Nelson Mandela Metropolitan University

for tomorrow

Department of Computing Sciences

An Architecture for the Effective Use of Mobile Devices in Supporting Contact Learning

Nemr Methyab Alnseerat

Supervisor: Prof. Jean Greyling

Co-Supervisor: Dr Dieter Vogts

January 2014

Submitted in fulfilment of the requirements for the degree of
Magister Scientiae in the Faculty of Science
at the Nelson Mandela Metropolitan University

Declaration

I, Nemr Alnseerat, hereby declare that the dissertation for the degree Magister Scientiae is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

Nemr Alnseerat

Acknowledgments

I would like to thank my supervisors, Prof Jean Greyling and Dr Dieter Vogts, for their invaluable support, feedback, direction and continuous encouragement throughout this research. This dissertation would not have been possible without their advice and guidance.

I would also like to thank:

- Dr Melisa Koorsse my sincere appreciation for her continuous help and support to shape my interest and ideas.
- My parents, Mathyab and Zena, and my brother Ibrahim, receive my deepest gratitude and love for their dedication that provided the foundation for this work;
- My wife, Natalia Batvenkova, for her support and patience through the past two years;
- Kathryn Bell for her assistance with the usability evaluations;
- Simone Beets for the technical checking of this dissertation;
- My friends, Ahmad Jamal and Bilal Basuni, my greatest appreciation goes to them for their support and encouragement and being great reliable people;
- Dr Hussain Vawda for his attention and care about me.

Lastly, a special word of gratitude to my family and close friends for their support and understanding during the many hours it took to complete this dissertation.

Summary

The features and capacities of mobile devices offer a wide range of significant opportunities for providing learning content in workplaces and educational institutions. This new approach of teaching, called mobile learning, allows for the delivery of learning content on the move at any time. Mobile learning supports learning by producing learning content to learners in a modern and acceptable way. The number of mobile learning applications has increased rapidly in educational environments. There are, however, limited mobile learning applications that take advantage of mobile devices to support contact learning in the classroom environment.

The aim of this research was to design a mobile learning architecture to effectively support contact learning in the classroom. The researcher investigated the historical and theoretical background of mobile learning and reported these findings. This included an overview of existing mobile learning architectures. After identifying their limitations, the researcher designed the Contact Instruction Mobile Learning Architecture (CIMLA) to facilitate the use of mobile devices in the classroom.

The researcher developed the LiveLearning prototype based on the proposed architecture as a proof of concept. He conducted a usability evaluation in order to determine the usability of LiveLearning. The results indicated that the LiveLearning prototype is effective in supporting contact learning in the classroom.

Keywords: Mobile Learning Architecture, Mobile Learning in Classroom, Contact Learning, Mobile Devices, Mobile Technologies, Components of Mobile Learning, Mobile Learning Infrastructure, Mobile Learning Application, Learners’ Mobile Devices, Collaboration.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

NMMU	Nelson Mandela Metropolitan University
UPE	University of Port Elizabeth
PDA	Personal Digital Assistant
IBM	International Business Machines
HTML5	Hyper Text Markup Language
USB	Universal Serial Bus
MLI	Mobile Lecture Interaction
JPG	Photographic Expert Group
GIF	Graphics Interchange Format
WLAN	Wireless Local Area Network
NFC	Near Field Communication
GUI	Graphical User Interface
GPRS	General Packet Radio Service
API	Application Program Interface
mGBL	The Mobile Game-Based Learning
WAP	Wireless Application Protocol
Mbps	Megabits Per Second
MB	Megabyte
CIMLA	Contact Instruction Mobile Learning Architecture
PDF	Portable Document Format
GPS	General Packet Radio Service
PNG	Portable Network Graphics
SQL	Standard Query Language
TCP	Transmission Control Protocol

CIF	Common Industry Format
SUS	Systems Usability Scale

Chapter 1: Introduction

1.1. Background

Nelson Mandela Metropolitan University (NMMU) opened on 1 January 2005 and resulted from the merging of the PE Technikon, the University of Port Elizabeth (UPE) and the Port Elizabeth campus of Vista University (Vista PE). This union of three decidedly different institutions followed the government's countrywide restructuring of higher education, which was intended to deliver a more equitable and efficient system to meet the needs of South Africa in the 21st century (NMMU, 2013a).

NMMU has approximately 2,500 staff members and approximately 25,000 learners. The University draws over 3,000 international learners. Learners at NMMU can study towards attaining diplomas and degrees, which culminate in doctoral level qualifications. A number of courses include workplace experience as part of the curriculum. Therefore, the NMMU learner body consists of different types of learners with different cultural and linguistic backgrounds.

NMMU strives to improve the quality of service offered and to develop a lively atmosphere in which learners can improve their learning experiences and, in turn, improve their quality of education. In April 2008, NMMU identified its vision 2020, which contains strategic directional statements and determines strategic priorities that will secure the long-term sustainability of the institution.

Vision 2020 identifies alternative modes of educational delivery: "NMMU will need to expand and intensify strategies that provide for blended or electronic learning, as well as for part-time lectures offered in the evenings, to cater for flexible modes of learning geared to the needs of a diverse range of learners" (NMMU, 2010). The mobile learning environment can assist electronic learning and deliver learning models to learners anywhere and at any time. This opportunity can potentially bring knowledge to the fingertips of thousands of learners.

The majority of learners have mobile devices, including laptops, smartphones, and tablets, with features such as media content support, Wi-Fi connectivity and internet access. Numerous global organisations and universities are using mobile learning, but NMMU does not have an effective framework that uses smartphones to enhance and improve learning experiences to close the gap between mobile devices, technology and education. This research aimed to address this problem by using NMMU as a case study.

As mobile devices become popular and affordable, the demand for mobility extends to teaching and learning purposes. This demand is a recent and significant change in the learning environment (Sarrab and Elgamel, 2012). The considerable increase in the computational power of mobile devices has gradually made their use a viable option in educational settings (Yang and Lin, 2010). Initially mobiles had simple functions, such as making and receiving calls, as well as sending and receiving text messages. Improved data connections, displays, and memory capacity have made context-aware learning applications feasible (Idrus and Ismail, 2010). These capabilities encourage educational institutions to include mobile devices in mobile learning.

Mobile learning offers opportunities for the optimisation of interaction and communication between lecturers and learners, and among learners themselves (Vinu and Krishnan, 2011). Many schools and universities have introduced mobile learning to support education. Mobile learning can create new opportunities for learning, with ubiquitous connectivity allowing interactive and connected learning at school and university, in the workplace, at home and in the community (Wolf and Rummler, 2011).

The use of mobile learning will play a significant role in realising Vision 2020 by encouraging communication between learners and, at the same time, between learners and lecturers. Mobile learning can encourage the transformation of learners from passive recipients of information to active constructors of knowledge.

1.2. Problem Statement

"Today's learners are no longer the people our educational system was designed to teach" (Prensky, 2001). Access to ubiquitously connected, portable and powerful handheld computers has created the potential to bridge the gap between how teachers teach and whom they teach. Some universities and schools attempt to remove mobile devices from the classroom or demand that learners switch them off during lectures. However, organisations cannot keep technologies away from the traditional classroom, as society has changed. Teachers and educators cannot forever avoid using mobile devices inside the classroom. Instead, they should embrace the use of handheld devices in education and use them as teaching tools. This creates the potential to convert traditional classrooms into modern classrooms that use mobile devices to improve learning. Therefore, many universities worldwide have included mobile learning in education as an aspect of learning. Mobile learning has been extremely limited because of expensive equipment and large numbers of learners required for it to be effective. Current mobile learning models seldom take advantage of the availability of learners' own mobile devices.

To date, NMMU does not have a formal model for using mobile devices to support contact learning on campus, despite the University's infrastructure capacity (wireless, network, server, and internet) to include mobile learning in education. This system does not take advantage of the availability of learners' mobile devices.

This research aims to develop a model for an educational environment using learners' mobile devices to enrich and enhance education on campus.

1.3. Thesis Statement

An architecture can be designed to facilitate the use of mobile devices to support contact learning in the classroom.

1.4. Research Objectives

This study aims to develop a mobile learning architecture for using mobile devices in supporting contact learning at NMMU.

The objectives of this research include:

1. To investigate the environment regarding the use of mobile technologies in education;
2. To propose a mobile learning architecture for the use of mobile devices on campus; and
3. To implement a prototype as proof of concept and evaluate the usability of the prototype.

1.5. Research Questions

This research aims to utilise mobile devices used by learners on campus (including smartphones, Personal Digital Assistant (PDA), laptops, and tablets) for mobile learning. The main research question of this study is:

How can an architecture for mobile learning contribute to support contact learning on campus?

The researcher answers this question by addressing the following sub-questions:

1. Mobile learning as a tool for education

    1.1 What is the historical background to mobile learning?

    1.2 How are mobile devices used in the workplace and in higher education?

2. Existing theory regarding mobile learning

    2.1 Which issues need to be considered regarding mobile learning in the classroom?

    2.2 Which existing mobile learning architectures exist?

3. How can an architecture for mobile contact learning be designed?
4. How can a prototype, as a proof of concept of the designed architecture, be developed that will support mobile contact learning?
5. How usable is the developed prototype in a contact learning environment?

1.6. Research Methodology

Positivist theory holds that social reality is objective because the observer is external from the research (Anne, 2008). Researchers use a scientific approach to generate acceptable knowledge. This philosophy requires the researcher to collect empirical data and facts for the use of quantitative research methods (Kock, 2013). In this study, the researcher used the positivist philosophy by evaluating a prototype as a proof of concept of the proposed architecture. The researcher obtained quantitative data after the evaluation to measure the satisfaction of the prototype.

The research methods below describe the research strategy implemented to address the identified research questions presented in the previous section.

- **Literature Study**

Literature studies provide analyses of existing research relevant to specific research topics (Randolph, 2009). The researcher conducted a literature study to investigate the use of mobile learning locally and internationally, in the workplace as well as in educational institutions. This included an overview of different mechanisms of delivery and different ways of using mobile learning in contact learning. The researcher discussed the advantages and disadvantages of mobile learning, as well as the components of mobile learning in the classroom. He examined several existing mobile learning architectures and determined their functionality. Furthermore, he investigated the characteristics of mobile devices and existing connectivity infrastructure on campus.

- **Design of an Architecture**

A mobile learning architecture must be designed to support specific learning tasks (Gruhn, 2006). Based on the information obtained from the literature study, the researcher designed an architecture to obtain a possible solution for the effective use of mobile devices to support contact learning. This architecture considered issues such as the existing connectivity infrastructure, selection of the most appropriate mobile devices and the incorporation of mobile learning in the contact learning environment.

- **Implementation of Prototype**

One can use a prototype implementation as a research tool to provide a proof of concept (Gil-Garcia, Pardo and Baker, 2007). The researcher developed a prototype based on the proposed architecture as a proof of concept to determine whether one can develop a mobile application that supports the use of mobile technologies in contact learning by using the existing connectivity infrastructure on campus.

- **User Study**

The researcher conducted a usability evaluation to determine the usability of the prototype (Nielsen, 2010). The investigator achieved this by using the prototype within a module in the department of Computing Sciences over a period of 2 to 3 weeks and requesting selected learners to make use of the mobile functionality. The researcher used qualitative and quantitative data to determine the success of the application, using instruments such as focus groups and questionnaires, involving learners as well as the lecturer.

1.7. Scope of Research

Various educational institutions have used mobile devices for learning (Mamat and Azmat, 2013). This research is only focused on the use of mobile devices to effectively support contact learning in the classroom and the researcher designed the mobile learning architecture to facilitate learning in the classroom environment. The implemented prototype is a proof of concept of the proposed mobile learning architecture.

The researcher deployed the prototype on Android mobile devices. As the prototype served as a proof of concept only, the researcher did not extend development to a wide range of platforms.

1.8. Chapter Outline

The dissertation consists of six chapters that address the research questions (Section 1.5). Table 1-1 summarises the chapters and the research questions answered in each.

Table 1-1: Summary of research questions, methods and chapters

Research Question	Research Method	Chapter
1. Mobile learning as a tool for education 1.1 What is the historical background to mobile learning? 1.2 How are mobile devices used in the workplace and in higher education?	Literature Study	Chapter 2
2. Existing theory regarding mobile learning 2.1 Which issues need to be considered regarding mobile Learning in the classroom? 2.2 Which existing mobile learning architectures exist?	Literature Study	Chapter 2
3. How can an architecture for mobile contact learning be designed?	Designing	Chapter 3
4. How can a prototype, as a proof of concept of the designed architecture, be developed that will support mobile contact learning?	Prototyping	Chapter 4
5. How usable is the developed prototype in a contact learning environment?	Experiment	Chapter 5

This chapter introduced the topic of the study, described the purpose of the research, and identified the research problem of the dissertation. The researcher presented the thesis statement, research objectives and research questions before identifying the scope and constraints of the study.

Chapter 2 contains a literature study regarding the history of education and e-learning. The researcher investigated the use of mobile learning applications in the workplace and education and identified components of mobile learning in the classroom. Finally, the investigator discusses various existing mobile learning architectures.

Chapter 3 examines the physical infrastructure of mobile learning. This section includes a description and the results of an experiment that the researcher conducted at NMMU to investigate the actual Wi-Fi coverage and signal quality on campus. In addition, the researcher designed a mobile learning architecture for the use of mobile devices in the classroom.

Chapter 4 discusses the design patterns related to a mobile user interface. The researcher examined several cross-platform mobile learning applications to select a proper platform for the development of the prototype. In addition, the investigator implemented a mobile learning application as a proof of concept of the proposed architecture and conducted a pre-evaluation to assess the prototype and obtain feedback and comments. The researcher refined the prototype to incorporate any changes suggested based on these comments.

Chapter 5 focuses on the evaluation of the prototype. The researcher conducted a user study in a real classroom scenario, which determined the effectiveness and efficiency of the mobile learning system in the classroom environment, as well as user satisfaction.

Chapter 6 concludes the dissertation. The author reviews the research objectives and discusses the research achievements before identifying the theoretical and practical contributions of the study. The chapter closes with a discussion of the limitations of the research and suggestions for future research.

Chapter 2: Background of Mobile Learning

2.1. Introduction

Mobile learning is an important research area in education due to the high number of mobile devices used by learners at educational institutions, as well as the remarkable improvements made to these devices (Rapetti, Picco and Vannini, 2011). This chapter addresses the first and second groups of research questions identified in Chapter 1:

1. Mobile learning as a tool for education

1.1 What is the historical background to mobile learning?

1.2 How are mobile devices used in the workplace and in higher education?

2. Existing theory regarding mobile learning

2.1 Which issues need to be considered regarding mobile learning in the classroom?

2.2 Which existing mobile learning architectures exist?

To gain a comprehensive understanding of using mobile devices as a tool in education, the researcher investigated the history of technology tools used in education in Section 2.2. An overview of the evolution of computers and the emergence of e-learning as a result of using computers in education follows. In addition, the researcher discusses the development of cell phones and mobile devices. In Section 2.3, the researcher identifies the objectives and purposes of using mobile learning in the workplace and educational institutions. Section 2.4 contains a discussion of global and national case studies of mobile learning, while Section 2.5 consists of an investigation of mobile learning components that identifies the role of each component in the classroom. In Section 2.6, the researcher determines general guidelines for applying mobile learning. The researcher discusses several mobile learning architectures to identify their objectives in Section 2.7.

2.2. Background

The following section presents a historical overview of the development of learning, from primitive traditional education methods to modern education and teaching techniques employed in e-learning and mobile learning.

2.2.1. History of Education

Over time, learning has taken numerous forms. It began with oral learning, which involves passing information from one generation to another by word of mouth (Almstrum, Owens and Adams, 2005). However, this was an unreliable education method because it produced no documented or written learning material. Later, the learning method changed from oral learning to traditional learning. This method involved face-to-face teaching together with the use of stone slates as technical writing tools to document learning content (Gaskill, 2001).

Using technical innovations in education is not a new phenomenon and started in ancient times. The oldest example occurred in Ancient Rome in approximately 200 BC (Leeuwe, 2007) (Figure 2-1). Historians found a picture depicting a teacher and learners in a classroom; each learner has a slate on which to write.

Figure 2-1: Romans with their writing slate (Leeuwe, 2007)

Learning did not reach the common people due to the limitations and difficulties of writing techniques. The first significant change in writing methods took place in 1041 when Johannes Gutenberg invented a printing press that could print papers quickly and at low cost (Bellis, 2012a). With the emergence of paper and printing machines, a new form of education emerged. Printing revolutionised education and had a significant impact on learning. It allowed teachers to create written learning materials and to diffuse knowledge among learners easily.

The education process evolved simultaneously with the development of new technology. This technology provided innovative opportunities and tools to improve learning (Walsh, 2010). For centuries, traditional teaching relied on face-to-face instruction. An English educator, Sir Isaac Pitman, developed a new teaching method in 1840. He was the first person who used distance-learning methods and started his first distance-learning course by mailing learners the content of lessons and assignments. The learners returned completed work by mail (Schlosser and Simonson, 2006). Forty-three years later, in 1873, Anna Ticknow established a society that provided education to women at home (University of Florida, 2012).

Only individuals attempted to establish distance-learning courses, and these courses were not officially recognised. In 1883, educational institutions attempted to adopt distance learning. Cornell University in Ithaca established a Correspondence University, which allowed learners to study at home. Learners were awarded degrees after completing their course (Nasseh, 1997). Initially, distance learning was limited and confined to certain places due to the technological restrictions of that time (Schlosser and Simonson, 2006).

The search for new learning techniques to improve education has never stopped throughout the history of teaching (Seixas and Wineburg, 2000). In 1910, radio broadcasting emerged as a new technology. This technology allowed the broadcasting of voices from a radio station to anyone who had a radio (Yüzer and Kurubacak, 1994). Some educational institutions, such as the State University of Iowa, tried to use radio as a learning tool to provide distance learning. The public was loath to accept the use of a radio in distance learning and this teaching medium did not attract a large number of learners. Radio offered only voice and learners could not interact or collaborate with each other.

In 1923 in America, Charles Jenkins invented the first television system, adding visuals to voice (Jezek, 2012). Some educators attempted to include television in the learning process. In 1956, researchers conducted a survey to assess how television stations could be used to support education in terms of distance learning (Jeffries, 2012). In 1969, David Smith launched his first geography course via television. He called it “flying classroom” and it was broadcast from Western Oregon’s airport (Herald, 1969). Learners recognised an opportunity to gain degrees, improve their work experiences and to learn about business concepts.

Collaboration television in learning has several disadvantages (Nasseh, 1997). The lack of learner interaction in the courses is a significant disadvantage. Television makes learners receivers of information and the direction of learning is from teacher to learners only. Therefore, educators later recommended incorporating emails with television courses as a method to improve communication between teacher and learners (Nasseh, 1997). The development of computer technology, which has affected and changed the nature of modern learning, is similar to these innovations.

2.2.2. E-Learning

E-learning is a direct result of the development of computer technologies. This section provides an overview of the evolution of computers followed by a discussion of e-learning in general.

2.2.2.1. Evolution of Computers

The development of contemporary personal computers involved multiple stages. The idea of using calculation and computational tools to help human beings stems from ancient times. A good example of this is the abacus, a hand calculator made from wood and small stones, which people used as an aid to perform simple calculations. The earliest abacus was found in China in 300 BC (Kopplin, 2002). In 1942, John Atanasoff and Clifford Berry made the first serious attempt to create an electronic computer at the University of Pennsylvania (Kopplin, 2002). They called it the Electronic Numerical Integrator and Computer. Due to the thousands of large vacuum tubes, crystal diodes, resistors, and capacitors, it was complex, large and heavy. The computer covered 167 square metres and weighed 27 tons. Figure 2-2 shows the first electronic computer.

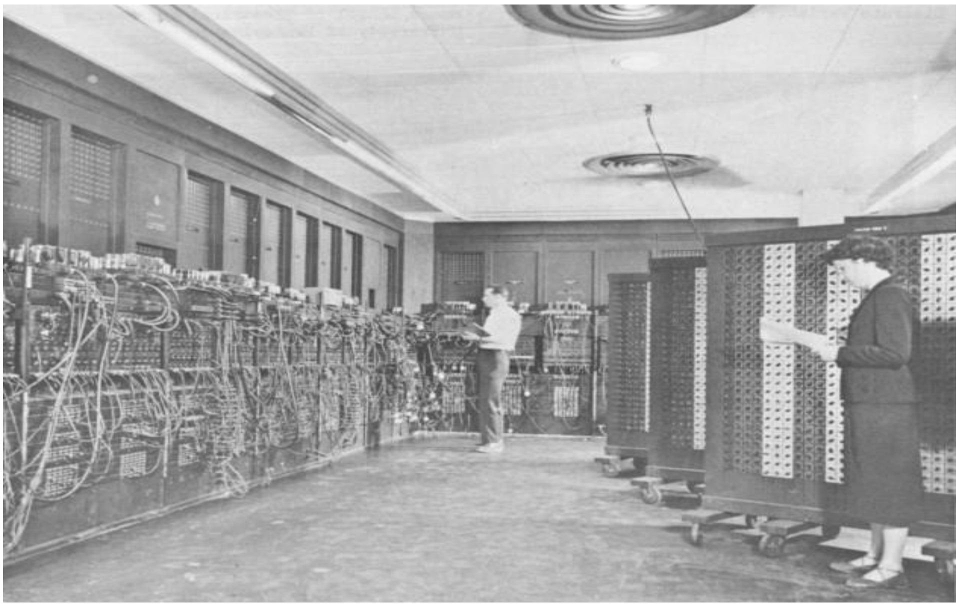

Figure 2-2: First electronic computer (Kopplin, 2002)

The main function of the first computer was to perform a complete range of logical operations. At that time, computers were not popular with educational institutions and people in general because of their high cost, large size, limited functionality, and unreliability (Kopplin, 2002).

The invention of transistors and microchips led to the creation of a new generation of computers. These were smaller than those that contained vacuum tubes, as compact transistors replaced cumbersome vacuum tubes in computer design (Bellis, 2012b). In 1953 the University of Manchester created the first transistor computer and in 1959 the International Business Machines company (IBM) created the first electronic computer using transistors (Kopplin, 2002). By the 1960s, numerous companies began replacing transistors with microchips (Haack and Yuma, 2012). The computers built with microchips showed tangible advantages over previous models, as they could perform multiple functions and offered improved processing speeds (Bellis, 2012c). Subsequently, computers became widespread in the education environment, in business and in industry.

In 1970, the Xerox Corporation set out to transform computing to a mobile platform. In 1977, Alan Kay and his colleagues at Xerox PARC envisioned a mobile electronic device called the “Dynabook” (Dalakov, 2012). They described the concept as a personal dynamic medium that was the size of a notebook. Anyone could own a Dynabook and the device had the power to handle virtually all of its owner’s information-related needs (Dalakov, 2012). The goal of the Dynabook project was to develop a small portable computer that looked like a book. The project aimed to provide children with the opportunity to have interactive software applications and media on their own handheld computers. The Dynabook showed the potential of mobile devices as learning tools in education.

In 1981, IBM manufactured the first laptop, the Osborne 1 (McCracken, 2011). This laptop was small enough to fit inside a handbag and achieved great success in the trading market despite its limited 5-inch screen and 52-character-per-line display. Mobile computers have developed dramatically since. The phenomenon of computers becoming smaller and more functional has led to the emergence of new mobile technologies. In turn, these improved mobile technologies resulted in new teaching methods, such as distance learning.

Distance learning rapidly changed with the emergence of the internet and the onset of the technological revolution. This revolution, which involved mass media and mass communication, created new dimensions in distance learning. Furthermore, these technologies added significant benefits to education by enabling the utilisation of new notable technologies (Scalise, Gifford and Russell, 2006). Thus, new technologies allowed researchers to provide education to learners by using various interactive components such as text, sound, video, animation, games and a virtual classroom (Block, 2006). The combination of emerging technology and innovative pedagogical concepts has created novel education methods for some educational institutions and allowed them to develop platforms for providing learning online by using accessible internet and multimedia. This new approach of learning is called e-learning.

2.2.2.2. Overview of E-Learning

E-learning is a relatively new term in education. The word first emerged in October 1999 in Los Angeles (Fisher, 2001). One can define e-learning as the delivery of a learning, training or education program by electronic means. This implies that e-learning involves the use of a computer or electronic device (such as a mobile phone) to provide training, educational or learning material (Tick, 2006).

Some educational institutions, such as the University of Tampere in Finland, began offering e-learning study as part of their educational approach. In 2001, the University of Tampere implemented e-learning in the Faculty of Education, providing online courses where learners could remotely access assignments wherever they were and complete them before a weekly deadline. In addition, the University encouraged learners to interact, communicate and discuss the course’s issues with educators via a web-based platform that provided online text, sound and video (Varis, 2005). E-learning has overcome the limitations of time, learning materials and distance by employing existing technologies (Nedeva, Dimova and Dineva, 2005).

E-learning delivers learning content in various ways using computer technology (Bonanno, 2005). This has helped e-learning to become widely used among educational institutions as a new method of learning. The advantages of using e-learning in education include flexibility, reusability and efficiency:

Flexibility: The development of internet technologies has noticeably accelerated in the last decade. This has provided effective tools for e-learning and improved these teaching methods, allowing educators to adjust learning course delivery, presentation, training and interaction methods (Bonanno, 2005). This process creates a suitable learning environment that allows easy and seamless acquisition of knowledge for learners.

Reusability: The main aspect of e-learning is using educational materials, which are stored in a repository or online and to make them available and accessible at any time via a network connection (Song, 2010). Therefore, learners can access the learning materials as many times as they wish. In addition, course content could be divided into mini paragraphs or numerous parts based on the content and reused in other courses, examples and presentations (Arman, 2010).

Efficiency: E-learning saves time by providing modern learning tools for streamlining teachers' administrative tasks and facilitating the creation, delivery and receiving of learning materials (Bonanno, 2005). In addition, e-learning provides opportunities for learners to interact with the current course through writing comments and notes and having discussions with the teacher. This promotes an effective learning experience.

Because e-learning relies on the network and physical place to produce learning materials, it has disadvantages, such as slow connections, geo-location education and a lack of interpersonal communication (Song, 2010):

Slow connection: E-learning offers varied learning content such as text, photos, sound, video and learners receive assignments or interact in dissimilar formats by means of network connectivity (Virtič, 2012). Sending and receiving large amounts of data through a network may be slow because of internet speed or bandwidth limitations.

Geo-location education: Although e-learning provides learning materials online at any time, the learner must have access to a computer to gain access to the course content (Bonanno, 2005). Thus, the learner cannot learn anywhere, since he or she requires hardware such as a computer and an internet connection.

Lack of interpersonal communication: In industry and commerce, face-to-face communication is important, and verbal and visual communication between teachers and learners are significant factors in effective education (Fortune, Spielman and Pangelinan, 2011). However, online learning via a web-based platform and computer technologies is the main feature e-learning offers (Song, 2010). Thus, e-learning isolates the teacher and the learner has limited or no face-to-face communication with the teacher.

E-learning focuses on remote education using information technology. The increasing use of mobile devices, especially among young people, has caused e-learning to evolve into mobile learning. The combination of mobile devices and e-learning has shaped a new form of education resulting in access to learning materials regardless of the particular place or time (Vinu and Krishnan, 2011).

2.2.3. Mobile Learning

Mobile learning has developed significantly since cell phones emerged. This section provides an overview of the development of cell phones, followed by a general discussion of the evolution of mobile learning.

2.2.3.1. History of Cell Phones

Since the 1980s, mobile devices have become increasingly popular (Padiapu, 2008). The objective of the first portable computer, the Dynabook, was to help learners with their studies and to improve communication. Using technology for learning in educational institutions could achieve these objectives (Dalakov, 2012). The first attempt to include mobile devices into learning did not achieve wide acceptance from educational institutions because of usability limitations (Maxwell, 2012). People initially viewed mobile devices as being too complicated for children to use in learning.

In the 1970s, Motorola invented the mobile cell phone and introduced it to the commercial market (Eddy, 2011). These cell phones, later known as the first generation of cell phones, could communicate only between each other (Brookes, 2012). Nonetheless, people accepted these basic devices, which inspired other companies, such as Apple and Nokia, to develop cell phones in the 1990s. Technological improvements in microchips and battery storage led to the development of a second generation of cell phones (Brookes, 2012). Due to the use of new technology in the manufacturing of second-generation cell phones, these devices were significantly smaller than their predecessors. In addition, this technology sparked enhancements, advancements and possibilities, such as text messaging and payments for other services via cell phone (Brookes, 2012).

With the emergence of second-generation phones, rival manufacturers developed devices with innovative features and designs. These apparatuses, called Palm or Personal Digital Assistance (PDA) devices, were distinct in terms of new features, such as larger sizes than that of existing cell phones; improved battery life, storage and memory; email access; and QWERTY keyboards (Viken, 2009). These features of PDA and Palm devices led to the development of a third generation of cell phones.

Third-generation cell phones emerged from a combination of second-generation cell phones and other mobile devices (Viken, 2009). With third-generation phones, mobility innovations moved from those found in a typical laptop to those found in smart mobile devices and tablets. These cell phones are not typical phones that allow users to only make and receive calls and send and receive text messages. They allow users to browse the internet, support Hyper Text Markup Language (HTML5), facilitate email, capture video, record sound and store data. Reductions in size and weight turned mobile devices into handheld devices that are easy to carry. They typically feature high-resolution cameras, microphone recorders, touchscreens and Wi-Fi connectivity. These improvements have led to a dramatic increase in the public's acceptance of mobile technology. A survey by The International Telecommunication Union estimated that there were 6 billion mobile subscriptions worldwide at the end of 2011 (MobiThinking, 2012). The widespread use of mobile devices by the youth has led researchers to consider the inclusion of mobile devices in education as a new approach to learning, referred to as mobile learning (Benedek, 2004).

2.2.3.2. Overview of Mobile Learning

Mobile learning is a form of e-learning that employs mobile devices (such as PDAs, tablet personal computers, laptop personal computers and mobile phones) to extend, provide and deliver educational content to personal mobile devices by using mobile networks and tools (Tortosa *et al*, 2011). Educational content refers to digital learning assets, which include any form of content or media made available on a personal device. However, mobile learning is different from e-learning because learners can use their mobile devices to learn anywhere and at any time.

Mobile learning expands the digital learning channel; it increases educational information, and provides educational resources and services any time and anywhere (Sarrab and Elgamel, 2012). Mobile learning has the following features: learning convenience, teaching personalisation, abundant alternatives and context association. Furthermore, the technological advances in mobile devices have established new possibilities for diffusion of learning among learners and provided an opportunity for the realisation of mobile learning in an educational environment. Providing equal access to learning materials, resources, encouragement and information to all learners regardless of their background, culture, disability and where they live is a significant human rights issue (Mello, 2004). Mobile learning offers an excellent opportunity to achieve this objective by making education more accessible.

Since 2001, the concept of using mobile devices in education has been applied in different educational environments (Attewell, 2005). Researchers have conducted numerous studies with different goals regarding the use of mobile learning in various fields. The following section examines mobile learning projects designed to assist employers in their workplaces and to provide learning in educational environments.

2.3. Application of Mobile Learning

In Section 2.3.1 the researcher addresses sub-question 1.2 by discussing the use of mobile devices for education in non-educational organisations. Section 2.3.2 consists of an examination of sub-question 1.2 and presents a discussion of the use of mobile devices as learning tools with the purpose of achieving various educational objectives at higher education institutions.

2.3.1. Mobile Learning in the Workplace

Supportive training for staff and customers is an immense concern for companies because of the cost and time involved. Companies need a way to provide faster, more effective and cheaper support. The availability of mobile devices and the features of smartphones (such as connectivity, media, storage and adequate screen resolution) have made mobile devices viable learning tools for the workplace and have led some companies to use these devices in learning plans.

Mobile devices have achieved great success in terms of prevalence, proliferation and acceptance among people (Garg, 2011). Since mobile devices are handheld and easy to carry, employees do not have to use computers at specific places to learn or to do their jobs (Iriss, 2012). Furthermore, the significant capacities and features that modern mobile devices offer are similar to those of desktop personal computers. These factors have made mobile devices common tools in the workplace.

There are numerous applications for mobile technologies in the workplace. These applications vary in their use of content learning, connectivity mechanisms and mobile technologies, which depend on their functions and global location. Developers use different methods, including course delivery and audio and video training, to teach employees via mobile devices.

2.3.1.1. Course Delivery

Modern technology has turned the world into a village. With mobile technology, distance is no longer of great significance. Therefore, mobile learning creates a rational learning environment for learners and there is immediate availability of learning materials anywhere without geographic restrictions (Attwell, 2010). Hence, mobile learning has enabled companies to overcome geographic boundaries and to train staff by using different, flexible mobile connectivity mechanisms such as Wi-Fi and internet.

Course delivery is pushing learning content from the learning source to the mobile device via an available network connection (Ally, 2009). It is widely used in the workplace because it considers the delivery of important information and employees' needs while minimising the cost of training in terms of hiring teachers and obtaining venues for education. In addition, it reduces time spent on training, since employees do not have to attend courses during fixed hours and at specific locations as with traditional course training. Course delivery extends the mobile learning experience through the availability of learning materials on mobile devices (Fortune *et al*, 2011). Since mobile devices run on various platforms and have different features (size of screen, storage, processor and so on), the learning content must be designed to be integrated and adjusted to any sort of mobile device to achieve a higher level of knowledge acquisition by learners (Ally, 2009).

Different transferring methods are used to deliver course content to mobile devices. These include 3G, Bluetooth, physical Universal Serial Bus (USB) cable and Wi-Fi. Due to the low cost and high speed, the most common method is via USB cable or via Wi-Fi connectivity (Attwell, 2010).

2.3.1.2. Audio and Video Training

Most modern mobile devices support multimedia, such as audio and video, and deal with them effectively. The features of modern mobile devices, such as improved screen resolution, cameras, sensitive microphone recorders and powerful speakers, have allowed these devices to support the creating, streaming, recording and editing of multimedia content (Ally, 2009). Incorporating rich multimedia in learning materials as a learning tool improves the quality of learning content. Educators produce attractive learning materials that make it easy for learners to learn and remember content by watching, listening, and being stimulated. Learners are more interested and attentive during the learning process (Yan Liu, Ren-fa Li, Cheng Xu, 2007). People learn better when they use more than one sense in learning (Nooriafshar, 2003). These advantages inspired designers of mobile learning systems to produce learning content through multimedia tools.

Some companies and institutions in different fields are using media training via mobile devices to train their employees. This method lessens the need to train each new employee individually and supports the retraining of existing employees, whether to refresh their memories or to update existing information. Simple efforts can have significant impacts on companies. For example, Homewood Suites by Hilton has published video mobile training programs for 6000 employees (Brown and Metcalf, 2008). The training video content is organised into playlists for use in job coaching and guidance. It allows employees to learn when and where they desire and repeat the video content as often as they want.

Using multimedia in learning makes learning more effective by bridging the gap between the training course and the application of the knowledge.

2.3.2. Mobile Learning in Higher Education

Modern mobile devices offer various presentation tools, including text, graphics, media, and animations (Ally, 2009). These factors have increased the potential uses of mobile devices in education.

Universities worldwide currently use mobile learning for various purposes, such as collaboration, communication, facilitating learning content, posing questions and supplying answers, and managing class assignments.

2.3.2.1. Collaboration

Collaborative learning outside the classroom is vital for many educational disciplines (Vasiliou and Economides, 2007). One of the greatest drawbacks of traditional teaching methods is that learners often attend the course, take notes and leave without any collaboration in the classroom (Vasiliou and Economides, 2007). The prevalence of mobile devices among learners and the availability of wireless connectivity on campus have helped learners learn and collaborate any time and anywhere. Sharing one task among a group of learners via mobile devices provides a platform that allows them to collaborate on campus and to learn skills from each other.

Learning is not an exclusively individual process; it usually includes social aspects. Interaction and communication with other persons in the learning group, such as the teacher, course participants or classmates, always affect the learning process (Vasiliou and Economides, 2007). Therefore, learning in the traditional classroom where the role of the learner is only that of an information receiver does not provide the learner with a perfect and deep knowledge. Hence, interactive learning between learners and lecturer during a lecture makes learning more useful and interesting for learners. This occurs through asking questions and receiving answers, writing comments, discussion, finding a solution together, and providing feedback.

2.3.2.2. Communication

Examination of web usage statistics shows that social media sites are the most visited because they provide users with the opportunity to communicate. These social network websites have implemented applications to support communication via mobile devices (Helmer, 2011). For instance, Facebook has an application that runs across popular platforms (Android, BlackBerry and iPhone), supporting communication through its social network.

The availability of mobile devices and Wi-Fi connections across campus supports communication and an improved academic life on campus. Academic communication is based on learning content; therefore, activities should include the use of video, sound, questions, assessments, quizzes, surveys and messages between learners and a teacher, as well as between learners themselves. Together these elements create effective communication in the classroom. In fact, effective collaboration comes only through effective communication (Traxler, 2010).

2.3.2.3. Presenting Learning Content

Mobile learning depends on producing digital learning materials and delivering these to learners through mobile devices for the purpose of enhancing education and increasing cognitive acquisition of knowledge (Magal-Royo, Montañana and Alcalde, 2010). Hence, learning content is one of the most important components of mobile learning.

The most important function of mobile learning is presenting content, and one can present mobile learning content effectively on a mobile device. The educational expert is responsible for creating this content. Learners can then browse the learning content from the

Learning Client Module directly through a reliable network connection or download it onto mobile devices. The aim is to provide available and accessible learning content for learners whenever they need it. To construct effective mobile learning content, one must consider several issues:

Light content: Since mobile devices have limitations in screen size and processor speeds, the designed content must consider this to keep the learners motivated and empowered by preventing long delays and slow content presentation. Ignoring this has a negative effect on the learning process and knowledge acquisition of learners (Traxler, 2010).

Simplicity: A complicated design with numerous options and a long list of content confuses learners. Therefore, it is important to keep the learning content as simple as possible (Traxler, 2010). Sending learning content to the learner as a small portion of information is the main aspect of content simplicity. This makes it easy for learners to remember the content (Parsons and Ryu, 2007). In addition, this method enables the mobile learning system to present learning materials to the learner without information overload (Bruck and Foerster, 2012).

Addressing the issues of light content and simplicity in the design of mobile learning content has a positive effect on the learners' acquisition of knowledge.

2.3.2.4. Facilitating Questions and Answers

Asking questions during lectures helps learners to focus on the subject of the lecture and to prevent distractions. Furthermore, the lecturer can gain a valuable background of learners' understanding and abilities to follow the lesson (Pachler, 2007). However, the group may consist of numerous learners, making it difficult for the lecturer to ask all of them questions and to obtain responses from them during the lecture. Using learners' mobile devices makes this task possible and easy. The teacher simply sends the question from his or her device to the learners' devices via wireless connectivity in the classroom. As soon as the learners answer, the lecturer receives responses from them. These answers reflect the learners' understanding of the content and positively affect education.

2.3.2.5. Managing Class Assignments

Teacher set assignments for learners to assimilate learning material and guide them in their studies, thus simplifying significant goals and preparing learners for final exams. In addition, the aim is to encourage learners to participate in the learning process and improve interaction and collaboration (Vermetten, Vermunt and Lodewijks, 2002). Mobile learning offers the opportunity to achieve these goals by using mobile devices with wireless connectivity in the classroom. The teacher can distribute tasks and obtain responses from learners in real time. Some universities have conducted research to enhance conventional classroom teaching and learning approaches by overcoming the difficulties learners and teachers experience in conventional classrooms using mobile devices in wireless classrooms. Using mobile devices in the classroom enables teachers to review assignments during lectures, providing them with a measure of the learners' understanding.

Delivering assignments on learners' mobile devices helps to achieve learning objectives. Learners become involved in the teaching process and are encouraged to learn and study the main goals of the current lesson, increasing the understanding of course content (Vermetten *et al*, 2002).

2.4. Case Studies of Mobile Learning

Initially, people used mobile devices exclusively for communication through voice calling. Once people gained a clearer insight of the possibilities offered by mobile devices, such as communication, interaction with the entire world and information accessibility regardless of the location and time, they incorporated these devices in various ways at educational institutions (Tuttle, 2012). Globally, numerous mobile applications are used for educational purposes.

2.4.1. Global Use of Mobile Devices in Higher Education

The prevalence of mobile devices and the flexibility of mobile learning are eroding geographic restrictions (Helmer, 2011). This has led to some companies using mobile devices in their businesses to train and prepare employees.

Training staff and customers is an immense concern for companies because of the cost and time involved. They need to provide support in a faster, more efficient and cost effective manner. The availability of smartphones has inspired companies to use mobile devices in training, although they use different applications to teach employees and customers. A discussion of these applications follows.

Sun Microsystems has implemented Sun Mobile Learning System (Bows, 2010). The system aims to improve the quality of performance support and to deliver company training to employees and partners on mobile devices. Sun Microsystems employees simply connect their mobile devices to iTunes via a USB plug-in to automatically preload content. After synchronisation, employees can use the training videos stored on their mobile devices as needed.

Sun Microsystems refers to this approach as "just in time, just the right size for the mobile screen". The Sun Mobile Learning System is user-friendly, with a simple interface and course content that is easy to access. The interface also provides personalisation features based on each employee's job and personal settings. Sun Microsystems' employees have improved their support performance and knowledge by carrying instruction sources with them during the working day (Bows, 2010).

Valero Energy wanted to provide support for employees to enhance the quality of inspections when they were in the field and away from their personal computers (Bows, 2010). The company developed a learning system for installation on employees' mobile devices. It runs on a Microsoft Windows operating system and can work with a touchscreen device. All the necessary documentation for conducting an inspection loads via either USB or wireless network connection. Employees can use mobile devices to learn and perform their jobs without internet connectivity. This mobile learning system facilitated teaching Valero Energy's staff exact skills regardless of physical location.

These methods of course delivery have several advantages, including simplicity and that they do not require an internet connection. Furthermore, the user can access content at any time or in any place. There is no need for instructors to provide employees with training on company protocols and procedures. A company can implement a mobile learning system at minimal cost.

Some universities involve mobile devices in the learning process. Mobile learning aligns with various educational objectives, such as improving collaboration, enhancing communication and interaction, providing learning content, and completing class assignments. A discussion of some examples follows.

The University of Oulu in Finland implemented the Mobile Lecture Interaction (MLI) application for enhancing lecture interaction between teachers and learners (Ojala and Korhonen, 2008). With their personal mobile phones, learners can ask questions anonymously and support questions from other learners by voting for them. The questions are displayed in real-time to the teacher who can address them as he or she deems appropriate. An empirical evaluation of the MLI application in a real usage context at eight university lectures showed that the MLI improves lecture interaction in a meaningful way (Ojala and Korhonen, 2008).

In 2008, **Abilene Christian University** incorporated mobile learning into the daily mobile life of the faculty (Perkins, 2012). The university implemented its own mobile learning framework, which aimed to provide learners with greater access to information. The framework set out to encourage learners to seek learning materials that are relevant to their interests and assist them in finding solutions for study obstacles. After two years of using mobile learning, the university achieved its objectives. Learners began sharing ideas and information in groups, which assisted them in finding peers in their field.

In 2004, **Duke University** began supplying iPods to faculty members and freshmen as a first step to including mobile devices in learning on campus (Chinnery, 2006). This led Duke University to develop a mobile learning application for its learners. One of the main objectives was collaboration with Public Radio International to provide radio reports as supplements to Duke’s courses. In addition to this, the system allowed learners to review orientation information, retrieve course descriptions, schedules and venues from the Duke course timetable, write notes, record sound and capture video. Figure 2-3 illustrates Duke’s mobile learning application. It achieved wide acceptance among learners. Learners can easily obtain access to the latest information from the University through the mobile application. The variety of advanced features attracts a large number of learners.

Initially mobile devices had very simple functions (Hodgkinson-Williams and Ngambi, 2009). Because of technological development, the mobile device developed into a multifunction device. This turned the mobile device into a significant learning tool in various environments, as confirmed by the above-mentioned case.

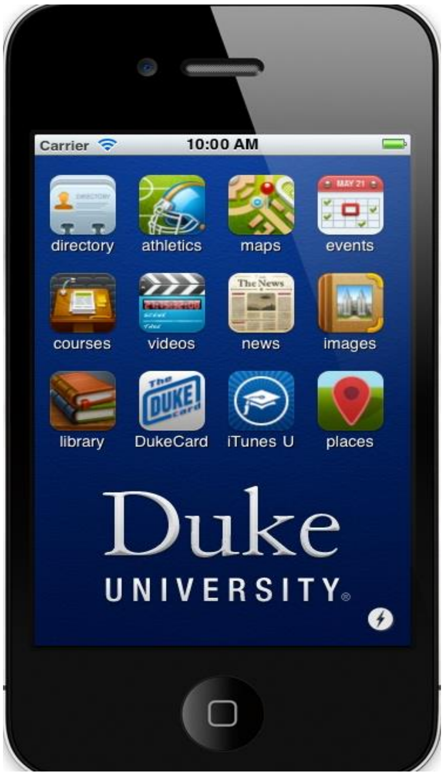

Figure 2-3: Mobile application of Duke University (Perkins, 2012)

2.4.2. National Use of Mobile Devices in Higher Education

Recent reports show that South Africans had more than 62 million active cellular subscriptions at the end of 2011 (Bronkhorst, 2012). This makes South Africa one of the biggest mobile markets in the world (Lategan, Solomon and Visser, 2012). A large proportion of mobiles are smartphones, which implies that they are third-generation phones that support multimedia and various types of connectivity. In addition, the youth own the majority of mobile devices (Roberts and Vänskä, 2011). These factors contribute towards South Africa's potential to play a significant role in the diffusion of mobile learning in education.

A series of attempts has been made to apply mobile learning at different educational levels, in schools and universities.

When the cost of text messaging was high in South Africa, the necessity of developing a free distance text-messaging platform arose. In 2001, developers created MXit, a mobile chat application, in Stellenbosch. It provides MXit users with the ability to send and receive messages to and from each other over the internet (Mxit, 2012). Three years later, the MXit mobile application gained wide acceptance among South Africans, with more than 50 million people using it. Developers evolved MXit to run on multiple mobile platforms, including Blackberry, Windows Phone, Android and iPhone. MXit can connect to social networks and chat applications, such as Facebook, Yahoo and Google Talk (Mxit, 2012). Because of these factors, MXit is a widely used communication platform. It provides an opportunity to disseminate educational knowledge over the internet, especially among the youth.

One of the mobile learning projects on the MXit platform is Dr Math (Butgereit, 2009). Implemented in 2010, it involved 500 learners. The main aim of this project is to support and enhance learners' mathematics skills and performance (Isaacs, 2012). In addition, it supports teachers and overcomes the problem of using modern mobile technology in the classroom. Dr Math enables learners to use their mobile devices in the classroom, interact with their teachers, discuss difficulties in solving mathematics homework with each other, learn from their own and other learners' mistakes, and complete assignments sent to them. The foremost finding of this project was that the application builds self confidence in teachers and learners while they use their cell phones in the learning process (Isaacs, 2012).

Vodacom, in association with Microsoft, Cisco and Mindset Learn, has implemented the Vodacom Mobile Education Programme (Reporter, 2011). This initiative aims to provide South African teachers with teaching resources through mobile devices and offers modules such as mathematics and physical science. Moreover, it has two goals:

- Bringing knowledge and information to as large a group of South African learners as possible via their own mobile devices; and
- Improving teachers' teaching quality by offering them access to the latest teaching materials and resources (Reporter, 2011).

Further, the presidency officially requested that developers conduct research in applying mobile learning in several schools across the North West, Eastern Cape, and Western Cape provinces (Roberts and Vänskä, 2011). The South African government, with Nokia and other private companies, implemented an educational mobile application in 30 schools from January to June 2010. The project enabled learners to build confidence by providing unlimited access to mathematics materials and exercises on mobile devices. In addition, learners were provided with an extensive collection of questions of different levels (easy, medium and advanced), which they could answer before comparing their results with those of other learners. Teachers could review learners' answers as well as modify and customise the learning materials. Researchers found that learner interaction and collaboration increased (Roberts and Vänskä, 2011).

In terms of delivering teaching and learning material to learners' mobile devices, the University of Pretoria has launched a mobile application to assist their learners on and off campus (Tsunke, 2012). This application, UP Mobile, operates across different mobile platforms (Android, BlackBerry, iOS and mobile web browser). The application provides courses, learning activities and assignments. The University of Pretoria upgraded Wi-Fi capacity and network coverage on campus to ensure that every learner has access to learning resources from anywhere on campus. UP Mobile has achieved remarkable acceptance among learners: 8,000 people downloaded the application. Between 2,500 and 3,200 learners access the Learning Client Module via their mobile devices daily (Tsunke, 2012). This initiative makes the University of Pretoria one of the first South African higher educational institutions to use mobile learning officially in the educational paradigm.

The University of Cape Town also acknowledged the widespread use of mobile devices on campus. Over 98 percent of their learners have smartphones. This has encouraged the university to launch a mobile learning application (Hodgkinson-Williams and Ngambi, 2009). The purpose of the application is to bring the University of Cape Town into the 21st century in terms of using the latest technology to reinforce education. Making the accessibility and availability of learning materials commonplace for learners is an additional objective. The mobile learning application allows lecturers to create courses and add content supplemented by multimedia elements. When a lecturer needs to send the course material to learners, he or she can deliver it easily by distributing it to a certain group. The learners can review delivered course content on their own mobile devices. If learners seek additional information, they can provide feedback or send a question to the lecturer. In addition, they can download course material and class assignments and upload assignments upon completion. Learners have used mobile learning in different departments for various modules and have received news and important notifications from their departments via text message (Hodgkinson-Williams and Ngambi, 2009).

The high number of mobile subscriptions in South Africa, especially among the youth, has created an ideal environment for implementing mobile learning initiatives. Several mobile learning projects have been implemented across the country with the aim of providing learning materials to learners and improving the quality of education.

2.5. Components of Mobile Learning in the Classroom

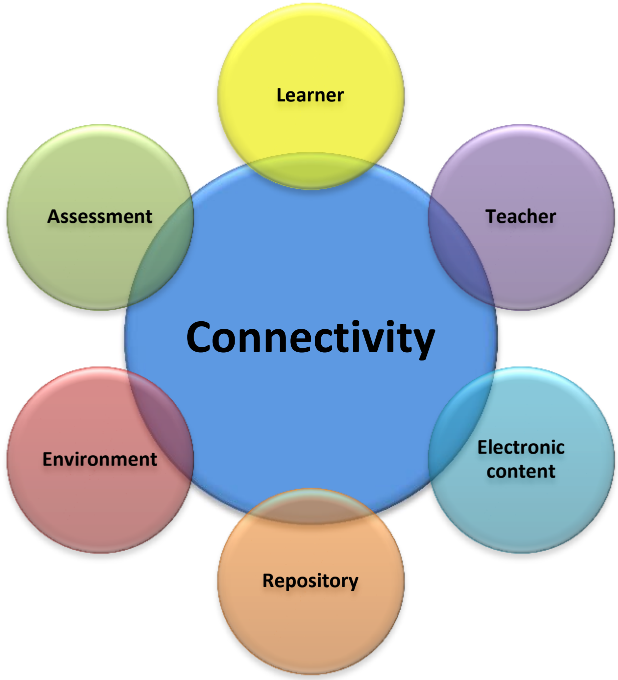

Figure 2-4: Mobile learning components

Due to the growth in availability of mobile devices among learners at universities, the integration of mobile learning into an educational approach is easier with these devices than with desktops computers (Nordin, Embi and Yunus, 2010). To adopt a mobile learning system in the classroom, there must be a model that allows learners to improve their academic performance and understanding of the learning materials (Ozdamli and Cavus, 2011). Therefore, before implementing an effective mobile learning system, it is important to understand the basic components of a mobile learning framework and to define the characteristics of these components. These components relate to the role players in the learning process. The components of mobile learning are thus the learner, teacher, environment, repository, electronic content, connectivity and assessment (Figure 2-4).

2.5.1. Learner

Learners are an essential component of the learning cycle (Ozdamli and Cavus, 2011). Educational programmes and learning materials are designed to offer learners the best knowledge available and to improve their understanding of various subjects. Mobile learning aims to place the learner at the centre of the learning process. Objectives in this process include accessibility, communication, collaboration, evaluation, individuality, knowledge and discovery (Ally, 2009).

- **Accessibility** Learners should have access to the learning materials as needed, with no boundaries or restrictions.
- **Communication** There must be effective communication between teachers and learners, as well as between learners.
- **Collaboration** Sharing a task among learners allows them to collaborate effectively with each other in learning activities.
- **Evaluation** Mobile learning provides the opportunity for learners to evaluate themselves.
- **Individuality** The mobile device allows each learner to create his or her own learning environment.
- **Knowledge** Using mobile learning in the classroom encourages learners to increase their knowledge through the capacities of mobile devices.
- **Discovery** Mobile devices have features such as internet connectivity that teachers can use to encourage learners to discover knowledge by themselves.

According to these objectives, learners should have mobile devices with specific features and capacities that support the goals of mobile learning. Mobile learning systems present learners with various learning materials (text, photos, video and sound), so mobile devices must meet certain requirements to be appropriate for the mobile learning system (Mostakhdemin-Hosseini and Tuimala, 2005). The following table (Table 2-1) describes the requirements related to different mobile device features.

Table 2-1: Description of mobile devices' requirements

Feature	Explanation
Screen	A screen of adequate dimensions allows the learner to collaborate easily and comfortably.
Speed	The speed decreases the system's response time to the learner's input.
Wireless capabilities	It provides a fast, cheap and secure connection between devices.
Input and output capabilities	Keyboards, touchscreens, styluses and monitors improve interaction between learners and mobile devices.
Storage	Storage allows learners to create and save learning materials on the mobile devices. This supports availability.
Size and weight	Size and weight have an effect on the mobility of mobile devices and consequently on supporting learning anywhere.
Streaming, sound and images	Support the use of multimedia in learning.
Extended battery life	Extended battery life makes learning in the classroom stable.
Operating system stability	Since it is the framework of the mobile learning system, it influences the learning process.

2.5.2. Teacher

The role of the teacher in the pedagogical approach is to manage the entire learning process during the lesson and to determine how to present information to the learners (Avalos, 2011). Therefore, the teacher's role in mobile learning should not be less than in traditional learning. To place the teacher in an effective management role in a mobile learning system, the system should provide appropriate mobile learning tools and technologies (Ozdamli and Cavus, 2011).

Effective tools and technologies can empower the teacher to achieve the main aims of his or her role to promote and reinforce learners' motivation, engagement, collaboration, interaction and data presentation (Ally, 2009). Teachers must be able to send and respond to assignments and give feedback instantly and without any barriers (Mostakhdemin-Hosseini and Tuimala, 2005). Mobile devices have capacities that allow learners to access any information from the internet or another digital source. However, using them without any control could exceed the objectives of the use of mobile learning in the classroom (Glahn, 2011). The role of the teacher thus becomes more than simply sending learning activities and presenting results. The teacher must limit the use of mobile devices in the learning process. Teachers should have the ability and authority to send the necessary learning activities (Ozdamli and Cavus, 2011). This allows the teacher to control the mobile learning process during each session.

To enable teachers to perform and adjust learning tasks, they initially need assistance to understand the features of the mobile learning system and the capacities of mobile devices (Isaacs, 2012). Furthermore, they need to be supplied with devices with greater capacities and more advanced features than those of the learners. This includes a sufficiently large screen to manage the learning activities easily (Chao and Chen, 2009). High processor speeds and adequate available local storage space are also important for teachers. High acceleration data bandwidth from local storage to learners' mobile devices is essential. Providing teachers with adequate facilities and features of supportive learning tools gives them the opportunity to improve their teaching methods and reflects well on the learning process and the learners.

2.5.3. Environment

The traditional learning environment is the place where a teacher presents information to learners (Ozdamli and Cavus, 2011). With the emergence of new technologies, such as computers and mobile devices, the learning environment has changed (Cavus, 2011). Thus, emphasis on the design and quality of the learning environment reflects on the learning process and learners' knowledge acquisition (Kirschner, 2001). The learning environment affects both sides of the learning process, the teacher and the learners. To create a powerful mobile learning environment, the physical environment must be equipped and designed to support accessibility to and availability of the learning material (Parsons and Ryu, 2007). It must enhance the transfer of education as well as assist learners and teachers in communicating and interacting with each other (Ally, 2009). Therefore, the environment must support satisfactory network connectivity, as this promotes accessibility and availability. The connection must be fast, safe, reliable, available and inexpensive, and it should support numerous mobile devices simultaneously (Mostakhdemin-Hosseini and Tuimala, 2005).

Other equipment, such as interactive whiteboards and projectors, has been used in the classroom environment for supporting learners and teachers working collaboratively (O'Malley and Fraser, 2004). The interactive whiteboard provides an excellent opportunity for the teacher to present learning content, although the time spent writing on the whiteboard might become an issue in the classroom (Alvarez, Salavati and Nussbaum, 2013). Using a projector allows teaching and learning to convert the traditional classroom to the modern classroom (Sharples, 2006). Displaying learning content on the display board in real time increases flexibility and provides new opportunities for interaction in the classroom.

2.5.4. Repository

The repository is secure storage that allows teachers and experts to save the learning objects and materials (text, photo, video, audio, notes, supplemental materials and so on) to deliver it to learners later (Almstrum *et al*, 2005). The mobile learning system provides access to learning materials for learners whenever they require information. Teachers should have the ability to create, edit, delete, group, sort and preview the learning materials in an easy and comfortable way (Hilera *et al*, 2007). The repository needs to be secure and safe from data loss or damage. Authority to access the repository must be given according to the user's tasks and responsibilities.

2.5.5. Electronic Content

The mobile learning content should take advantage of diverse technologies offered by mobile devices by using graphics and multimedia components and presenting text (Ozdamli and Cavus, 2011). Thus, the mobile learning content is associated with the mobile device's features and tools. In addition, the mobile electronic content is a source of knowledge to learners and must be suitable for mobile learning goals (Magal-Royo *et al*, 2010). Therefore, the electronic content must be easy and comfortable to explore, read and review (Gimenez López, Magal Royo and Laborda, 2009).There are different types of mobile learning electronic content including static, adaptive and interactive content.

2.5.5.1. Static Content

Static content consists of learning materials pushed to and stored on mobile devices. This type of content has some advantages, including accessibility. The user can browse learning content any time and anywhere regardless of the availability of network connectivity. In addition, it is a low cost option because there is no need to connect to a learning source every time a user needs to access content.

2.5.5.2. Adaptive Content

Adaptive content is a method of sorting, categorising and delivering learning materials to the learner based on his or her need to acquire knowledge (Magal-Royo *et al*, 2010). The creation of the content has to follow certain rules based on the learners' specialisation and study topic as well as the features of the device (Chorfi, Sevkli and Bousbahi, 2012). The learning materials are filtered before being pushed to the learner at the point of need. The system explores the facilities of the mobile device and, based on what is available, provides compatible content to individual devices. For example, if a device supports only Photographic Expert Group (JPG) format, but the learning content is in Graphics Interchange Format (GIF) format, the content should be adapted to JPG format before being provided to the device.

2.5.5.3. Interactive Content

Interactive content in mobile learning implies interaction between the learner and learning materials during the learning process via typing, clicking, touching or sound commands (Pachler, Bachmair and Cook, 2010). The use of interactive content with mobile devices' multimedia technologies reinforces the acquisition of knowledge in the classroom (Song, 2010). Hence, the learning content must consider the user's methods of interaction with the mobile device. For instance, the user of the mobile device might be using two fingers to interact with the learning material. It is thus important to keep the design of learning content simple and easy to explore (Traxler, 2010).There must be enough space between the parts of the content to create a clickable area for ease of use. In addition, the content creator should consider the various keyboards of mobile devices (physical or virtual) to create comfortable areas for learners to type.

2.5.6. Connectivity

Despite the above-mentioned components, connectivity is the essential element that connects the mobile learning components (Padiapu, 2008). This allows for an effective, communicative, interactive and collaborative learning environment. Mobile devices have different connectivity technologies, which fall into two groups (Malm and Insight, 2012). The first group is wireless connectivity including Wi-Fi, Bluetooth, Wireless Local Area Network (WLAN), Near Field Communication (NFC) and 3G. The second group is physical connectivity, which requires connection through a network or USB cable. These connectivity mechanisms have different limitations, such as speed, cost, bandwidth boundaries and network coverage range (Padiapu, 2008).

Sufficient network speed to transfer learning materials between teacher, learners and the repository supports effective mobile learning in the classroom. Low cost or free network access provides a significant opportunity to exceed bandwidth obstacles and send and receive learning activities between mobile devices and the repository (Pachl*er et al*, 2010). Network coverage range plays a crucial role in mobile learning stability in the classroom (Alexander, 2004). The sizes of classrooms differ and learners may move around during the lecture. The connectivity coverage range should cover the entire the classroom and avoid network linking (Pachler *et al*, 2010).

2.5.7. Assessment

Assessment is a critical component of mobile learning (Ozdamli and Cavus, 2011). Generally, it takes place in the classroom and is a method for learners to learn the required skills and knowledge by themselves. In addition, it helps teachers to evaluate how much mobile learning has taken place in the learning progress and allows them to track and measure the growth of learners' achievements by reviewing statistics obtained from learner data (Oman, 2012).

From a technical perspective, a vast number of mobile devices have the capacities and abilities to track and report learners' performance during the assessment process. A teacher can conduct learner assessments in numerous ways, including tests, quizzes, online exams and peer evaluations (Pollara, 2011). Teachers should deliver assessments to learners with succinct instructions and sufficient information that suits the learner's ability to learn effectively (Traxler, 2010).

A mobile learning assessment should generate an outcome report as a self-assessment for the learner and it should provide feedback of the learners' progress to the teacher. Teachers can use these reports and the outcome of assessment feedback to understand where learners are lacking information and where there is a need to improve the quality of the learning content.

2.6. General Guidelines for Mobile Learning

Mobile devices have the potential to impact education significantly by offering tools for learning that provide an affordable and sustainable method of using mobile technologies for education (Vosloo, 2012). To achieve these objectives and promote the value of mobile learning in the classroom, developers and teachers must design mobile learning platforms and learning content while adhering to general guidelines. Some guidelines propose content delivery during lectures. One strategy is providing learners with learning materials suited and related to the current topic and the learners' knowledge level (Jung and Park, 2006). The teacher must balance the amount of information sent to a mobile device between important learning information and the time available during the lecture.

Mobile devices have various features and capabilities, but they also have limitations. Therefore, the teacher must present the learning content in a format that is appropriate to the limitations of the mobile device (Chorfi *et al*, 2012). This overcomes the problem of incompatible content delivery.

Educational institutions have large and increasing numbers of employees and learners. Learners have computers and mobile devices that they connect to the network and use for various purposes. Networks at these institutions have extremely heavy traffic, especially during working hours. Sending and receiving selected small quantities of information from the repository reduces network traffic, granting equal and fast access to every learner (Seong, 2006).

The use of mobile devices by learners in the classroom may be distracting and take attention away from the lecturer. In order to address this distraction, the duration of interaction with a mobile device must be no longer than 10 percent of the lecture time (PikiFriends, 2011). Lecturers should send only relevant information to learners and restrict the use of mobile devices to prevent learners becoming distracted or overloaded with information. The teacher must have the authority to moderate content, whether sent to or received from learners (Kolb, 2008).

A mobile learning system should provide a registration and login service to allow the system to identify users (PikiFriends, 2011). The use of access control tracking and interaction behaviour makes it possible to predict the learner's interest through interaction with a certain topic or subject. This information can be used to customise the learner's experience by identifying the learner's demands and so avoid sending duplicate data (Seong, 2006). User tracking may assist developers in finding inadequacies and errors in the mobile learning system that concerns the learner during the learning process.

Using a mobile learning environment may initially be confusing for learners (Seong, 2006). The establishment of an information help desk can assist learners in learning how to use the system, troubleshooting problems such as setting up mobile applications on their devices, registering accounts, recovering passwords, and resolving any other issue that may arise (Nahrstedt, Angrave and Caccamo, 2010).

Mobile learning does not only concern presenting learning materials on a learner's mobile device. It is also a confluence of technology and teaching that improves important aspects of education, such as communication and interaction. Synchronous tools and network connectivity can create a human social network between users (Kadle, 2010a). Therefore, a mobile learning system must provide effective social networking tools to achieve these objectives (Kadle, 2010b). These tools create the potential to facilitate interaction in the classroom and close the communication gap during a lecture.

2.7. Architectures of Mobile Learning Systems

Numerous mobile learning systems have been developed in educational institutions using several designs of architectures for different purposes. This includes supporting education, improving communication and fulfilling the needs of the mobile learning components. The following architectures are representative of those relevant to contact learning. A discussion of four examples of mobile learning architectures follows.

2.7.1. Architecture for Adaptive Mobile Learning

The adaptive architecture developed by Jung and Park (2006) considers learners' knowledge level by providing learning materials based on individual learners' profiles.

It consists of four parts: repository, web server, client and relay server (Jung and Park, 2006). The repository represents a store of learner materials created by educators, such as courses and assignments.

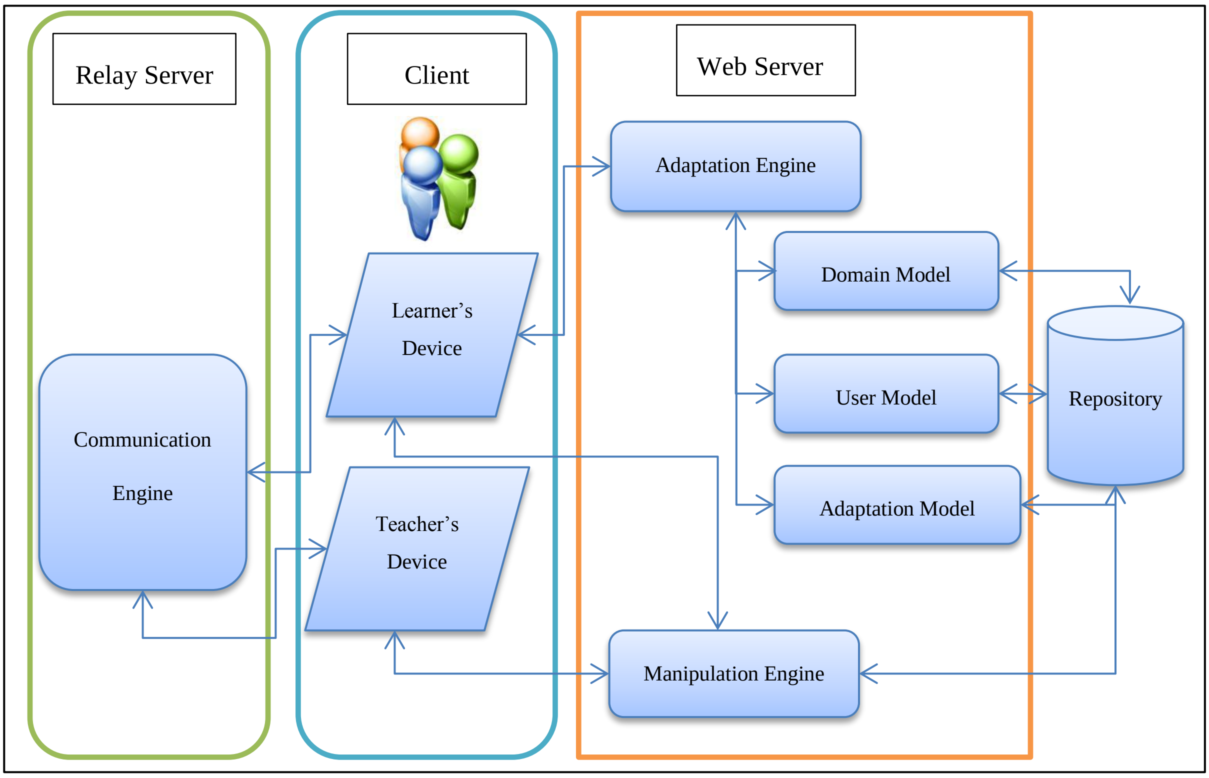

Figure 2-5: Adaptive mobile learning system (Jung and Park, 2006).

The web server is the core of the adaptation system. It has an adaptation engine linked to three models. These models help the adaptation engine to customise the mobile learning experience to each learner. The web server has a manipulation engine, which writes a report of learners' behaviour. Learners and teachers can obtain learning material from the repository through the web server. The relay server provides communication channels between the learners and the teacher. Figure 2-5 depicts the architecture of the adaptive mobile learning system, discussed in detail below.

Web server: The server receives learning materials and activities from the repository and provides these to the learners depending on the knowledge level and experience of each learner. The adaptation engine initiates when a learner connects to the mobile learning system. The adaptation engine classifies and categorises the current connected user from the user list (Jung and Park, 2006). This classification relies on the learner's level of knowledge and allows the system to provide easy or difficult learning content. The adaptation engine obtains information from the domain model, user model and adaptation model to classify a user. This information assists the adaptation engine in providing the appropriate learning content to the user.

The user model contains data about the user's characteristics (Jung and Park, 2006). The system uses this information to identify the knowledge level of the user depending on the modules completed, the number of years of study required to accomplish the qualification and the current year of study. Other factors that affect knowledge level include the period of completed learning, important subjects, learning topics that are relevant to the learner's major, and the time of access to the mobile learning system. This information is available to the learner's mobile device in order to change the learning content related to his or her study field and learning progress.

The domain model organises and structures the content of learning materials depending on which subject the lecturer plans to present during a particular lesson (Chouvet and Le Ber, 1999). Where a learner is using mobile learning for the first time, the domain model delivers simple content. On subsequent usage, it determines which content to provide to the learner based on the learner's achievements and progress. The manipulation engine generates a report detailing the learner's achievements and progress and the system saves this information in the user model.

Identification of the knowledge level of a user occurs based on some adaptation rules. These rules include the level of solid content learning, the time spent to learn a certain amount of content and the learner's response to the learning materials.

When a learner completes his or her interaction with the mobile learning system, the manipulation engine measures the knowledge improvement of the learner. The learner's knowledge level is defined according to his or her interaction and progress during the learning process (Jung and Park, 2006). It creates a report that includes the progress details and delivers this to the teacher. The teacher can modify the report and add his or her comments.

Client: This part of the adaptive system supports communication between a teacher and his or her learners via a communication engine during the learning process. Teachers may interact with the system using either mobile devices or computers. Laptop or desktop computers provide more control in managing functions in the mobile learning system. Sharing information and exchanging ideas among learners help them to improve their cognition. If a learner has difficulty solving a task or understanding an issue, he or she can share the problem with peers to determine a solution (Mumbai, 2011). Learners' every action is saved into a database to be used later to analyse learning progress.

Relay server: The relay server supports interaction between learners and the teacher or between learners themselves. The communication engine allows learners to send messages to teachers or to groups of learners. The teacher has the ability and teaching experience to identify the most appropriate information to provide to the learner.

This architecture for mobile learning attempts to personalise the content to individual learners. The adaptive processor relates to the level of learner knowledge and individual learning progress and achievements. In addition, it is an important factor in improving communication among learners and between learners and the teacher.

The adaptation system contains most of the mobile learning components discussed in Section 2.5. Common components are the learner, teacher, repository, content and assessment. The adaptation system does not include the environment because one can apply it in different educational areas, such as in the classroom or on campus.

2.7.2. Architecture for Web-Based Architecture

Internet access has reached almost everybody around the world. Educators can freely access articles, blogs and reports. The internet has become a learning resource for learners rather than information scattered in space (Glava and Glava, 2012). The web-based architecture developed by Alzaabi, Berri and Zemerly (2010) considers existing web resources in generating and providing learning materials to learners' mobile devices. It addresses their need to learn a specific model and close the information gap (Alzaabi, Berri and Zemerly, 2010). Figure 2-6 presents the architecture of the web-based mobile learning system.

The web architecture contains five main components: Web Services Management, Learning Resources Management, Courseware Authority, Graphical User Interface (GUI) and General Packet Radio Service (GPRS)/Wi-Fi connectivity.

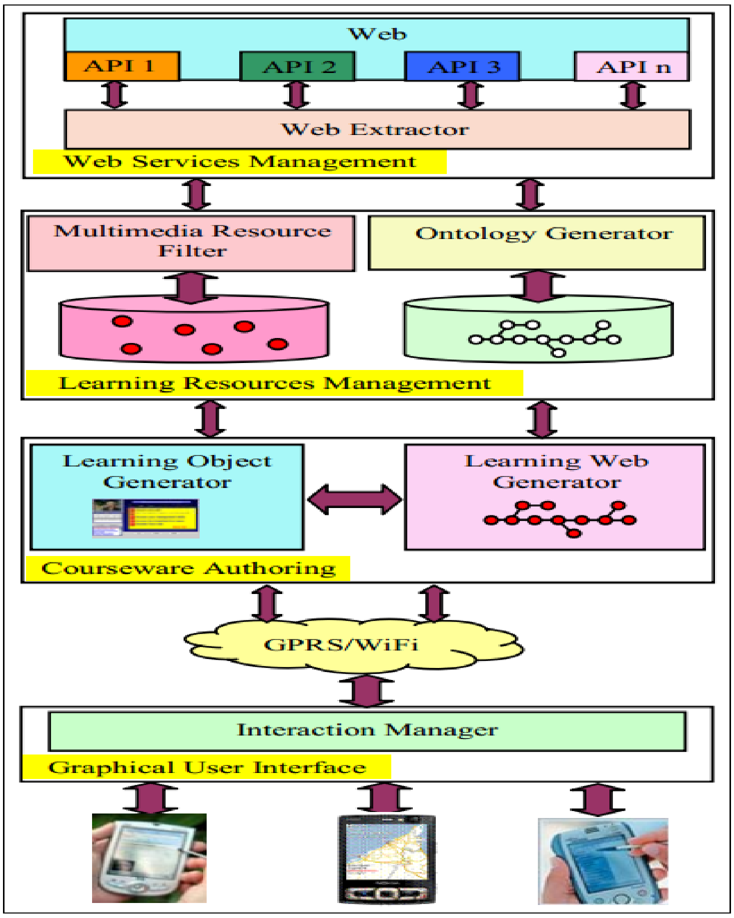

Figure 2-6: The architecture of the web-based mobile learning system (Alzaabi *et al*, 2010)

Web Services Management: This is the main component of this architecture, as the learning materials are received from web resources through web services. A learner sends a request about a specific topic from the device to collect related information about the topic. The web service begins searching for learning materials on the internet. Once the web service has gathered sufficient details about the target subject, the system sends the collected data back to the learner's device. The Application Program Interface (API) assists web services management in gathering multimedia files from specific multimedia web sites. Learning materials pass through learning resources management.

Learning Resources Management: This component considers the type of information received by the web services management. This data could be text, sound, pictures or video. The leaning resources management contains multimedia resource filters and an ontology generator.

The multimedia resource filter sorts and classifies the multimedia resources. The sorting of these multimedia resources relies on the learner's research keys and latest uploaded data to the internet. The web extractor first collects learning material from the chosen learning materials.

The ontology generator forms an ontology each time the learner makes an enquiry about web pages. The ontology generator, associated with the web extractor, creates a hierarchical structure from the learning materials. This extractor saves data into a repository under a web page title and subtitle. This makes the retrieval of information from the repository easier and faster.

Courseware authority: After filtering and storing learning objects, the course authority packages learning objects from the repository, depending on the learner's needs. This process consists of two factors: the learning object generator and the learning web generator.

Before collecting learning materials, the learning object generator considers the attributes of the learner and his or her mobile device. Each learner has his or her own profile where personal information, such as age and grade, are stored. It saves the specifications of the learner's mobile device within a learner profile. This data assists in the collection of specific learning materials from the large amount of data in the repository.

The learning web generator charts web pages based on information from the ontology. The ontology saves only the text information of web pages, namely title and subtitle, whereas the learning web generator creates a graph map of learning objects. This method simplifies the leaner's navigation of learning materials on a mobile device.

Graphical User Interface (GUI): This represents the mobile learning application installed on the learner's mobile device. The teacher can install the mobile learning application on a tablet or desktop computer. This user interface allows teachers to observe and collaborate with learners by assisting them to find learning materials. The graphical user interface attempts to adjust, adapt and present learning materials supported by each learner's mobile device. This step adapts learning material to different mobile devices.

The graphical user interface contains an interaction manager. The interaction manager assigns the responsibility of receiving a learner's request before forwarding it to the appropriate service. This procedure increases the speed of searching and collecting data from the web.

GPRS/Wi-Fi connectivity: This is a vital component in this architecture because it shapes the main communication channel between the learners and learning materials. It delivers a user's query and receives information from the repository before presenting the results on a mobile device. This architecture facilitates mobile learning accessibility and availability by allowing users to connect to the system via the internet through GPRS or Wi-Fi connectivity.

The web-based architecture selects information in web pages by searching for valuable learning materials for learners. The data collection process undergoes numerous steps to filter and categorise information into beneficial and helpful forms. A specific component determined by the learner's profile and mobile device pushes the learning materials to an address. This architecture could be useful for researchers due to the large amount of information it gathers from various resources.

2.7.3. Architecture for Mobile Game-Based Learning

Due to the significant advances in mobile devices, the number of mobile games available has increased rapidly across numerous mobile platforms (Mitchell, Lane and Inchingolo, 2006). Mobile games are pervasive among youths and learners at educational institutions. This phenomenon suggests that educators should use mobile games to supplement education (Kim *et al*, 2012).

The Mobile Game-Based Learning (mGBL) architecture is designed to present educational content on a learner's mobile device in an easy and effective manner (Kromer, 2010). The main components of the architecture are database, server, connectivity and client. Figure 2-7 describes the structure of the architecture.

Database: This represents the repository of the learning materials prepared and stored by educators. Learning materials may include courses and video training. Learners can access all of these learning objects through the server by using object relational mapping. The use of object relational mapping for storing learning materials in a repository creates an effective virtual database. This virtual database reduces the code needed to manage the repository and results in faster retrieval times (Kromer, 2010).

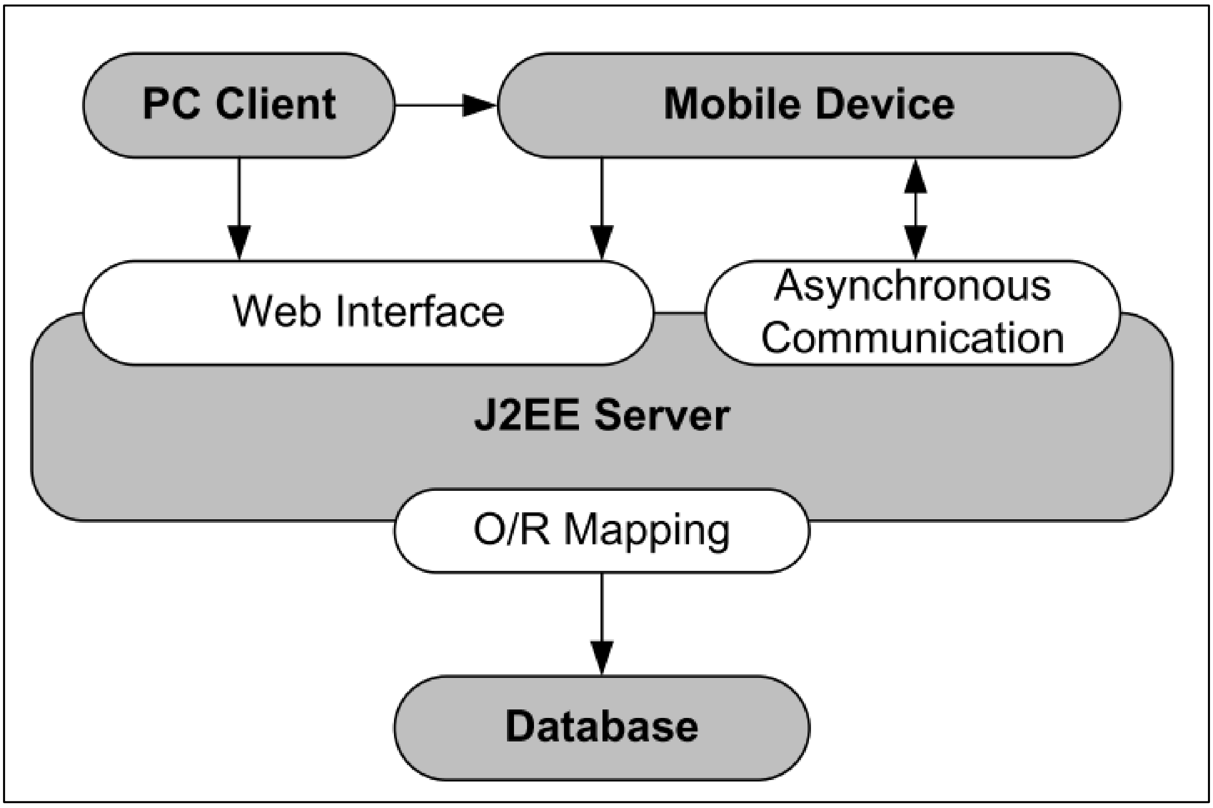

Figure 2-7: mGBL architecture (Kromer, 2010)

Server: In this architecture, most of the processing takes place on the server side. This process enables the inclusion of a wide range of simple mobile devices into the mobile learning system. The role of the server is to retrieve information from the database and deliver it to the client. The system brings this data to the mobile device or computer according to the learner's needs or the teacher's query. Clients' devices can access the learning materials directly from the web browser of the server. This architecture includes a web interface to allow convenient access and modification of the content via a web browser. Teachers can create, edit and delete the content of learning materials from their desktops. The three methods discussed below support the fetching and accessing of content.

Connectivity: With the first connectivity support, the user has to plug his or her mobile device into a server to retrieve learning material. The server has download tools that allow easy and quick data transfer. The second type of connectivity is a Wi-Fi connection. This connectivity is based on a mobile device's GPRS feature. This is a built-in feature in numerous modern mobile devices. The third type of connectivity is an asynchronous method using short message services (SMS) or multimedia messaging services (MMS) for information transfer from the server.

Client: The client side is a learner's mobile device or a teacher's desktop. The mobile device presents learning materials through the mobile application. The teacher's desktop is allowed to browse and manage the learning content in the repository. This management of the learning content accelerates the modification process of learning materials.

The architecture of the mobile Game-Based Learning project aims to take advantage of the proliferation of mobile games. Applying this kind of architecture decreases the teaching time of how to use the mobile learning application due to the ease of use of games and their acceptance amongst the youth. However, this architecture does not offer any type of learner adaptation. It merely retrieves learning materials for mobile devices.

2.7.4. Architecture for a General Mobile Learning Architecture

The architecture developed by Trifonova and Ronchetti (2003) takes advantage of the popularity of e-learning and the mobile technology revolution to create a new learning platform. The structure of this general mobile learning architecture aims to extend e-learning to a mobile learning platform (Trifonova and Ronchetti, 2003).

E-learning is popular and prevalent in many educational institutions (Sokolová, 2011), and mobile technologies and connectivity mechanisms have improved remarkably in the last decade (Haag, 2011). E-learning differs from mobile learning in that it utilises a personal computer or laptop to present learning content; the crux of mobile learning is providing the learning content through mobile devices such as cell phones. The differences in the facilities of desktop computers and mobile devices influence the structure and presentation of learning content. These differences include the size of the screen, the amount of memory and local storage available, the keyboard and the amount of input support of media files. This architecture addresses the issues of transitioning the learning content from e-learning to mobile learning. This extension of e-learning to mobile learning should offer all the e-learning services on a mobile learning platform.

Figure 2-8 depicts the general mobile learning architecture and describes the method of extending e-learning to mobile learning. The components found in the architecture are the storage layer, business layer and presentation layer.

Because this architecture combines an existing e-learning platform with mobile learning, it uses the components of e-learning in addition to mobile learning components.

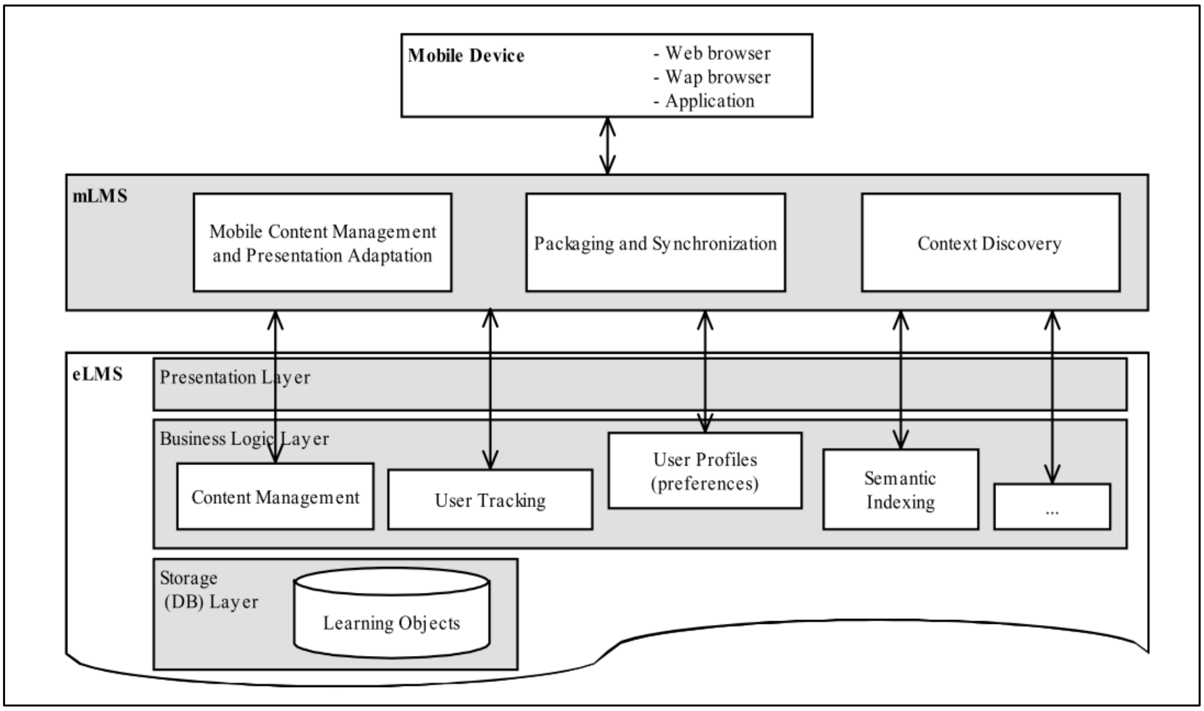

Figure 2-8: General mobile learning architecture (Trifonova and Ronchetti, 2003)

Storage layer: This manages the storage of digital learning materials such as courses, lectures, tests and quizzes. Teachers create and modify this information, which the system delivers to learners later. Retrieving and delivering data occurs via the business logic layer.

Business logic layer: This layer considers the procedure of sourcing learning materials from the repository according to the learners' demand. Simultaneously, it saves important information about each user, such as content management, tracking and profile. This layer aims to create an adaptive learning system and a background of users' needs. The business layer prepares learning materials to present them on a mobile device.

Presentation layer: This layer does not consider the computer's capacities or features. It merely presents the content as created or modified by the educator.

In order to expand e-learning management systems to mobile learning, the following components need to be added to this architecture.

Mobile content management and presentation adaptation: Content management presents the learning content on different personal computers in the same way. Mobile content management and presentation adaptation methods restructure and redesign the learning content based on the features and connectivity of a learner's mobile device. Learning materials on a mobile device could be presented in different applications, such as via a web browser or mobile application. This layer considers the method of transferring data to a mobile device (Wi-Fi or internet) to improve the speed of transactions between the repository and mobile devices.

Packaging and synchronisation: These components offer offline usage of learning materials irrespective of the availability of connectivity. Learning material is produced, delivered and stored on a learner's mobile device. The mobile device connects to the source computer via a network cable. When the mobile device is connected, the computer starts packaging learning materials to prepare for transfer. Next, the system initiates the synchronisation processes to fetch learning materials from the server to save them on the connected mobile device.

Context discovery: The system needs consider the learning context. Therefore, it needs to discover the capacities and limitations of the learners' devices. This detection obtains information that assists the learning system in deciding which services it can deliver to a specific device. To overcome the limitations of mobile devices, context discovery identifies the learner's device position. It establishes whether the mobile device is in Wi-Fi or GPRS network range. Based on a learner's mobile device connectivity, it decides to use one of these networks to deliver learning content. This step takes over to create content that fits each mobile device according to it features.

Mobile device: A learner can browse learning materials on a mobile device via a web browser, Wireless Application Protocol (WAP) browser or mobile application. The system can fetch the learning materials from the server via Wi-Fi. The packaging and synchronisation components store learning materials directly in the storage on a learner's mobile device while he or she is offline. These two methods of producing learning materials allow mobile learning that is more flexible.

This architecture proposes an alternative solution for providing learning content in e-learning and mobile learning. Thereafter it creates blended learning in educational institutions by extending existing e-learning components. In this manner, it optimises the distribution of learning materials among learners to make it more accessible.

2.8. A Comparison of Mobile Learning Architectures

The researcher analysed four existing mobile learning architectures to understand the significant themes explored in earlier research. There is a significant overlap between these architectures. Mobile learning architectures have generic objectives, such as providing information and learning content as well as making use of communication technologies. Each mobile learning architecture has its own design that uses different methods and tools to build a foundation for a mobile learning environment. The architectures share one common goal: to achieve improvement and enhancement in education via mobile devices.

Table 2-2 compares the features and capabilities of the four mobile learning architectures discussed. These features are:

1- Content customisation, which highlights the learner's knowledge level and depth. The system delivers simple or advanced learning materials according to his or her progress in learning;
2- Collaboration tools, which consider any mobile device's features suitable for the learning process to improve learners' productivity by working together (Chatti, Hamdan and Schaper, 2012). These tools might be sharing a problem, chatting or assisting each other;
3- Support rich media, which considers providing different types of multimedia content, such as video and images;
4- Existing platforms integration eligibility, which refers to the ability to extend existing learning platforms at educational institutions to mobile learning. Existing learning platforms could be e-learning or blended learning;
5- Authorisation and management, the access policy and rules identified by mobile learning architecture. This authorisation determines users' access rights based on their rules;
6- Content presentation adaptation, which discovers mobile devices' features and capabilities. The system presents the learning content based on the mobile device's specifications;
7- Knowledge sharing, which enables the users of mobile learning to share knowledge with each other. Knowledge sharing takes various forms, for example sending and receiving learning materials; and
8- Assessments, which are sets of questions or tasks that measure learners' knowledge or skills.

Table 2-2: Comparison of mobile learning architectures

		Features							
		Content Customisation	Collaboration Tools	Support Rich Media	Existing Platform Integration Eligibility	Authorisation and Management	Content Presentation Adaptation	Knowledge Sharing	Assessment
Architectures	**Adaptive**	✓	✓	✓	✗	✓	✗	✓	✗
	Web-Based	✗	✓	✓	✓	✗	✓	✗	✗
	Mobile Game-Based	✗	✗	✓	✗	✓	✓	✗	✗
	General Mobile Learning	✗	✗	✓	✓	✓	✓	✗	✗

The researcher’s comparison of the four mobile learning architectures identified the limitation in supporting the use of learners’ mobile devices in the classroom environment. These four architectures are representative of the bigger set of architectures (as stated earlier). Therefore this limitation highlights the need for a new architecture. None of these existing architectures supports the presentation of learning content on a presentation display in real time reinforces this conclusion. Furthermore, none of these architectures supports assessments via mobile devices.

2.9. Conclusion

This chapter addressed the first two research questions. It investigated the history of education and educational development from primitive to modern methods. E-learning emerged though the evolution of computers in education. The researcher presented an overview of the evolution of cell phones and mobile devices, followed by an introduction regarding the use of mobile devices in learning. The chapter highlighted that mobile devices have been used for education in the workplace and in educational institutions. The researcher further examined several examples of the existing mobile learning applications used globally and nationally.

As discussed in Section 2.8, none of the architectures investigated supplies all the important features of mobile learning, specifically those required for contact learning. Therefore, the researcher designed a mobile learning architecture suitable for use in the classroom; a description of this architecture follows in Chapter 3. The researcher identified appropriate learning activities for contact learning (Section 2.3.2.2) that one must consider to design a mobile learning architecture.

The following chapter discusses the components of mobile learning required for mobile learning as addressed by this research. A presentation of the design of a mobile learning architecture incorporating the learning components and activities identified follows.

Chapter 3: Design

3.1. Introduction

The previous chapter examined research into the use of mobile learning and identified seven components of mobile learning in the classroom (Section 2.5). It also contained a discussion of the history of mobile learning and various ways of applying it in industry and in educational institutions. The researcher investigated four architectures of mobile learning systems and identified their structures and functions. These architectures do not support contact learning in the classroom and this deficiency raised the need to design a new mobile learning architecture.

This chapter addresses the third research question identified in Chapter 1: *how can an architecture for mobile contact learning be designed?*

To design an architecture for use in contact learning, the researcher identifies the available connectivity mechanisms for mobile learning in Section 3.2. Section 3.3 investigates the possibility of using Wi-Fi connectivity at Nelson Mandela Metropolitan University (NMMU). Section 3.4 discusses the design of an architecture for mobile devices to support contact learning in the classroom environment.

3.2. Connectivity Mechanisms

The investigation of connectivity mechanisms is essential to delivering learning content to mobile devices efficiently. An overview of these mechanisms follows.

The evolution of mobile technology has produced various connectivity mechanisms for data transmission (Acharya and Kumar, 2011). Connectivity is a feature of mobile devices that is under constant development. Connectivity allows mobile devices to access and exchange data with servers and other mobile devices (Nahrstedt *et al*, 2010). Mobile devices use wireless networks such as 3G and Wi-Fi for transmission. These networks have various advantages, including:

Simplicity and expandability: New mobile devices can easily connect to the existing network with no extra equipment or infrastructure required (Fosu, 2011). Using less equipment and cables creates a reliability of connectivity by reducing interference from the environment, such as damage to the equipment and time spent on maintenance (Yu *et al*, 2011). These features assist wireless networks in expanding more easily than other networks. This characteristic has brought significant advantages to large institutions like universities where the number of learners and employees continuously increase.

Breaking physical boundaries: Wireless connectivity provides an opportunity to eliminate the restrictions of physical locations by connecting mobile devices without wires. These factors make the diffusion of information between network users convenient and simple (Bein and Zheng, 2010).

Low installation cost: The most significant feature of using wireless technology is the lack of wires. This advantage makes the cost of implementing a wireless network lower than that of a wired network. In addition, it enables users to establish these networks in numerous areas where wires would be inconvenient, such as airports, universities and other public areas.

The following three sections discuss the existing connectivity mechanisms that developers can consider for mobile learning systems in the classroom environment, namely short-range connectivity, 3G and Wi-Fi.

3.2.1. Short-Range Connectivity

Short-range connectivity synchronises various devices over a limited distance in order to share data and enable interaction between them (Ghosh and Das, 2008). The two most common short-range connectivity methods are Bluetooth and Near Field Communication (NFC).

Bluetooth is a wireless short radio frequency technology used to exchange data over a short distance (Challoo, Oladeinde and Yilmazer, 2012). Due to the integration of Bluetooth in many mobile devices and the prevalence of the use of mobile devices, the use of Bluetooth technology has grown. Its ease and simplicity of use bolsters its popularity.

This technology, however, has some limitations, such as slow transfer rates and distance restrictions. Different Bluetooth versions have different communication standards and spectrum frequencies (Franklin and Layton, 2013). Due to these differences the quality and speed of the data transfer deteriorates severely between the devices (Ally, 2009). Bluetooth supports the connection of devices over distances between 1 and 10 metres (Vasiliou and Economides, 2007). This factor excludes the use of Bluetooth in lecture venues because most lecture venues are longer than 10 metres (Chall*oo et al*, 2012).

Bluetooth has added to the development of technology and heralded the expansion of other technologies such as NFC. NFC is a very short radio wave signal permitting modern mobile devices to communicate and exchange data with each other directly. NFC establishes a connection within a close distance, from 0 to 5 centimetres apart (Fernández *et al*, 2013). The limited, short distance connection gives NFC a high security level. Devices further than 5 centimetres away cannot interfere with an NFC connection. This security advantage has been used for secure transactions such as mobile bank payments (Leong *et al*, 2013). Similar to Bluetooth, NFC is not suitable as a connectivity mechanism for mobile learning in the classroom due to its short distance connection.

3.2.2. 3G

One of the high bandwidth infrastructure networks that provides network connection between hand held devices is 3G (Kinshuk, 2003). The essential objective of developing 3G in mobile devices is to keep abreast of the growth of mobile applications using multimedia and to support high-speed data transfer (JunWu and JunLing, 2012). Most modern mobile devices come with 3G built in, which allows the devices to connect to a global network through telecommunication agents. 3G is widely used because it is easy to use and does not need any infrastructure on users' mobile devices to connect to the network. Upload and download speeds are increasing rapidly. The download speed of a 3G network has reached up to 7.2 Megabits Per Second (Mbps) (Marling, 2013).

In some countries, 3G connectivity costs are low. For example, companies in the United States charge $ 0.05 (R0.50) per Megabyte (MB) (Verizonwireless, 2013). However, several factors affect 3G broadband speed and availability. In South Africa, connectivity costs remain high. For example, Vodacom charges R2 per 1 MB (Vodacom, 2013), while MTN provides a 3G internet service at R 1 per 1 MB (MTN, 2013). Network coverage and availability depends on the carrier's tower location and the distance from the subscriber to the tower. Furthermore, weather conditions play a significant role in the quality of the network. These factors make 3G an unreliable connection for mobile devices in certain areas. Since this study was conducted at NMMU, which has a tower on the premises and good 3G-network coverage, reliability is not an issue. Using 3G to exchange data in the classroom is, however, not an affordable connectivity method due to the high data costs in South Africa.

3.2.3. Wi-Fi

There is a growing need to transfer large amounts of digital content frequently, quickly and effectively. Wi-Fi communication systems can address this need (Carvalho *et al*, 2012). This has promoted the rapid spread of Wi-Fi technology in general and more specifically in large structured institutions such as educational establishments.

The Wi-Fi mechanism has advantages that makes it more popular for broadband usage in specific scenarios (Carvalho *et al*, 2012):

Free access: Wi-Fi provides a significant advantage in that it allows users to access servers and exchange data between mobile devices at no cost (O'Reilly, 2013). Many educational institutions, public places and workplaces provide free access with no limitations.

Coverage area: Wi-Fi uses radio signals that enable mobile devices to connect to the access point as transmission media (Carvalho *et al*, 2012). To expand the range of a Wi-Fi coverage area, the access point uses antennas or repeaters to increase the area of radio coverage. Some Wi-Fi access points cover up to 5 kilometres (Fitzpatrick, 2012).

High-speed data transfer: Wi-Fi produces a high-capacity data transfer speed (up to 300 Mbps) (Wolf and Rummler, 2011). Wi-Fi has thus overcome numerous obstacles and has contributed to quality internet around the world (Fosu, 2011).

Wi-Fi has the following limitations:

Reliability and limited range: Because Wi-Fi uses radio waves to transfer data, environmental conditions affect its coverage range (Chall*oo et al,* 2012). For example, the use of Wi-Fi indoors may reduce the range to less than half of the range of the same Wi-Fi network installed outdoors. Indoors factors that affect network range include the thickness of walls and doors.

Wi-Fi uses wave frequency transmission to exchange data. This may cause unreliable connections. Wind or rain can cause noise, which can reduce the quality of the wireless connection (Yu *et al*, 2011).

Bandwidth: The router's download speed settings may cause limited speed capacity, irrespective of the options contemporary technology presents. For example, when a network user who has access to unrestricted speed browses or downloads high volume data, the speed on the rest of the network's devices is reduced (Li and Yu, 2008). Conversely, when a network user who has access to a limited speed is browsing with a device with a much higher ability, he or she is constrained to the set limited speed.

3.2.4. Comparison of Connectivity Mechanisms

Based on the preceding discussion, one can conclude that Wi-Fi is the most suitable connectivity mechanism for use in the classroom. Wi-Fi offers several advantages, such as free access and a superior coverage range. Using 3G connectivity in the classroom is unaffordable due to high cost of data transfer. 3G connects to the data service provider, but Wi-Fi does not need to do so. In addition, Wi-Fi is available to learners for free on campus. Bluetooth has a limited coverage range, which is problematic in large lecture venues, and NFC has an even smaller coverage range. Before the researcher committed to Wi-Fi for this study, he determined the Wi-Fi coverage on campus at NMMU. In Section 3.3, the researcher examines the actual signal strength of Wi-Fi in different lecture venues.

3.3. Wi-Fi Connectivity at NMMU

In 2013, NMMU conducted a survey among first year learners of the Department of Computing Sciences. The survey was administered to 570 learners as a printed questionnaire.

The survey results indicated that 99.8 percent (n=569) of learners have at least one mobile device. Of these devices, 80 percent (n=456) have integrated Wi-Fi capabilities. This implies that 80 percent of existing devices have the capacity to connect to the NMMU Wi-Fi network.

This encouraged NMMU to create internal networks on its campuses to complement contact learning. Each campus has numerous buildings where lecture venues are located. To provide Wi-Fi access at NMMU, routers were installed at various positions in each building.

Information and Communication Technology Services at NMMU created a heat map, which depicts the location and Wi-Fi coverage for a particular floor in each building. Figure 3-1 presents the mapping coverage of the Wi-Fi network in the Embizweni building on South Campus.

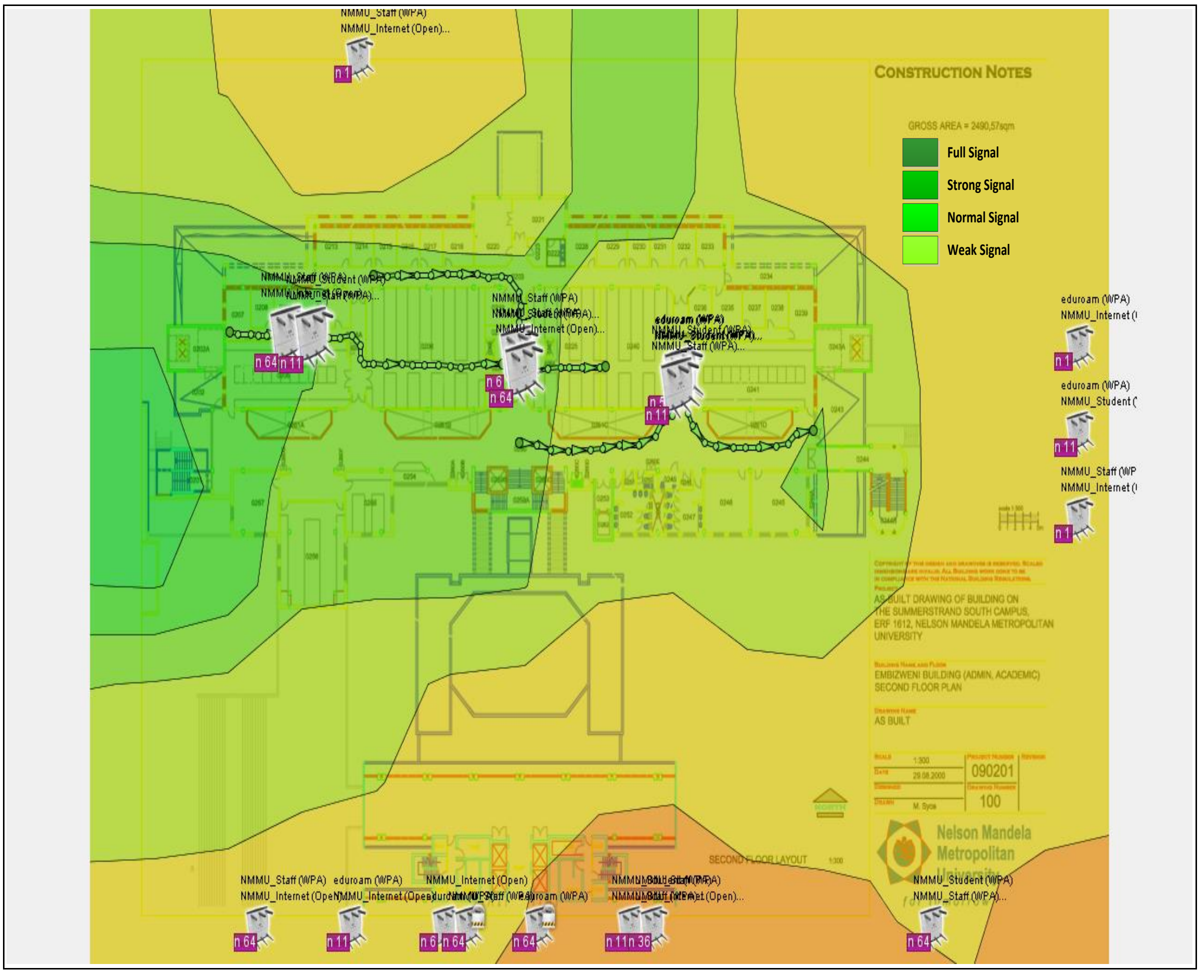

Figure 3-1: Wi-Fi heat map of Embizweni building, second floor (NMMU, 2013b)

Each of the wireless networks on campus has limitations and several factors influence the quality of the Wi-Fi signal. This includes the distance between a mobile device and the access point. Because Wi-Fi uses radio signal bandwidth to transmit data, the spectrum of another Wi-Fi router may interfere with the Wi-Fi signal, limiting the Wi-Fi range. Data download speeds are unstable during the day, as the number of learners connected to the network affects these speeds.

The researcher conducted an experiment on South Campus at NMMU to investigate actual Wi-Fi coverage and the signal quality in different lecture venues. To achieve this, the researcher developed a mobile application that performed two functions. The first function was to send a message from a mobile device to a server, which included a text message and a picture of 1 MB in size. The second function was to send a message from the server to the mobile device after receiving the message. The goal of this exercise was to calculate the delay between a mobile device and the server for different Wi-Fi signal strengths. This indicated the actual Wi-Fi coverage and signal strength quality in different lecture venues.

This experiment focused on the Embizweni building because the main evaluation of the mobile application was to take place in this building. Before sending a data package, the researcher observed and recorded the signal strength to compare the delay time with the signal quality. Figure 3-2 presents the outcome of the Wi-Fi performance measurements at various locations.

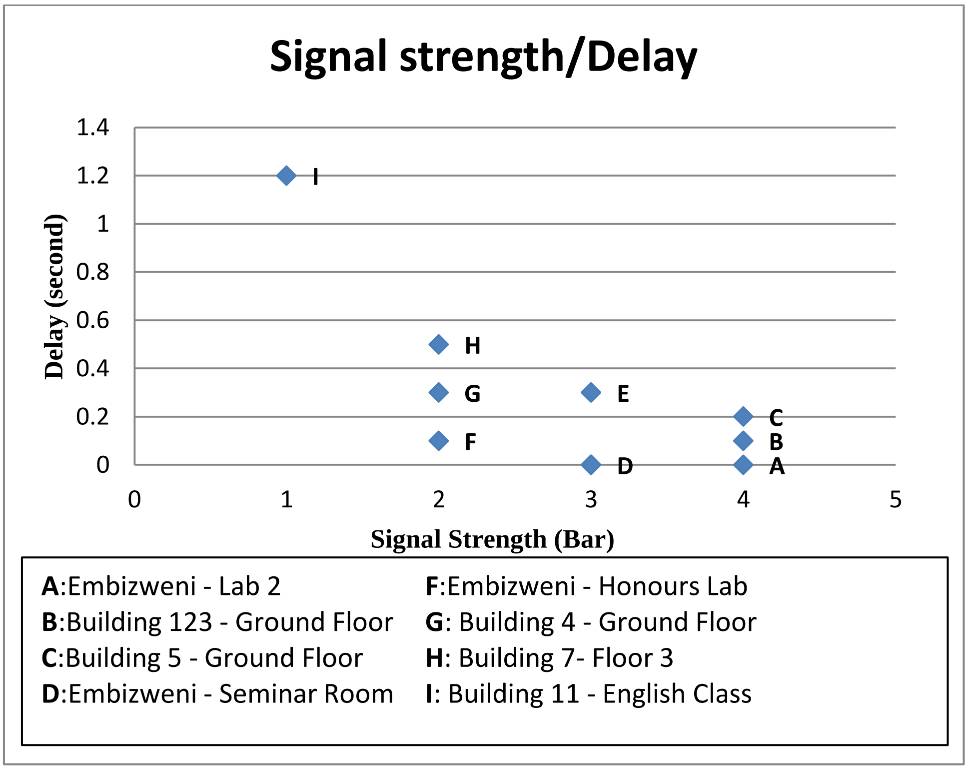

Figure 3-2: Wi-Fi measurements

Figure 3-2 displays two axes. The horizontal axis is the signal strength representing Wi-Fi quality, which is measured in bars (four bars is a full signal and one bar is the weakest signal). The vertical axis is the delay time; the unit of measurement in this experiment is seconds.

As expected, there is a correlation between signal strength and delay. The experiment shows that the strongest Wi-Fi signals incur the shortest data transfer delays and vice versa. The thickness of the walls and doors as well as the traffic on the network at the time of the experiment may explain the lack of linear correlation. In all cases, the time delay was small enough not to be problematic. This evaluation confirmed that Wi-Fi connectivity is the appropriate connectivity technology for this research.

3.4. Mobile Learning Architecture

In the previous chapter (Section 2.7), the researcher reviewed four mobile learning architectures. These architectures presented a method and structure to provide learning via mobile devices. Each architecture discussed had to perform certain learning activities (Section 2.8).

The architecture of adaptive mobile learning provides learning content based on the learner’s level of knowledge (Section 2.7.1). However, it does not consider contact learning in the classroom. The web-based architecture examines existing web resources to generate learning materials and provide it to learners’ mobile devices (Section 2.7.2). This architecture omits the role of the teacher, as the learner obtains learning content directly from the internet. The mobile Game-Based Learning architecture presents educational content on a learner’s mobile by taking advantage of mobile games (Section 2.7.3). This architecture does not consider presenting learning content in the classroom environment. The general mobile learning architecture takes advantage of existing e-learning and extends it to mobile learning (Section 2.7.4). This architecture provides learning content to mobile devices in a general education environment.

These architectures support learning, but not in a contact learning environment. None of them supports presenting learning content on a presentation display during the lesson. They do not provide specific learning activities, such as assessments or surveys (Section 2.8). Furthermore, the architectures do not consider providing learning contact and communication between the teacher and learners in real time. These deficiencies confirmed the need to design a specific mobile learning architecture for use in contact learning in the classroom environment.

3.4.1. Overview

One of the main objectives of this research was to develop a mobile learning architecture for the use of mobile devices in the classroom, specifically for use at NMMU. The first stage in developing a mobile learning application was to determine the most suitable mobile learning architecture (Castillo *et al*, 2013). The researcher identified learning components that should feature in a mobile learning architecture (Section 2.5). Figure 3-3 illustrates the main components of mobile learning as applicable to this research.

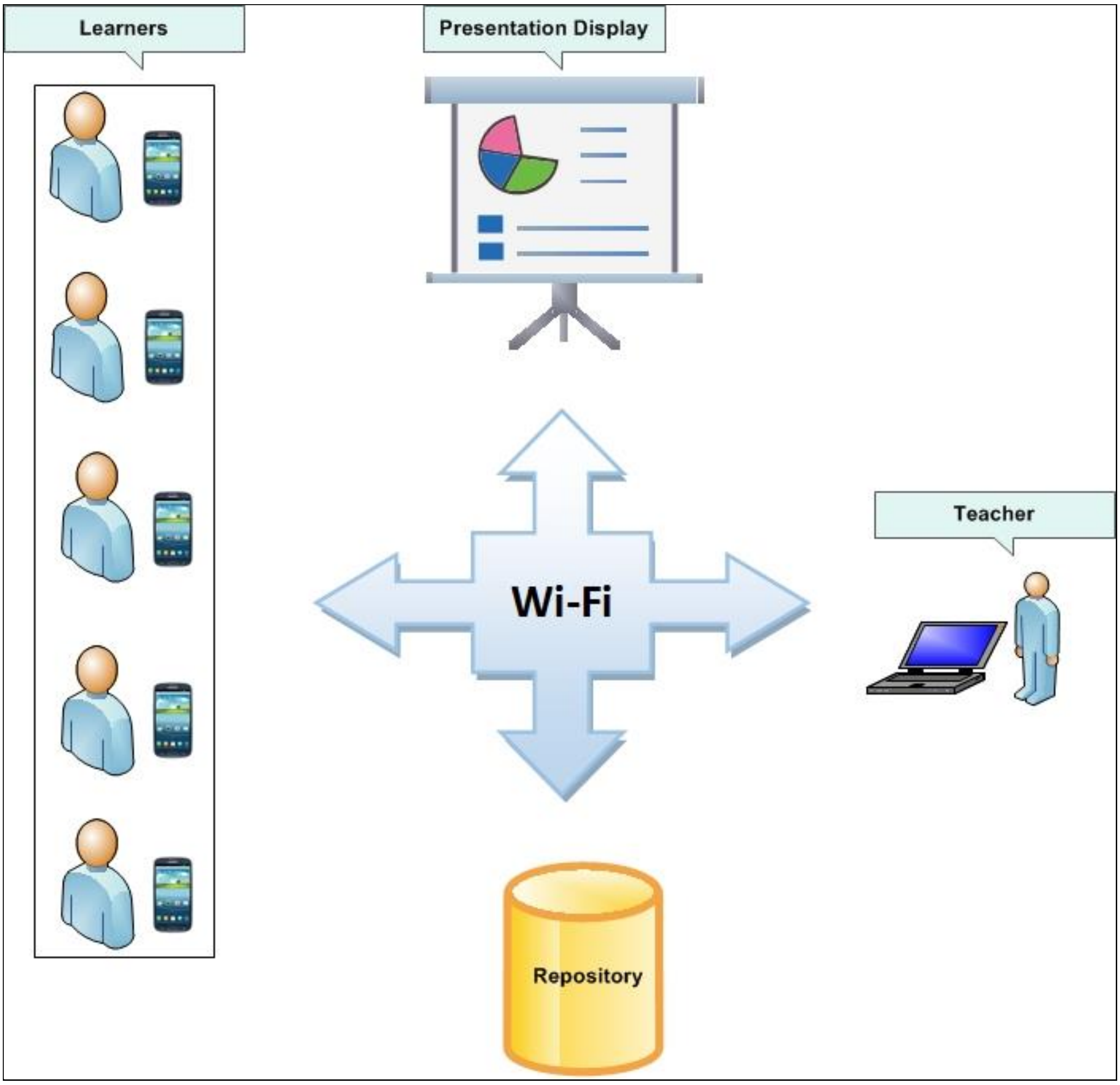

Figure 3-3: The main components of mobile learning in the classroom

The researcher further identified several objectives of mobile learning (Section 2.3.2). These are collaboration, communication, presenting learning content, facilitating learning content and managing class assignments. Based on these objectives and mobile learning components, the researcher designed a general mobile learning architecture. This architecture, called Contact Instruction Mobile Learning Architecture (CIMLA) and is presented in Figure 3-4, offers functionality that allows the teacher to create learning activities and deliver them to the learners.

The architecture manages various kinds of information, supports the generation of reports and regulates the display of selected data on a presentation display. It supports mobile devices, which have the following minimum requirements:

- Wireless connectivity
- Mobile camera
- Storage
- Keyboard

The mobile learning architecture comprises five main modules based on the components of mobile learning in the classroom (Section 2.5). These modules are Learner Client, Teacher Client, Presentation Client, Repository and Learning Server. Each module has different components, which could be a model, engine or service. A model is a component of a module that addresses certain issues of information, for example the type of mobile device used. The engine organises and groups different actions or tasks to be used in another component of a module. A service assists other models or engines by providing the necessary data or information to accomplish a specific goal.

The Learning Server runs on the server machine, which manages the communications between different modules. The Learner Client runs the mobile device and allows the learner to interact with the mobile learning system. The Teacher Client runs on the teacher's device and allows him or her to create and send learning content to learners as well as receive results of learning activities. The Presentation Client presents the results of learning activities on the presentation display. The Repository stores all learning activities and learners' results. The researcher discusses each of these modules in detail in the following sub-sections.

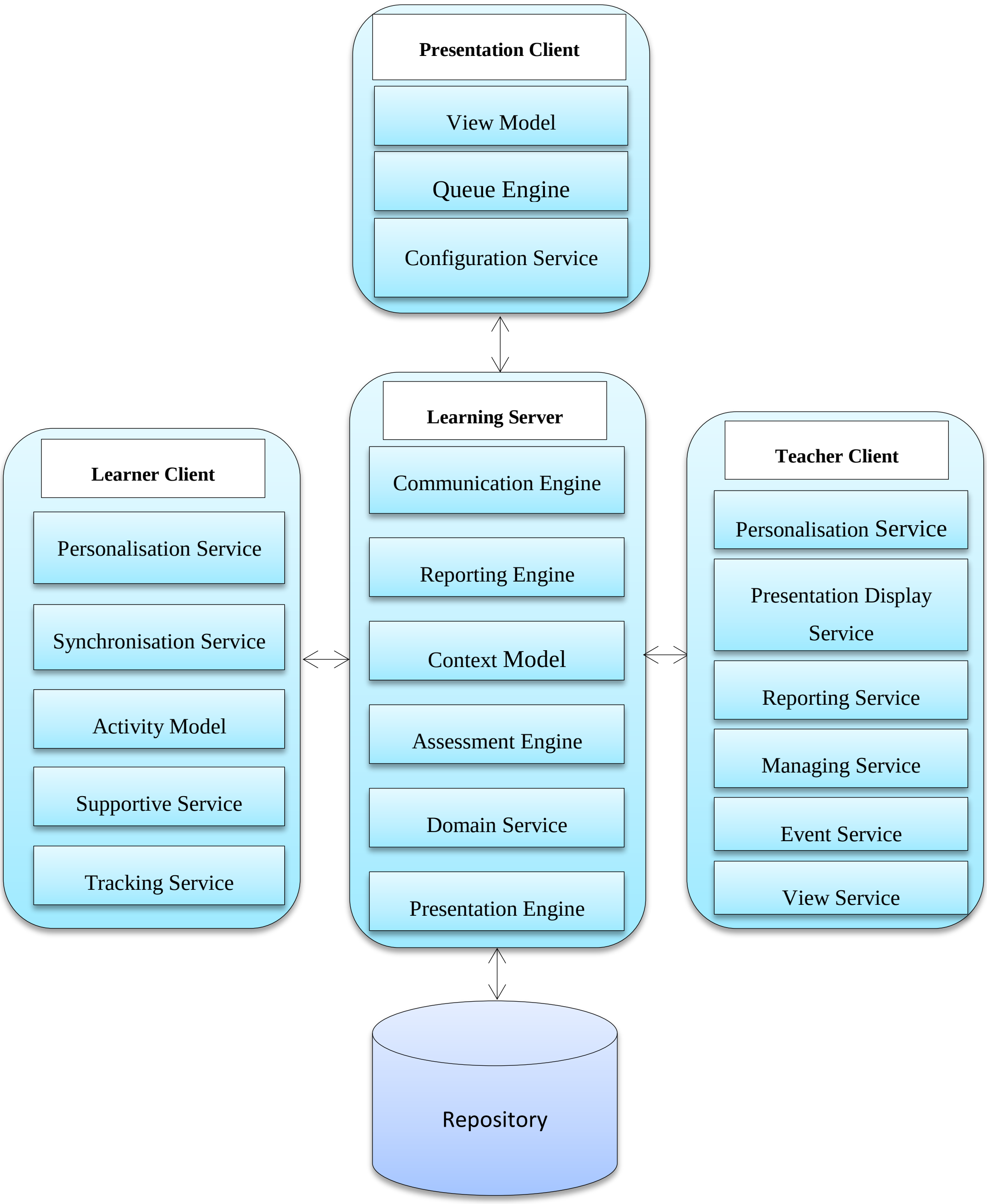

Figure 3-4: The Contact Instruction Mobile Learning Architecture (CIMLA)

3.4.2. Learning Server

The Learning Server is at the core of CIMLA. Most of the processing must occur on the server side to reduce the amount of processing required on the mobile device. This enables the delivery of learning activities to mobile devices without depending on smart features. The Learning Server manages communication between the teacher and learners, controls learning activities, and saves and fetches data from the repository. It generates reports and presents data on a presentation display. The Learning Server consists of different components to achieve these tasks.

Communication Engine

The Communication Engine is the channel that provides real-time communication between a teacher and the learners during the lesson. This engine supports communication between different platforms, including mobile platforms and desktop computer operating systems. In addition, it manages data transfers between the Learning Server, clients and the Repository.

Reporting Engine

The Reporting Engine gathers different parameters from the Reporting Service of the Teacher Client to generate reports. This engine generates the reports from the Repository according to the parameters.

Context Model

In this model, the architecture describes information about learners' mobile devices. Information gathering initiates when the learner logs into the mobile application. The collected information includes screen resolution, processor capacity, local memory storage and the model of the mobile device.

Assessment Engine

The Assessment Engine is responsible for fetching data from the Repository and delivering the relevant prepared learning activities to the teacher during classroom time. This engine minimises the amount of time the teacher spends on administrative tasks by automatically fetching and delivering learning activities. In addition, this engine is responsible for marking the learners' tasks and sending the results to the Supportive Service via the Communication Engine.

Domain Service

This service converts the learning content from the original source files to suitable formats for different mobile devices. The conversion optimises the content based on the physical features of mobile devices, obtained from the Context Model.

Presentation Engine

The Presentation Engine is the interface between the Presentation Client and the Teacher Client's Presentation Display Service. This engine stores the configuration of the display elements in the Repository. Presentation elements include a collection of different display components used to present and visualise the content of learning activities such as image, text and chart elements. The configuration of elements includes changing the location height and width of the elements on the presentation display as well as showing or hiding the elements.

3.4.3. Teacher Client

The Teacher Client facilitates and simplifies the teacher's role as leader in the classroom without losing the effectiveness of the teaching and learning environment. To achieve these objectives, the researcher proposed the following components: Personalisation Service, Event Service, Presentation Display Service, Report Service, Management Model and View Service.

Personalisation Service

This service authenticates the teacher's credentials during the login process. The authenticating information is sent from the Teacher Client to the Repository via the Communication Engine of the Learning Server. The Personalisation Service further informs the teacher of the lecture venue, lecture time and the current module, based on the lecture timetable.

Presentation Display Service

This service is responsible for manipulating the presentation display elements in real time from the teacher's application. After the manipulations, it captures and delivers the configuration of the elements to the Presentation Engine of the Learning Server.

Reporting Service

The Reporting Service captures a set of parameters from the teacher and sends it to the Reporting Engine of the Learning Server. It presents various reports about the learners' progress and achievements, received from the Learning Server, to the teacher.

Managing service

The Managing Service provides functionality supporting the creation and modification of learning activities by the teacher. This service assists the teacher in creating rich learning content that includes text and graphics. Once the teacher has prepared the learning, it transfers to the Event Service.

Event Service

The Event Service organises the queue of learning activities it received from the Managing Service before sending them to the Learning Server. Learning activities consist of a collection of different types of tasks. The learning content is transferred to and saved in the Repository via the Communication Engine for delivery to the learners.

View Service

This service is responsible for receiving the results of the learning activities from the Assessment Engine. It provides functionality to display the results on the Teacher Client. The View Service can send these results to the Presentation Client via the Presentation Engine.

3.4.4. Learner Client

The Learner Client provides functionality that allows the development of a mobile application supporting the functionalities required by learners. The Learner Client comprises the following components: Personalisation Service, Activity Model, Tracking Service, Synchronisation Service, and Supportive Service.

Personalisation Service

The Personalisation Service allows learners to log into the mobile learning application. This service matches the account of the learner attempting to log in to the list of user accounts in the Repository via the Communication Engine of the Learning Server. The result is sent back to the learner’s mobile device with confirmation or rejection to proceed further into the mobile application. This service provides information about the features of the relevant mobile devices to the Context Model.

Synchronisation Service

This service aims to ensure that the learning content is updated and the latest learning activities are delivered to the learners. The Synchronisation Service requests learning activities and messages from the Communication Engine.

Activity Model

The Activity Model describes learning activities obtained from the Synchronisation Service and presents it on the learner's mobile device.

Supportive Service

This service sends learners' tasks to the Assessment Engine for marking. Once the marking is complete, this service receives results from the Assessment Engine and provides it to the learners. In addition, the service can email a summary of completed learning activities as soon as learners have been completed them. The support for the email notification facility ensures that learners receive their results instantly and without teacher involvement.

Tracking Service

This service records the learners' actions, such as time spent performing tasks and interactions while using the mobile learning system. The tracking data is stored in the Repository via the Communication Engine.

3.4.5. Presentation Client

The Presentation Client presents important information about specific learning activities or assessment results on the presentation board. Showing and sharing this data encourages immediate interaction between a teacher and the learners. To achieve these objectives, the Presentation Client contains the following components: Configuration Service, Queue Engine and View Model.

Configuration Service

The Configuration Service is responsible for obtaining the current configuration. This service fetches the configuration via the Presentation Engine for the current teacher when the system initiates.

Queue Engine

The Queue Engine is responsible for fetching new commands sent by the teacher and holding them in a queue. It obtains new display commands from the Presentation Engine of the Learner Server. This process is crucial to keeping the data constantly updated in the View Model.

View Model

This model receives information sent from the Queue Engine to present various transmitted data on the Presentation Client. The view model adapts the sent information to fit and allow for proper viewing on the Presentation Client according to the presentation display's resolution, length and width.

3.4.6. Repository

The Repository plays a significant role in this architecture because all the other modules save their settings, configurations and generated content into it. The Repository allows the learning mobile architecture to manage and share data between its own modules and components. All the learning content is saved in and retrieved from the Repository. It is a digital content collection containing all the learning materials, learners' profiles, mobile device capacities, teachers' settings and presentation display configurations. Different methods of conversion are applied to the learning content before saving it. These methods of conversion are based on the learning content, such as text, Portable Document Format (PDF) files and images. The Learning Server adapts data fetched from the Repository according to the proposed mobile device's specifications. This process provides learning content in a format appropriate for various characteristics of mobile devices without losing the quality of the original source files.

3.4.7. Main System Use Cases

The researcher discusses two examples of use case studies, namely learning and reporting activities, for a simplified understanding of the functionality supported by CIMLA.

Learning Activities:

The teacher is responsible for creating and sending learning activities to learners and displaying the results on the presentation display. The learning activities include the following: questions, assessments, quizzes, surveys, documents, events and messages.

Figure 3-5 shows the sequence of processes initiated by the Teacher Client. The teacher creates learning content via functionality provided by the Managing Service. Once the learning activity is completed, it transfers to the Event Service. The Event Service organises the queue of the received learning activities and sends it to the Learning Server. On the Learning Server side, the learning activity is transferred to and stored in the Repository via the Communication Engine.

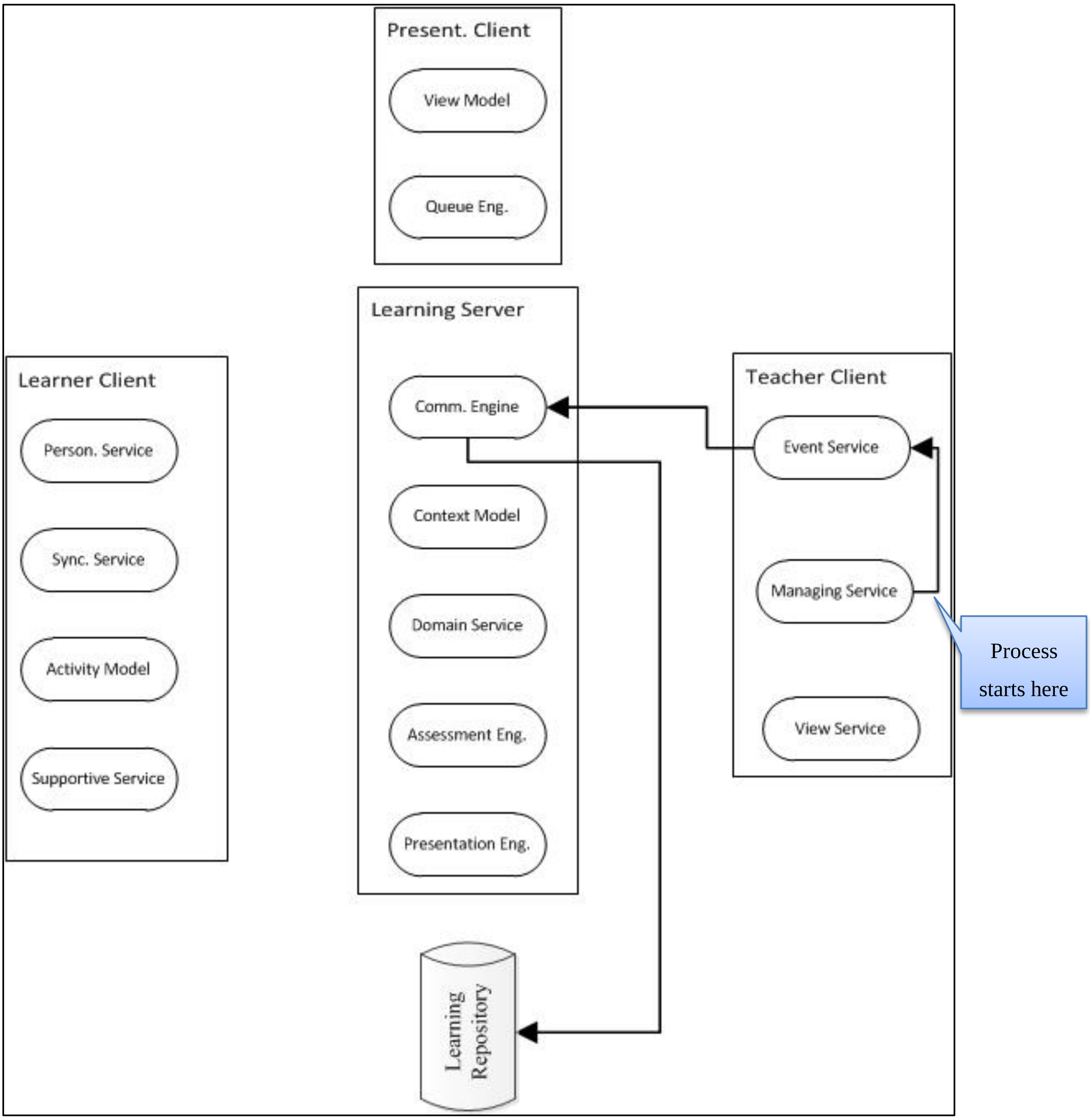

Figure 3-5: Sequence of creating a task by the teacher

Figure 3-6 depicts the process of delivering a task to the learner.

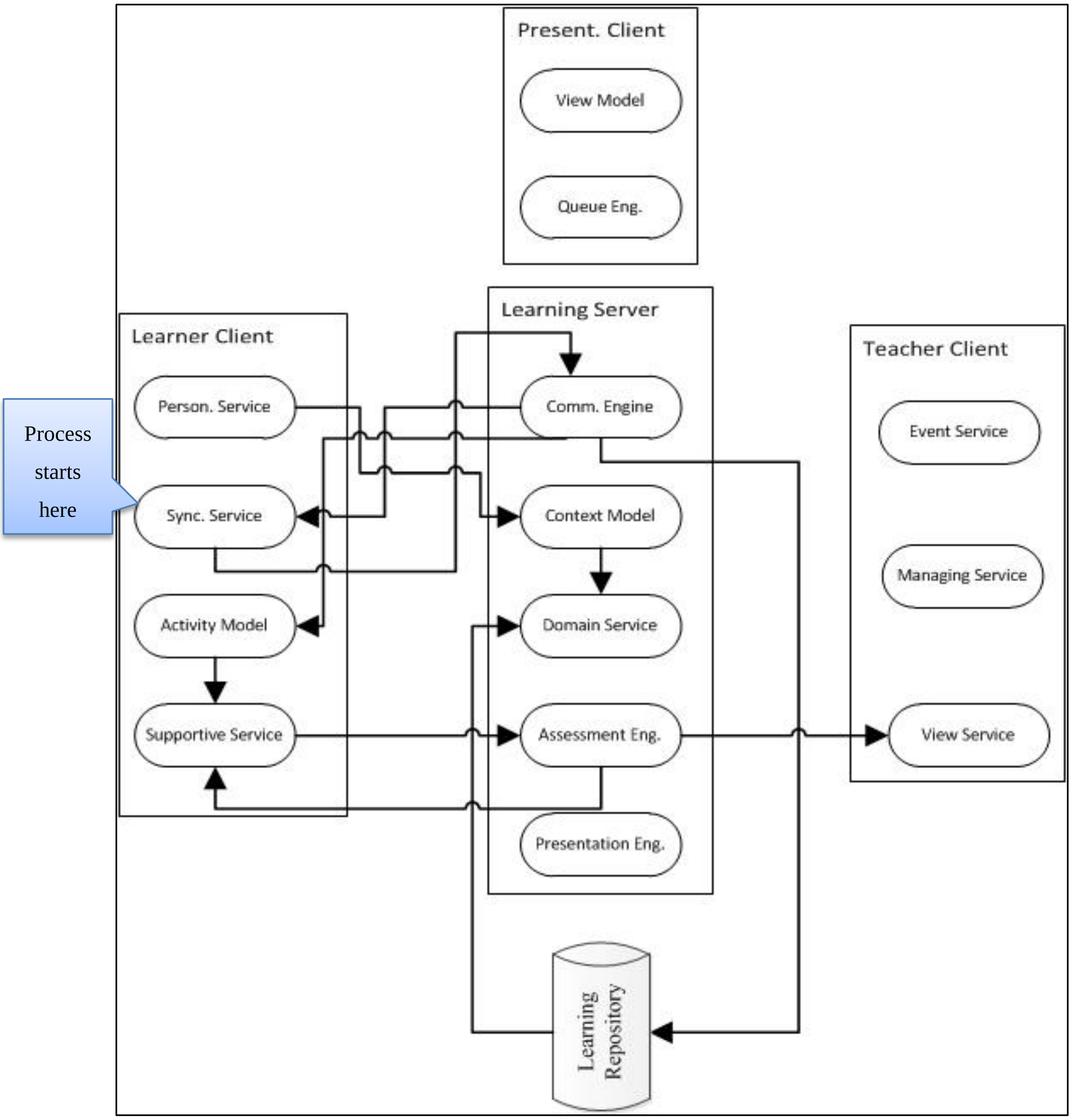

Figure 3-6: Process of delivering a task to the learner

The Synchronisation Service of the Learner Client searches for the latest learning activities via the Communication Engine. This engine fetches the learning activity and sends it to the Domain Service. It converts the content of the learning activity from the original source file to a suitable format based on the features of mobile device as received from the Context Model. The Context Model gathers information about the features of the mobile device after the learner's login via the Personalisation Service. The Synchronisation Service receives the learning activity via the Communication Engine. The Activity Model of the Learner Client receives the learning activity from the Synchronisation Service. The learning activity is described and presented on the learner's mobile device via the Activity Model.

Once the learner reviews and completes the learning activity, it is sent to the Supportive Service to be transferred to the Assessment Engine for marking. The results are stored in the Repository and a brief summary returned to the Supportive Service. The View Service of the Teacher Client receives the data from the Assessment Engine and displays the results on the teacher's device.

Reports case study

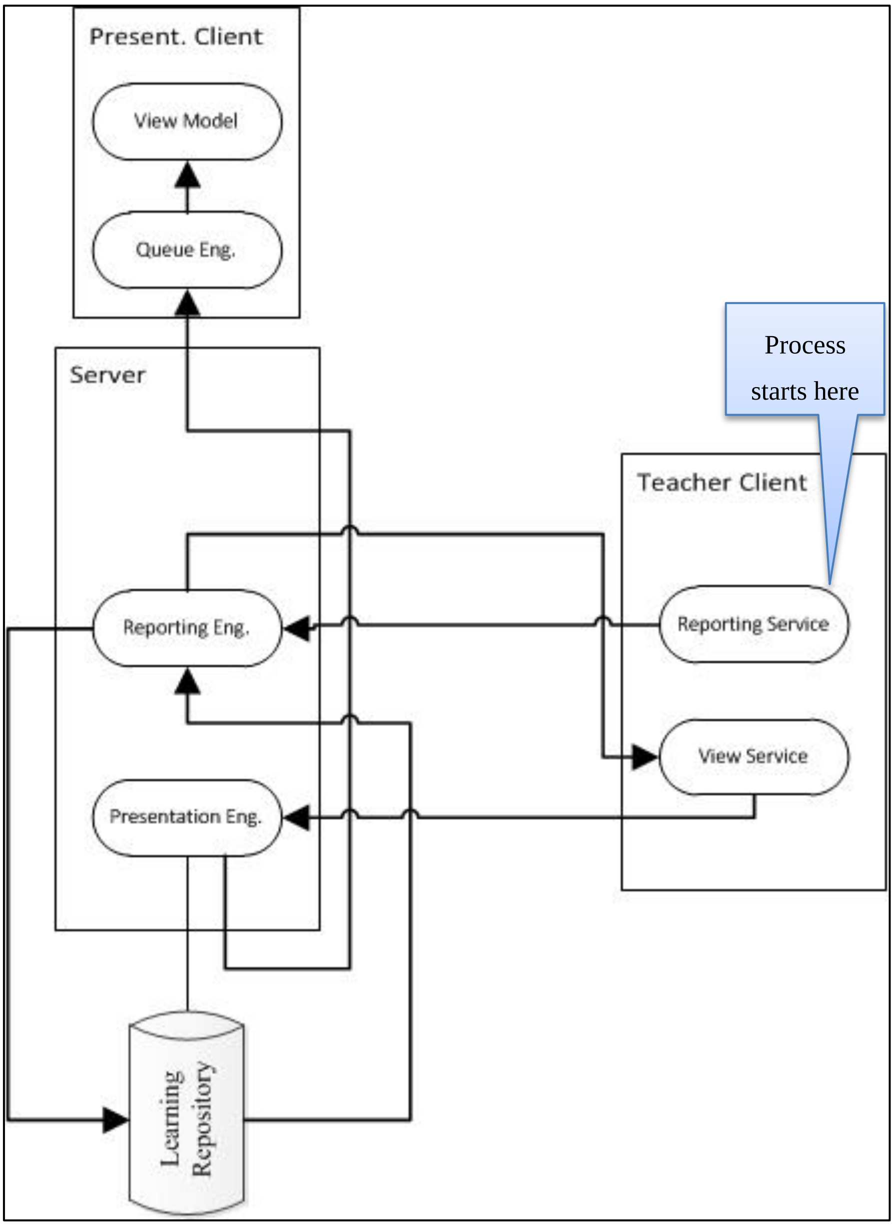

Figure 3-7: Sequence of generating and displaying reports

Users can generate reports in the CIMLA (Figure 3-7). After learners have completed the learning activities, the teacher can generate reports about their achievements and results. The Reporting Service of the Teacher Client captures various search parameters from the teacher and sends it to the Reporting Engine of the Learning Server. This engine generates a report from the Repository based on the received parameters. Once finalised, it sends the report to the View Service and displays it on the Teacher Client. The teacher can review the report on his or her device.

One can view the results on the Presentation Client by sending them to Queue Engine via the Presentation Engine. The Queue Engine obtains the content of the learning activity and sends it to the View Mode of the Presentation Client. This model presents the results on the presentation display.

3.4.8. Summary

In this section, the researcher proposed an architecture for mobile learning that is particularly suitable for mobile learning in the classroom. The modules provide learning content based on the capacities and features of mobile devices. The architecture allows the teacher to create the learning content and distribute it to the learners in real time. This architecture assists the teacher in evaluating learners by tracking their progress while they use the system. Additionally, the modules facilitate communication between a teacher and learners. The main objective of the architecture is to provide guidelines for developing a mobile learning system for the classroom. The researcher designed and implemented a mobile learning application as a proof of concept of this architecture. He discusses this in Chapter 4.

3.5. Conclusion

This chapter addressed the third research question listed in Chapter 1, namely:

How can an architecture for mobile contact learning be designed?

The researcher answered this question by designing the CMLA for the use of mobile devices in the classroom. To design this architecture, the researcher identified the available connectivity mechanisms for mobile learning, and investigated and compared four existing mechanisms, namely Bluetooth, NFC, 3G and Wi-Fi. The researcher identified Wi-Fi as the most suitable connectivity mechanism due to its accessibility and coverage area. As this research intended to apply mobile learning in contact lessons at NMMU, the researcher conducted an experiment on NMMU South Campus. The experiment proved that Wi-Fi is acceptable and feasible for mobile learning in the classroom.

The researcher based the proposed architecture on the components of mobile learning in the classroom as identified in Section 2.5. The CIMLA includes five modules, namely the Learning Server, Teacher Client, Learner Client, Presentation Client and Repository. The researcher identified each of these modules and discussed them in detail before providing main system use cases to explain the architecture functionality and the interaction between its components.

The following chapter presents the implementation of the mobile learning prototype. The researcher developed this prototype based on the CIMLA as a proof of concept.

Chapter 4: Implementation

4.1. Introduction

In Chapter 3, the researcher discussed the design of a mobile learning architecture that addresses the thesis statement of this research. The proposed architecture contains five modules that function separately to perform certain processes. These are the Learning Server, Teacher Client, Learner Client, Presentation Client and Repository.

Based on this architecture, the researcher developed the LiveLearning mobile learning system as a proof of concept. Section 4.2 contains a discussion of the mobile user interface design patterns, Section 4.3 an examination of implementation tools, and Section 4.4 an overview of the implementation of LiveLearning. A detailed discussion of the pre-evaluation process, which includes an expert review, a pilot study, and the findings and results of the pre-evaluation, follows in Section 4.5.

4.2. Mobile User Interface Design Patterns

Desktop user interfaces are designed for viewing on a wide, high-resolution screen (Ribeiro and Carvalhais, 2012). Due to the limitations of screen sizes, processor speeds and differences between desktop computers and mobile devices, developers must consider special designs to adapt to different mobile devices adequately (Collard, 2011), (Hanna, 2012).

Mobile design patterns are general and reusable solutions to frequently occurring complications and problems in the design of mobile software (Osmani, 2012). One can adapt these common mobile design patterns to a specific need in certain design situations. A design pattern is not machine code or a static pattern; it is a public template and format that one can apply in a specific situation. This allows one to apply design patterns in various mobile operating systems, such as Android and iOS. Design patterns for mobile applications have evolved over time (Pauwels *et al*, 2010). They assist in preventing subtle issues that can cause obstacles in the development process. The mobile design pattern focuses on solving the problem by using a combination of user-friendly aesthetics and simplicity. Aesthetics and user friendliness require that developers choose icons related to the contents as well as expressive and meaningful labels that provide an idea about the context. The simplicity of the patterns allows users to interact easily and effectively, which creates a responsive environment. Furthermore, simplicity should enable users to reproduce tasks by taking easy-to-learn steps and procedures.

This research focused on mobile learning in the classroom situation. The mobile learning application operates on different mobile devices used by many learners simultaneously. The researcher had to consider several characteristics in the design of the mobile learning application to gain broad acceptance among learners. These characteristics are ease of use, immediacy, interactivity, responsiveness and effectiveness (Ah-choo *et al*, 2012). The use of effective common design patterns makes it possible for the mobile learning application to achieve these characteristics.

To design patterns for use in a mobile application, the developer must consider three aspects: realising the design problem, understanding the pattern, and knowing how to adapt the pattern properly to solve the problems encountered (Javatechig, 2011).

Design patterns are categorised into several groups depending on their functionality and the way users interact with mobile devices to create interaction patterns. The main categories involve data presentation, user input and navigation.

4.2.1. Data Presentation

Due to limitations in the width and length of the screen of the mobile device, displaying a large amount of data becomes a significant issue that needs to be addressed (Lammers, Clarke and Schoenmakers, 2012). To overcome this issue, mobile design patterns present solutions such as Grid Layout, Expanding List and List View. In this study, the researcher discusses List View, as it is one of the most suitable patterns to display a list of data, such as a list of assessments.

List View: The List View composes and displays the content one line at a time. A clear demarcation separates the lines from each other and separates the information. The List View streamlines browsing and navigating of the presented information to learners in an easy and simple way . Each item might comprise an image and brief information. The information provides an overview and summary of the context of the specific item. Figure 4-1 displays a List View widely used in mobile design patterns. It includes an icon, a main label and short description for each item.

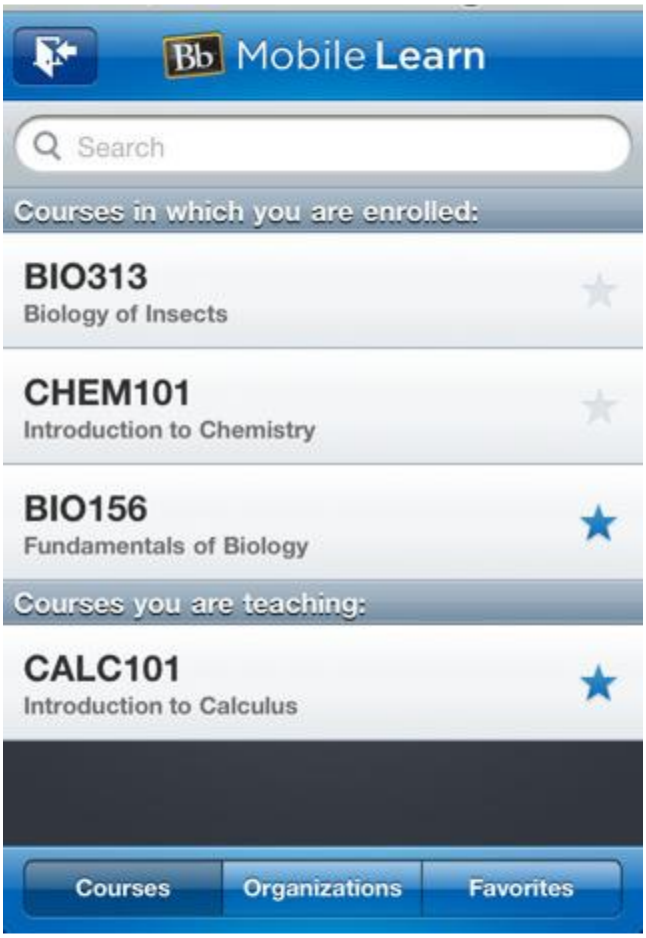

Figure 4-1: List View pattern (Neil, 2012)

4.2.2. User Input

Due to the limitations of screen size and the small keyboard of a mobile device, typing and inserting data is a difficult task for most mobile device users. Mobile design patterns provide a Text Box pattern to accelerate data entry, with a camera pattern to input multimedia entries.

Text Box:

Clearing an input using the virtual keyboards of mobile devices is inconvenient due to the limited screen size. The Text Box pattern provides a text entry area that fits the screen width with a Text Clear Button (Ribeiro and Carvalhais, 2012). Figure 4-2 shows that the clear button is to the right of the Text Box, which decreases the likelihood of clicking it by mistake. Addressing this task simplifies interaction with mobile devices and allows users to accomplish their tasks.

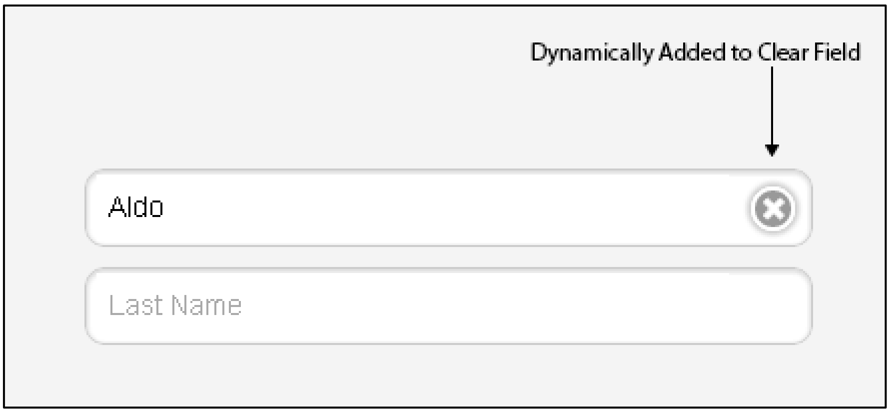

Figure 4-2: Text Box pattern with clear button (Ribeiro and Carvalhais, 2012)

Camera:

Most modern mobile devices have high-resolution cameras as well as photo and video capturing capabilities. Capturing a photo and processing it (zooming, rotating, and retaking) before saving the image into a mobile device can be time consuming. Mobile design patterns offer a camera pattern to address these issues. This pattern presents options to cover all media capturing requirements that fit on a single screen. Figure 4-3 depicts a camera pattern with standard functionality. Applying the camera pattern with standard features provides a simple and effective mobile user interface (Itzkovitch, 2012).

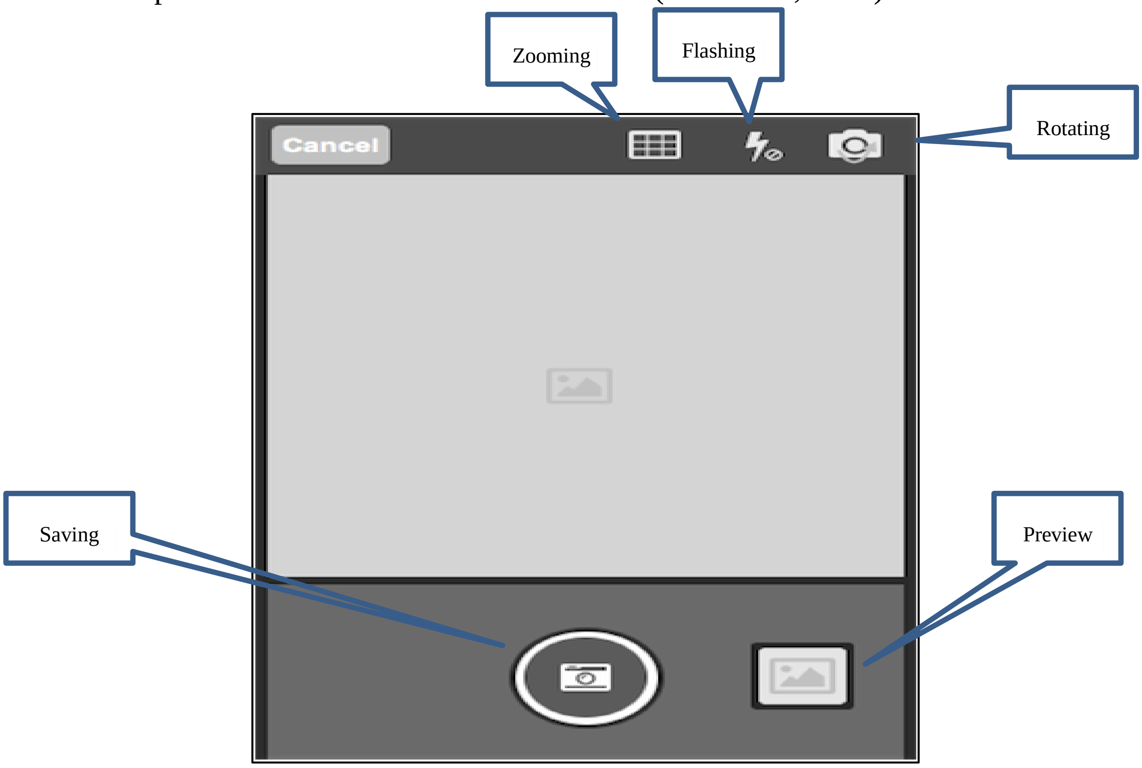

Figure 4-3: Camera pattern (UXPin, 2013)

4.2.3. Navigation

Navigation is a crucial issue in mobile design; it provides quick access to the mobile application for users (Android, 2013). The main objective of navigation is to allow the user to navigate from one place to another simply, rapidly and responsively on a small screen. Many mobile design patterns have been developed to represent compatible navigation patterns. These include context menus and wizards.

Context menu: On mobile screens, every pixel and space must count. To maximize the use of limited space, the mobile screen may request the use of hidden patterns, which appear only when needed. A context menu consists of a list of commands specific to a target, or a selected object, on the screen. Thus, it does not reserve any specific place on the screen (Ribeiro and Carvalhais, 2012). A user can keep touching on an object for a few seconds before the context menu appears, offering certain commands that navigate the user to the target object quickly. Applying this pattern facilitates the use of many context menus on narrow-screened mobile devices and keeps design simple. Figure 4-4 illustrates the general context menu pattern.

Figure 4-4: Context menu (Ribeiro and Carvalhais, 2012)

Wizard: Sometimes the user must achieve a single objective that consists of multiple sequential and related subtasks. There are numerous difficulties associated with accomplishing an entire task on a single screen because of screen limitations. A wizard pattern overcomes these difficulties and assists in the completion of the task. The wizard displays several sections of content on separate screens and saves screen space by creating a series of forms. This method simplifies and facilitates the user's data input and the essential task by dividing it into many tasks and keeping the user's focus on the current task. Navigation buttons allow for quick navigation between sections of the wizard. Figure 4-5 illustrates a simple wizard that works by offering the ability to proceed to the next step or return to the previous step.

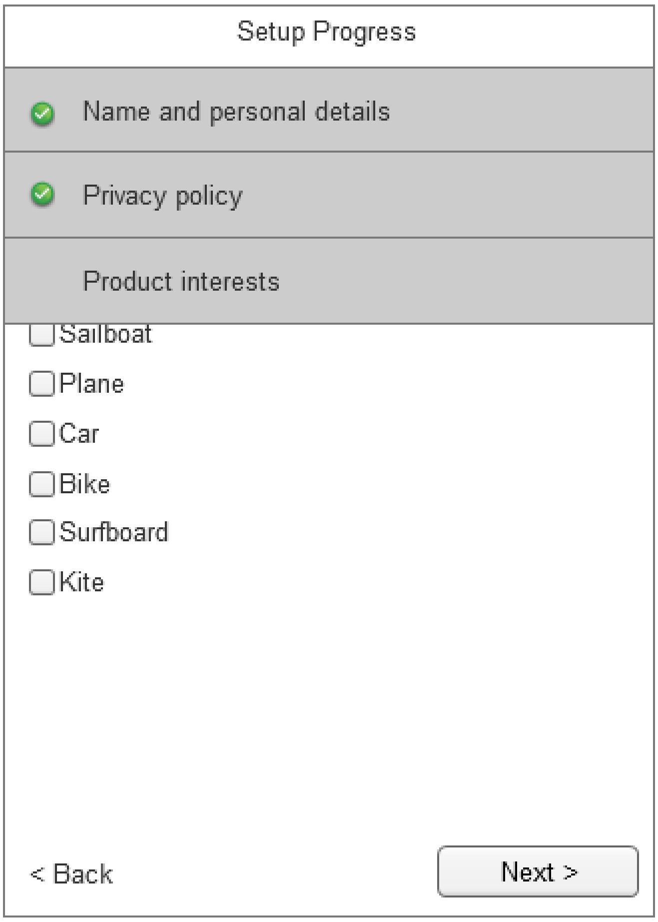

Figure 4-5: Navigation pattern (Rouben, 2012)

4.3. Implementation Tools

As part of this study, the researcher had to distribute the mobile learning application to learners by installing LiveLearning on their mobile devices. Because the learners possess different types of mobile devices, the researcher considered developing the implemented mobile learning application for only the most popular mobile platforms. The researcher investigated various cross-platform mobile applications to identify the most suitable development framework. Table 4-1 illustrates a method of comparing the available cross-platform applications that one can use for the development of the mobile application. The researcher based the selection criteria on whether the framework supports the most popular mobile operating systems and allows for the development of a native mobile application. He also considered the cost of a licence. A native mobile application is an application that can interact with the capabilities of a mobile device and take advantage of the operating system installed on that platform. This native application allows users to obtain access to the mobile camera, General Packet Radio Service (GPS), and storage and system files.

A native application also improves the user’s experience as the look and feel of the application is consistent with the hardware platform. Some frameworks allow developing across platforms based on Hyper Text Markup Language (HTML5). This, however, has limitations compared to native applications.

Table 4-1: Comparison of cross-platform applications for developing a mobile application

		Platforms					
		Android	**iOS**	**BlackBerry**	**WinPhone**	**Native**	**Cost**
Frameworks	**RhoMobile**	Yes	Yes	Yes	Yes	Yes	$500
	PhoneGap	Yes	Yes	Yes	Yes	No	Free
	jQuery Mobile	Yes	Yes	Yes	Yes	No	Free
	Corona SDK	Yes	Yes	No	Yes	Yes	$250
	iBuildApp	Yes	Yes	No	No	Yes	$10 a month
	appMobi XDK	Yes	Yes	No	Yes	Yes	25 % of application sale price
	Xamarin C#	Yes	Yes	No	Yes	Yes	$100

From Table 4-1, the researcher matched three frameworks to the selection criteria: PhoneGap, jQuery and Xamarin. PhoneGap and jQuery frameworks are HTML5-based.

According to Agarwal (2013), HTML5 has numerous limitations regarding developing native mobile applications (Agarwal, 2013). As a result, the researcher excluded PhoneGap and jQuery as potential developmental frameworks for this research and selected Xamarin, as it is suitable for producing a cross-platform mobile application using native resources. This platform was also the most affordable.

Xamarin is a framework that allows developers to write native cross-platform applications in Visual Studio using C# or Visual Basic. Due to the significant differences in mobile platforms and their development environments, Xamarin produces software development tools that allow developers to write cross-platform applications. Android, iOS and Windows Phone 7 are dissimilar operating systems that differ greatly in their native applications. Xamarin offers compiler integration with .Net platform that allows developers to write their code in C# and deploy it to any target mobile platform. Xamarin develops a separate and independent User Interface for each mobile operating system, as they all have their own design guidelines, design controls and screen resolution.

Most Nelson Mandela Metropolitan University (NMMU) learners use Blackberry mobile devices; however, Blackberry shows a sharp decrease in market penetration. Therefore, the researcher decided to exclude it from the target platforms. To test the proposed mobile learning architecture and for the proof of concept, the researcher developed the mobile application for Android. Various mobile devices that facilitated the evaluation stage of the prototype were available from the Department of Computing Science.

Android is one of the global leaders in terms of market and mobile applications (Son, Lee and Kim, 2013). The researcher designed and developed the mobile application using Microsoft Visual Studio 2010 and the C# programming language. The application targeted any mobile device with an Android 3.2 and higher operating system. The researcher initiated the mobile application on a Samsung Galaxy S3 mobile device with a 1280 x 720 screen resolution and a touchscreen. In addition, the researcher installed the mobile learning application on a Samsung Tablet 10.1 with a 1280 x 800 screen resolution and a touchscreen. These devices have Android 4.1.2 operating systems.

4.4. LiveLearning Mobile Learning System

The Contact Instruction Mobile Learning Architecture (CIMLA) was designed for mobile learning in the classroom (Section 3.4). The researcher developed the LiveLearning prototype based on the proposed architecture as a proof of concept. This section contains a discussion of the implementation of LiveLearning in terms of the specific usage scenario and the tools used to implement the mobile learning system. It includes a discussion of obstacles encountered during the implementation process.

The researcher developed LiveLearning (Figure 4-6) in four different applications: a mobile application for learners, a desktop application for a teacher, a presentation application to connect to a projector and a server application.

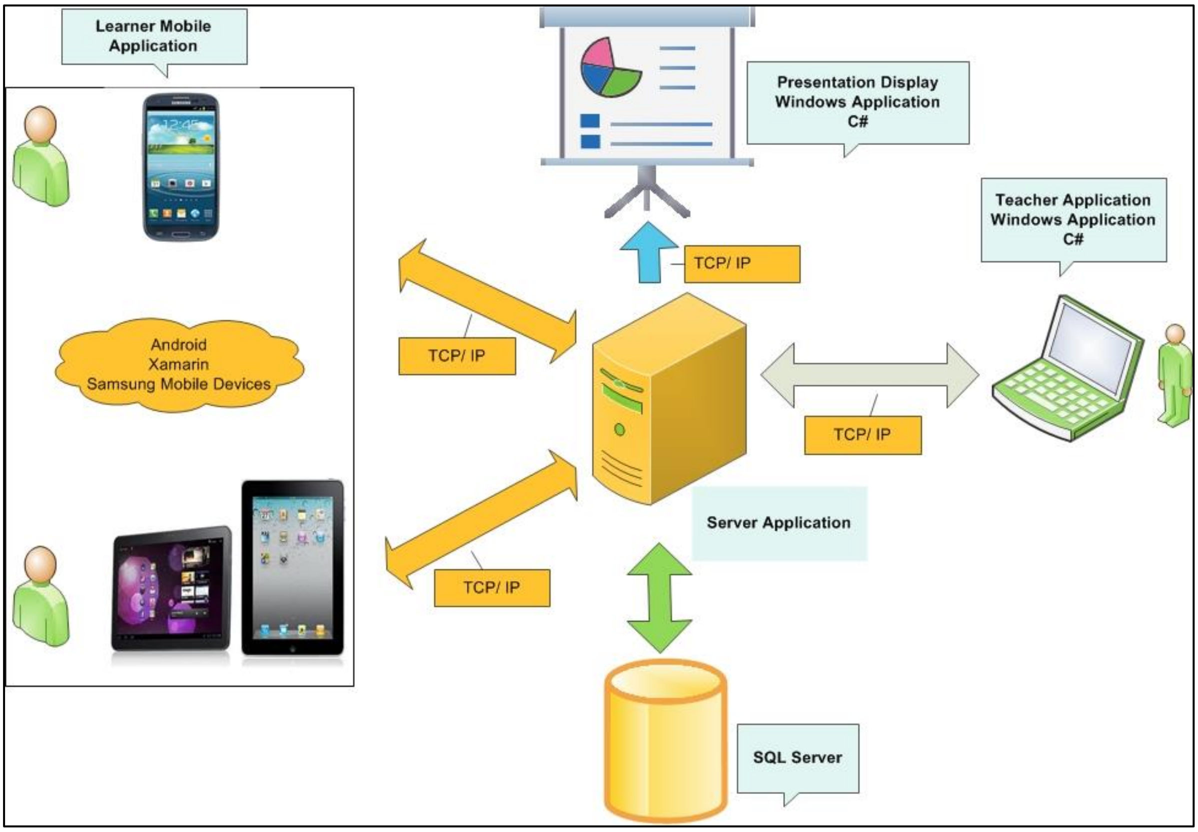

Figure 4-6: LiveLearning prototype

4.4.1. Server Application

The server application has the most responsibilities and addresses the limitations of mobile devices. The researcher implemented it as a middleware layer between the other applications in the LiveLearning prototype to reduce the complexity and improve the stability of other applications, such as the mobile application and the presentation application. The researcher implemented the server application as two modules, namely the Learning Server and the Repository.

The server application is responsible for inserting, updating and deleting data in the repository. In addition, it provides communication between users of the mobile learning system. The researcher implemented it as an application-programming interface (API) that interfaces with all the other applications. In API software, each component contains a particular code library to perform certain operations and all components interact with each other (Orenstein, 2000).

4.4.1.1. Database Design

An effective database design with well-structured relationships between tables plays an important role in system performance (Song, Yin and Ray, 2007). As the researcher developed the server application in C#, he selected the Microsoft Standard Query Language (SQL) Server database because of its compatibility with C#. The Repository contains all database structures and is responsible for access, queries, storing and retrieving as well as interacting with the Learning Server.

Appendix H depicts different tables used in the database and their relationships. The Task table contains three types of tasks, namely assessments, quizzes and surveys. Each may include more than one question. The User table is the main table, as the application must assign every sent task to a specific learner. Every user can be registered for more than one module. The Module table contains all the modules for a classroom. Each Module has many lectures on different dates and at different times, as structured by the lecturer. The Document table contains various documents (such as Portable Document Format (PDFs) in binary code) that are sent to learners. The Event table includes teachers' messages or events, identified by the ActivityKind field. The LearnerMessage table stores the messages learners have sent to the teacher. The PresentationControls table stores properties of the display elements, such as charts and images. These properties include an element's position on and size in the display screen.

4.4.1.2. Media Types

Sharing and transferring different media types between platforms such as Android and Windows may hold various challenges (Wallen, 2011). There are different reasons for these challenges, such as different methods of requiring communication protocols as well as different network security mechanisms (Yaodong *et al*, 2008). The Learning Server is the middleware in LiveLearning that addresses these challenges by dealing with media types such as images and PDF documents.

The learning content requires different media types, such as text and graphics, to be stored in the Repository. Text data is normally stored in the database. Memory limitations in mobile devices require the processing of large graphics images before they are stored in the database. This processing ensures that high quality graphics are stored and retrieved from the database in a short time. The server receives the graphic object from the Teacher Client in the same quality as it was loaded. A graphic object may be in a particular image format, such as Joint Photographic Expert Group (JPG), Graphics Interchange Format (GIF) or Portable Network Graphics (PNG) format. The server compresses the horizontal and vertical resolution of the received graphical object, reducing its size, before converting and encoding it to binary data. Once the server has transformed the graphic to binary data, it becomes easy to store in the database as digital content (bytes format). The system determines the quality of the graphic required based on the mobile device's features before reconverting it.

In addition, the system converts PDF documents to binary format before storage in the database. Using PDF in the mobile learning system allows the teacher to create a document and distribute it to different platforms without losing its original format (Castiglione, De Santis and Soriente, 2010). The Learning Server converts and stores a PDF document in binary format and converts it from binary to PDF format upon retrieval, allowing learners to open and preview PDF documents on their mobile devices easily. This method provides the delivery and display of rich format documents on mobile devices.

4.4.1.3. Communication Protocol

The researcher developed the server application as a multi-thread process where each thread is separately responsible for the different applications' function. This approach allows the server to provide different services, such as communication, to other applications simultaneously. The server application provides the communication layer over Transmission Control Protocol (TCP). The Communication Engine of the Learning Server manages all procedures and interactions with low-level network programming interfaces.

The communication protocol organises the communication between all parts of the system. Each message has a particular sender and receiver and contains data. The communication protocol contains rules for exchanging messages and data synchronisations between the server and clients. The researcher implemented this protocol to address message sending as well as to arrange delivery to the selected device. The Communication Engine considers retrying failed connection attempts in the case of corrupt or closed connections.

4.4.2. Learner Mobile Application

The researcher developed the mobile learning application as an independent application to make it possible to use the application on a mobile device without the need for any additional hardware or software.

The researcher developed the mobile learning application as a native mobile application. The native mobile application is suitable for installation on a mobile device and can use all the device features such as the network connections and camera. The design of the native mobile application features consistency in the user interface, which makes it easy for users to interact with the application.

During the development of the mobile learning application, the researcher repeatedly redesigned, prototyped and evaluated the mobile user interfaces and features to implement a viable mobile learning system.

The learner logs into the mobile application using a unique username and password combination. Figure 4-7 illustrates the login screen on the mobile learning application. It captures the login information and matches it to the existing data in the Repository. Once the learner has logged into the system, the mobile application begins fetching learning activities from the Repository.

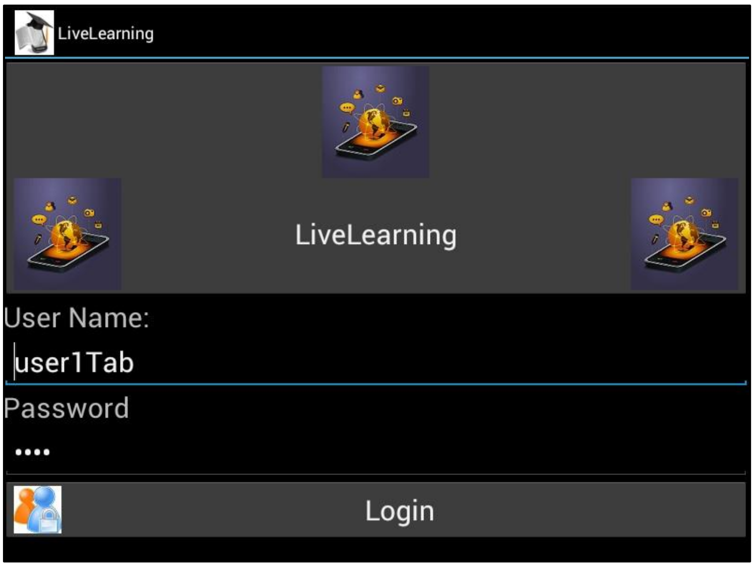

Figure 4-7: Login screen on the mobile learning application

The main objective in the development of LiveLearning was to provide learning activities to mobile devices in the classroom in real time. To achieve this, the researcher developed a synchronisation method to ensure that mobile devices have the latest learning activities. Synchronisation occurs only when a teacher sends a task to a particular group of learners during classroom time. Once the mobile application has obtained the latest tasks sent, it will not fetch more information from the database unless a teacher sends new learning activities to avoid overuse of the mobile device memory and the Wi-Fi connectivity. This automatic process prevents fetching the same tasks repeatedly.

The design of the mobile application followed the recommended design patterns discussed in Section 4.2. Some of the mobile design patterns, such a List View, are useful for presenting data lists that contain many items. Figure 4-8 illustrates an example of using List View on the mobile application design as a learner dashboard where learning activities are categorised. The leaner's dashboard contains all learning activities supported by the prototype. The number that appears after the learning activity category indicates the number of received learning activities.

Figure 4-8: Learner dashboard

Once the learner, for example, taps on the Assessments item, the mobile application navigates him or her to the list of assessment tasks. Figure 4-9 depicts assessments the teacher has sent. The interface layout and functionality are the same for Assessments, Quizzes and Surveys.

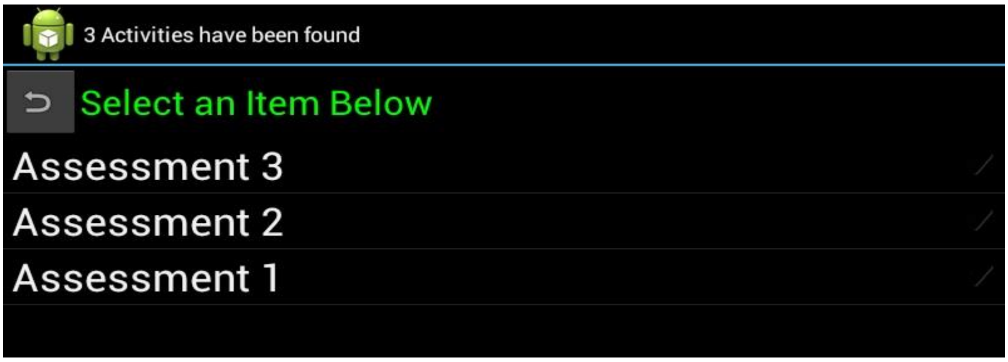

Figure 4-9: Sent assessment list

Choosing an assessment from the sent list navigates the user to the set of questions. Figure 4-10 depicts a question with multiple answer options. The wizard contains two buttons and text information for moving forward and backward.

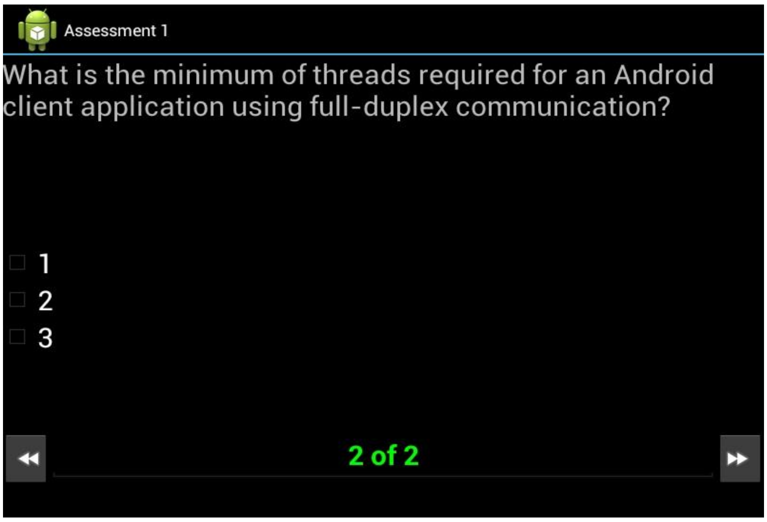

Figure 4-10: Wizard for multiple-choice questions

Once a learner completes the set of assessment questions, the application displays his or her achievements (Figure 4-11). Providing an assessment and displaying its result gives the learner immediate feedback regarding his or her level of knowledge. These kinds of learning activities help learners to reinforce skills that are relevant to the assessment topic the teacher sends.

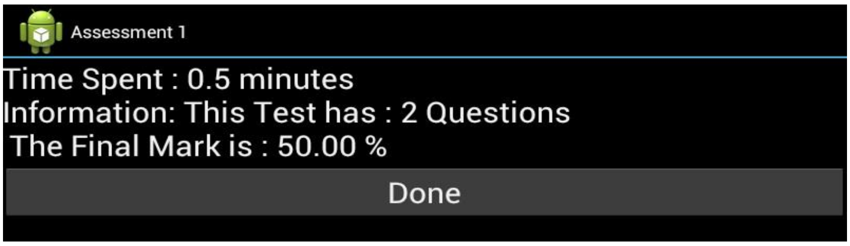

Figure 4-11: Instant feedback and result

The mobile learning application supports PDF documents. Figure 4-12 illustrates the list of documents the teacher sent.

Figure 4-12: PDF list

Figure 4-13 shows an example of a PDF document displayed on the mobile device. The learner can open a document by selecting it.

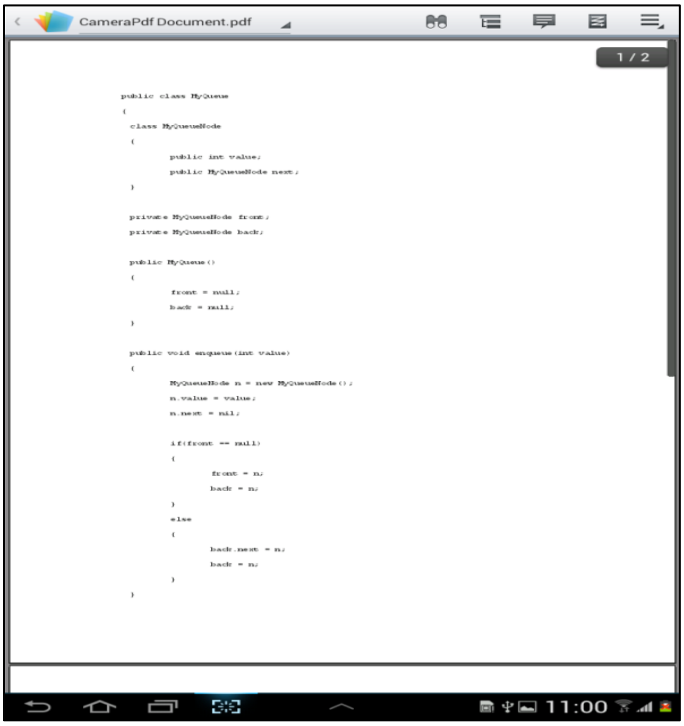

Figure 4-13: Displaying PDF document

The learners can read about new events sent from the teacher by opening an event item and reviewing the content. Each event contains the date, location and description (Figure 4-14).

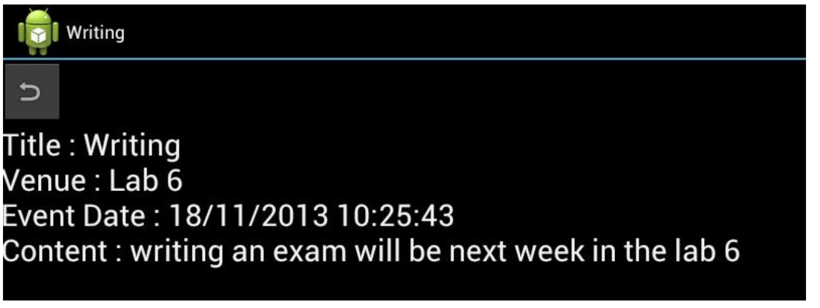

Figure 4-14: Displaying an event

The mobile learning application facilitates learner interactions and contributions in the form of messages from the learners to the teacher. Learners may write questions or capture images and send these to the teacher during the lesson. Figure 4-15 illustrates an example of a learner’s message.

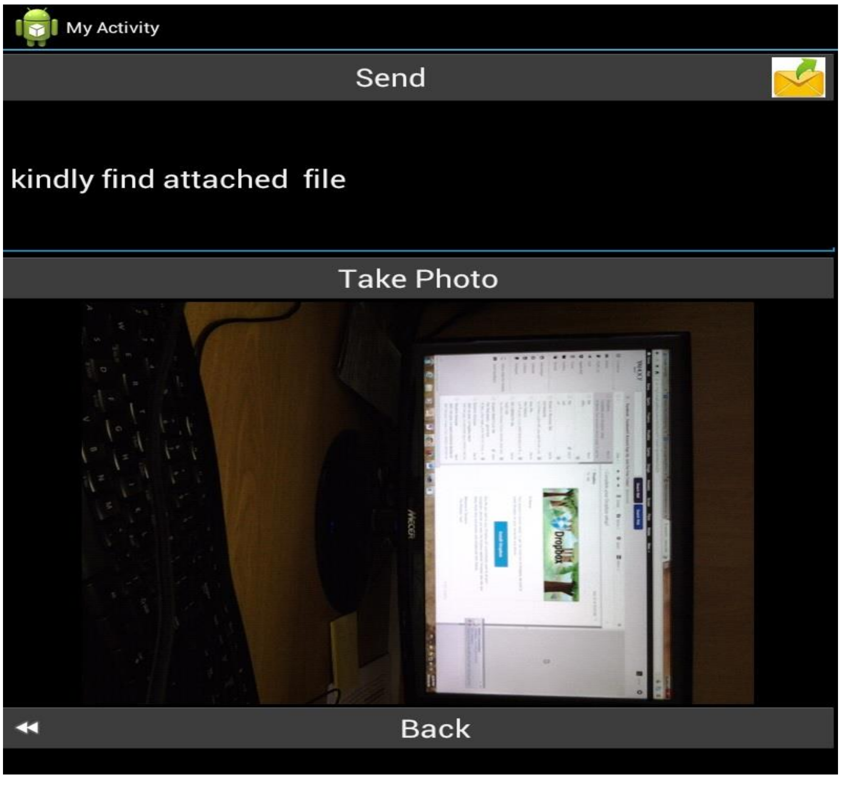

Figure 4-15: Form of learner's message

4.4.3. Teacher Application

The teacher is responsible for managing the classroom and the LiveLearning system, thus the researcher implemented the teacher's application to accomplish tasks in a simple and efficient manner. The researcher developed the teacher application based on the Teacher Client of the proposed mobile learning architecture as described in Section 3.4.3.

The researcher implemented the system in such a way that each teacher's profile has his or her own settings, configurations, timetable, learning activities and learners. If the teacher enters login details that do not exist in the database, he or she receives a notification that the system could not find the details. In addition, it offers an option to register a new user and create a profile for the teacher. If the login is successful, the teacher's application fetches the data for the relevant lesson. This can include assessments, surveys and documents prepared before class.

The user interface of the teacher application uses windows controls such as menus, text boxes and combboxes. The Ribbon menu is an important component used in the main form in the teacher application (Scarr, Cockburn and Gutwin, 2012). A Ribbon is a set of toolbars placed on several tabs, which assists the teacher in finding the tools and options to complete a task efficiently and directly with the minimum number of clicks. Because of the lack of Ribbon menu on the native .Net platform and Visual Studio 2010, the researcher used a Professional Ribbon Control in the main form of the teacher application (Adriancs, 2010). The Professional Ribbon Control is a free and open source Ribbon menu that integrated with .Net Windows platforms. It provides tools, which developers can group logically and functionally. This method of visualising and grouping similar system commands in Ribbon's tabs aims to assist a teacher in performing tasks in a short time. Figure 4-16 depicts the Ribbon menu used in the teacher application.

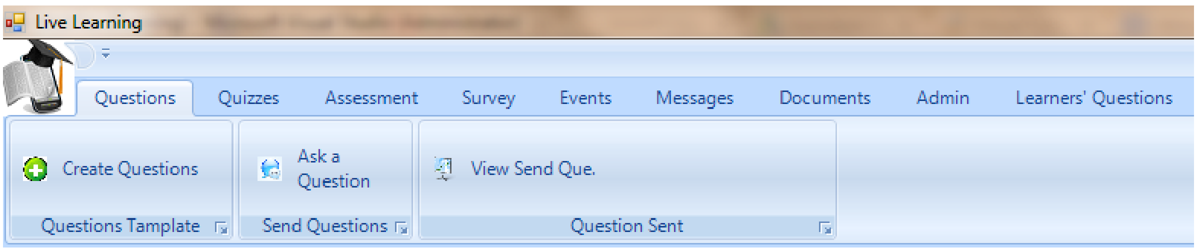

Figure 4-16: Ribbon menu

The researcher used consistency as a characteristic of the user interface to simplify the teacher's management role. Figure 4-17 illustrates two different forms (Assessment and Surveys forms) where each has its own functions, but both have the same menu toolbar commands. Implementing consistent user interfaces minimises learning time and streamlines task performance for the teacher.

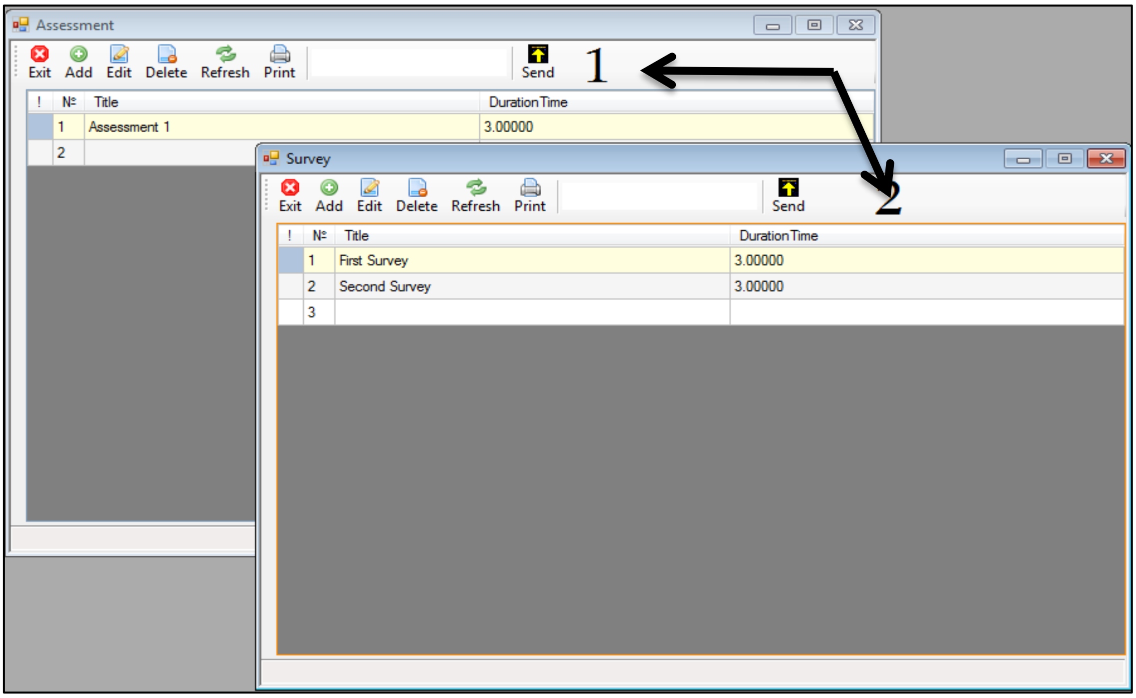

Figure 4-17: Using self-taught interface

The teacher can also create, send and receive tasks. To create a task such as an assessment, quiz or survey, the teacher must create a set of questions. Figure 4-18 illustrates the form for creating and modifying a question.

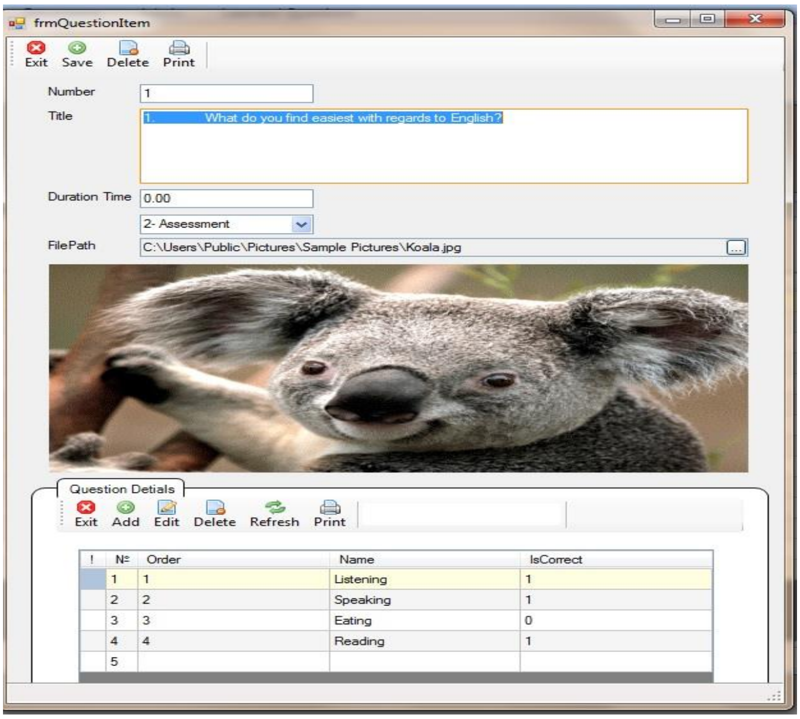

Figure 4-18: Form for modification of a question

A question has multiple answers, which the teacher can set on the question form (Figure 4-18). Assessment questions have only one correct answer. Quiz and survey questions may have more than one correct answer. In Figure 4-18, the bottom section shows where the teacher can specify the correct options.

To create an assessment, the teacher must set a group of questions, a title and the time allocated for the completion of the entire task. The assessment, quiz and survey forms have the same layout and procedure to simplify the user interface for the teacher. Figure 4-19 shows the form for creating an assessment.

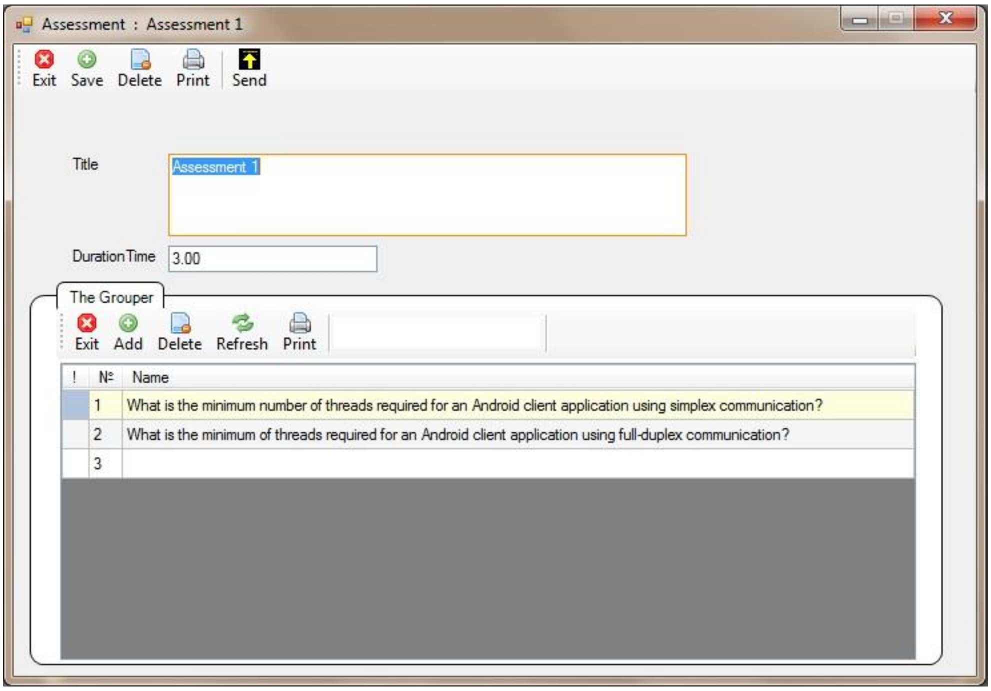

Figure 4-19: Form for creating an assessment

Once the assessment is completed, the teacher can send it to learners when required. The teacher application provides a notification that shows the number of tasks sent when the teacher sends a task to learners. In addition, the teacher application shows the number of learners that completed their tasks. The system automatically updates these notifications. Figure 4-20 illustrates a notification of tasks sent to learners.

Figure 4-20: Notification form

Once learners complete their tasks, the teacher's application obtains the results immediately. The teacher can display results on the presentation display. The teacher's application provides a manipulation control that allows a teacher to show or hide, zoom into or out of, or relocate the presentation elements. The presentation elements include chart view, text view and picture view elements. Figure 4-21 shows the manipulation control of the presentation display's elements.

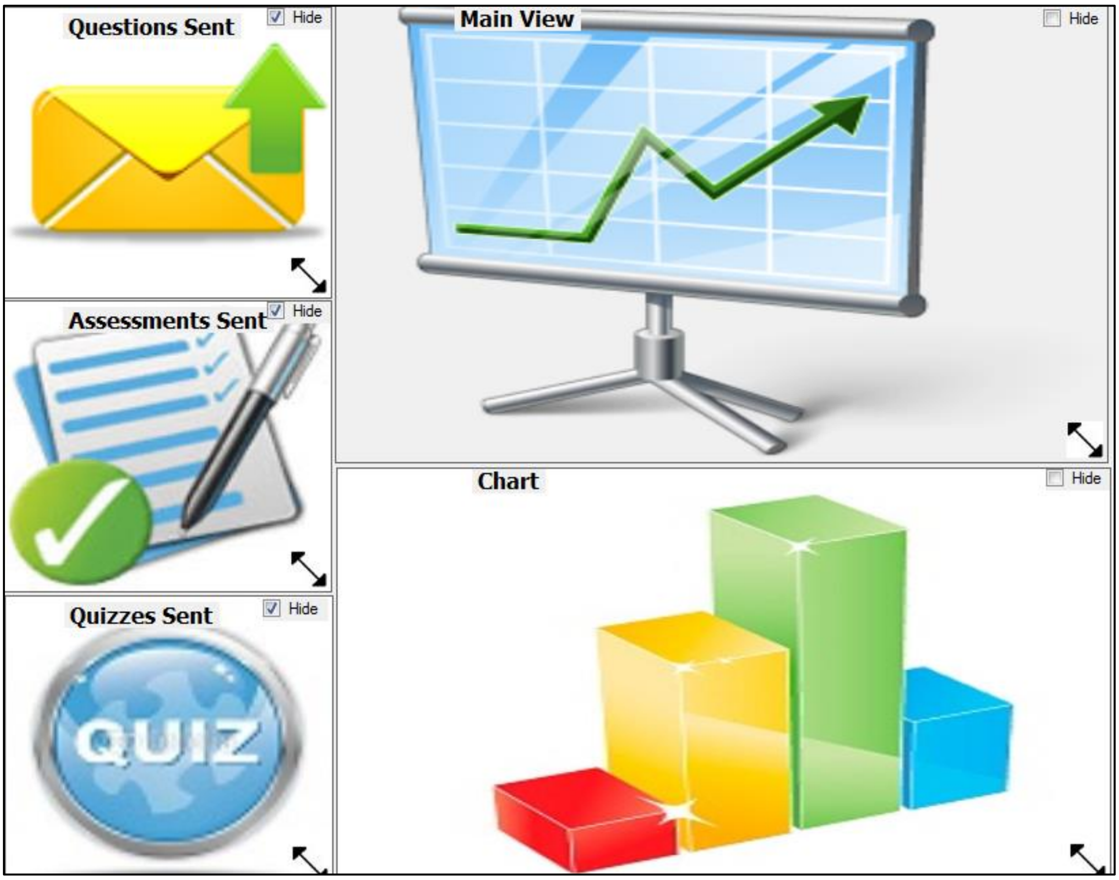

Figure 4-21: Manipulation controls

The teacher application allows reporting tools to generate various types of reports. These reports show learners' achievements during a certain period as well as their results. It provides an option to generate reports for a class, group of learners or an individual learner, as shown in Figure 4-22. Information in the report can include various fields, such as the learner's name, details of the task, the date the teacher sent it, the result received as well as the date and time the teacher received it. The teacher can determine which information to show or hide in the report. The teacher can view the generated reports on the application, export the data to a PDF file or print it. Section 4.4.4 provides further details on these reports

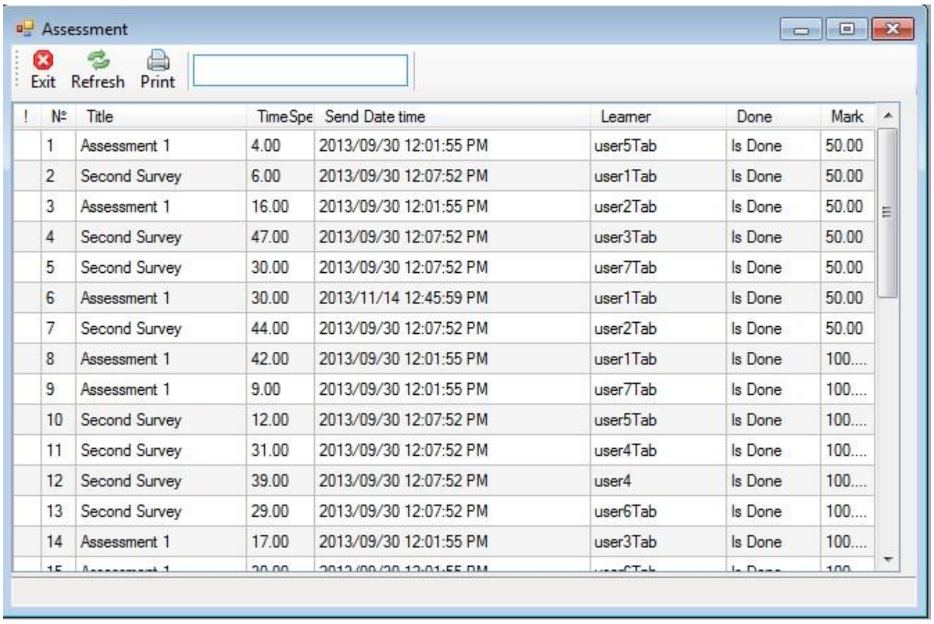

Figure 4-22: Report generating

4.4.4. Presentation Display Application

The Presentation Display Application allows the display of results in more than one slide. The researcher designed and implemented this application as an independent application connected to a data projector. As the teacher manages the learning content on the presentation display, the research aimed to streamline the presentation process and make it as simple as possible.

The researcher developed this application to allow the user to control it remotely from the teacher application. When the teacher clicks to display a task, the system sends the content of the task and displays it on the presentation display using specific presentation tools based on the type of data.

The presentation display application displays three types of information, namely text, graphics and charts. This information requires effective presentation tools to present the learning content in an easy and attractive way. The researcher implemented three different presentation tools to present information. The first tool is a text presentation tool, which displays text information in a clear font and colour. The second presentation tool is a graphics tool. This tool supports the presentation of different types of images, such as JPG and PNG. Because users may capture some images in different rotations, the teacher can rotate the image and present it on the graphics tool. Figure 4-23 illustrates the use of the graphics tool on the presentation display, showing a message from a learner that contains a picture.

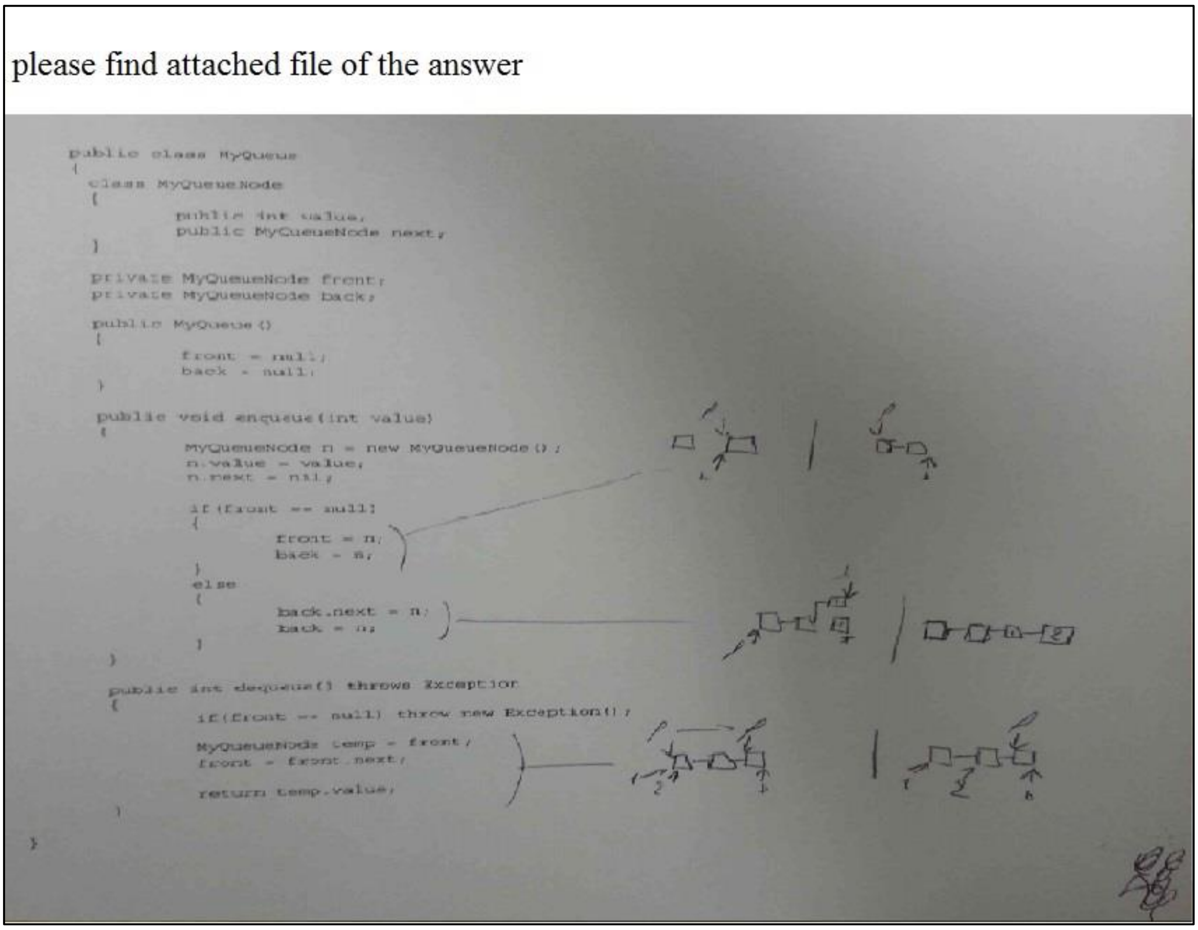

Figure 4-23: Image graphics tool

The third tool is a chart tool, which presents the results of learners' tasks. The presentation display application presents data in two different types of charts, namely pie and column or bar charts. The application displays the result of an assessment using a pie chart as it shows the percentage of correct and incorrect answers.

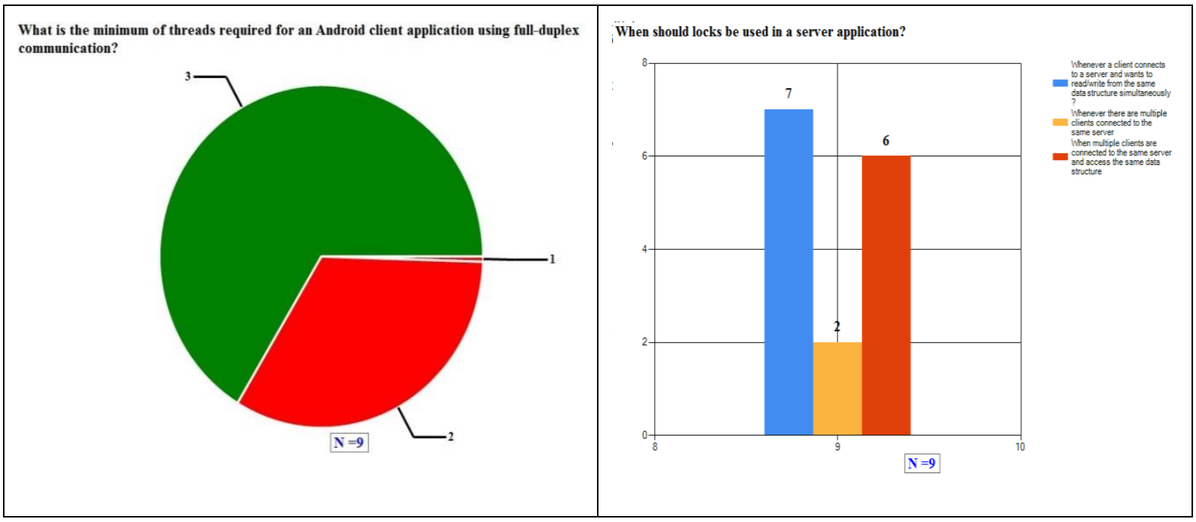

Figure 4-24: Image graphic tool Image of two different charts

The second chart is a bar chart, used to display the values of options where each option displays in an individual column. Figure 4-24 shows examples of the two different types of charts.

This method of real time presentation displays learners' results and encourages them to interact in the learning process.

4.5. Pre-Evaluation

The implementation of the prototype followed an iterative development process. Therefore, the researcher initiated an expert review and conducted a pilot study. These identify potential usability issues that researchers can use to improve prototypes. The researcher discusses the expert review in Section 4.5.1, the pilot study in Section 4.5.2, the findings of both evaluations in Section 4.5.3, and the design implications in Section 4.5.4.

4.5.1. Expert Review

The expert review is a vital component of creating an effective prototype when designing an interactive application for users in the real world (Chapman, 2011). The design and implementation of LiveLearning followed an iterative development process. This section discusses the expert review conducted to identify and address usability issues to improve efficiency. The researcher discusses the evaluation methodology used and the result of the evaluation in this section.

4.5.1.1. Evaluation Objectives

The main objective of the expert review was to establish whether LiveLearning had any usability issues before applying it in the classroom.

4.5.1.2. Evaluation Methodology

A heuristic evaluation is a form of usability inspection that evaluates elements of a user interface design so that they can be attended to as part of an iterative design (Güngör and KılıçDelice, 2009). Conducting a heuristic evaluation requires a set of three to five evaluators (González *et al*, 2009).

The researcher selected the usability experts based on their experience with usability evaluations and the domain experts based on their knowledge about mobile learning. The experts were three lecturers from the Computing Sciences Department who had adequate knowledge about mobile applications. In a heuristic evaluation, the experts are given typical tasks that end users will have to perform in the proposed system to achieve specific goals in a particular environment (Lai, 2007). According to Lai, this technique, by which five users can identify 85 percent of prototype usability problems at an early stage of development, is best suited for evaluating a prototype. Expert reviewers must identify and report advantages and disadvantages of the interface by considering a set of heuristics after the performance of each task. This method provided beneficial results that influenced the efficiency of LiveLearning. According to Nielsen (2010), Nielsen identified the most common heuristics to evaluate a prototype and usability issues. These are:

1. Visibility of system status;
2. Match between the system and the real world;
3. User control and freedom;
4. Consistency and standards;
5. Error prevention;
6. Recognition rather than recall;
7. Flexibility and efficiency of use;
8. Aesthetic and minimalist design ;
9. Help user to recognise, diagnose and recover from errors; and
10. Help and documentation.

The experts used techniques 1 to 8 on this list during the expert review. The experts did not use the "*Help and documentation*" and "*Help user recover from errors*" heuristics to evaluate LiveLearning, as they focused on the usability issues of the Learner Mobile Application, Teacher's Application and Presentation Display Application.

4.5.1.3. Research Design

Based on the previous set of heuristics and best practice rules, the researcher initiated the expert review to identify potential usability issues in the early stages of the LiveLearning development process. The experts conducted the review of LiveLearning in two steps, namely evaluation preparation and assigning severity ratings.

Evaluation Preparation

The expert teacher sent tasks from the teacher's application to other experts' mobile devices. The reviewer sent each task separately. This allowed adequate time to complete each task and permitted the experts to provide detailed opinions for valuable feedback. The experts worked in groups during the review to simulate learners in a classroom scenario. The reviewers successfully completed the set tasks after discussing each task and identifying the best ways to perform them. In addition, they discussed the mobile user interface and visual tasks on the presentation display board. To use a Think Aloud protocol, a voice recorder was set to record experts' discussions and record any comments made by individual experts or by the group. The voice recording was transcribed after the expert reviews to document the discussions and feedback, and the observer noted their observations after completing the tasks in LiveLearning.

Assigning Severity Ratings

When the experts had completed all the evaluations, the observer assigned severity ratings to each of the potential usability issues identified. The researcher analysed the severity results and identified the usability issues.

4.5.2. Pilot Study

The researcher conducted a pilot study in a live classroom situation. Learners could test the mobile learning application and the teacher used LiveLearning during classroom time. The researcher identifies the goals of the pilot study in Section 4.5.2.1 and discusses the selection of learners in Section 4.5.2.2. Section 4.5.2.3 contains an explanation of the test process and the Result Section presents the outcome of the pilot study.

4.5.2.1. Goals

The objective of the pilot study was to test the LiveLearning prototype in a real classroom setting. This aimed to identify potential errors and system crashes. Since the questions and assessments format were very similar, it was decided to exclude the questions format in order to reduce complexity of the system.

4.5.2.2. Selection of Participants

The researcher chose participants from the NMMU International English class because of their ability to interact with mobile devices. The selected participants' ages ranged from 18 to 29 (n=14). Thirty-one percent of the participants were between 18 and 20 years old and the remaining 69 percent were between 21 and 29 years of age (Figure 4-25). From the 14 participants chosen, 4 were female (29%) and 10 were male (71%) (Figure 4-25). The selected group contained participants with basic computer knowledge and minimum smartphone experience. The majority of the chosen participants (46%) had up to two years of computer experience and the remaining portion had between three and ten years of experience (Figure 4-25). Fourteen percent (n=14) of the participants had more than ten years' experience with using mobile devices, but the majority had between five and nine years of experience (Figure 4-25).

Because LiveLearning uses the camera feature of mobile devices, the researcher asked the participants to state whether they had used this feature previously. Eighty-six percent of the participants stated that they had used a mobile device's camera. Regarding what kind of mobile keyboard they had used, 43% of the participants had only used a touch keyboard, 14% had used only a physical keyboard, and 43% had used both. The researcher chose an English lecturer based on her familiarity with and experience of using computers.

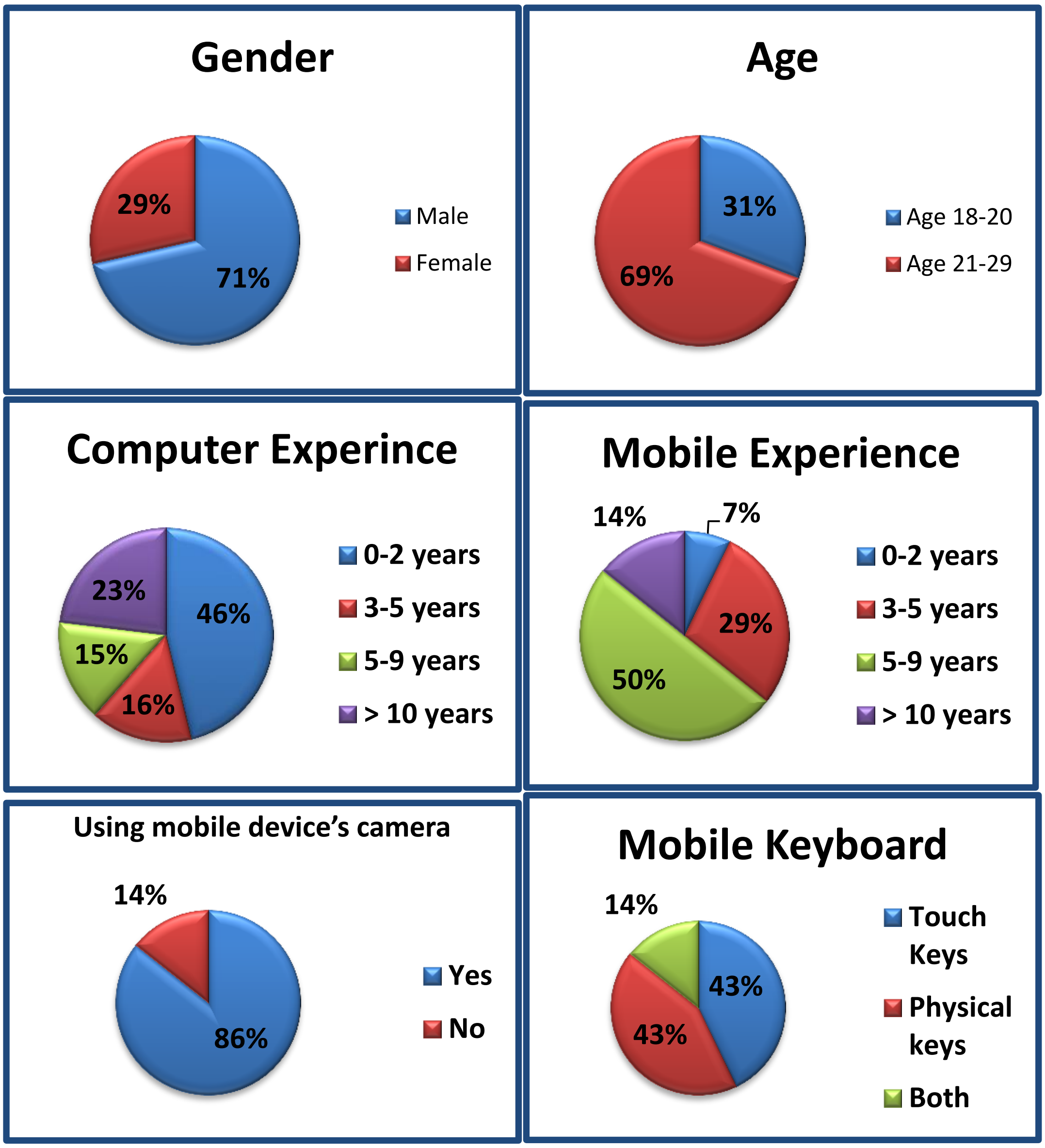

Figure 4-25: Demographic profile of pilot study participants (n=14)

4.5.2.3. The Test Procedure

The researcher chose an English classroom prepared with projector equipment to display the result of the tasks, and installed LiveLearning on Samsung Tablet 10.1 and Samsung Galaxy S3 mobile devices. The researcher installed and configured the teacher's application on a laptop and provided her with the laptop as well as a set of selected tasks (Appendix A). The researcher prepared and discussed these tasks, which provided an overview of using LiveLearning, with the teacher beforehand. Participants were briefed on the goal of the pilot study and on how to interact with the system before starting the study. The tasks were split into three sections and each section was tested in a lesson (see Table 4-2). The pilot study took place over three lessons presented over three days, with participants divided into seven pairs.

Table 4-2: Pilot study lessons and learning activities

Lesson / Day	Learning Activities
First	1-Assessments 2- Send a message
Second	1-Questions 2-Learner Messages
Third	1-Survey 2- Quizzes

The researcher recorded all three sessions of the pilot study by video camera to obtain qualitative feedback and to observe the learners' interactions with the mobile learning application.

The researcher collected data using a session questionnaire and a final post-intervention questionnaire. After each lesson, participants completed the session questionnaires regarding the prototype. The researcher handed the final post-intervention questionnaire to participants in the last lesson. The teacher also completed both questionnaires.

4.5.3. Findings

After completing the pre-evaluation, the researcher obtained results from the experts and learners and analysed these to identify usability issues he should address.

The feedback received from the experts is summarised in Table 4-3. This table illustrates the potential usability problems identified by the experts according to Nielsen's heuristics. After receiving the feedback, the researcher identified and assigned severity ratings to each usability issue. He selected severity ratings with values between zero and four from a Likert scale. These ratings are:

0. **Not a usability problem**;
1. **Cosmetic problem**: need not be fixed unless extra time is available;

2. **Minor usability problem**: fixing this should be given a low priority;
3. **Major usability problem**: important to fix, should be given a high priority; and
4. **Usability catastrophe**: imperative to fix this problem before releasing the product.

Table 4-3: General usability heuristic evaluation results

Usability Criteria	Potential Usability Issues	Severity Rating
1. *Visibility of system status*	Teacher application does not clearly indicate what new tasks are being sent	1
	Mobile application does not clearly illustrate the tasks received	2
	Mobile application does not provide simple navigation	3
	The learner cannot easily identify the task last received	2
	Presentation display: legends are not clearly visible	1
	Presentation display: lack of semantics on the graph	3
2. *Match between the system and the real world*	Some learning activities must be removed, which are similar principle.	3
	Terminology on the LiveLearning needs to be clearly defined	1
3. *User control and freedom*	LiveLearning does not indicate which learning activities have already been sent or accomplished.	1
	LiveLearning does not provide a good logical flow for learners to answer tasks.	2
	The prototype does not show the number of learners who have already responded to the teacher.	2
4. *Consistency and standards*	Colour usage is inconsistent between the different views	1
	Interaction is inconsistent between the different buttons in one view	3
5. *Error prevention*	The system does not allow the user to resume actions, as the device loses its network connection while navigating or performing certain actions.	3
	Teacher application does not provide a confirmation box when deleting a learning activity.	2
6. *Recognition rather than recall*	The prototype does not show the latest learning activity sent for the teacher.	2
	Learners cannot see the title of the learning activity while browsing the content.	1
7. *Flexibility and efficiency of use*	The prototype does not have graph tools such as zooming and rotating	2
	Navigation and display of visual components	2
8. *Aesthetic and minimalist design*	Notification information font small on the teacher application	1
	Presentation display: incorrect formatting of chart	1
	Colours in the learner dashboard are inconsistent	2

Experts noted that the visibility on the prototype had to improve. For example, the teacher was unaware whether the learners had received the sent tasks. Experts also commented that interaction with the mobile learner application was not simple. The assessment form had numerous buttons in different locations on the mobile screen that could confuse the learner. In addition, the experts were concerned that the mobile application did not provide consistency in presenting tasks. Another area of concern was the additional information on the presentation display, which posed a distraction to the learners. The most important problems and suggestions the experts made were to improve the user interface to simplify interaction with LiveLearning. The researcher considered these issues, as he had to address them.

When the pilot study was completed, the researcher analysed the questionnaires using thematic analysis (Fereday, 2006). The video recording was stored to observe the learners' behaviour while they were interacting with the prototype. The researcher classified the data collected into two categories based on the session questionnaires and final post-intervention questionnaire. A summary of remarks received follows.

Identify the most positive aspect of LiveLearning

- *Ease of use 85% (n=14)*
- *Encourage participation 26%(n=14)*

Identify the most negative aspect of LiveLearning

- *Inconsistency 53% (n=14).*
- *The mobile application was slow at the time 13% (n=14).*
- *Learnability 53 % (n=14).*
- *Visibility 62 % (n=14).*

Please provide any general comments or suggestions for improvement

- *Improve visual data on the presentation display*
- *Provide instructions and guidelines about using the prototype before the study*
- *Add sound effects to the mobile learning application*
- *Add a rotating image facility to the teacher application*

From the above remarks, one can deduce that the participants could interact with the prototype and respond to the tasks. Participants could complete the tasks sent without significant difficulty. In addition, they showed interest in using the prototype during the lesson.

The most negative aspect highlighted was that participants had difficulty interacting with some of the tasks. This was due to inconsistency and insufficient on-screen description. Participants could not see the data clearly enough on the presentation display, as the system displays all results and charts at the same time. To improve data visuals, the researcher added a new function to the teacher application that could control viewing data elements. This control could display sent information piecemeal, where each piece had only one chart to display. Wi-Fi coverage was quite weak (one bar only) in the English classroom, which slowed sending and responding to tasks.

The researcher considered some suggestions to improve data visuals on the presentation display, but did not implement others, such as adding sound effects. This could distract learners from the learning process and these types of changes are irrelevant to the system's improvements.

4.5.4. Implementation of Design Changes

Table 4-3 in the previous section shows that expert reviewers found no usability catastrophes; the severity ratings illustrated that the majority of the issues identified were minor usability issues. The usability issues discovered showed that the researcher had to address these issues to improve the usability of LiveLearning. The experts felt that the mobile application did not provide simple navigation between views and within one view, as the design did not clearly indicate the labels of navigation buttons and their positions. To address this issue, the researcher relocated the navigation buttons on the bottom of the view next to each other. In addition, he renamed the labels of the buttons and assigned suitable icons.

Another issue raised was that the presentation display application did not clearly show the chart's legends. Legends displayed a large amount of information in a limited space, which caused misunderstanding when experts tried to read them. The chart did not indicate the meaning of the displayed data. This was an issue when the teacher sent an assessment that had more than one question to display on the presentation display. The experts had to ask which chart belonged to which question. This was a concern as the experts felt confused while viewing multiple charts at the same time. The researcher addressed this by displaying each chart separately.

The experts and learners' reviews noted that some of the functions (such as questions and assessments) were similar in terms of functionality. The researcher consequently removed similar functions from the prototype.

The researcher also had to improve the consistency of the mobile and teacher applications. The greatest concern was that the interaction involved in different events was inconsistent within one view. For example, the application used different colours in different views. Removing different colours from the view and keeping to a single colour improved and maintained consistency.

Experts and learners lost some data while completing tasks and had to restart tasks from the beginning due to network disconnections during interaction with the prototype. The researcher considered changing that application to resume the task from the point of network discontinuation to avoid the loss of data.

In the first lesson of the pilot study, the researcher installed a video camera at the back of the classroom. This position did not record learners' interaction with the mobile devices well due to the large area of the class. In addition, learners were sitting with their backs to the camera, which hindered observation. In subsequent lessons, the researcher placed the camera in front of the learners and in a higher position.

Once the researcher implemented all the improvements, he conducted the final evaluation. Chapter 5 contains a discussion of the process of the final prototype evaluation.

4.6. Conclusion

This chapter addressed Research Question 4 presented in Chapter 1: *How can a prototype, as a proof of concept of the designed architecture, be developed that will support mobile contact learning?*

The researcher developed LiveLearning as a proof of concept of the designed architecture, with four sub-applications: a mobile application for learners, a desktop application for a teacher, a presentation application and a server application. These applications were integrated and worked together to provide learning activities in the classroom. Since the researcher developed the mobile application for different mobile devices, he applied mobile design patterns in the design of the user interface.

The researcher conducted a pre-evaluation to identify potential usability issues. This consisted of an expert review and a pilot study in parallel. Experts were selected from the Department of Computing Sciences, while participants in the pilot study were chosen from learners completing the NMMU international English module. The pre-evaluation identified usability issues that the researcher addressed in the implementation of the prototype.

In the next chapter, the researcher discusses the usability evaluation of LiveLearning to determine the viability of the prototype.

Chapter 5: Evaluation

5.1. Introduction

In Chapter 4, the researcher discussed the implementation of the LiveLearning mobile learning system in the classroom. The proposed mobile learning architecture formed the basis for the design and implementation of LiveLearning.

This chapter addresses the fifth research question:

How usable is the developed prototype in a contact learning environment?

An examination of the evaluation phase of LiveLearning, conducted to confirm the effectiveness and efficiency of the mobile learning system in the classroom environment at Most Nelson Mandela Metropolitan University (NMMU), follows. This begins with a discussion of the evaluation design, which contains the evaluation objectives. The researcher identifies and presents the evaluation results and concludes the chapter with a discussion of the results of the study as well as recommendations.

5.2. Evaluation Design

The evaluation design is conducted in order to identify the usability of the prototype and assists in suggesting improvements during the evaluation (Ryan, 2010). The researcher designed the Contact Instruction Mobile Learning Architecture (CIMLA) to facilitate the use of mobile devices to support contact learning in the classroom environment; the researcher developed LiveLearning as proof of the concept. The objective of this evaluation is to determine the usability of LiveLearning and, therefore, to show that an effective prototype could be developed based on the proposed architecture.

An overview and discussion of the evaluation design, including participants' selection, evaluation metrics, questionnaires, evaluation structure, tasks and the procedure of the evaluation, follows.

5.2.1. Participants

The researcher selected participants for evaluating the LiveLearning system from the NMMU learner body because the application was intended for use in the classroom. The researcher chose participants from the third-year learners in the Advanced Programming course in the Department of Computing Sciences. This class contained participants with an adequate level of computer and smartphone experience. This level of experience is typical to all learners at NMMU, as shown in Section 3.3. During the evaluation, the researcher divided participants into pairs at random; each pair had access to LiveLearning on a mobile device.

To identify most usability problems, the researcher must carry out an evaluation with at least 5 participants who take part in a test (Nielsen, 2010). Figure 5-1 depicts the demographics of the selected participants. Eighteen participants were recruited to evaluate the prototype; 61 percent (n=11) of them were male and 39 percent (n=7) were female. The participants selected were from the age group 18 to 30 years, the typical age group of learners at a tertiary institution. Seventy-eight percent (n=14) of the participants considered themselves expert users and had at least 10 years' experience in using a computer, while 11 percent (n=2) of the participants had 5 to 9 years of computing experience. Two had 3 to 5 years of computing experience. The criterion for recruiting participants was that they had to have experience with using mobile devices. Participants that met this criterion could provide feedback on the usefulness of the prototype that is more realistic than that obtained from those who did not. The demographic analysis of the participants shows that 50 percent (n=9) had more than ten years of experience using mobile devices; 39 percent (n=7) had between 5 and 9 years' experience; and 11 percent (n=2) had less than 5 years' experience. In addition, the researcher asked participants to indicate whether they had used mobile applications before and, if so, to mention the application or applications they used. All of the participants had used a variety of mobile applications.

5.2.2. Evaluation Metrics

The aim of developing LiveLearning was to support contact learning in the classroom at NMMU. The objective of the evaluation was to determine the usability of LiveLearning and evaluate the architecture used. The researcher measured three groups of metrics for each task:

- Efficiency – measured by the time taken for learners to complete each task successfully;
- Effectiveness –measurement of the task completion rate by the teacher and participating pairs; and

- User satisfaction – measured by ratings provided in the questionnaire at the end of entire evaluation by participating pairs and the teacher.

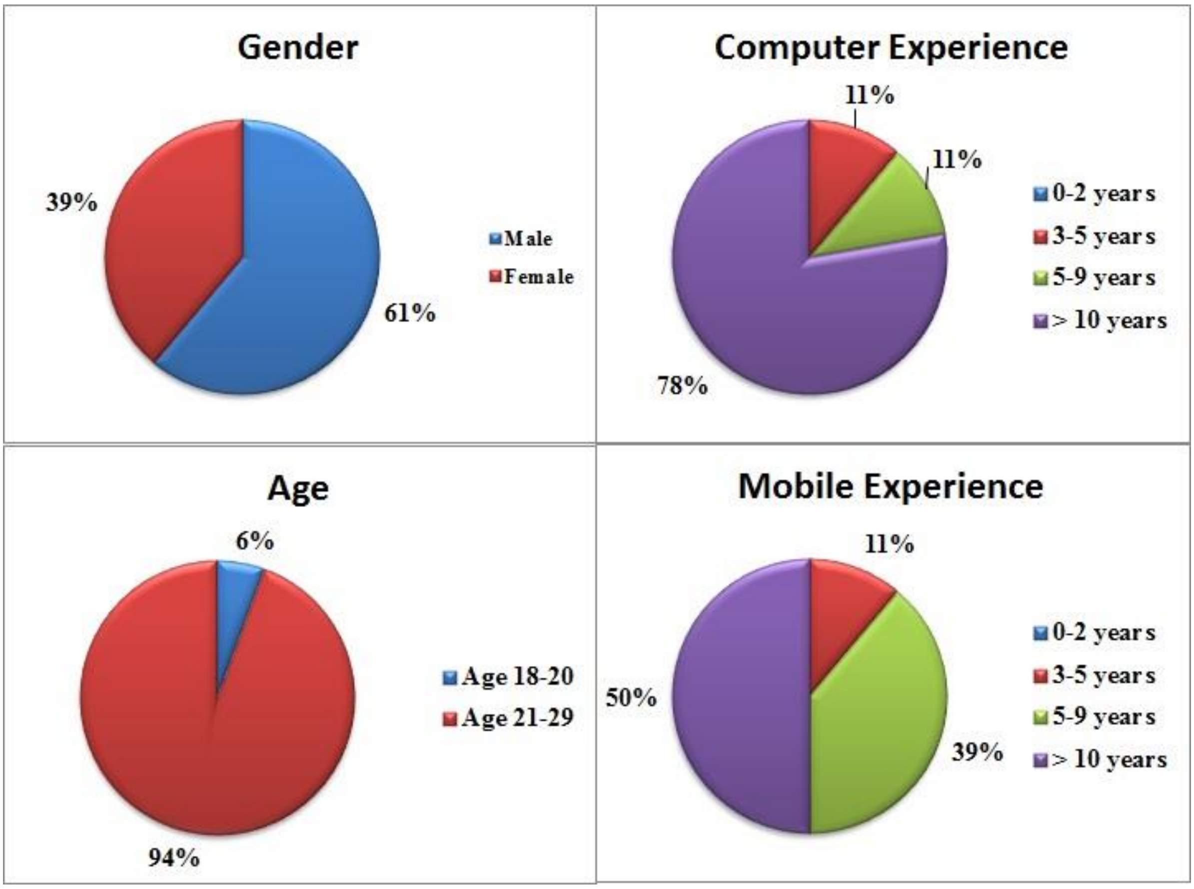

Figure 5-1: Demographic profile of evaluation participants (n=18)

5.2.3. Questionnaires

The researcher provided each participant with a biographical data collection form at the beginning of the evaluation (Appendix E) for the collection of demographic and experience details for each participant. This biographical questionnaire, based on the Common Industry Format (CIF) for usability testing, allowed the researcher to collect the anonymous biographic information of each participant. The investigator used this information to support the analysis of performance and satisfaction results.

In addition, the researcher provided every participant with a session questionnaire after completing each task (Appendix F), which he used to evaluate the respondents' satisfaction with LiveLearning. Participant pairs completed these questionnaires at the end of each lesson to avoid distractions during classes.

The researcher administered a final post-intervention questionnaire (Appendix G) to all participants at the end of the entire evaluation to evaluate their satisfaction with the prototype. The final post-intervention questionnaire was based on the Systems Usability Scale (SUS) measuring usability (Finstad, 2006). The adapted version contains additional questions to support the evaluation of LiveLearning.

5.2.4. Evaluation Structure

The evaluation of the prototype took place in a Department of Computing Sciences laboratory at NMMU. The researcher chose the laboratory because it fulfilled the requirements of the classroom scenario needed to evaluate LiveLearning. The evaluation required a venue with Wi-Fi connectivity and a presentation display. The researcher divided the 18 participants into nine participant pairs. Participant pairs were monitored using a video camera and observed by an observer. The observer assisted the teacher in the preparation of tasks before the lesson.

5.2.5. Tasks

The researcher provided the teacher with a task list (Appendix B) in every lesson because the teacher had to manage the classroom. In addition, the researcher provided the teacher with basic instructions for interacting with LiveLearning. The participants had to complete tasks received on their mobile devices.

The researcher structured the task lists in the form of a scenario. The following tasks illustrate the tasks selected for the teacher:

1. Send an assessment to learners
2. Send a survey to learners
3. Send a message to learners
4. When a learner sends a question, present it on the presentation display
5. Manipulate layout
6. Send a document to learners

The participant pairs’ tasks included the following:

1. Respond to an assessment
2. Respond to a survey
3. Send a short message

5.2.6. Procedure

The evaluation began with the researcher explaining its purpose and procedure to the participants. Participants completed the consent forms (Appendix D) and biographical questionnaires (Appendix E) provided. They completed these forms once for the entire evaluation. Each of the participant pairs received either a Samsung Tablet 10.1 or a Samsung Galaxy S3 mobile with LiveLearning installed.

The researcher divided the prototype evaluation into two lessons. The teacher received a laptop with the teacher application installed on it as well as a task list to be completed. The participant pairs had to complete tasks on their mobile devices. Once the participant pairs completed their tasks, the teacher sent the results to the presentation display. The teacher and participants discussed the outcomes of the tasks. The participant pairs had to complete a session questionnaire (Appendix F) after completing the lesson. The session questionnaire consisted of three categories: the most positive aspects of LiveLearning, the most negative aspects of LiveLearning and general comments or suggestions for improvement.

After completing the entire evaluation, the researcher required the participant pairs to complete a final post-intervention questionnaire (Appendix G) to evaluate the entire prototype. In addition, the researcher asked the participants to provide comments or suggestions to improve the prototype and recorded the evaluation process by video camera. The observer observed the participant pairs while they were interacting with the prototype while the LiveLearning user tracking service captured participants' performance. The researcher captured the data collected with the questionnaires on an Excel spreadsheet and analysed it. A discussion of the results follows.

5.3. Evaluation Results

The researcher used three evaluation metrics in the usability evaluation, namely effectiveness, efficiency and user satisfaction. He used tracking data to measure the performance results and questionnaire data to identify user satisfaction. Section 5.3.1 contains the performance results and a discussion thereof.

5.3.1. Performance Results

This section contains a discussion of the results of the evaluation in terms of efficiency and effectiveness in completing tasks on LiveLearning. The researcher collected performance results for each participant pair. All the participant pairs could complete tasks on their mobile devices.

5.3.1.1. Efficiency

The researcher identified the efficiency of LiveLearning by measuring the time taken to complete each task. Each of the nine participant pairs received a task from the teacher via the mobile device. The prototype tracked the time spent on each task from start to finish while participants interacted with the mobile application. The evaluation included six tasks (Section 5.2.5). The researcher considered assessment and survey tasks to measure efficiency as the interaction time was measurable. Figure 5-2 outlines the time taken on the assessment task.

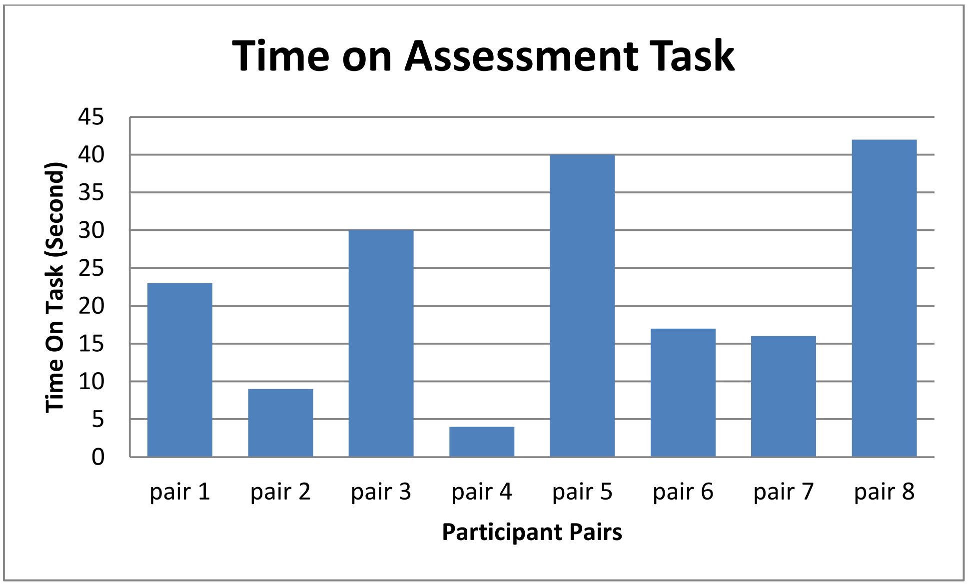

Figure 5-2: Time spent on assessment task across nine participant pairs

The assessment task had two questions where each question had multiple options. Only one of these options was correct and the rest incorrect (Appendix C). The participant pairs were requested to select an option for each question and the mobile application would allow the participants to choose only one option.

The researcher evaluated the second task (survey) twice in the classroom, each time with different learning content. Participant pairs received the first task at the beginning of the lesson. The teacher decided to do this to measure the participants' knowledge. The multi-choice survey task had more than one correct answer per question (Appendix C) and the mobile application allowed the participants to choose more than one option per question.

The participant pairs received the task on their mobile devices, reviewed it and answered the survey. When the participants selected the Done Task button, the tracking service of the mobile application captured the time. Figure 5-3 depicts the time taken to complete the first survey.

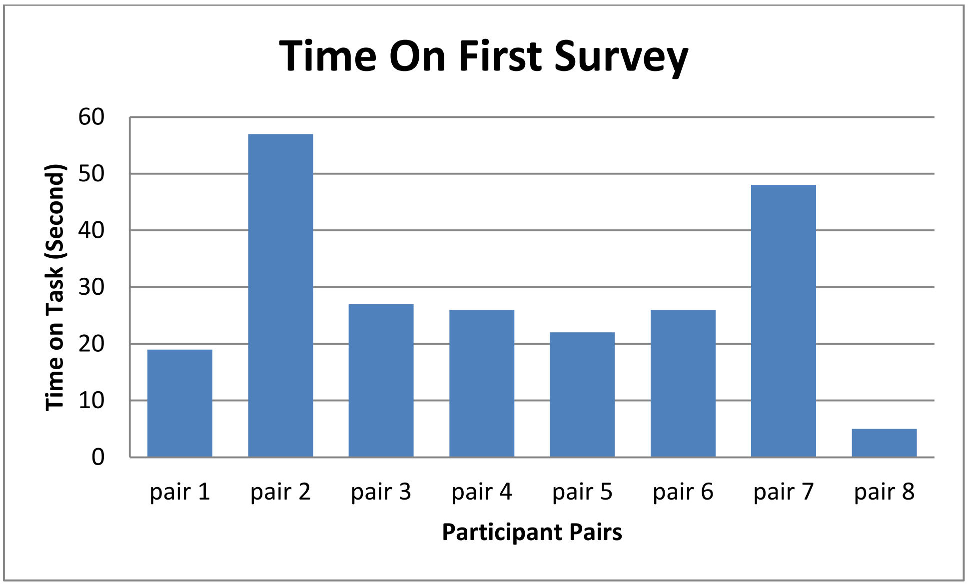

Figure 5-3: Time spent on first survey task across nine participant pairs

Participants received the second survey at the end of the lesson. This task contained one question related to the lesson topic, with three answer options where two were correct (Appendix C).

The application captured the time taken by the nine participant pairs to complete the second survey, as illustrated in Figure 5-4.

The results show that the participants completed all three tasks in less than one minute. Learners discussing questions while completing the task caused slower response times. The observer observed this and the researcher captured it on video. The longer completion times thus do not reflect negatively on the efficiency of LiveLearning. These results confirm that LiveLearning is an efficient tool and an improvement on manually collecting answers from learners.

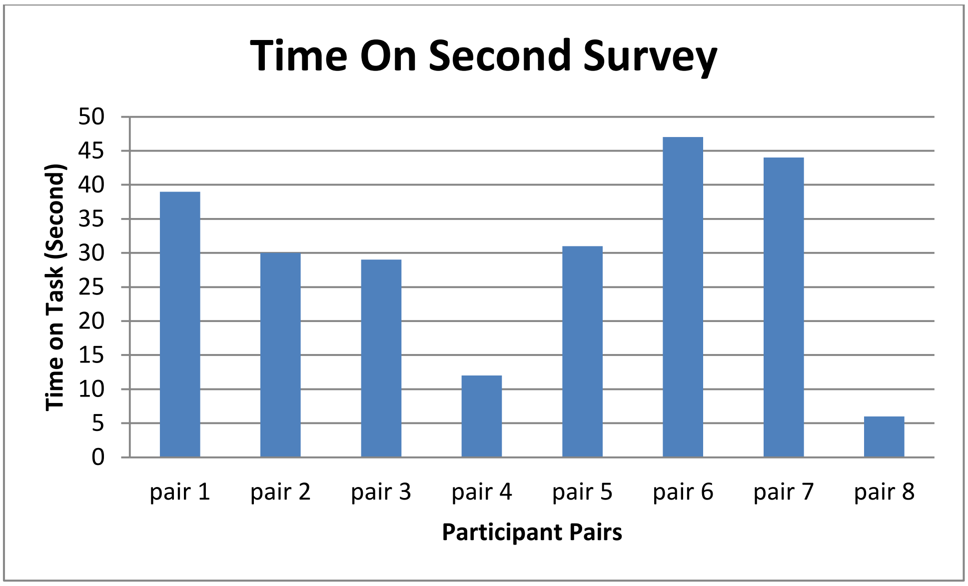

Figure 5-4: Time spent on second survey task across nine participant pairs

5.3.1.2. Effectiveness

The teacher had to send each task in the task list to participants and display the results on the presentation display. The extent to which the teacher could complete the tasks provided and participants' ability to complete or review tasks successfully determined effectiveness.

The teacher completed all the tasks with a 100 percent success rate. In addition, participant pairs received tasks and reviewed documents on their mobile devices equally successfully. Some of the participants indicated that the prototype was slow to show tasks on their mobile devices at times. Due to the high completion rate for the teacher and participants' tasks, one can conclude that the prototype effectively supported contact learning in the classroom situation.

5.3.2. Satisfactions Results

The researcher used the session questionnaires (Appendix F) and the final post-intervention questionnaire (Appendix G) to capture user satisfaction results. The results of the two questionnaires were populated into a Microsoft Excel spreadsheet and divided into qualitative (Section 5.3.2.1) and quantitative (Section 5.3.2.2) results.

5.3.2.1. Qualitative Results

After each task, the participant pairs and the teacher had to complete a session questionnaire. This questionnaire contained three questions, which asked participants to list the positive aspects of the prototype, the negative aspects of the prototype and general comments. The researcher obtained and captured the questionnaires. In addition, the researcher moderated some of the participants' feedback; for example, he moderated "nice live overview" to "instant feedback". The researcher conducted an analysis of the qualitative data gathered and categorised feedback as positive aspects and negative aspects.

Positive Aspects

The majority of the participants responded positively to the use of LiveLearning in the classroom.

The findings show a positive response from the learners, as they feel comfortable, supported and motivated to use the mobile learning application. One of the most positive common comments was that the system provided results as the participants completed tasks. The system presented the results and feedback to participants on their mobile devices and on the presentation display as soon as a task was completed. Learners also appreciated the anonymity of the system. The prototype did not show participants' names when they submitted questions or completed tasks. The application showed the results of these tasks on the presentation display as percentages or numbers of answers only. This made the participants feels free to participate and interact with the system. Some participants reported that the system increased productivity in the classroom, while other participants felt that the system made the class more interactive. The prototype allowed participants to interact with each other and the teacher effectively by receiving tasks and sending messages. Other positive aspects related to the intuitive interface of the system, which made it easy to understand its functions.

Some of the positive comments were:

- *"Easy and simple to use"*
- *"It made the learning process more fun"*
- *"Instantly providing feedback"*
- *"Sending anonymous question to the teacher, increased asking questions"*
- *"Showing results of the task immediately was great"*
- *"The system improves productivity"*
- *" It provides different way of learning"*
- *"It makes the learning more interactive"*
- *"It was very intuitive"*

- *"I liked it because the system did not require much typing to complete a task since its multiple answers"*

Negative Aspects

The participants provided useful negative comments about LiveLearning throughout the evaluation. The most common negative comment obtained was that the mobile application's user interface needs improvement. Some of the participants explained that this was due to the use of green in the learner dashboard, which is not compatible with Android's default colours. Other participants felt that the interface of the mobile application was not intuitive. Some of the participants indicated that the system did not display the photos they took clearly on the presentation board. However, some of the participants did not capture pictures competently. Capturing a satisfactory picture from the Samsung mobile devices used requires one to aim the mobile device at the target subject and touch the screen to focus on a specific area. Participants who had adequate experience in using a camera on a mobile phone submitted better quality photos than inexperienced users did. The negative comments regarding these issues include:

- *"User interface needs to be improved"*
- *"Not a pretty colour, android uses black and blue colour"*
- *" Layout is not very appealing"*
- *"sending a picture was not clear on presentation display"*

A few participants made negative comments regarding the mobile application being slow and freezing at times. The researcher observed from the video recording that mobile devices entered sleep mode when participants did not interact with them. This mode turns off W-Fi connections for Android mobile devices. After returning the mobile devices to active mode, it took some time to connect to Wi-Fi. Participant comments include:

- *"It was slow at times"*
- *"some tasks took long time to load"*
- *"the mobile application got frozen in times"*
- *"connection issues"*

Although the researcher received some negative comments, participants' overall response was positive.

5.3.2.2. Quantitative Results

The researcher collected quantitative data from the final post-intervention questionnaires (Appendix G). This questionnaire contained 10 questions intended to measure the learners' satisfaction. These questions were adapted from and based on the SUS measuring the usability of LiveLearning (Finstad, 2006). Each question made use of a five-point Likert scale (5 strongly agree, 1 strongly disagree). The researcher classified the questions of the SUS into four groups, namely ease of use, consistency, satisfaction and learnability. The researcher provided the final post-intervention questionnaire to the participants at the end of the entire evaluation and captured the results from participant pairs using Microsoft Excel 2010. Figure 5-5 presents the results of the 10 questions of the final post-intervention questionnaire.

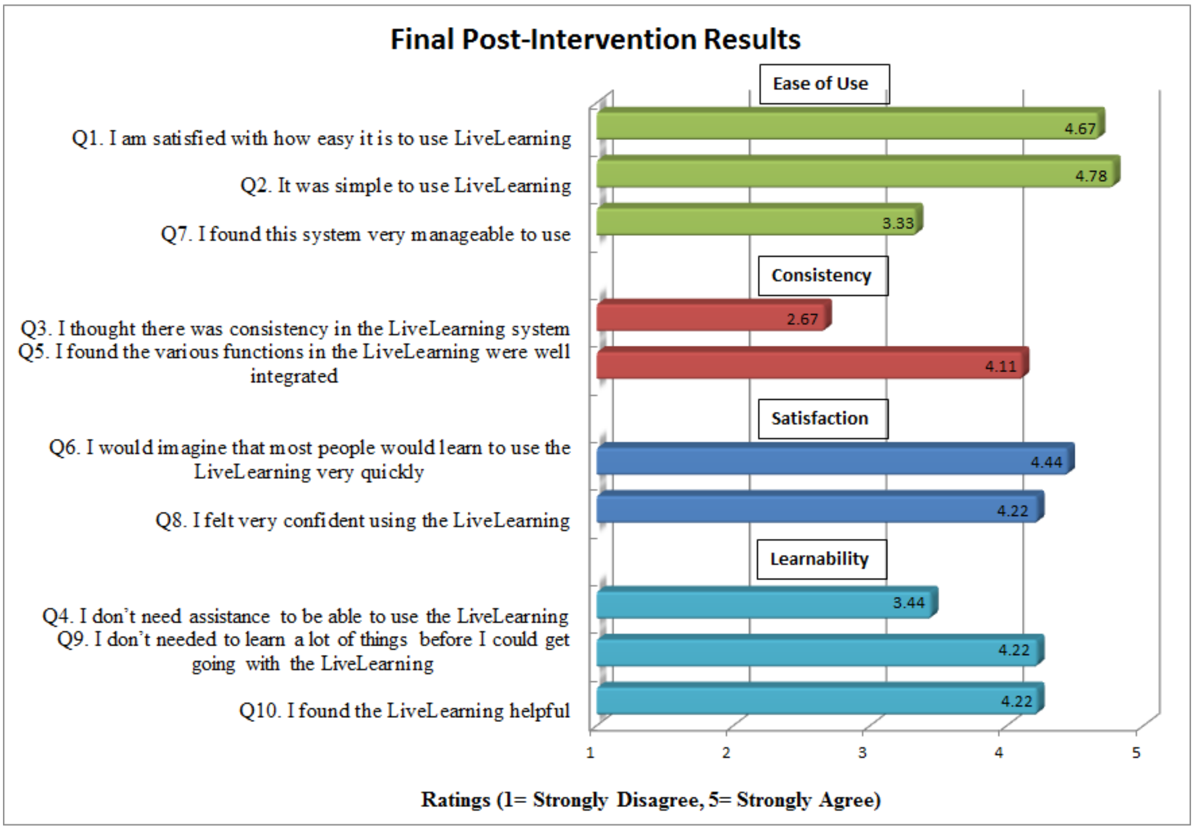

Figure 5-5: Final post-intervention results (n=18)

From Figure 5-5, one can observe that the results for the questions in the final post-intervention questionnaire were positive. The ease of use questions received the highest ratings of the 10 satisfaction questions.

The participants rated the consistency of the prototype as 2.67. This rating was the lowest among the responses to the usability questions. This could be due to the inconsistency of the user interface and the use of green colour for the main screen. Some participants commented that the interface was not attractive and not compatible with the typical Android interface.

The questionnaire contained two questions intended to measure the participants' satisfaction. The results obtained from these questions indicate that the majority of participants were satisfied with LiveLearning.

The ease of learning results were strongly positive. The participants reported that they did not need to learn much to complete their tasks. The researcher obtained these results because of the system modifications carried out following the suggestions of the expert review and pilot study. The applied suggestion improved the flow in task performance. However, some participants felt that they needed assistance to guide them in using the mobile learning application.

5.3.3. Conclusion

The aim of the evaluation was to assess the usability of LiveLearning in supporting contact learning in the classroom environment. The researcher designed the CIMLA and implemented the LiveLearning system based on the proposed architecture as a proof of concept. The researcher conducted a usability evaluation with 18 participants divided into nine participant pairs. The researcher captured and analysed performance and user satisfaction data to meet the evaluation objectives.

The performance metrics evaluated were efficiency and effectiveness. From the efficiency results, one can conclude that LiveLearning can competently support learning in interaction with the mobile learning prototype.

The metrics of effectiveness were positive, as the results indicated that the teacher completed all the tasks successfully. The participant pairs received the tasks on their mobile devices and responded to them. The teacher effectively controlled and displayed the results of the tasks on the presentation display. The result for effectiveness indicates that the prototype was reliable in delivering tasks and can be used to support contact learning.

The researcher obtained the satisfaction results from qualitative and quantitative results captured by collecting positive, negative and general comments. The quantitative results were collected from the final post-intervention questionnaires to evaluate the prototype.

Participants identified some minor issues based on the negative aspects. The main negative aspects focused on the user interface and its limitations. This evaluation proves that the prototype as a proof of concept is usable in the classroom and the proposed architecture is functional.

Chapter 6 concludes the research by highlighting achievements, discussing the contribution of the research and describing possible future research and development.

Chapter 6: Conclusions

6.1. Introduction

The primary objective of the research was to develop an architecture for using mobile devices in supporting contact learning in the classroom. The researcher designed the Contact Instruction Mobile Learning Architecture (CIMLA) to achieve this objective. He developed and implemented a mobile learning prototype (LiveLearning) based on this architecture and conducted a usability study to evaluate LiveLearning.

6.2. Achievements of Research Objectives

This research has shown that one can develop a mobile learning system based on the proposed CIMLA architecture. The implementation of this architecture can be used to support contact learning in the classroom.

The main objective of this research was to design an architecture for mobile learning to support contact learning. The sub-objectives of the research were as follows:

1. To investigate the environment regarding the use of mobile technologies in education;
2. To propose a mobile learning architecture for the use of mobile devices on campus; and
3. To implement a prototype as proof of concept and evaluate the usability of the prototype.

The researcher formulated research questions on these objectives and addressed them in the chapters of this research. By addressing these research questions, the researcher achieved the research objectives.

The first and second groups of research questions were as follows:

1. Mobile learning as a tool for education

1.1 What is the historical background to mobile learning?

1.2 How are mobile devices used in the workplace and in higher education?

2. Existing theory regarding mobile learning

2.1 Which issues need to be considered regarding mobile learning in the classroom?

2.2 Which existing mobile learning architectures exist?

The researcher addressed these questions in Chapter 2. To gain insight into the use of mobile devices in general education environments, the researcher investigated the history of mobile devices and their use in education (Research Question 1.1). The mobile devices developed significantly with the addition of features such as Wi-Fi, touchscreens and cameras. Mobile learning emerged because of utilising mobile devices for teaching. In answering Research Question 1.2, the researcher investigated the use of mobile devices for learning in industry (Section 2.3.1), discussed the integration of mobile devices in educational institutions (Section 2.3.2), and investigated several benefits of the use of mobile learning in education.

To answer Research Question 2.1, the researcher analysed different components of mobile learning in Section 2.5 and identified seven components to gain an overview of mobile learning frameworks. Four mobile learning system architectures (Research Question 2.2) were investigated in Section 2.7 to understand the different ways of designing mobile learning architectures. After discussing these architectures, the researcher completed a comparison of their features and capabilities (Section 2.8).

Chapter 3 dealt with Research Question 3:

How can an architecture for mobile contact learning be designed?

This chapter focused on the design of a mobile learning architecture to support the use of mobile devices for learning in the classroom. Section 3.2 identified connectivity mechanisms mobile learning systems use to deliver learning content to mobile devices. The researcher compared four types of connectivity to identify the most suitable option for mobile learning and chose Wi-Fi as the most suitable candidate (Section 3.2.4). An experiment was conducted at NMMU to identify the W-Fi features on campus (Section 3.3).

The researcher addressed the main objective of this research in Section 3.4 by reporting on the design of the CIMLA.

Chapter 4 addressed Research Question 4:

How can a prototype, as a proof of concept of the designed architecture, be developed that will support mobile contact learning?

The researcher developed the LiveLearning prototype based on CIMLA and intended the implementation of the prototype as a proof of concept of the designed architecture. Four separate applications were implemented to facilitate mobile learning in the classroom. These applications were the server application, mobile learning application, teacher application and presentation display application (Section 4.4). To identify usability and improve efficiency issues of the prototype, the researcher conducted a pre-evaluation (Section 4.5). The results of the pre-evaluation were analysed and addressed to improve LiveLearning (Section 4.5.3 and Section 4.5.4).

The fifth research question was:

How usable is the developed prototype in a contact learning environment?

The researcher discussed the evaluation of the LiveLearning prototype in Chapter 5. The usability evaluation took place in a laboratory in the Department of Computing Sciences at NMMU (Section 5.2). The researcher provided the teacher with a set of tasks to send to participant pairs during the evaluation process (Section 5.2.5). These participants were required to perform the received tasks on their mobile devices. The researcher used session questionnaires and a final post-intervention questionnaire (Section 5.2.3) to evaluate the usability of LiveLearning.

The evaluation results yielded positive outcomes regarding the efficiency and effectiveness of the prototype. Participant pairs could complete the sent tasks in a reasonable amount of time and all the tasks were sent and received successfully (Section 5.3.1). The participants were generally satisfied with the ease of use of LiveLearning (Section 5.3.2). The results were positive and supported the finding that LiveLearning was helpful in supporting contact learning in the classroom.

As this section shows, the researcher addressed all the research questions. The negative and positive aspects highlighted by the evaluation were used to identify recommendations for improvement. The researcher highlights and discusses design recommendations in the following section.

6.3. Research Contribution

The researcher discusses the research contribution in terms of the theoretical and practical contributions of this study. The theoretical contributions focus on designing an architecture for the use of mobile devices to support contact learning. The practical contributions relate to the development and implementation of the mobile learning architecture to support contact learning.

6.3.1. Theoretical Contributions

The research has made several theoretical contributions. The objective of this research was to design a mobile learning architecture for using mobile devices in supporting contact learning in the classroom environment. The researcher investigated several mobile learning architectures for this purpose (Section 2.7). As CIMLA was intended to support the use of mobile devices in the classroom, the researcher identified the basic components for a mobile learning framework (Section 2.5). These components are learner, teacher, environment, electronic content and assessment. The proposed architecture contained five modules, namely Learning Server, Teacher Client, Learner Client, Presentation Client and Repository. The researcher integrated these modules to perform functions between each other to support contact learning in the classroom.

The successful implementation of the mobile learning system provided evidence that the proposed architecture can be used successfully to develop an effective mobile learning application. The proposed architecture provides solid foundations for developing mobile learning applications for the classroom situation.

6.3.2. Practical Contributions

The practical contribution of the research includes the LiveLearning prototype, the mobile learning system for supporting contact learning in the classroom environment. The researcher developed the LiveLearning prototype based on the modules of CIMLA and implemented four separate applications as a proof of concept for the proposed architecture. These applications are the server application, mobile application, teacher application and presentation application. The researcher developed the server application to manage most of the system responsibilities due to the limitations of mobile devices and to achieve satisfactory performance for the mobile learning system. The researcher implemented the mobile learning application as a native mobile application for Android operating systems and installed it on Samsung Galaxy S3 and Samsung Tablet 10.1 mobile devices. The teacher application was implemented to facilitate the teacher's role by offering tools to complete tasks in a simple way. To obtain this goal, the researcher developed the teacher application on Windows Form as an independent application to present learning content via a projector and installed it on a laptop. All the applications mentioned worked together to perform tasks in the classroom.

Eighteen participants and an NMMU lecturer evaluated the prototype. Most of the participants felt comfortable using it. During the evaluation, the teacher sent tasks to participants' mobile devices and displayed task results on the presentation display. This process encouraged participants to interact with the prototype. The results of the evaluation provided evidence that the LiveLearning prototype is usable in the classroom environment (Section 5.3).

6.4. Limitations and Problems Encountered

The researcher encountered several problems and limitations during the design of the architecture and the implementation and evaluation of LiveLearning. Because of the research focus, CIMLA was designed to support contact learning in the classroom only. This architecture thus does not support learning on or off campus. Furthermore, the proposed architecture is not adaptive and cannot provide learning content based on the learner's level of knowledge.

Throughout the implementation, the researcher encountered several difficulties. The prototype was developed as four separate applications, with the mobile application on Android and the rest on a Windows platform. These platforms deal with files in different ways. Consequently, creating learning content that included these files was challenging. A solution was to convert files to binary data and store them in the database before reconverting them and sending them to the mobile devices.

A major limitation was that LiveLearning does not support different learning content formats, such as Microsoft Word, Microsoft Excel or Microsoft Power Point, as pointed out by the teacher during the learning content preparation session for the lesson.

6.5. Future Research

Several recommendations for the enhancement of the proposed mobile learning architecture and prototype can be considered for future research. The proposed architecture can be enhanced to support adaptive learning content based on the learner's knowledge and interests.

In this research, the researcher implemented and applied the mobile learning application for Android operating systems only. Extending the mobile application for other platforms, such as iOS and Windows Phone, would be an improvement. Learners have different mobile devices with various operating systems, not only Android. Participants provided some suggestions for improvement to the prototype, such as improving the user interface for the mobile learning application. Future work for the prototype could implement these recommendations to gain more acceptance from learners. Supporting various document formats, such as Microsoft Power Point and Microsoft Word, would simplify the teacher's role.

Some features could be implemented to expand the use of mobile devices in the classroom to create a more interactive mobile learning application. These features include supporting communication between learners to allow them to send a task from one learner to another to obtain suggestions or feedback. This could help learners to assess and evaluate each other. Therefore, the application could support collaboration to improve the mobile learning experience in the classroom. Allowing learners to collaborate on mobile devices and display their activities on the presentation display would make mobile learning more efficient.

This research has shown that one can design an architecture to facilitate the development of a mobile learning application that can be used effectively in the classroom environment. This has highlighted the feasibility of using mobile devices in the classroom.

List of References

Acharya, D. and Kumar, V., 2011. Security of MBAN Based Health Records in Mobile Broadband Environment. *Procedia Computer Science*, 5(1877), pp. 539–545.

Adriancs, 2010. A Professional Ribbon Control. Available at: http://ribbon.codeplex.com/ [Accessed October 17, 2013].

Agarwal, A., 2013. Pros and Cons of PhoneGap. Available at: http://www.optimusmobility.com/2013/03/08/pros-and-cons-of-phonegap/ [Accessed November 13, 2013].

Ah-choo, K., Mohd, A., Harji, M.B. and Kiluwasha, A., 2012. What Probability Students Say About Mobile Learning Through ProbMobile Learning Framework. In *1st International Conference on Mobile Learning, Applications, and Services*. Multimedia University: Selangor, Malaysia, pp. 1–6.

Alexander, B., 2004. M-Learning : Pedagogical and Campus Issues in the Mobile Learning Environment. *Bulletin*, 2004(16), p. 10.

Ally, M., 2009. *Mobile Learning Transforming the Delivery of Education and Training* M. Ally, ed., Athabasca University: Edmonton.

Almstrum, V., Owens, B. and Adams, E., 2005. Building a Sense of History Narratives and Pathways of Women Computing Educators. *SIGCSE Bulletin*, 37(4), pp. 173–189.

Alvarez, C., Salavati, S. and Nussbaum, M., 2013. Collboard: Fostering New Media Literacies in the Classroom Through Collaborative Problem Solving Supported by Digital Pens and Interactive Whiteboards. *Computers & Education*, 63(0360), pp. 368–379.

Alzaabi, M., Berri, J. and Zemerly, M., 2010. Web based Architecture for Mobile Learning. *International Journal for Infonomics*, 3(1), pp. 207–216.

Android, 2013. Navigation with Back and Up. Available at: http://developer.android.com/design/patterns/navigation.html [Accessed August 20, 2013].

Anne, R., 2008. Post-Positivist Approaches to Research. In *Researching and Writing Your Thesis: a Guide for Postgraduate Students*. MACE: Maynooth Adult and Community Education, pp. 12–26.

Arman, N., 2010. E-learning Materials Development Applying and Implementing Software Reuse Principles and Granularity Levels in the Small. *International Journal of u- and e- Service, Science and Technology*, 3(2), pp. 31–42.

Attewell, J., 2005. *Mobile Technologies and Learning*, Technology Enhanced Learning Research Centre: London.

Attwell, G., 2010. Using Mobile Devices for Learning in the Workplace. Available at: http://www.pontydysgu.org/2010/03/using-mobile-devices-in-the-workplace/ [Accessed September 17, 2012].

Avalos, B., 2011. Teacher Professional Development in Teaching and Teacher Education Over Ten Years. *Teaching and Teacher Education*, 27(1), pp. 10–20.

Bein, D. and Zheng, S.Q., 2010. Energy Efficient all-to-all Broadcast in all-Wireless Networks. *Information Sciences*, 180(10), pp. 1781–1792.

Bellis, M., 2012a. Johannes Gutenberg and the Printing Press. *About.com Guide*. Available at: http://inventors.about.com/od/gstartinventors/a/Gutenberg.htm [Accessed August 5, 2013].

Bellis, M., 2012b. The History of the Transistor. Available at: http://inventors.about.com/od/tstartinventions/a/transistor_history.htm [Accessed February 28, 2012].

Bellis, M., 2012c. The History of the Integrated Circuit aka Microchip. Available at: http://inventors.about.com/od/istartinventions/a/intergrated_circuit.htm [Accessed August 28, 2012].

Benedek, A., 2004. *Mobile Learning and Lifelong Knowledge Acquisition*, UNESCO: New York.

Block, G., 2006. What is e-Learning. Available at: http://blogs.msdn.com/b/gblock/archive/2006/10/23/faq-what-is-e-learning.aspx [Accessed August 5, 2012].

Bonanno, K., 2005. *Online learning: The Good, the Bad, and the Ugly*, Australian School Library Association: Biennial.

Bows, R., 2010. 11 Mlearning Examples. Available at: http://www.mlearningassociates.com/11 examples.htm [Accessed October 15, 2012].

Bronkhorst, Q., 2012. SA Mobile Subscriber Numbers Compared. Available at: http://businesstech.co.za/news/telecommunications/11451/sa-mobile-subscriber-numbers-compared/ [Accessed September 25, 2012].

Brookes, T., 2012. A Brief History Of Mobile Phones. Available at: http://www.makeuseof.com/tag/history-mobile-phones [Accessed August 28, 2012].

Brown, J. and Metcalf, D., 2008. *Why Mobile Learning Now*, The MASIE Center & The Learning Consortium: Saratoga Springs.

Bruck, P.A. and Foerster, F., 2012. Mobile Learning with Micro-Content : A Framework and Evaluation 1 Introduction. In *Reliable and Trustworthy eStructures, eProcesses, eOperations and eServices for the Future*. Research Studio Micro-learning and Information Environment: Bled, pp. 527–543.

Butgereit, L., 2009. How Dr Math reaches Pupils with Competitions and Computer Games by using MXit. In P. Cunningham and M. Cunningham, eds. *IST-Africa 2009 Conference Proceedings*. Pretoria: IIMC International Information Management Corporation, pp. 7–13.

Carvalho, J.A.R.P. De, Veiga, H., Pacheco, C.F.R. and Reis, A.D., 2012. Performance Evaluation of Laboratory Wi-Fi ieee 802.11g wpa Point-to-Point Links Using TCP, UDP and FTP. *Procedia Technology*, 5(2212), pp. 302–309.

Castiglione, A., De Santis, A. and Soriente, C., 2010. Security and Privacy Issues in the Portable Document Format. *Journal of Systems and Software*, 83(10), pp. 1813–1822.

Castillo, A., Clunie T., C., de Clunie, G. and Rodríguez, K., 2013. A System for Mobile Learning: A Need in a Moving World. *Procedia - Social and Behavioral Sciences*, 83(1877), pp. 819–824.

Cavus, N., 2011. Investigating Mobile Devices and LMS Integration in Higher Education: Student Perspectives. *Procedia Computer Science*, 3(01), pp. 1469–1474.

Challoo, R., Oladeinde, A. and Yilmazer, N., 2012. An Overview and Assessment of Wireless Technologies and Co- existence of ZigBee, Bluetooth and Wi-Fi Devices. *Procedia Computer Science*, 12(1877), pp. 386–391.

Chao, P. and Chen, G., 2009. Augmenting Paper-Based Learning with Mobile Phones. *Interacting with Computers*, 21(3), pp. 173–185.

Chapman, C., 2011. Comprehensive Review Of Usability And User Experience Testing Tools. Available at: http://uxdesign.smashingmagazine.com/2011/10/20/comprehensive-review-usability-user-experience-testing-tools/ [Accessed October 17, 2013].

Chatti, M.A., Hamdan, N.A. and Schaper, H., 2012. *Collaboration in Mobile Learning us*, RWTH-Aachen University: Aachen.

Chinnery, G.M., 2006. Going to the MALL : Mobile Assisted Language Learning. *Language Learning & Technology*, 10(1), pp. 9–16.

Chorfi, H.O., Sevkli, A.Z. and Bousbahi, F., 2012. Mobile Learning Adaption Through a Device Based Reasoning. *Procedia - Social and Behavioral Sciences*, 47(1877), pp. 1707–1712.

Chouvet, M.-P. and Le Ber, F., 1999. An Agent-based Model for Domain Knowledge Representation. *Data & Knowledge Engineering*, 29(2), pp. 147–161.

Collard, M., 2011. Android Pattern Library. Available at: http://unitid.nl/2011/03/android-pattern-library/ [Accessed August 15, 2013].

Dalakov, G., 2012. The Dynabook of Alan Kay. Available at: http://history-computer.com/ModernComputer/Personal/Dynabook.html [Accessed August 10, 2012].

Eddy, M., 2011. A History of Mobile Productivity. Available at: http://www.geekosystem.com/mobile-device-infographic [Accessed August 28, 2012].

Fereday, J., 2006. Demonstrating Rigor Using Thematic Analysis : A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), pp. 80–92.

Fernández, M.J.L., Fernández, J.G., Aguilar, S.R., Selvi, B.S. and Crespo, R.G., 2013. Control of Attendance Applied in Higher Education Through Mobile NFC Technologies. *Expert Systems with Applications*, 40(957), pp. 4478–4489.

Finstad, K., 2006. The System Usability Scale and Non-Native. *Journal of Usability Studies*, 1(4), pp. 185–188.

Fisher, B., 2001. Funding International eLearning Projects. Available at: http://www.usdla.org/html/journal/JUN01_Issue/article07.html [Accessed December 22, 2013].

Fitzpatrick, J., 2012. Voice Call Capacity Analysis of Long Range WiFi as a Femto Backhaul Solution. *Computer Networks*, 56(5), pp. 1538–1553.

Fortune, M., Spielman, M. and Pangelinan, D., 2011. Students Perceptions of Online or Face to Face Learning and Social Media in Hospitality Recreation and Tourism. *Merlot Journal of Online Learning and Teaching*, 7(1), pp. 1–16.

Fosu, I., 2011. Exploring the Potential of Wireless Technologies to Accelerate Universal Internet Access in Ghana. *Telecommunications Policy*, 35(6), pp. 494–504.

Franklin, C. and Layton, J., 2013. How Bluetooth Works. Available at: http://electronics.howstuffworks.com/bluetooth2.htm [Accessed November 19, 2013].

Garg, A., 2011. Mobile Learning In The Workplace – Survey. Available at: http://www.upsidelearning.com/blog/index.php/2011/09/21/mobile-learning-in-the-workplace-survey/ [Accessed September 17, 2012].

Gaskill, D., 2001. A Virtual Conversation on Bernadette Longo's Spurious Coin A History of Science Management and writing.pdf. *Journal of Computer Documentation*, 25(2), pp. 50–62.

Ghosh, A. and Das, S.K., 2008. Coverage and Connectivity Issues in Wireless Sensor Networks: A Survey. *Pervasive and Mobile Computing*, 4(3), pp. 303–334.

Gil-Garcia, R., Pardo, T. and Baker, A., 2007. Understanding Context through a Comprehensive Prototyping Experience: A Testbed Research Strategy for Emerging Technologies. In *Proceedings of the 40th Hawaii International Conference on System*

Sciences. Center for Technology in Government, University at Albany: Suny, Albany: Ieee, pp. 1–10.

Gimenez López, J.L., Magal Royo, T. and Laborda, J.G., 2009. Methods of Adapting Digital Content for the Learning Process via Mobile Devices. *Procedia - Social and Behavioral Sciences*, 1(1), pp. 2673–2677.

Glahn, C., 2011. The Role of the Teacher in Mobile Learning. Available at: http://lo-f.at/glahn/2011/05/the-role-of-the-teacher-in-mobile-learning.html [Accessed August 21, 2012].

Glava, C.C. and Glava, A.E., 2012. Teachers' Views on Using the Internet As a Learning Tool. *Procedia - Social and Behavioral Sciences*, 46(104), pp. 3556–3560.

González, M., Masip, L., Granollers, A. and Oliva, M., 2009. Quantitative Analysis in a Heuristic Evaluation Experiment. *Advances in Engineering Software*, 40(12), pp. 1271–1278.

Gruhn, V., 2006. *Aligning Software Architectures of Mobile Applications on Business Requirements*, University of Leipzig: Leipzig.

Güngör, Z. and KılıçDelice, E., 2009. The Usability Analysis with Heuristic Evaluation and Analytic Hierarchy Process. *International Journal of Industrial Ergonomics*, 39(6), pp. 934–939.

Haack, J. and Yuma, J., 2012. *Electrifying Microchips*, Courtney Ingersoll and Maggie Krause: Mentors.

Haag, J., 2011. From eLearning to mLearning : The Effectiveness of Mobile Course Delivery. In *Interservice/Industry Training, Simulation, and Education Conference*. Advanced Distributed Learning Initiative: Alexandria, USA, pp. 1–13.

Hanna, 2012. Mobile Apps Inspiration and Design Patterns. Available at: http://www.tripwiremagazine.com/2012/10/mobile-apps-inspiration-design-patterns.html [Accessed July 20, 2013].

Helmer, J., 2011. Mobile Learning and Communications : Your Key Decisions. *Line Communications*, 1(0012), pp. 2–23.

Herald, T., 1969. Geography Techer Uses Flying Classroom, 21 February, p. 37.

Hilera, J.R., Gutiérrez, J.A., Marcos, L. De, Pagés, C. and Martínez, J.J., 2007. *Implementing Learning Objects Repositories for Mobile Devices*, University of Alcalá: Madrid, Spain.

Hodgkinson-Williams, C. and Ngambi, D., 2009. *Case Study 5 Mobile learning*, University of Cape Town: Cape Town.

Idrus, R.M. and Ismail, I., 2010. Role of Institutions of Higher Learning Towards a Knowledge-Based Community Utilising Mobile Devices. *Procedia - Social and Behavioral Sciences*, 2(2), pp. 2766–2770.

Iriss, P., 2012. *Mobile Learning in the Workplace - A Cost Effective Approach to Improving Learning Retention*, Scottish Social Services Council: Scotland.

Isaacs, S., 2012. *Mobile Learning for Teachers in Africa and the Middle East: Exploring the Potential of Mobile*, United Nations Educational, Scientific and Cultural Organization: Fontenoy, France.

Itzkovitch, A., 2012. Designing For Device Orientation: From Portrait To Landscape. Available at: http://uxdesign.smashingmagazine.com/2012/08/10/designing-device-orientation-portrait-landscape/ [Accessed August 20, 2013].

Javatechig, 2011. Observer Design Pattern in Blackberry. Available at: http://javatechig.com/others/observer-design-pattern-in-blackberry/ [Accessed August 15, 2013].

Jeffries, M., 2012. Research in Distance Education. Available at: http://www.digitalschool.net/edu/DL_history_mJeffries.html [Accessed July 31, 2012].

Jezek, G., 2012. The History of Television. Available at: http://www.thehistoryoftelevision.com/ [Accessed July 31, 2012].

Jung, H. and Park, S., 2006. An Architecture for Adaptive Mobile Learning. In *20th International Conference on Advanced Information Networking and Applications - Volume 1 (AINA'06)*. IEEE, pp. 219–223.

JunWu, X. and JunLing, L., 2012. Develop 3G Application with The J2ME SATSA API. *Physics Procedia*, 25(1875), pp. 651–658.

Kadle, A., 2010a. The Advent of Mobile Learning Technology. Available at: http://www.upsidelearning.com/blog/index.php/2010/01/07/the-advent-of-mobile-learning-technology/ [Accessed October 20, 2012].

Kadle, A., 2010b. Five Mobile Learning Implementation Tips. Available at: http://www.upsidelearning.com/blog/index.php/2010/03/01/five-mobile-learning-implementation-tips/ [Accessed November 15, 2010].

Kim, P., Buckner, E., Kim, H., Makany, T., Taleja, N. and Parikh, V., 2012. A Comparative Analysis of a Game-Based Mobile Learning Model in Low-Socioeconomic Communities of India. *International Journal of Educational Development*, 32(2), pp. 329–340.

Kinshuk, T.L., 2003. *Improving Mobile Learning Environments by Applying Mobile Agents Technology Client-Server*, Palmerston North, New Zealand.

Kirschner, P.A., 2001. *Using Integrated Electronic Environments for Collaborative Teaching / Learning*, Open University of the Netherlands: The Netherlands.

Kock, N., 2013. Action Research. Available at: http://www.free-knowledge.org/encyclopedia/action_research.html [Accessed December 23, 2013].

Kolb, L., 2008. What is Your Classroom "Rules" List for Integrating Cell Phones in the Classroom? Available at: http://cellphonesinlearning.blogspot.com/2008/05/what-would-be-in-your-classroom-rules.html [Accessed December 15, 2013].

Kopplin, J., 2002. History of Computers. Available at: http://www.computersciencelab.com/ComputerHistory/History.htm [Accessed August 7, 2012].

Kromer, F., 2010. *SOMA - A Service-Oriented Mobile Learning Architecture*. The Vienna University of Technology: Betreuung.

Lai, T., 2007. Iterative Refinement of a Tailored System for Self-Care Management of Depressive Symptoms in People Living With HIV/AIDS Through Heuristic Evaluation and End User Testing. *International Journal of Medical Informatics*, 765(1386), pp. 317–324.

Lammers, R., Clarke, M. and Schoenmakers, B., 2012. Dealing With Data. Available at: http://www.androidpatterns.com/uap_category/dealing-with-data [Accessed August 15, 2013].

Lategan, L., Solomon, S. and Visser, E., 2012. Mobile marketing in South Africa. Available at: http://www.purplecow.co.za/mobile-internet/mobile-marketing-in-south-africa/ [Accessed September 25, 2012].

Leeuwe, M., 2007. Learning Machines. *Power Learning*. Available at: http://powerlearning.blogspot.com/2007/02/learning-machines.html [Accessed July 31, 2012].

Leong, L., Hew, T., Tan, G.W. and Ooi, K., 2013. Predicting the Determinants of the NFC-Enabled Mobile Credit Card Acceptance : A Neural Networks Approach. *Expert Systems with Applications*, 40(957), pp. 5604–5620.

Li, C. and Yu, C., 2008. Quasi-FIFO back-off Scheme for Collision Resolution in Wireless Networks. *AEU - International Journal of Electronics and Communications*, 62(4), pp. 251–259.

Magal-Royo, Montañana, I.T. and Alcalde, F.G., 2010. New Educative Methods in the Usage of Audiovisual Content in Mobiles. *Procedia - Social and Behavioral Sciences*, 2(1877), pp. 4492–4496.

Malm, A. and Insight, B., 2012. *Handset Connectivity Technologies*, NGT Research Series: Gothenburg, Sweden.

Mamat, K. and Azmat, F., 2013. Mobile Learning Application for Basic Router and Switch Configuration on Android Platform. *Procedia - Social and Behavioral Sciences*, 90(1877), pp. 235–244.

Marling, C., 2013. How Fast is Mobile Broadband? A Guide to 3G and 4G Broadband Speeds. Available at: http://www.broadbandgenie.co.uk/mobilebroadband/help/how-fast-is-mobile-broadband-a-guide-to-3G-broadband-speed [Accessed June 15, 2013].

Maxwell, J.W., 2012. Dynabook: Once and Future. Available at: http://tkbr.ccsp.sfu.ca/dynabook/book/chapter-4-translating-smalltalk/ [Accessed August 10, 2013].

McCracken, H., 2011. The Machine, the Man, and the Dawn of the Portable Computing Revolution. Available at: http://technologizer.com/2011/04/01/osborne-computer/ [Accessed December 24, 2013].

Mello, S.V., 2004. Teaching Human Right. *United Nations Publication*, 3(E.03), pp. 50–52.

Mitchell, A., Lane, B.H. and Inchingolo, P., 2006. *mobile Game-Based Learning to Promote Decision-Making Skills – a Pan- European Project*, University of Trieste: Trieste, Italy.

MobiThinking, 2012. Global Mobile Statistics 2012 Part A: Mobile Subscribers; Handset Market Share; Mobile Operators. Available at: http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/a#subscribers [Accessed September 14, 2012].

Mostakhdemin-Hosseini, A. and Tuimala, J., 2005. Mobile Learning Framework. In *IADIS International Conference Mobile Learning 2005*. Forssa: Helsinki University of Technology, pp. 203–207.

MTN, 2013. MTN Data Plans. Available at: http://hub.simfyafrica.com/index.php/new-data-plans/mtn-data-rates [Accessed October 20, 2013].

Mumbai, N., 2011. Applicability of Mobile Learning Engine – Moodle in Computer Application Course. *Journal of Information Technology Management A Publication of the Association of Management*, XXII(3), pp. 51–58.

Mxit, 2012. About Us History. Available at: http://site.mxit.com/pages/about [Accessed October 1, 2012].

Nahrstedt, P., Angrave, L. and Caccamo, M., 2010. *Mobile Learning Communities Are We There Yet ?*, University of Illinois: Urbana-Champaign.

Nasseh, B., 1997. A Brief History of Distance Education. *Ball State University*. Available at: http://www.seniornet.org/edu/art/history.html [Accessed July 31, 2012].

Nedeva, V., Dimova, E. and Dineva, S., 2005. *Overcome Disadvantages of E-Learning for Training English as Foreign Language*, University of Bucharest and University of Medicine and Pharmacy Târgu-Mureş: Yambol, Bulgaria.

Neil, T., 2012. Mobile Design Pattern Gallery. Available at: http://www.mobiledesignpatterngallery.com/mobile-patterns-details.php?colid=65438029-72157627607680275&setid=72157627762097550&s=2 [Accessed November 5, 2013].

Nielsen, J., 2010. 10 Usability Heuristics for User Interface Design. Available at: http://www.nngroup.com/articles/ten-usability-heuristics/ [Accessed October 26, 2013].

NMMU, 2010. *Nelson Mandela Metropolitan University Vision 2020 Strategic Plan*, NMMU: Port Elizabeth.

NMMU, 2013a. History of NMMU. *Nelson Mandela Metropolitan University*. Available at: http://www.nmmu.ac.za/About-NMMU/Management---Identity/History [Accessed December 10, 2013].

NMMU, 2013b. WiFi Coverage Paps. Available at: http://wifi.nmmu.ac.za/WiFi-coverage-maps [Accessed December 26, 2013].

Nooriafshar, M., 2003. *A Multi Sense Approach to Information Reception and Knowledge Creation in Learning*, University of Southern Queensland: Toowoomba, Australia.

Nordin, N., Embi, M.A. and Yunus, M.M., 2010. Mobile Learning Framework for Lifelong Learning. *Procedia - Social and Behavioral Sciences*, 7(1877), pp. 130–138.

O'Malley, C. and Fraser, S., 2004. *Literature Review in Learning with Tangible Technologies*, University of Nottingham: Nottingham.

O'Reilly, D., 2013. How to Find Truly Free Wireless Access. Available at: http://howto.cnet.com/8301-11310_39-57576384-285/how-to-find-truly-free-wireless-access/ [Accessed December 3, 2013].

Ojala, T. and Korhonen, J., 2008. Making Technology and Learning Click. In *Mobile Lecture Interaction*. University of Oulu: Oulu, Finland, pp. 119–124.

Oman, 2012. Mobile Learning and Cloud-Based Assessment Set to enter Oman's University Campuses. Available at: http://www.ameinfo.com/mobile-learning-cloud-based-assessment-set-enter-314203 [Accessed October 15, 2012].

Orenstein, D., 2000. Application Programming Interface (API). Available at: http://www.computerworld.com/s/article/43487/Application_Programming_Interface?pageNumber=1 [Accessed September 15, 2013].

Osmani, A., 2012. Learning JavaScript Design Patterns. Available at: http://addyosmani.com/resources/essentialjsdesignpatterns/book/ [Accessed July 25, 2013].

Ozdamli, F. and Cavus, N., 2011. Basic Elements and Characteristics of Mobile Learning. *Procedia - Social and Behavioral Sciences*, 28(1877), pp. 937–942.

Pachler, N., 2007. *Mobile Learning Towards a Research Agenda*, University of London: London.

Pachler, N., Bachmair, B. and Cook, J., 2010. *Mobile Learning A Topography*, Boston, MA: Springer US. Available at: http://www.springerlink.com/index/10.1007/978-1-4419-0585-7 [Accessed July 22, 2012].

Padiapu, R., 2008. *Towards Mobile Learning A SCORM Player for the Google Android Platform*. University of applied science: Hamburg.

Parsons, D. and Ryu, H., 2007. A Study of Design Requirements for Mobile Learning Environments. *Sixth IEEE International Conference on Advanced Learning Technologies (ICALT'06)*, 2(4), pp. 5–100.

Pauwels, S.L., Hübscher, C., Bargas-Avila, J. and Opwis, K., 2010. Building an Interaction Design Pattern Language: A Case Study. *Computers in Human Behavior*, 26(3), pp. 452–463.

Perkins, S., 2012. Mobile Learning Fellows. *Abilene Christian University*. Available at: http://www.acu.edu/academics/adamscenter/funding/Mobile_Learning_Fell.html [Accessed September 25, 2012].

PikiFriends, 2011. How to Set Up a Classroom Blog: 10 Essential Steps. Available at: http://pikifriends.wordpress.com/2011/11/07/lesson-plan-things-you-need-to-do-before-blogging-with-students/ [Accessed October 15, 2012].

Pollara, P., 2011. *Mobile Learning in Higher Education: A Glimpse and a Comparison of Student and Faculty Readiness, Attitudes and Perceptions*. Louisiana State University and Agricultural and Mechanical College.

Prensky, M., 2001. Digital Natives, Digital Immigrants Part 1. *On the Horizon*, 9(5), pp. 1–6.

Randolph, J.J., 2009. A Guide to Writing the Dissertation Literature Review. *A peer-Reviewed Electronic Journal*, 14(1531), p. 13.

Rapetti, E., Picco, A. and Vannini, S., 2011. Is Mobile Learning a Resource in Higher Education ? Data Evidence From an Empirical Research in Ticino. *Journal of e-Learning and Knowledge Society*, 7(2), pp. 47–57.

Reporter, Sa., 2011. Mobile Technology for Better Teaching. *Southafrica Info*. Available at: http://www.southafrica.info/about/education/vodamobile-241011.htm#.UGKp8LJlRWw [Accessed September 25, 2012].

Ribeiro, J. and Carvalhais, M., 2012. *Web Design Patterns for Mobile Devices*, University of Porto: Porto.

Roberts, N. and Vänskä, R., 2011. Challenging Assumptions: Mobile Learning for Mathematics Project in South Africa. *Distance Education*, 32(2), pp. 243–259.

Rouben, A., 2012. How do I handle Secondary Navigation Within a Wizard Style Form That Will Work for Touch Screens. Available at: http://ux.stackexchange.com/questions/21901/how-do-i-handle-secondary-navigation-within-a-wizard-style-form-that-will-work-f [Accessed December 27, 2013].

Ryan, V., 2010. The Evaluation. Available at: http://www.technologystudent.com/designpro/eval1.htm [Accessed September 19, 2013].

Sarrab, M. and Elgamel, L., 2012. Mobile Learning and Educational Environments. *International Journal of Distributed and Parallel Systems*, 3(4), pp. 31–38.

Scalise, K., Gifford, B. and Russell, E.M., 2006. Computer-Based Assessment in E-Learning. *The Journal of Technology, Learning, and Assessment*, 4(6), p. 45.

Scarr, J., Cockburn, A. and Gutwin, C., 2012. Improving Command Selection with CommandMaps. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM New York: New York, pp. 257–266.

Schlosser, L.A. and Simonson, M., 2006. *Distance Education Definition and Glossary of Terms* 2nd Editio., Nova Southeastern University.

Seixas, P. and Wineburg, S., 2000. *Knowing Teaching and Learning History National and International Perspectives* S. W. Peter Seixas, ed., University of New York: New York and London.

Seong, D.S.K., 2006. *Usability Guidelines for Designing Mobile Learning Portals*, The University of Nottingham: Nottingham, Malaysia: ACM Press.

Sharples, M., 2006. *Big Issues in Mobile Learning Report of a Workshop by the Kaleidoscope Network of Excellence*, University of Nottingham: Nottingham.

Sokolová, M., 2011. Comparison of the Effectiveness of Teaching with the Support of elearning to the Effectiveness of Traditional Higher Education in the Course of Principles of Management I - Comparison of the Growth Dynamics in the Performances. *Procedia - Social and Behavioral Sciences*, 28(34), pp. 179–183.

Son, N., Lee, Y. and Kim, D., 2013. A Study of User Data Integrity During Acquisition of Android Devices. *Digital Investigation*, 10(1742), pp. S3–S11.

Song, E., Yin, S. and Ray, I., 2007. Using UML to Model Relational Database Operations. *Computer Standards & Interfaces*, 29(3), pp. 343–354.

Song, S.M., 2010. *E-learning : Investigating Students' Acceptance of Online Lerning in Hospitality Programs* . Iowa State University: Department of Education.

Tick, A., 2006. *The Choice of eLearning or Blended Learning in Higher Education Concepts of e-Learning and Blended Learning*, Faculty of International Management and Business, Budapest Business School: Budapest.

Tortosa, S., de Marcos Ortega, L., Barchino Plata, R., Jiménez Rodríguez, M. and Ramon, J., 2011. Using M-Learning on Nursing Courses to Improve Learning. *Computers, Informatics, Nursing : CIN*, 29(5), pp. 311–317.

Traxler, J., 2010. *Developing Content for Mobile Learning*, Training Partners: Beijing.

Trifonova, A. and Ronchetti, M., 2003. *A General Architecture for M-Learning*, University of Trento: Povo, Trento.

Tsunke, S., 2012. University of Pretoria Launches a New Mobile Application. Available at: http://web.up.ac.za/default.asp?ipkCategoryID=8641&articleID=11953 [Accessed September 26, 2012].

Tuttle, H.G., 2012. Change Teaching Since Mobile Learning Devices as Outgrowth of Web 2.0. Available at: http://eduwithtechn.wordpress.com/2012/06/04/change-teaching-since-mobile-learning-devices-as-outgrowth-of-web-2-0/ [Accessed September 25, 2012].

University of Florida, 2012. Correspondence Education. Available at: http://iml.jou.ufl.edu/projects/spring01/declair/history.html [Accessed July 31, 2012].

UXPin, 2013. Instagram New UI Camera View UI Design Pattern. Available at: http://uxporn.uxpin.com/mobile/instagram-new-ui-camera-view/ [Accessed November 23, 2013].

Varis, T., 2005. *the Future of E-learning*, University of Helsinki: Helsinki.

Vasiliou, A. and Economides, A.A., 2007. Mobile Collaborative Learning Using Multicast MANETs Alexandros Vasiliou. *International Journal of Mobile Communications*, 5(4), pp. 423–444.

Verizonwireless, 2013. Choose a Prepaid Plan. Available at: http://www.verizonwireless.com/b2c/prepay/processPrePayRequest.do?rememberMyZip=&prevstate=AK&rememberMyZip=&prevstate=&type=ppmonthSP&go=/prepay/processPrePayRequest.do&&change=changed&zipcode=&state=AK&fd=&filter=&go=/prepay/processPrePayRequest.do&&change=changed&zipcode=&state=CO&fd=&filter=&&city= [Accessed June 20, 2013].

Vermetten, Y., Vermunt, J. and Lodewijks, H., 2002. Powerful Learning Environments How University Students Differ in Their Response to Instructional Measures. *Learning and Instruction*, 12(3), pp. 263–284.

Viken, A., 2009. The History of Personal Digital Assistants 1980 – 2000. Available at: http://agilemobility.net/2009/04/the-history-of-personal-digital-assistants1/ [Accessed August 28, 2012].

Vinu, P. and Krishnan, R., 2011. Towards Pervasive Mobile Learning – the Vision of 21st Century. *Procedia - Social and Behavioral Sciences*, 15(1877), pp. 3067–3073.

Virtič, M.P., 2012. *The Role of Internet in Education*, University of Maribor: Maribor.

Vodacom, 2013. Broadband Standard Prepaid and Top Up Once-off. Available at: http://www.vodacom.co.za/personal/phonesandpackages/datapriceplans/broadbandstandardprepaid [Accessed June 15, 2013].

Vosloo, S., 2012. *UNESCO's Mobile Learning Guidelines*, UNESCO: Washington.

Wallen, J., 2011. Five Tips for Sharing Files on a Mixed-Platform Network. Available at: http://www.techrepublic.com/blog/five-apps/five-tips-for-sharing-files-on-a-mixed-platform-network/ [Accessed December 7, 2013].

Walsh, C., 2010. The Role of Technology in Learning and Development. Available at: http://lcp.org.uk/blog/index.php/2010/10/tech-learning-development [Accessed August 27, 2012].

Wolf, K. and Rummler, K., 2011. Mobile Learning with Videos in Online Communities : The example of draufhaber. *Mobile Learning in Widening Contexts: Concepts and Cases*, 19(1424), p. 13.

Yan Liu, Ren-fa Li, Cheng Xu, F.Y., 2007. Design and Application of Multimedia Mobile Learning. In *Proceedings of the Sixth International Conference on Machine Learning and Cybernetics*. Hong Kong, pp. 19–22.

Yang, J.C. and Lin, Y.L., 2010. Development and Evaluation of an Interactive Mobile Learning Environment with Shared Display Groupware. *International Forum of Educational Technology & Society*, 13(1), pp. 195–207.

Yaodong, C., Lu, W., Aigui, L. and Gang, C., 2008. Sharing LCG Files Across Different Platforms. *Journal of Physics: Conference Series*, 119(6), pp. 1-6.

Yu, K., Gidlund, M., Åkerberg, J. and Bj̈orkman, M., 2011. Reliable and Low Latency Transmission in Industrial Wireless Sensor Networks. *Procedia Computer Science*, 5(1877), pp. 866–873.

Yüzer, T.V. and Kurubacak, G., 1994. *Producing Interactive Educational Radio Programs for Distance Education What is Interactive Educational Radio Programs ?*, Eskisehir Anadolu University: Anadolu, Turkey.

Appendix A Expert Review Task List

Tasks Description

This expert review will be conducted using eight tasks relating to the different categories of learning activities. The teacher will be provided with a task list to send learning activities during the expert review. The other experts will then work in pairs to perform the various tasks and tasks list was provided to them as well. Experts are provided with a set of heuristics, which will be used to evaluate the prototype. The goal of conducting these tasks is to identify any usability issues and rate the severity of the issues identified. All the tasks below will focus on the feasibility of using mobile devices in classroom.

Teacher's Tasks

Task No	Task	Preparation	In Lecture	Post-Lecture
1.	Send a question to learners	1. Create a question 2. Set options of the question 3. Set an image for the question 4. Save it	1. Select a question 2. Send it to learners 3. Present the results of the question on the presentation display	1. Preview the result 2. Export the result to Excel file 3. Analyse results
2.	Send a quiz to learners	1. Create a quiz 2. Set questions of the quiz 3. Set options for each question 4. Save the quiz.	1. Select a quiz 2. Send it to learners 3. Present the results of the quiz on the presentation display	1. Preview the result 2. Export the result to Excel file 3. Analyse results
3.	Send an assessment to learners	1. Create an assessment 2. Set questions of the assessment 3. Set options for each question 4. Save an assessment	1. Select an assessment 2. Send it to learners 3. Present the assessment of the assessment on the presentation	1. Preview the result 2. Export the result to Excel file 3. Analyse results

			display	
4.	Send a survey to learners	1. Create a survey 2. Set questions of the assessment 3. Set options for each question 4. Save a survey	1. Select an assessment 2. Send it to learners 3. Present the assessment of the assessment on the presentation display	1. Preview the result 2. Export the result to Excel file 3. Analyse results
5.	Is any learner has sent a question, present it on the presentation display		1. Select a learner's question 2. Send it to presentation view	1. Export learners' question to Excel
6.	Send a short message to learners	1. Create a message 2. Set a title of the message 3. Type a content	1. Select a message 2. Send a message to learners	
7.	Send an event to learners	1. Create an event 2. Set a title of the event 3. Type content 4. Set a date 5. Set a venue	1. Select an event 2. Send an event to learners	
8.	Manipulation layout	1. Hide a chart control 2. Hide a survey control 3. Move an assessment control to the middle of the screen		
9.	Send a document to learners	1. Create a document as a PDF file 2. Upload a document to the system 3. Set a title of the document 4. Type a description about the document	1. Set a document	

Learners' Tasks

Task No	Task	Preparation
1.	Respond to a question	1. Select the "Questions" from the main menu 2. Select the latest sent question from the questions list 3. Read the question 4. Choose the correct answer from the available options
2.	Respond to a quiz	1. Select the "Quizzes" from the main menu 2. Select the latest sent quiz from the quizzes list 3. Read the quiz title 4. Choose the correct answer from the available options
3.	Respond to an assessment	1. Select the "Assessments" from the main menu 2. Select the latest sent assessment from the assessments list 3. Read the assessment title 4. Choose the correct answer from the available options
4.	Respond to a survey	1. Select the "Surveys" from the main menu 2. Select the latest sent survey from the surveys list 3. Read the survey title 4. Choose the correct answer from the available options
5.	Send a message	1. Select the "Send a Message" from the main menu 2. Type message content 3. Take a photo if needs 4. Press on button "Send"
6.	Review a short message	1. Select the "Messages" from the main menu 2. Select the latest sent message from the messages list 3. Read the sent message
7.	Review an event	1. Select the "Events" from the main menu 2. Select the latest sent event from the events list 3. Read the event content
8.	Review a document	1. Select the "Documents" from the main menu 2. Open the latest sent event from the documents list

		3. Read the document content

Appendix B Evaluation Task List

Tasks Description

This evaluation will be conducted using six tasks relating to the different categories of learning activities. The teacher will be provided with a task list to send learning activities during the expert review. The participants will then work in pairs to perform the various tasks and tasks list was provided to them as well. The goal of conducting these tasks is to identify any usability issues. All the tasks below will focus on the feasibility of using mobile devices in classroom.

Task No	Task	Preparation	In Lecture	Post-Lecture
1.	Send an assessment to learners	1. Create an assessment 2. Set questions of the assessment 3. Set options for each question 4. Save an assessment	1. Select an assessment 2. Send it to learners 3. Present the assessment of the assessment on the presentation display	1. Preview the result 2. Export the result to Excel file 3. Analyse results
2.	Send a survey to learners	1. Create a survey 2. Set questions of the assessment 3. Set options for each question 4. Save a survey	1. Select an assessment 2. Send it to learners 3. Present the assessment of the assessment on the presentation display	1. Preview the result 2. Export the result to Excel file 3. Analyse results
3.	Is any learner has sent a question, present it on the presentation display		1. Select a learner's question 2. Send it to presentation view	1. Export learners' question to Excel

4.	Send a short message to learners	1. Create a message 2. Set a title of the message 3. Type a content	1. Select a message 2. Send a message to learners	
5.	Manipulation layout	1. Hide a chart control 2. Hide a survey control 3. Move an assessment control to the middle of the screen		
6.	Send a document to learners	1. Create a document as a PDF file 2. Upload a document to the system 3. Set a title of the document 4. Type a description about the document	1. Set a document	

Learners' Tasks

Task No	Task	Preparation
1.	Response to an assessment	1. Select the "Assessments" from the main menu 2. Select the latest sent assessment from the assessments list 3. Read the assessment title 4. Choose the correct answer from the available options
2.	Response to a survey	1. Select the "Surveys" from the main menu 2. Select the latest sent survey from the surveys list 3. Read the survey title 4. Choose the correct answer from the available options
3.	Send a message	1. Select the "Send a Message" from the main menu 2. Type message content 3. Take a photo if needs 4. Press on button "Send"
4.	Review a short message	1. Select the "Messages" from the main menu 2. Select the latest sent message from the messages list

		3. Read the sent message
5.	Review a document	1. Select the "Documents" from the main menu 2. Open the latest sent event from the documents list 3. Read the document content

Appendix C Efficiency Tasks

The assessment task had two questions where each question had multiple options. Only one of these options was correct and the rest of them were incorrect. The following assessment was sent to the participant pairs where the sign (✓) indicates to the correct answer.

Assessment

Question 1

What is the minimum number of threads required for an Android client application using simplex communication?

- 1
- 2✓
- 3

Question 2

What is the minimum of threads required for an Android client application using full-duplex communication?

- 1
- 2
- 3✓

The following survey was sent to the participant pairs:

First Survey

Question 1

What type of network communication would this code be classified as?

- Simplex
- Half-Duplex
- Full-Duplex

The second survey contained the following content:

Second Survey

Question 1

When should locks be used in a server application?

- Whenever a client connects to a server and wants to read/write from the same data structure simultaneously ✓
- Whenever there are multiple clients connected to the same server
- When multiple clients are connected to the same server and access the same data structure✓

Appendix D Informed Consent Form

NELSON MANDELA METROPOLITAN UNIVERSITY

INFORMATION AND INFORMED CONSENT FORM

RESEARCHER'S DETAILS	
Title of the research project	**A Model for the Effective Use of the Mobile Devices in Supporting Contact Learning**
Reference number	
Principal observer	**Nemr Alnseerat**
Address	
Postal Code	
Contact telephone number (private numbers not advisable)	**0843535591**

A. DECLARATION BY OR ON BEHALF OF PARTICIPANT		**Initial**
I, the participant and the undersigned	(full names)	
ID number		

A.1 HEREBY CONFIRM AS FOLLOWS:		**Initial**
I, the participant, was invited to participate in the above-mentioned research project		
that is being undertaken by	**Nemr Alnseerat**	
from	**Department of Computing Sciences**	
Of the Nelson Mandela Metropolitan University.		

THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT:					**Initial**
2.1	**Aim:**	The observers are studying how mobile devices in the classroom support contact learning. The information will be used for research purposes.			
2.2	**Procedures:**	I understand that I am required to use a system to evaluate mobile learning system LiveLearning. I understand that an overhead camera will be recording the evaluation.			
2.3	**Risks:**	I understand that there are no risks involved by participating in this process			
2.4	**Possible benefits:**	As a result of my participation in this study there are no definitive benefits for me.			
2.5	**Confidentiality:**	My identity will not be revealed in any discussion, description or scientific publications by the observers.			
2.6	**Access to findings:**	Any new information or benefit that develops during the course of the study will be shared as follows: in the dissertation on the research, available from the Department of Computing Sciences.			
2.6	**Voluntary participation / refusal / discontinuation:**	My participation is voluntary	YES	NO	
		My decision whether or not to participate will in no way affect my present or future care / employment / lifestyle	TRUE	FALSE	

3. THE INFORMATION ABOVE WAS EXPLAINED TO ME/THE PARTICIPANT BY:	**Initial**
(name of relevant person)	
in Afrikaans / English / Xhosa / Other	
and I am in command of this language, **or** it was satisfactorily translated to me by	
(name of translator)	
I was given the opportunity to ask questions and all these questions were answered satisfactorily.	
4. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation.	
5. Participation in this study will not result in any additional cost to myself.	

A.2 I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT:			
Signed/confirmed at		on	20

Signature or right thumb print of participant	Signature of witness:
	Full name of witness:

B. **IMPORTANT MESSAGE TO PARTICIPANT**	
Dear participant Thank you for your/the participant's participation in this study. Should, at any time during the study: - an emergency arise as a result of the research, or - you require any further information with regard to the study, or - the following occur (indicate any circumstances which should be reported to the observer)	
Kindly contact	
at telephone number	(it must be a number where help will be available on a 24 hour basis, if the research project warrants it)

Appendix E Biographical Information

Biographical Information (Participant Details)						
1.	**Name**					
2.	**Gender**	Male	Female			
3.	**Age**	18-20	21-29	30-39	40-49	50+
4.	**Education**	Matric	Bachelors Degree	Honours Degree	Masters Degree	PhD Degre e
5.	**Occupation**	Learner	Academic Staff			
6.	**Have you completed an end-user computing course? (e.g. WRFC, WRFE)**	Yes	No, but computer literate	No		
7.	**Computer Expertise**	Novice	Intermediate (frequent user)	Expert (in the field of computers)		
8.	**How many years have you been using computers?**	0-2	3-5	6-9	10+	
9.	**How many years have you been using mobile devices?**	0-2	3-5	6-9	10+	
10.	**How often have you worked in pairs?**	Never	Rarely	Frequently	Daily	
11.	**Have you used mobile applications before?**	Yes	No			
	If so, which kind of applications					
12.	**Have you used mobile learning software before?**	Yes	No			
	If so, what software?					
13.	**Which mobile device(s) have you used often during the past 12 months?**	Samsung	Blackberry	Nokia	other	
14.	**What kind of mobile keyboard have you used?**	Physical keys	Touch Keys			
15.	**Have you used a mobile device's camera?**	Yes	No			

Appendix F Session Questionnaire

A. Task: Questions
1. Identify the most positive aspect of LiveLearning
2. Identify the most negative aspect of LiveLearning
3. Please provide any general comments or suggestions for improvement

Appendix G Final Post-Intervention Questionnaire

B. Usability (System Usability Scale)							
1. I am satisfied with how easy it is to use LiveLearning.							
	Strongly disagree	1	2	3	4	5	Strongly agree
2. It was simple to use LiveLearning							
	Strongly disagree	1	2	3	4	5	Strongly agree
3. I thought there was too much inconsistency in the LiveLearning system							
	Strongly disagree	1	2	3	4	5	Strongly agree
4. I think that I would need assistance to be able to use the LiveLearning							
	Strongly disagree	1	2	3	4	5	Strongly agree
5. I found the various functions in the LiveLearning were well integrated							
	Strongly disagree	1	2	3	4	5	Strongly agree
6. I would imagine that most people would learn to use the LiveLearning very quickly							
	Strongly disagree	1	2	3	4	5	Strongly agree
7. I found this system very cumbersome/awkward to use							
	Strongly disagree	1	2	3	4	5	Strongly agree
8. I felt very confident using the LiveLearning							
	Strongly disagree	1	2	3	4	5	Strongly agree
9. I needed to learn a lot of things before I could get going with the LiveLearning							
	Strongly disagree	1	2	3	4	5	Strongly agree
10. I found the LiveLearning helpful							
	Strongly disagree	1	2	3	4	5	Strongly agree

Appendix H Database Diagram