. Tutors who participated in the post-intervention study were also asked to comment and give suggestions about the EnjoyMath system. One of the tutors suggested that the system should be introduced and advertised more to students as it might be very helpful. Another tutor stated that Internet data is expensive, thus it might be expensive for students to use the system. Another tutor suggested that Mathematics symbols should be represented properly. (S)/He was quoted saying: "*find a way to represent mathematical symbols properly. For example, use 2x2 instead of 2*2 as the use of 2*2 might confuse first year students*". Another tutor suggested an incorporation of complex calculations, for instance, the system should be able to prove mathematical theories.

Participants who did not use the system were asked to state factors that hindered them from accessing the system. Three students of the five were eager to use the system. However, they did not have web-enabled mobile phones at the time the system was implemented at UNAM. One of the participants was quoted saying: "*I was having my Samsung cell phone that is not Internet enabled*". One student was not eager to use a mobile phone to access the EnjoyMath system. This student was quoted saying: "*I don't like accessing the Internet using my mobile phone and I am not keen on using the system*". Lastly, the fifth student stated that (s)/he did not have enough credit to access the system and had a busy schedule.

4.4 Discussion

The purpose of this study was to investigate whether it is viable for first-year students enrolled at UNAM to use mobile phones for ad-hoc learning of mathematical concepts, as a compliment to traditional learning. Chapter 3, together with the previous sections in this chapter, described two studies, and their results, conducted with first-year students (at ESU and UNAM) enrolled for Mathematics. Results from these studies have been combined for further analysis and discussion in this section. This was done to better understand the first-year students' perceptions of M-learning systems. Furthermore, the results from this study were aligned and compared to findings of other M-learning studies. Notably, the findings from the two studies suggested that an M-learning system could be successfully implemented for the ad-hoc learning of Mathematics at UNAM.

Firstly, the results of the use of computers among the students will be discussed, highlighting the level of computer access and computer exposure of the participants. Thereafter, the use of mobile phones among students will be discussed. Lastly, a brief discussion on the post- intervention study will be presented.

My study found that 64% of the participants from UNAM owned their own computers but they had limited Internet access. As a result, the participants were limited in accessing E-learning systems, especially when off campus. It was also found that 91% of the participants had used computers prior to commencing their university studies; however the study found that 88% also registered for computer literacy. The fact that 88% registered for computer literacy simply implied that the participants did not acquire enough computer skills in the past to help them throughout their university careers. Although the participants had computer skills, it was not a guarantee that all the participants would be fluent in using the EnjoyMath system. "Knowledge of ICT skills does not mean that these skills are always applied" (Watson, 2001,p. 255). One participant was quoted saying, "*First year students first have to understand how to use computers for education before employing mobile phones in education. I think it will be easier to use mobile phones for educational purposes once we are fluent in using computer in education*". From these results, it is clear that there were participants who felt that they were hindered by not knowing enough about computers, and that in turn made it even harder for them to learn to use mobile phones for these purposes.

However, there were participants who were eager to use mobile phones in education as one of the participants was quoted saying "*I will use whatever is available that will assist me with my studies*". It was found that all students in the two studies conducted in this research project owned a mobile phone. Since access to E-learning systems was limited due to limited access to the Internet via computers, it was clear that mobile phones could be used to complement computers. In addition, there were participants who felt that they were hindered by not knowing enough about computers and felt that the use of mobile phones would be harder. The user interface of EnjoyMath was therefore designed in a simple and intuitive way, ensuring that non-technical people could use the application.

Numerous studies investigated the use of mobile phones in education and found that M-learning enhances students' learning at the tertiary level (Kalloo& Mohan, 2012; Whattananarong, 2004). In my study, participants showed interest in the developed prototype and 78% were enthusiastic about using new technologies (e.g. mobile phones) in education. This is a common thread found in most M-learning studies, for example in (Holley, n.d.). Participants (78%) in my study suggested that the M-learning materials would enhance students' understanding and assist them with regard to focusing on practicing their skills in Mathematics. These results encourage the use of mobile technology (mobile phones) solutions for learning at UNAM.

M-learning projects are said to be likely to succeed at the tertiary level as most participants in M-learning projects tend to be young people and they are known to embrace new technologies (Prensky, 2001). As stated in the previous sections, the majority of the participants were young: below the age of

26 years (Section3.4.2.1 and 4.2.1). Students at ESU and UNAM are therefore more likely to embrace the use of M-learning systems, like the students from other M-learning studies reported in the literature.

Participants in an M-learning study conducted by (Dyson et al., 2007) were provided with mobile phones to use, and it was found that most students had difficulty learning to use the mobile phones provided in the short period of time. Students should therefore be encouraged to use their own mobile phones because they are more familiar with their own mobile phones and find them simpler to use (Dyson et al., 2007). If students are provided with mobile phones, the mobile environment would be consistent and support the creation of an application tailored for a specific task. However, providing students with mobile phones may require additional time for them to become proficient in their use of the new devices. This would result in a slowing of the learning process as students would focus on learning how to use the mobile phone provided instead of focusing on studying the subject matter addressed through the M-learning system. Participants in my study used their own phones in order to avoid having to learn to use new phones and could thus concentrate on learning the mathematical concepts the system was attempting to assist with.

Other advantages of using the students' own mobile phones were to avoid operational issues like cost, training, support, etc.(Holley, n.d.). This is important for developing countries that are already struggling to provide students with enough computing facilities. Since the students could not be provided with mobile phones, the development platform could not be standardised. Students' mobile phone capabilities were then ascertained to determine the platform to be used to develop the EnjoyMath system. Considering the mobile phones' capabilities has a significant impact on the possible content to be delivered. Technologies chosen for use throughout my M-learning project therefore had to be considered before embarking on the system development due to the wide range of different types of mobile devices, their operating systems, form factors, language runtimes and browser mark-up. As such, the participants' phone capabilities from both studies, as shown in Figure 4.10, were combined and examined to draw conclusions regarding the technologies to be used. From the combined results (Figure 4.10), it can be seen that the majority of participants from the two studies owned Internet-enabled mobile phones. The significance of determining the mobile phone capabilities of the participants was based on the assumption that the sample would provide a representation of the typical handsets (and capabilities of the handsets) available to students from similar socio-economic backgrounds. As a result of the near-ubiquitous ability of the phones to access the Internet the EnjoyMath system was therefore developed as a web application and not an application that ran directly on the phone.

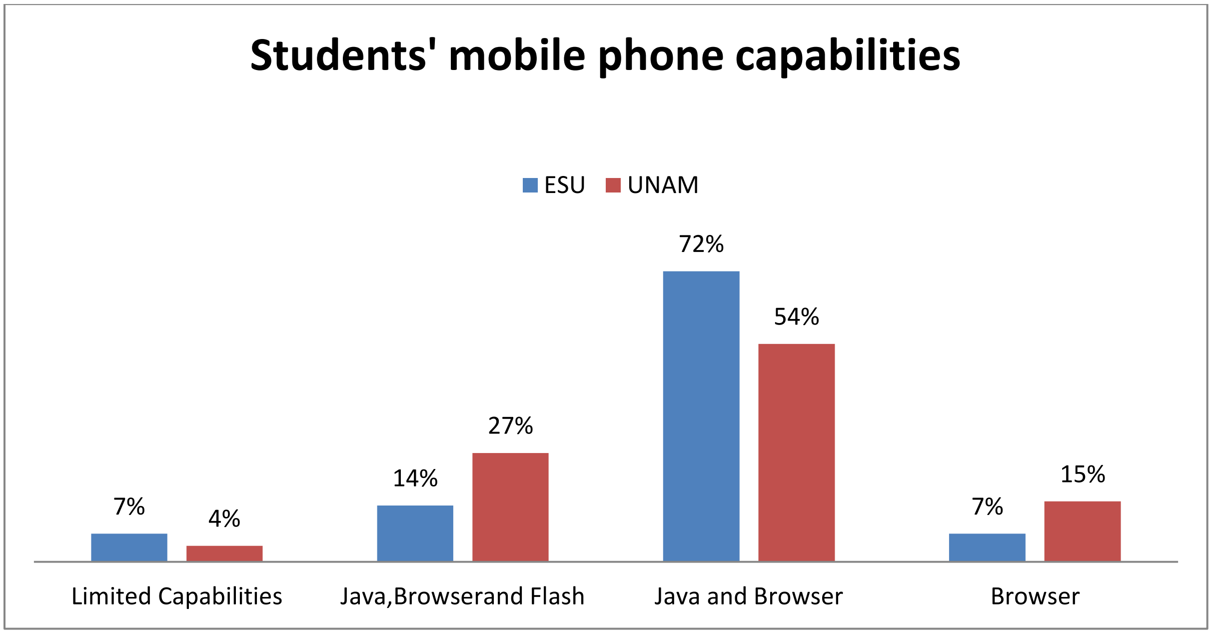


Figure 4.10: Combined students' mobile phone capabilities

Although the majority (96%) of participants could access the EnjoyMath system, a web based M-learning did not completely solve the problem of access to information. At times during the user study, students had to use their own Internet data to connect to the EnjoyMath system instead of using the campus Wi-Fi network because the network could only be accessed from certain locations on campus. Students had to spend their own money to access the system, which dissuaded some students from using the system, even though technically they could do so. Network inconsistency also dissuaded students from accessing the system. Moreover, 4% of the UNAM participants could not access the EnjoyMath system as their phones had limited capabilities (not Internet-enabled).

The EnjoyMath system was tested out of the classroom, aiming specifically to ascertain whether it would assist students in practicing their skills in Mathematics beyond the normal classroom environment. One of the participants suggested that the system should be improved to replace the classroom (i.e. traditional classroom lectures) in case students cannot make it to class. However, this study cannot comment on whether it is possible to use an M-learning system to replace classroom learning, as it is beyond the scope of this project. Motiwalla(2007) however stated that M-learning will never replace classroom learning but can complement and add to the value of the existing conversation theory if leveraged properly. The conversation theory states that learning can only be successful if there are continuous two-way conversations and interactions between the teacher/learner and amongst the learners (Motiwalla, 2007). The EnjoyMath system has the capacity to support this theory, as one of its functions is to allow interaction between the tutors, lecturers and the students.

Results based on the study conducted with the UNAM students also found that the participants had experience using a mobile phone, and the majority (67%) of the participants accessed the Internet using their mobile phones daily (Section4.2). Those students generally had sufficient experience with mobile phones to use them for M-learning, and also they had enough knowledge about using their phones to access the EnjoyMath system.

Quality of use was one of the problems that my study intended to address. Otherwise stated, one of the projects' objectives was to ensure that the system enabled the students to perform the intended tasks. For example, if a step of an equation is omitted, students might find it difficult to understand the equation presented. Information was therefore presented to participants in chunks in order to avoid discarding any information. The mobile phone "small screens mean navigational aids available to users are limited and it might be difficult to have long lines of information that are too large to display effectively" (Whattananarong, 2004, p. 6). Presenting information in small chunks ensured that the information displayed fitted the mobile phones' screens.

Participants were concerned about the potential challenges posed by the small features of mobile phones as some of the participants commented that they did not want to use a mobile phone because they are small and preferred to use a laptop. These participants further stated that they would only use a mobile phone for educational purposes when computers were not available, as it did not make sense to use small screens unless they are left with no other choice, for example when travelling (Ericsson, 2005). As a result, one of the challenges encountered in this study was to avoid too much information being displayed to the user at any given time because of the space constraints of the screen. Regarding the small screen features of the mobile phones, this was not unique to my study as these results are similar to the findings in a study conducted by the Ericsson sub-project (Ericsson, 2005). Other mutually limiting factors highlighted by the participants in both the studies at UNAM and ESU were: inconsistent network coverage, network problems, busy daily schedules and very slow Internet connections on participants' mobile phones. Despite all those limiting factors, students used the system without any practical assistance, thus my system was found to be easy to learn.

Although it was found that more attention needed to be given to Mathematics students at UNAM, as they experienced a 78% failure rate in Mathematics during 2011, participants indicated that they needed help with all the courses they were enrolled for at UNAM. As such, the largest sub-group (48%) of the participants indicated that they wanted all the courses offered at UNAM to be incorporated into the EnjoyMath system (refer to Figure 4.6). At the time of the study this was not possible, due to time constraints. Of the individual subjects listed for incorporation in the EnjoyMath system, Mathematics was at the top of the list. This survey supported the understanding that students experienced difficulties in studying Mathematics at UNAM.

My study could not determine whether the M-learning system improved the students' overall results in Mathematics as the M-learning system was implemented for only a short period of time, therefore no conclusion could be made in this regard. It is also hard to correlate changes in Mathematics performance directly to a particular intervention. That said, the general positive response to using the system could indicate increased practice and support of mathematical concepts for the participants, which would hopefully result in an improved mathematical ability in the future. This study however looked at basic mathematics only, thus the conclusion from the results of this study should not be related to other subjects as it may not benefit students enrolled for different subjects, or may not benefit students at different universities enrolled for Mathematics.

In this project, participants who took part in the post-intervention study indicated that an M-learning system is viable. This was based on the results obtained via the SUS questionnaire. Although the results obtained from the SUS questionnaire did not provide insight into where to focus improvements to the system, the score of the SUS questionnaire provided feedback on whether the EnjoyMath system was usable. This system was found to be passable with a SUS score of 76. This project did not reveal any negative effects in the use of mobile phones in education. Therefore, mobile phones could be used as a technology for educational reform and to increase access to educational material.

4.5 Summary

This chapter discussed the results obtained from the pre-intervention and post-intervention studies conducted among the first-year students enrolled for basic mathematics on "slow mode" and the mathematics tutors at UNAM, together with the results of the ESU study presented in Chapter 3. The participants' perspectives and suggestions on the developed EnjoyMath system were obtained. Based on the results obtained from the participants by means of the SUS questionnaire implemented at

UNAM, the EnjoyMath system was found to be usable, with an average mean SUS score of 76. This score indicated that the system was passable. From the studies reported in Chapters 3 and 4, it is clear that an M-learning system could be used to compliment an E-learning system at UNAM. The next chapter presents possible future work that could be conducted in this area of study, and concludes the research study.

Chapter 5. **Conclusion and Future Work**

5.1 Summary

This thesis described a preliminary investigation into the feasibility of an M-learning system for the ad-hoc learning of mathematical concepts by first-year students at UNAM. Students' perceptions regarding the use of ICTs (mobile phones and computers) in education were also assessed. Furthermore, the thesis investigated whether an M-learning system that caters for different mobile phone types could be developed, and how it could be used to provide students with mathematics learning materials regardless of time and location. The conclusion of this study, a brief summary of each chapter, a review of the objectives of the study and suggestions for future work are presented in this chapter. Specifically, the study answered questions regarding the students' perceptions of the use of ICTs (mobile phones and computers) in education, issues pertaining to the use of M-learning systems, the development and implementation of an M-learning system that caters for different mobile phones types and the students' perceptions regarding the developed M-learning system, titled EnjoyMath.

The failure rate among mathematics students, the abundance of mobile phones amongst students at UNAM and the advancement in mobile technologies were the motivators for exploring the use of mobile phones amongst the first year students enrolled for Mathematics at UNAM. As stated in Chapter 1, it was found that UNAM experienced a 75% failure rate in the Mathematics courses (Academics without Borders,Canada, 2011). The cause for this failure rate was the poor background in Mathematics of students in Namibia (Academics without Borders, Canada, 2011). As a result, tertiary institutions in Namibia are faced with many challenges when teaching Mathematics.

Across all the studies explored in Chapter 2, it was found that the advancement in mobile phone capabilities made it possible for mobile phones to be used in education. It was also found that access to computing facilities is limited in developing countries, including Namibia, and Internet access is limited at homes. Introducing an M-learning system could therefore benefit the majority of students as those with Internet-enabled mobile phones will be able to access learning materials off campus. In Chapter 2, various prototyping tools were also examined, and Flowella was chosen to develop the horizontal prototype application which was used by the researcher to demonstrate the initial design of the EnjoyMath system.

As discussed in Chapter 2, Woodill(2011) categorised Learning Management Systems (LMS) with regard to their use, namely: LMSs not ready for mobile learning; LMSs graphically redesigned for mobile devices; mobile extensions (“plugins”) for an existing LMS; stand-alone, self-sufficient mobile LMSs; and innovative mobile LMSs that use some of the new affordances of mobile devices such as location or cloud computing. This thesis is concerned with the self-sufficient mobile LMS category because the EnjoyMath system manages the learning materials on its own without reference to an existing M-learning system.

Chapter 3 addressed the system design and implementation of the EnjoyMath system through the use of the HCD methodology, striving to ensure that the developed system was usable. For that reason, usability attributes, namely learnability, efficiency, memorability, low error rate or easy error recovery, and satisfaction (Hackos& Nielsen, 1993) were considered in this study. The HCD methodology was followed throughout this project, and involved two revolutions of the method. The first prototype developed, using screen mock-ups, was done using Flowella and deployed on a Nokia N97. The second prototype developed used PHP, JavaScript and MySQL and was deployed for a variety of student mobile phone types. The programming language used to develop the EnjoyMath system was chosen based on the user study conducted at ESU (in Section3.4.2.4), and was later confirmed in the second user study at UNAM (in Section4.2.1). A convenience sampling method was used in this study, and a web-based M-learning system was developed based on the majority of the participants’ mobile phone capabilities. The usability testing of EnjoyMath was conducted amongst first- year mathematics students enrolled for basic mathematics on “slow mode” at UNAM. A user study was conducted post-system deployment to evaluate the system and incorporate suggestions from the user study for the final EnjoyMath prototype.

Chapter 3 and 4 presented the user studies (with participants from ESU and UNAM). Findings from the user studies aimed at soliciting requirements for an M-learning system. Based on the results from the study, it was found that all students owned a phone, with most students already able to use their phones for data-based services such as connecting to the Internet. The results from the two studies combined also found that 86% of the participants were accustomed to accessing the Internet using their mobile phones. This was important as it showed that the majority of first-year students were familiar with using their phones to access the Internet. When asked if they would be interested in using an M-learning system, 93% responded positively.

This thesis has demonstrated that there is a need in developing countries and more especially in Namibia to develop mobile applications that will assist tertiary students to practice their mathematical skills regardless of time and location. It has shown that mobile phones can be considered a viable technology to use, especially when computers are not available. It is important to note that this thesis is not promoting M-learning as a replacement for traditional learning, but as a tool to complement it. The findings from this study notably suggested that an M-learning system could be successfully implemented for the ad-hoc learning of Mathematics at tertiary institutions. The EnjoyMath system was found to be usable with a mean SUS score of 76, implying that the system was perceived as passable by the participants. This project did not reveal any negative effects in the use of mobile phones in education. Six research sub-questions were proposed for investigation in this thesis and these research questions will each be address briefly in the subsequent sections.

5.2 Levels of access to and use of computers among UNAM first year students

The first research sub-question aimed at assessing the levels of access to and use of computers among the UNAM first year students. It was found that 64% of the participants owned computers and 91% had used computers prior to commencing university. However, only 12% met the requirements of the university's computer literacy level, as only those students were exempted from the computer literacy course. Hence it was found that in general the participants' computer skills were poor. It was found that 18% of the 92 participants (who stated their use of computers) used computers housed in the computer laboratories, 42% used computers housed in the library, 36% used computers housed in both the computer labs and the library, and 4% used computers located everywhere around campus. Students at UNAM have access to the UNAM E-learning system although 29% stated that they were not aware of the E-learning system. After a follow up was conducted to clarify this surprising result, it appeared that the students confused or did not understand the term "E-learning" as the UNAM E-learning system is referred to as the "UNAM portal".

5.3 Levels of access to and use of mobile phones among UNAM first year students

The second research sub-question aimed at assessing the levels of access to and use of mobile phones among the UNAM first year students. It was found that all students had mobile phones and 6% of the participants owned more than one mobile phone. Participants from UNAM were also found to have experience using mobile devices; all the participants had at least a year of experience using mobile devices. Furthermore, it was found that 92% had used their mobile phone to access the Internet. Based on these results, it appeared that the students did not require training in the use of mobile phones; students were familiar with the use of mobile phones prior to commencing their university careers.

5.4 Challenges and benefits of using mobile phones amongst first year students at UNAM

The third research sub-question aimed at ascertaining the challenges and benefits suggested and experienced by the UNAM first year students. Participants listed the following challenges to using their mobile phones for the ad-hoc learning of mathematical concepts: the small features of mobile phones (such as small screen size); high cost of data; limited knowledge of accessing the Internet using mobile phones (even though 92% of participants initially claimed having used their phones to access the Internet); inconsistent network coverage (network problems); busy daily schedules; very slow Internet connections on participants' mobile phones; and mobile phones in poor condition. Participants identified the following benefits of using mobile phones in education: "anytime" and "anywhere" access to learning materials off campus, the affordance of practicing their skills in Mathematics and the ability to access learning materials in unfavourable conditions e.g., during a power failure.

5.5 Ascertain whether an M-learning system can be implemented, complementing the E-learning system at UNAM

The fourth research sub-question aimed at ascertaining whether it is possible to implement an M-learning system that complements the E-learning system at UNAM. Of the 94 participants who answered this question, 90% stated that they would use the M-learning system if it was available. The biggest sub-group of participants (48%) suggested that the M-learning system should be incorporated in all courses offered at UNAM. Thus a significant number of participants were in favour of a system for all courses.

The prototype demonstrated that it is possible to implement an M-learning system for use by students at UNAM. UNAM currently has an E-learning system, used to support current courses offered by the university including all Mathematics courses. This prototype was used in conjunction with the E-learning system by first year students and tutors to further compliment learning.

5.6 Technologies to be used to develop an M-learning system that is accessible by the majority of the UNAM first year students

The fifth research sub-question aimed at ascertaining the technologies that should be used to develop an M-learning system that would cater for the majority of first year students at UNAM. After surveying the participants' mobile phones capabilities, it was found that 96% had Internet-enabled mobile phones. As such, the decision was made to develop a web-based application rather than a series of mobile apps specific to various handsets. Therefore, HTML, JavaScript, PHP and MySQL were used to develop the EnjoyMath system in client server architecture.

5.7 Students' perceptions regarding the usability of the developed system

The sixth research sub-question aimed at ascertaining the students' perceptions regarding the usability of the EnjoyMath system. In general participants in this study were supportive of M-learning for education. In addition, five attributes of system usability, namely learnability, efficiency, memorability, low error rate or easy error recovery, and satisfaction (Hackos& Nielsen, 1993) were ascertained during this study using the SUS questionnaire. The EnjoyMath system was found to be usable, with a mean SUS score of 76, which implied that the EnjoyMath system was passable.

5.8 Future Work

These recommendations of future work and improvements to the EnjoyMath system are suggested based on the user studies surveyed in the literature and suggestions from the participants in this study. To ascertain whether this M-learning system (EnjoyMath) will improve students' results, support from the lecturer should be encouraged. Active involvement of lecturers will motivate students to use the system. In order to ascertain whether the system has had a positive effect on the overall mathematical understanding of the first year students, the system could be extended to run for a longer period of time so that the students' results obtained during the pre-introduction of the M-learning system could be compared to their results obtained during the post M-learning system introduction. A correlation study between the expenses groups (amount of Namibian dollars spent on Internet data per week) and the type of access technology (wireless network technologies used to connect to the Internet using mobile phones) used by the first year students could be analysed in order to determine the medium which would be most viable for the students. For instance, if the access technology used (e.g. 3G) is expensive, the use of M-learning through that medium would not be a viable solution for first year students. Furthermore, the system could be upgraded by adding more features, for example, upload past examination papers on the system that will allow students with Internet-enabled mobile phones to download documents using their mobile phones. In addition, support for complex calculations, for instance proving mathematical theories, could be incorporated.

Studies could also be conducted with students enrolled for other subject areas and the system could be extended to different universities as it might be helpful to students in other developing countries, especially where access to computers and the associated Internet access are limited. An M-learning system developed using an offline and online architecture could also be investigated as it will allow students to work in conditions when the Internet is not available. Moreover, different approaches catering for numerous mobile phone platforms could be considered in order to cater for those students with limited or no Internet access via their phones. This would be achieved by developing native applications that run directly on the mobile phone, supplementing the web-based system.

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Appendices

Appendix A. M-learning Questionaire1

How old are you?

Do you own a mobile phone?

Yes No

If you answered yes to the previous question, how many years have you had your own mobile phone?

How many years have you been using a mobile phone? (Note: it doesn't have to have been your own phone):

What is the make and model of your mobile phone (Nokia 5230, Samsung D900)? If you own more than one mobile phone, please write down the make of the handset that you use the most

Do you use the internet on your mobile to look up for information while in transit?

Yes No

What is it that limits the amount of time you spend browsing the Internet on your mobile phone?

Too expensive Phone do not support it don't know how to set it up

Difficult to use Other, specify?

Do you download applications using your mobile phone?

If an m-learning system was available, would you use the system that would help you to study for your courses?

Yes No

Please explain your answer to the previous question. Would your answer be the same across all courses that you are taking at ESU (e.g yes for Mathematics but no for Biology)

Thanks for participating. Have a good day

Appendix B. Permission to conduct research at UNAM in the Mathematics Department

Department of Computer Science

Building

Rhodes University

Grahamstown

6140

05 July 2012

Dr Martin Mugochi

Department of Mathematics

Private Bag 13301

Windhoek

9000

Dear Dr Martin Mugochi

RE: Permission to conduct research at UNAM in the Mathematics Department

Maria NdapewaNtinda, an MSc (Computer Science) candidate, is undertaking an investigation into the use of mobile phones in education (mobile learning) as part of her degree. The study aims to investigate the use of mobile phones for ad-hoc learning of mathematical concepts for first year students at the University of Namibia. Specifically, it will investigate if an m-learning system that caters for different mobile phone types could be developed and how it could be used to provide students with Mathematics learning materials regardless of time and location. The study is being supervised by Prof Hannah Thinyane and Ingrid Siebörger of the Computer Science department at Rhodes University.

We would like to interview Mathematics tutors and the first year students enrolled for pre-calculus by means of questionnaires. The study is voluntary and confidential. The study is divided into two phases. In the first phase, questionnaires will be distributed to the students. In addition, an m-learning system will be introduced and discussed. The system is anticipated to be up and running around mid-July to mid-August. Thereafter, the second phase of the study will embark. A second questionnaire will be distributed to the students who wish to participate. The second questionnaire will focus on usability testing. Usability testing is used to measure the performance and quality of the application. In addition, tutors will be interviewed informally and the interview will be recorded. The interview aims at ascertaining the tutors' perception on the m-learning system. Thus, I am requesting permission to conduct my survey and test the m-learning system with the first year students enrolled for pre-calculus.

From this study I hope to gain a better understanding of how m-learning systems could be implemented and whether students are enthusiastic about using an m-learning system. It will hopefully inform future work and hopefully an m-learning system will be implemented for Universities in Namibia and different subjects will be integrated. Further negotiations regarding how and when the research could best proceed will be conducted when I return to Namibia in July.

If you have any further questions about the project, please feel free to e-mail or phone me (Maria Ntinda) or either of the two supervisors, Prof Hannah Thinyane or Ingrid Siebörger. A list of our contact details is attached for your convenience. Thanking you in advance.

Yours sincerely

Maria Ntinda

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Appendix C. Consent Form

Project Title
An M-learning system for ad-hoc learning of mathematical concepts in developing countries

Project Description
The lack of Information and Communication Technology (ICT)-related infrastructure such as computers at some tertiary institutes in Africa makes it difficult for e-learning systems to be utilized. Alternatively, mobile devices have been used at some Universities to compliment computers. As a result, this project aims to ascertain whether it is possible to implement an m-learning system at ESU.

Researcher
Ntinda Maria Ndapewa

- I have received information about this research project.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage.
- I understand that participation in this user study is done on a voluntary basis,
- To the best of my knowledge I have no physical impediments that will prevent me participating in this study.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

Participant's signatureDate

______________________________ ______________________________

I have provided information about the research to the research participant and believe that he/she understands what is involved.

Researcher's signature Date

______________________________ ______________________________

Appendix D. Mobile learning (M-learning) Questionnaire 2

Mobile phones

1. What is your age group (tick ✓ one)?

□ 15-20 □ 21-35 □ 26-30 □ 31-35 □ Over 35

2. How many years have you been using a mobile phone (tick ✓ one)? (Note: it doesn't have to have been your own phone):

□ 0-5 □ 6-10 □ Over 10

3. Do you own a mobile phone (tick ✓ one)?

□ Yes □ No

4. If you answered yes to the previous question, how many years have you had your own mobile phone (tick ✓ one)?

□ 0-5 □ 6-10 □ Over 10

5. What is the make and model of your mobile phone (Nokia 5230, Samsung D900) (tick ✓ one)? If you own more than one mobile phone, please write down the make of the handset that you use the most.

□ Nokia □ Samsung □ Blackberry □ Sony Ericcson

□ Motorola □ Other, please write down your phone model

Please specify your phone model:

6. On average, how often do you use your mobile phone to access the Internet (tick ✓ one)?

□ Daily □ Weekly □ A few times a month □ Very rarely □ Never

7. How do you usually connect to the Internet on your mobile phone (tick ✓ one or more)?

□ Home WiFi □ Campus WiFi □ OfficeWiFi
□ Public Hotspot (WiFi) □ 3G □ Edge
□ Don't know □ Never
□ Others, please specify______________________

8. Where did you use your mobile phone to access the Internet over the last 6 months (tick ✓ one or more)?

□ At Home □ On Campus □ While travelling
□ At the office or work □ Not applicable
□ Other, please specify___________________

9. What is it that limits the amount of time you spend browsing the Internet on your mobile phone (tick ✓ one)?

□ Too expensive □ Phone does not support it □ Don't know how to set it up

□ Difficult to use □ Other, please specify____

10. On average, how much money do you spend on Internet access on your mobile phone per week (tick ✓ one)?

□ N$0 □ N$1-5 □ N$6-10
□ N$11-15 □ N$16-20 □ N$21-25
□ N$26-30 □ Above N$30 □ Don't know

Computers

11. Where did you use a computer for the first time (tick ✓ one)?

□ Home □ Primary School □ Secondary School

□ University □ Other, please specify

12. Do you own a computer (tick ✓ one)?

□ Yes □ No

13. Do you use computers on campus (tick ✓ one)?

□ Yes □ No

If yes, tick where you access the computers from (tick ✓ one)?

□ Computer Laboratory □ Library □ Both

□ other, please specify____

14. Which semester did you register for CLC3509 COMPUTER LITERACY (tick ✓ one)?

□ Semester one □ Semester two □ Exempted from CLC3509

15. If you registered for semester two or Exempted from CLC3509, did you use computers on campus in semester one (tick ✓one)?

□ Yes □ No

16. On average, how many times do you use UNAM's computers to access the Internet (Choose one category that best reflects your daily/weekly/monthly use and the tick ✓one of the hourly options that best reflects your use in that category)?

1-2 day/week 3-4 day/week 5-6 day/week Everyday
□ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day

17. Do you access the UNAM's Wireless Internet using a personal computer (tick ✓one)?

□ Yes □ No

If you answered Yes above, on average, how many times do you access the University's Wireless Internet (Choose one category that best reflects your daily/weekly/monthly use and the tick ✓one of the hourly options that best reflects your use in that category)?

1-2 day/week 3-4 day/week 5-6 day/week Everyday
□ Less than an hour/day

□ 1-5 hours/day

□More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day

18. Do you have access to the UNAM E-learning system (tick ✓one)??

□ Yes □ No

If yes, on average, how many times do you access the UNAM's E-learning system (Choose one category that best reflects your daily/weekly/monthly use and the tick ✓one of the hourly options that best reflects your use in that category)?

(E-learning system is a system allows you to access Web-based training and the training reside on a server or host computer that is connected to the World Wide Web.)

1-2 day/week 3-4 day/week 5-6 day/week Everyday
□ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day □ Less than an hour/day

□ 1-5 hours/day

□ More than 5 hours/day

If no, are you aware of the UNAM E-learning system?

□ Yes □ No

19. If an m-learning system was available, would you use a system that would help you to study for your courses (tick ✓one)?

(M-learning refers to learning that takes place regardless of the learner's location and time via mobile devices, like cellphones, regardless of time and location).

□ Yes □ No

20. Please explain your answer to the previous question. Would your answer be the same across all courses that you are taking at UNAM (e.g. yes for Mathematics but no for Biology)?

21. Thank you for participating in the first series of the m-learning questionnaire. Would you like to participate in the second series (tick ✓ one)?

(The second series consists of questions based on the m-learning system prototype that will run for few weeks on campus)

□ Yes □ No

If yes, please write down your contact details:

Cell phone number: ________________________________

Email address: _____________________________________

Thanks for participating. Good day

Appendix E. Questionnaire 2: M-learning Usability Testing

For each of the following questions, please tick ✓ one

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated
6. I thought the system was too inconsistent.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very awkward to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.
11. Any suggestions and comments on how we could improvement the features of m-learning system?

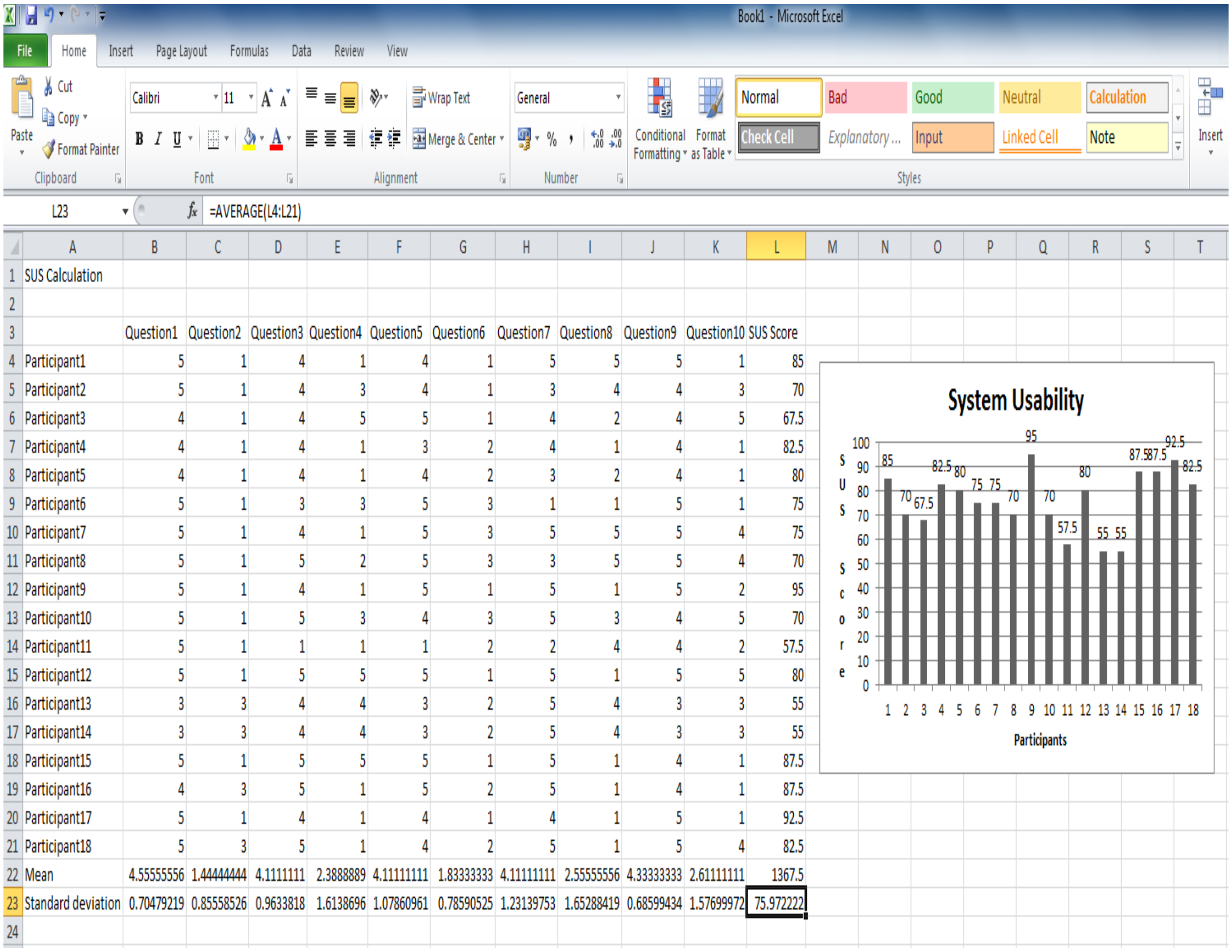
Thanks for participating. Good day

Appendix F. Questionnaire 2: Students who did not use the M-learning System.

Please tell us why you did not use the m-learning system (e.g. limited time, a lot of school work, expensive, etc.)?

Thanks for participating. Good day

Appendix G. SUS Results



	Question1	Question2	Question3	Question4	Question5	Question6	Question7	Question8	Question9	Question10	SUS Score
Participant1	5	1	4	1	4	1	5	5	5	1	85
Participant2	5	1	4	3	4	1	3	4	4	3	70
Participant3	4	1	4	5	5	1	4	2	4	5	67.5
Participant4	4	1	4	1	3	2	4	1	4	1	82.5
Participant5	4	1	4	1	4	2	3	2	4	1	80
Participant6	5	1	3	3	5	3	1	1	5	1	75
Participant7	5	1	4	1	5	3	5	5	5	4	75
Participant8	5	1	5	2	5	3	3	5	5	4	70
Participant9	5	1	4	1	5	1	5	1	5	2	95
Participant10	5	1	5	3	4	3	5	3	4	5	70
Participant11	5	1	1	1	1	2	2	4	4	2	57.5
Participant12	5	1	5	5	5	1	5	1	5	5	80
Participant13	3	3	4	4	3	2	5	4	3	3	55
Participant14	3	3	4	4	3	2	5	4	3	3	55
Participant15	5	1	5	5	5	1	5	1	4	1	87.5
Participant16	4	3	5	1	5	2	5	1	4	1	87.5
Participant17	5	1	4	1	4	1	4	1	5	1	92.5
Participant18	5	3	5	1	4	2	5	1	5	4	82.5
Mean	4.55555556	1.44444444	4.1111111	2.3888889	4.11111111	1.83333333	4.11111111	2.55555556	4.33333333	2.61111111	1367.5
Standard deviation	0.70479219	0.85558526	0.9633818	1.6138696	1.07860961	0.78590525	1.23139753	1.65288419	0.68599434	1.57699972	75.972222