EVALUATION OF USABILITY AND USER EXPERIENCE OF AN M-LEARNING ENVIRONMENT, CUSTOM-DESIGNED FOR A TERTIARY EDUCATIONAL CONTEXT

by

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I declare that EVALUATION OF USABILITY AND USER EXPERIENCE OF AN M-LEARNING ENVIRONMENT, CUSTOM-DESIGNED FOR A TERTIARY EDUCATIONAL CONTEXT is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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ABSTRACT

Undergraduate software engineering learners demonstrate a lack of motivation with face-to-face classroom education. Limited access to the Internet via PCs and laptops, hinders effective communication and collaboration. However, the majority of learners enrolled for studies in tertiary education, have cellphones and are proficient in the use of digital technology. A technology-enhanced m-learning solution is indicated.

This research project evaluates the usability and user experience of an m-learning environment, custom-designed for a tertiary educational context and delivered by mobile handheld devices, features a synthesized framework of categories and criteria, and determines the nature and scope of an emergent digital divide.

A design-based research model suited to the context of the study is implemented, gathering quantitative and qualitative data from experts and learners by survey questionnaires. Analysis of data highlights usability and UX problems, provides insight into an emergent digital divide and suggests guidelines specific to the design of m-learning implementations.

Keywords: Design-based research, Digital divide, m-Learning, Mobile handheld devices, Problem-based learning, Technology-enhanced learning, Tertiary educational context, Usability, User experience, Virtual learning environments.

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ACRONYMS

Acronym	Description
CAI	Computer Aided Instruction
CMS	Content Management System
CSCL	Computer Supported Collaborative Learning
CTI	Computer Training Institute
DBR	Design-based Research
DES	Differential Emotions Scale
FOSS	Free Open Source Software
HCI	Human Computer Interface
HE	Heuristic Evaluation
ICT	Information Computing Technology
ICT4D	Information Computing Technology for Development
ISO	International Standards for Organisation
IT	Information Technology
LCD	Learner Centred Design
LCMS	Learning Content Management System
LMS	Learning Management System
MEX	Mobile Experience
MLE	Mobile Learning Engine
m-LR	Mobile Learning Research
MOMO	Mobile Moodle
Moodle	Modular Object-Oriented Dynamic Learning Environment
MUUX	Mobil Usability and User Experience
m-VLE	Mobile Virtual Learning Environment
ODF	Online Discussion Forum
OSS	Open Source Software
PBL	Problem-based Learning
PC	Personal Computer
PDA	Personal Digital Assistant
SAM	Self-assessment Scale
SE	Software Engineering
SMS	Short Message System
SNS	Social Networking Site
TEL	Technology Enhanced Learning
UCD	User Centred Design
UEM	Usability Evaluation Method
UT	Usability Testing
UX	User Experience
UXEM	User Experience Method
VLE	Virtual Learning Environment
WBL	Web-based Learning

CHAPTER 1: Introduction

1.1 Introduction

Mobile handheld devices, such as smartphones and tablets, are increasingly utilised for purposes other than telephony. This usage trend can extend the traditional face-to-face classroom to many different and novel collaborative contexts of learning. In the context of tertiary education, learners make use of interaction with the Web for learning purposes. As well as doing so in desk-bound situations, they do so when brief opportunities occur to access the Internet, via mobile phone, whether in class, at home, or while travelling. Synchronous and asynchronous collaboration can be supported by mobile handheld devices and m-learning applications.

Section 1.2 outlines the real-world problem that forms a background for the study while Section 1.3 introduces m-learning environments. Research objectives are presented in Section 1.4 and Section 1.5 delineates the research questions. Section 1.6 introduces the proposed contribution of the study, followed by Section 1.7 where the research design and methodology is summarised. The scope of the study, Section 1.8, is followed by the structure of the dissertation in Section 1.9. Section 1.10 concludes the chapter.

1.2 Background: A Real-World Problem

The researcher is a lecturer at a tertiary education institution, which is a private international university with twelve South African campuses, and teaches software engineering (SE) and knowledge management to third level learners on two of these campuses, which are situated in different parts of the city of Cape Town. The SE course, in which this research is situated, comprises both class-based theoretical teaching and practical work done in collaborative teams. The learner bodies are characterised by diversity in socio-economic factors, as well as by geographical origin.

The institution has recognised the major influence of the digital era on education, acknowledging the positive impact of Web 2.0 social networking tools, such as Facebook. In a pilot study, the potential was investigated during 2012 of the electronic delivery of digital textbooks to all learners via tablet devices, in preparation for a proposed nationwide rollout across twelve campuses in 2013. In order to implement this pilot project, several issues were considered, including the provision of mobile hand-held devices to learners and the need for affordable, effective and safe Internet connectivity

via an on-campus wireless network. The success of such a project would be dependent on positive attitudes on the part of learners, together with satisfactory usability and good user experience responses to m-learning environments.

Several challenges contribute to a real-world problem.

1.2.1 Diverse and Dispersed Learner Body

Learners are scattered over diverse learning contexts, spending very little on-campus time together. Many travel time-consuming distances to reach the campuses; some return home to neighbouring African countries during periods when team-based project work is underway. Some learners do not have laptops with at-home Internet connectivity, which necessitates visits to Internet cafés. Although this is an option for communication and collaboration, the cost can be prohibitive. This results in problems, both in social communication (intra-team activities) and in academic pursuits (assessment of group projects).

In addition to the limiting effect of costly digital communication, contact-based learning, where face-to-face academic exposure is provided during twelve classroom-based SE lectures, is becoming less popular among the learners. Although examination of the theoretical part of the course contributes to the total assessment mark, classroom boredom can lead to poor attendance and minimal in-class participation, accompanied by resistance to the textbook research required for assessment of theoretical content. In addition, neither campus has adequate library facilities.

1.2.2 Context of Learning and Assessment

Evaluation of the practical component of the programme forms the major part of final year-end assessment. Assessment comprises both individual assessment and group evaluation. Collaborative real-world situations, which are simulated through problem-based learning (PBL) projects in a social-constructivist style, form an important part of the curriculum.

PBL originated within the Faculty of Medicine, McMaster University, Canada, *circa* 1960, when Howard Barrows and associates, a group of young physicians, championed the PBL learning model (Barrows, 1996). PBL is characterised by the challenge of open-ended problems to be solved in collaborative groups, supported by a teacher who serves more as a facilitator and guide than an instructor (Hmelo-Silver and Barrows, 2006). Findings of Qiu and Chen (2010) indicate that learner collaboration on PBL projects

generated a positive attitude to the interaction involved in PBL project work and understanding of its relevance.

In addition to the individual assessments, SE assessment includes marks allocated to practical group projects. One of the team-based software development projects is based on a real-world scenario, in keeping with a PBL strategy. The class is divided into groups of between five and seven learners, and each group tackles a different project. This practical component aims to prepare learners for the hands-on workplace and requires demonstration and assessment of individual technical programming, as well as team dynamics, leadership skills and time management capabilities.

Curriculum requirements prescribe that learners implement an agile software development methodology. In contrast to a waterfall approach to software development, where life cycle phases occur sequentially, an agile methodology emphasizes both incremental and iterative development (Highsmith and Cockburn, 2001). *SCRUM* is an agile method, applied for rapid design, development and implementation of software applications (*Introduction to SCRUM methodology*, 2009; Schwaber, 2004). Features of *SCRUM* include:

- An emphasis on teamwork and self-organizing groups;
- Working together in small teams for short periods called sprints, to deliver software;
- Time boxing; and
- Incremental and iterative software development.

In line with a *SCRUM* methodology, group projects based on real-world problem scenarios are conducted in the campus computer labs, on laptop computers and individually from home-based personal computers (PCs) or other personal computing devices. Project work requires groups of learners to collaborate and communicate to produce team deliverables that comprise the major proportion of the final assessment. Diverse cultural backgrounds and varying expertise in soft skills, contribute towards the complexities and challenges of teamwork. This technological work is currently partially supported by mobile phones and e-mail communication.

1.2.3 An Inherent Digital Divide

The background in the previous subsection indicates the important role of peer-to-peer communication in the group projects. During supervision of groups of software engineering learners, working together in groups, the researcher observed intra-group

conflict where, despite every learner owning a mobile device, certain learners did not have access to smartphone devices and mobile Internet connectivity. Some learners had personal laptop computers and access to the university's online portal, which offered subject matter guidance and provides administrative support. Most of the laptop owners also had personal Internet connectivity. Yet for practical components, there was little opportunity in the interactive group work of utilising Web 2.0 tools such as chat rooms, discussion forums, blogs or wikis. Limited digital communication occurred between team members by mobile phone chat (BBM, MXit); text messages (SMS); email; or mobile phone conversations.

The researcher noticed, paradoxically, that those learners with limited or no Internet access at home, and who could be viewed as being restricted by the digital divide, more readily conducted Internet research using mobile hand-held devices. This may have its origins in Web 2.0 and the milieu of social networking sites (SNSs). Social networking applications have introduced a digital information access option, preferred by some of today's mobile learners. Possibly, they no longer experience sufficient challenge in the learning experience and, instead, seek a more varied, 'noisy' and action-filled Internet-enabled experience that is personally meaningful. For some learners, their mobile phone is the only form of computing device that they possess. In a world energised by Web 2.0 possibilities, mobile technology can make communication more accessible and tangible.

1.2.4 Towards More Meaningful Learning Experiences

The real-world learner issues outlined here go beyond the complexities of the interactivity involved in the required coursework. Some learners also experience boredom and demonstrate academic apathy towards the topics of their projects. To ensure meaningful learning experiences, Quinn (2002) suggests the incorporation of challenge, relevance, activity, directness and affect into the learning experience. An interesting task which is as close to the learner's real world as possible and which incorporates an element of surprise, can offer meaningful outcomes whilst calling for learner commitment.

In order to address the real-world challenges described in this section, mobile educational technology could provide personal learning opportunities as well as communication and collaboration for groups of learners via supportive synchronous and asynchronous tools (MacCallum and Kinshuk, 2008). In the process, learners learn with each other, while lecturers fill the role of guide, facilitating supportively via an m-learning environment. This is addressed in the next section.

1.3 m-Learning Environments

An extensive and detailed literature review, which forms a foundation for this study, is presented in Chapters 2 and 3. However, an introductory overview is presented in the following subsections. Firstly, an understanding of m-learning environments is achieved by defining m-learning features. Then an outline of specific m-learning challenges is provided, followed by introductions to mobile usability and user experience (UX) and evaluation of such. Finally, factors associated with the development of an m-learning application development are considered.

1.3.1 Sources Consulted

Literature sources are cited that provide an understanding of m-learning environments (Section 1.3.2), as well as sources that address usability and UX and methods for evaluating them (Section 1.3.3). The sources include books, journal articles, websites, electronic articles and conference papers. The literature studies in Chapters 2 and 3 contribute to the synthesis conducted by the researcher, of a framework of usability and UX categories and criteria. This framework will be applied in the usability and UX evaluations in this research. The outcomes of the researcher's unpublished BSc Honours project, an early prototype study, also provided data.

1.3.2 Definition of m-Learning

In general, m-learning may be viewed as e-learning that is achieved with some form of handheld digital device, such as a smartphone or tablet device, whilst the learner is on the move. However, early attempts to define m-learning recognized m-learning as a distinct concept, characterized as:

- Spontaneous;
- Situated;
- Informal; and
- Context-aware (Traxler, 2005a).

In addition, Traxler suggested that a definition of m-learning would come to infer attributes, such as connected and interactive personalised learning. Yet another definition of m-learning combines usability of the mobile device; a mobile learning system; the wireless technology capabilities of a wireless network; and a collection of e-learning components (Mostakhdemin-Hosseini and Tuimala, 2005). This simplistic approach disregards the influence on a mobile learner of a personal mobile context of

learning, focussing instead on the device as the mobile facet. For the purpose of this study, it is necessary to synthesize a more detailed definition of m-learning. This has been undertaken using various corresponding and diverging opinions about the relationship between e-learning and m-learning. Unique features and challenges of m-learning became evident in the process.

Relationship between e-learning and m-learning

The relationship between e-learning and m-learning is based on literature sources, reviewed here as five different yet overlapping perspectives and detailed later in Section 2.6.2 as Figures 2-4 to Figure 2-8, respectively:

- Aspects of e-learning are transformed, contributing to a new m-learning paradigm (Deegan and Rothwell, 2010; Mostakhdemin-Hosseini and Tuimala, 2005; Sharma and Kitchens, 2004; Traxler, 2008);
- m-Learning is a complex phenomenon, remaining loosely connected to, yet relatively independent of, e-learning (Laouris and Eteokleous (2005);
- m-Learning can be viewed as a part of e-learning (Cobcraft, 2006);
- m-Learning is more significant than e-learning, although retaining core e-learning features (Quinn, 2012); and
- e-Learning and m-learning have shared, as well as independent, attributes (Moczarny, de Villiers and van Biljon, 2012).

In addition to the differences summarized here and detailed later in Chapter 2, e-learning and m-learning are both a consequence of, and influenced by, digital technology.

Features of m-learning

Sharples, Taylor and Vavoula (2007) suggest that an m-learning system includes, but is not limited to, three social factors – control (teachers, learners, technology), context (people, interactive technology, learning situation) and communication (via digital formats). Web-based learning (WBL) applications, accessed via the Internet, form the basis for m-learning systems, services and mobile device tools (Sharma and Kitchens, 2004). Mobile services are available to people who are mobile and they combine mobile usability, wireless technology and an e-learning system (Mostakhdemin-Hosseini and Tuimala, 2005). Georgiev, Georgieva and Smirkarov (2004) promote the concept that m-learning is characterised by a large variety of mobile device types, including netbooks, tablet PCs, personal digital assistants (PDAs), mobile phones and smart phones.

Challenges of an m-learning environment

Literature sources address various challenges within m-learning domains, including:

- The characteristics of mobile devices;
- Design guidelines for m-learning applications;
- The nature of mobile content;
- Complexities associated with various contexts of use;
- Technology;
- Ethical considerations;
- Educational institutions; and
- Security concerns

(Ally, 2009; Berri, Benlamri and Atif, 2006; Botha, Furnell and Clarke, 2009; Cheung, McGreal and Tin, 2010a; Cobcraft, Towers, Smith and Bruns, 2006; Cochrane and Bateman, 2010; Corbeil and Valdes-Corbeil, 2007; Costabile, De Angeli, Lanzilotti, Ardito, Buono and Pederson, 2008; Deegan and Rothwell, 2010; Georgiev *et al.*, 2004; Herrington, Herrington and Mantei, 2009; Hildreth and Kimble, 2002; Hussain and Aslam, 2009; Kukulska-Hulme, Sharples, Mildrad, Arnedillo-Sanchez and Vavoula, 2011; Laurillard, 2007; Mileva, Simpson and Thompson, 2008; Naismith, Lonsdale, Vavoula and Sharples, 2004; Najafabadi and Mirdamadi, 2011; Nie, 2006; Orna, 1999; Park, Parsons and Ryu, 2010; Park, 2011; Pilke, 2004; Semiawan and Middleton, 1999; Traxler, 2005b; Väänänen-Vainio-Mattila, Roto and Hassenzahl, 2009; Vavoula and Sharples, 2009; Zhang and Adipat, 2009).

1.3.3 Evaluation of Usability and User Experience of m-Learning Environments

In addition to taking cognizance of the features and challenges introduced in Section 1.3.2, the evaluation of m-learning environments should incorporate factors distinct to the domain of mobile technologies (Orna, 1999; Park *et al.*, 2010; Semiawan and Middleton, 1999; Vavoula and Sharples, 2009; Zhang and Adipat, 2009). Furthermore, such evaluation should include a focus on both usability and UX (Botha, Herselman and van Greunen, 2010a; Hildreth and Kimble, 2002; Najafabadi and Mirdamadi, 2011; Väänänen-Vainio-Mattila *et al.*, 2009).

Usability and UX

Conventional usability is defined in ISO 9241-11 (1998) as "… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

An e-learning application is more than a digital product; it is an educational technology application designed to achieve learning objectives. Evaluation of e-learning applications might not best be served by conventional views of usability, since learning systems have certain distinct characteristics (Masemola and de Villiers, 2006). Some of the fundamental principles and methods of evaluating e-learning are also relevant to the evaluation of m-learning.

According to Ji, Park, Lee and Yun (2006) mobile usability is more likely to be linked to user satisfaction. They emphasize that, relative to effectiveness and efficiency, user satisfaction is a more relevant measure of mobile usability, since mobile experiences are complex and unique to the user and the context of use. Coursaris and Kim (2006) accentuate the complex nature of mobile usability. A mobile context incorporates on-going interactive activities, the user, digital technology and environmental attributes. The usability of a mobile application is impacted by these dimensions.

Certain usability aspects are distinctly associated with mobile handheld devices. For example, screen size, keyboard limitations, memory capability and navigability issues differentiate to some extent between the usability of e-learning and m-learning applications. Usability has consequences for learning as it affects adoption, retention, loyalty, trust and satisfaction, all of which are also associated with UX (Coursaris and Kim, 2006).

In accordance with ISO 9241-210 (2010) UX represents " … a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service".

Bevan (2009) customizes the ISO 9241-210 definition of UX to include users' emotions, beliefs, and responses – both physical and psychological – together with what the user has achieved during the experience of learning. He proposes that UX is associated with all the experiences before, during and after an activity.

Evaluation of Usability and UX

According to Dix, Finlay, Abowd and Beale (2004), evaluation has a three-fold purpose. Firstly, the system's functionality is assessed. Secondly, the user's experience whilst interacting with the system is ascertained. Lastly, specific problems are identified, for which improvements may be suggested (Shneiderman and Plaisant, 2005). Evaluation is important in the quest for the enhancement of the following aspects:

- Quality of learning artefacts;
- Efficiency and effectiveness of use; and

- Assurance regarding ways to offer enjoyable experiences with products and services (Sharp, Rogers and Preece, 2007).

There are various types of evaluation that an educational system can undergo, yet in 2005 usability evaluation was seen as the main mechanism which drove the evaluation of e-learning applications (Ardito, Costabile, De Marsico, Lanzilotti, Levialdi, Roselli and Rossano, 2005). Usability evaluation retains its important role, yet the more recent focus is on the assessment of user experience.

Various usability evaluation methods (UEMs) and user experience evaluation methods (UXEMs) are available to assess interactive systems. UEMs fall into differing categories, such as usability testing, field studies and analytical techniques. Dix *et al.* (2004) classify UEMs according to expert analysis and user-participation methods, incorporating evaluation sub-categories such as experimental and query approaches, as well as observational and monitoring evaluation sub-categories. UXEMs aim to evaluate hedonic factors that are associated with subjective and dynamic environments, and that occur within specific contexts.

UEMs and UXEMs are discussed in greater depth in Sections 3.3.2 and 3.3.3 of Chapter 3.

The evaluation methods used in this study are heuristic evaluations and questionnaires. Heuristic evaluation (HE) by experts is an evaluation method which measures various aspects of a product against specific criteria, according to the opinion of Nielsen and Molich (1990). Questionnaire surveys are completed by end-users, i.e. learners. Survey questionnaires are completed by the experts and learners to capture their feedback (Dix *et al.*, 2004; Karoulis and Pombortsis, 2003; Nielsen, 1994; Zaibon and Shiratuddin, 2010). Evaluation guidelines for interactive technologies include hedonic, affective and aesthetic UX dimensions, in addition to pragmatic usability criteria. Both usability and UX factors should be incorporated into a single evaluation framework by which interactive WBL systems are investigated (Sharp *et al.*, 2007).

The same principle can be applied to m-learning systems, the evaluation of which is addressed in the next subsection.

Evaluation of mobile usability and mobile UX

m-Learning occurs in complex contexts which are unique for each learner. Evaluation of m-learning applications is necessary to improve the quality of the learning artefacts, enabling developers to build improved efficiency, effectiveness and the enjoyable experiences into products. Traditional usability evaluation may be augmented to suit m-

learning evaluation requirements. In addition, consideration is given to the user experience provided by the mobile environment. Relevant evaluation factors for mobile usability and UX include:

- Objective evaluation of mobile task functionality;
- A sustained focus on the pragmatic goals of efficiency and effectiveness;
- The user's personal and unique experience of the m-learning application; and
- Acknowledgement of hedonic experiences such as fun, perception, enjoyment, frustration, and beliefs

(Bevan, 2008a; Botha *et al.*, 2010a; Law, 2011; Nielsen, 2011; Väänänen-Vainio-Mattila *et al.*, 2009).

Existing literature can be used to build a mobile usability and user experience (MUUX) evaluation framework comprising criteria that evaluate usability and UX of m-learning applications. Such a framework should address:

- m-Learning contexts;
- Challenges associated with evaluating m-learning applications;
- Usability and usability goals;
- Usability evaluation;
- UX; and
- UX evaluation

(Beccari and Oliveira, 2011; Bevan, 2009; Coursaris and Kim, 2006; Diaz, 2003; Ehmke, Fulton and Akridge, 2004; Hassenzahl, 2008; Law, Roto, Hassenzahl, Vermeeren and Kort, 2009; Nielsen, 2005; Ozkan and Koseler, 2009; Schulze and Krömker, 2010; Sharp *et al.*, 2007; Squires and Preece, 1999; Ssemugabi and de Villiers, 2010; Väänänen-Vainio-Mattila *et al.*, 2009; Vavoula and Sharples, 2009).

On the basis of the theory relating to usability evaluation and UX evaluation, a single holistic evaluation framework, comprising several categories of usability and UX evaluation criteria, has been synthesized by the researcher as part of this study (Section 3.6). This approach is used in preference to an evaluation strategy that separates evaluation of usability and UX. The methodology discussed further in Chapter 3 (Section 3.5 – theoretical background) and Chapter 5 (Section 5.6 – practical implementation).

1.3.4 Development of m-Learning Environments

Developers of m-learning environments need to consider several pertinent factors, including:

- Design and development life cycle models;
- Differences between e-learning and m-learning environments;
- Evaluation of usability and user experience (UX); and
- Virtual learning environments for mobile technology (m-VLEs).

Sharp *et al.* (2007) suggest an iterative and interactive life cycle model for application design and development, associated with traditional planning phases. The development of m-learning applications should be guided by sound pedagogical principles; the context of use; and the application's motivational capability (Botha, van Greunen and Herselman, 2010c). Developers of mobile learning applications should make provision for user access to a learning management system (LMS) interface via desktop and mobile device. In this way, ease of use and transferability of skills is supported (Naismith *et al.*, 2004).

Course material delivered by an m-learning environment differs in format to e-learning content due to the nature of mobile interfaces. Although e-learning course content could form the basis for m-learning environments, software engineers should build mobile specifications into designs, enabling use of learning material either at the PC or on the move (Rodin, 2005). Consequently, the developer cannot merely transform an interactive web-based e-learning application and implement it via a mobile handheld device, assuming satisfactory usability and UX outcomes. Instead, a paradigm shift is suggested to a customised m-learning design and development life cycle model suited to interactive, human-centred environments (ISO 9241-210:2010, 2010; Sharp *et al.*, 2007). The strategy includes the evaluation of usability and UX.

Within the context of her own teaching and specifically for this research, the researcher developed a custom-designed m-learning environment for delivery by mobile handheld devices. The resultant m-learning application, named Mobile Learning Research (*m-LR*), is a mobile virtual learning environment (m-VLE), based on the open source software (OSS) platform Moodle™. The development of *m-LR* included the implementation of a mobile learning engine (MLE), which is a Moodle™ add-on, enabling mobile handheld device use. Documentation and features that support the development of Moodle™ and *m-LR*, include:

- The Moodle™ website;
- A Moodle™ wiki;
- Mobile Moodle™ training;
- Mobile extensions to Moodle™; and

- YouTube™ video resources

(Dougiamas, 2010; *Moodle Wiki*, 2008; Sakharkar, Iyer and Baru, 2010; Sourceforge.net, 2011; YouTube, 2012).

1.4 Research Objectives

This study aimed to develop an m-learning environment delivered by mobile handheld devices to support the communication and collaboration requirements associated with learners' practical work in an SE curriculum. The application was iteratively refined and was evaluated for usability and UX by experts (heuristic evaluation) and by learners (end-user questionnaire survey). In the process, an evaluation framework of usability and UX categories and criteria had to be specifically synthesized and customised for m-learning environments. It was based on the literature, together with findings of an early prototype study.

Figure 1-1 portrays the research goals (G1 to G4) and objectives (O1 to O5) graphically.

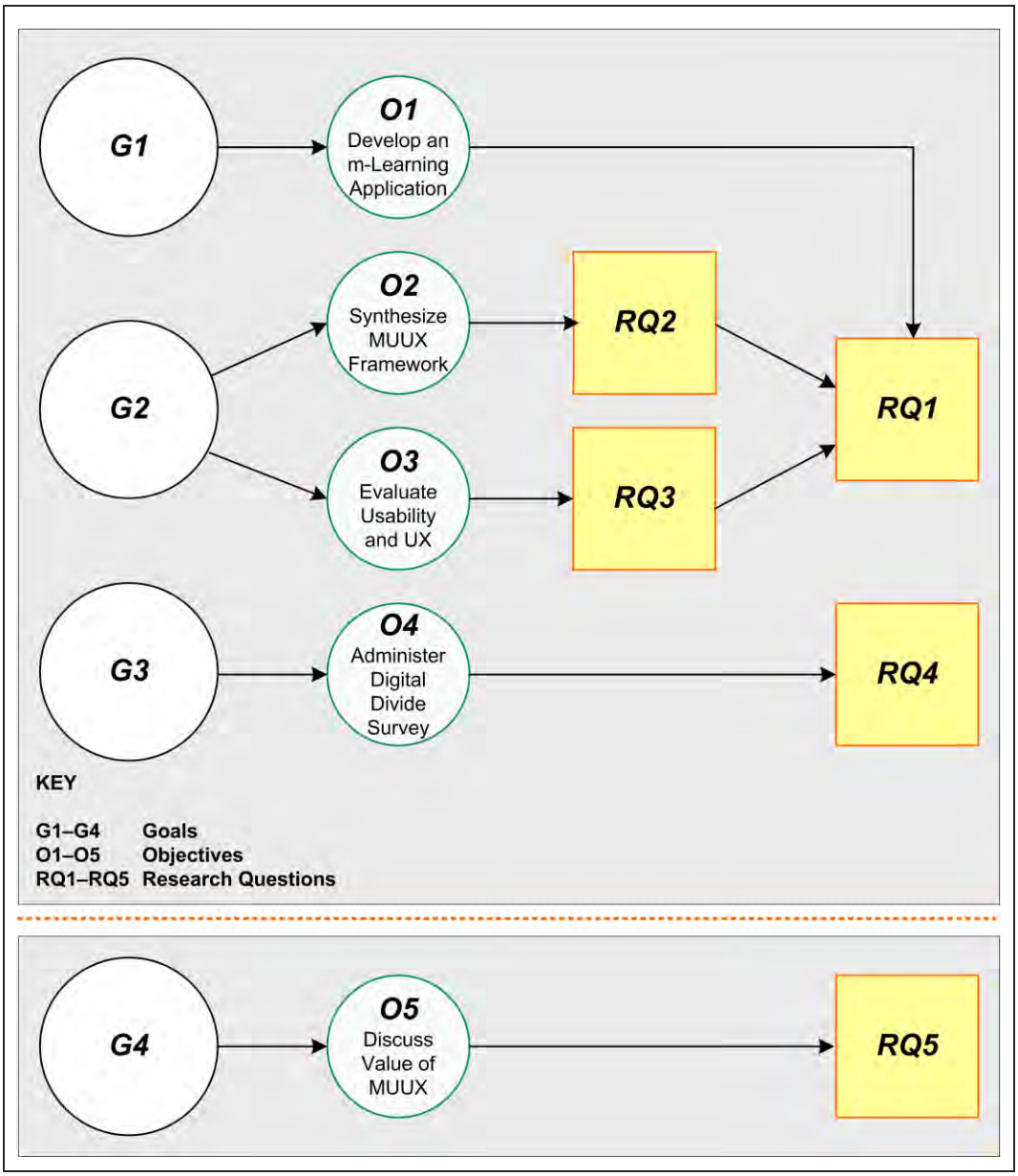

Figure 1-1: Relationship between research goals, objectives and research questions

The real-world situation introduced in Section 1.2 gave rise to the goals (**G1** to **G4**) and the objectives (**O1** – **O5**) of the study (Figure 1-1):

- ***G1***: Develop an m-learning environment for delivery by mobile handheld device:

  O1: To develop an m-learning environment, for scaffolding and fostering interactive team-based activities involving communication and collaboration between learners, as well as to present learning material and assessments.

- ***G2***: Subject the developed m-learning application to rigorous usability and UX evaluation by the MUUX framework within its context of use:

  O2: To synthesize an MUUX Framework of criteria to evaluate the usability and UX of m-learning environments;

  O3: To determine the extent of usability and UX conformance of the m-learning environment to the MUUX Framework of criteria; and

- ***G3***: Investigate the nature of the digital divide in a tertiary educational context:

  O4: To administer a digital divide survey in the particular target group.

- ***G4***: Make a theoretical contribution to the body of knowledge in educational technology, specifically in the domain of m-learning:

  O5: To discuss the general role and value of MUUX as a tool to evaluate m-learning environments.

The intentions of this m-learning study are in line with those of other researchers who call for a structured approach to the development of learning artefacts and design principles for educational technology (Reeves, Herrington and Oliver, 2004, 2005). Sharples (2009a) supports the call for findings that extend classroom research.

The goals and objectives outlined in Figure 1-1 are reflected in the research questions posed in Section 1.5.

1.5 Research Questions

This study addresses five research questions, ***RQ1*** to ***RQ5***:

RQ1*: To what extent does the m-learning environment, m-LR, custom-designed for a tertiary educational institution, conform to the criteria of the synthesized usability and UX evaluation framework?*

RQ2*: What categories and criteria should be included in a usability and UX evaluation framework for m-learning environments?*

RQ3*: What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

RQ4*: Can mobile technology reduce the digital divide in a tertiary educational context?*

RQ5*: How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

These research questions guide the literature surveys in Chapter 2 and Chapter 3, inform the research design and methodology in Chapter 5 and are answered in Chapters 6 and 7 on the empirical work, where the findings are presented and discussed. In Chapter 8, Conclusions and Recommendations, the answers are consolidated and the findings are briefly interpreted. The research questions take cognizance of the scope of the study and address the practical and scientific contributions of the study.

1.6 Proposed Contribution of the Study

The contributions associated with the research – both practical and scientific – are introduced in this section.

Design science research (DSR) is design research which has been applied to the design and development of IT artifacts (Hevner and Chatterjee, 2010). Design-based research is similar to DSR in that both philosophies relate to complex real-world problems and lead to theoretical as well as practical outcomes. However, DBR differs from DSR as the former is associated with educational technology whilst the latter is applied in the information technology domain (de Villiers, 2012). The focus of this study is *educational technology*, indicating the suitability of a DBR strategy. In line with the design-based research (DBR) strategy adopted for this study and explained further in Section 1.7.2, a dual contribution is made (Barab and Squire, 2004; Plomp, 2008; van den Akker, Bannan, Kelly, Nieveen and Plomp, 2007; Wang and Hannafin, 2005). The research project implements innovative educational technology to firstly, address a real-world problem and, secondly, to extend contextual design theories to share with practitioners and designers.

1.6.1 Practical Contribution

From a practical viewpoint, existing real-world educational problems require solutions. The traditional face-to-face teacher-learner environment is rapidly changing towards a more constructivist situation, where computer-supported collaborative learning (CSCL) (Roschelle and Pea, 2002) and e-learning (de Villiers, 2005a) have resulted in learners personally contributing to the creation of their own knowledge, while the educator serves as mentor and guide. The present research aims to contribute to this change.

This research may be used to influence the policies of an educational institution, so as to facilitate the implementation of m-learning strategies and illustrate them by the design of

m-LR. This could also have a positive impact on the way other academics view communication and collaboration with and between their undergraduate learners.

The main beneficiaries of this study are learners who are required to participate in collaborative activities and to access study-related material and information online. In addition, the Information Technology (IT) Faculty of the institution stands to benefit in future semesters if this exploratory research demonstrates potential for transfer to all twelve Computer Training Institute (CTI) campuses around South Africa.

1.6.2 Scientific Contribution

From a scientific and theoretical viewpoint, the study establishes a framework of criteria for evaluating the usability and UX of m-learning environments. The evaluation framework has the potential to be:

- Applied across a range of domains;
- Used to evaluate various m-learning applications and contexts; and
- Used to evaluate diverse types of handheld devices and technologies.

It is anticipated that a further consequence of this study will be use of the evaluation criteria as generic design principles and guidelines for the development of m-learning environments.

The meta-analytical research by Coursaris and Kim (2011) suggests that for the evaluation of mobile computing environments a structured approach which incorporates several dimensions, should be adopted. There is thus strong external motivation for the need for the research in that this study establishes a framework of criteria for evaluating the usability and UX of m-learning environments.

1.7 Research Design and Methodology

This study aimed to determine the extent to which the target system, *m-LR*, conformed to a framework of criteria specifically synthesized for usability and UX evaluation of m-learning environments. An initial framework of evaluation criteria was structured as part of an early study conducted by the researcher and then extended by a comprehensive exploration of the literature. Using these criteria, heuristic evaluation by experts and a survey among end-users (learners) were conducted to gather evaluation data in successive iterations as the m-LR environment evolved.

The research design and methodology presented in this section includes the philosophical paradigm underlying the research, the research design, research methods, sampling methods, data collection instruments, data analysis, validity and reliability, and research ethics.

1.7.1 Brief Outline of the Philosophical Paradigm

An interpretive study explores facets of a research environment, within a social context where participants may affect and be influenced by the context (Oates, 2008). According to Oates, an interpretivist paradigm has the characteristics given in italics below, followed by points justifying its applicability to this study:

- *Subjective factors* – Views of the researcher, experts and learners may not necessarily be synonymous;
- *Changing social meaning* – Different campuses and cohort groups may express varying attitudes to the possible benefits of technology-enhanced learning;
- *Reflexivity of researchers* – The researcher is an educator and participant in the research project;
- *The study of people in naturally occurring contexts* – Use of digital technology is based on personal preferences, individual capabilities and acquired habits associated with the use of mobile handheld devices; and
- *Quantitative and qualitative data analysis* – The study evaluates both usability and UX dimensions of the m-learning environment, gathering perceptions, opinions and verbal feedback in addition to numerical data.

1.7.2 Research Design

Design-based research

The underlying research paradigm of this work is design-based research (DBR). The DBR strategy involves methods which achieve direct problem investigation with concurrent data collection (Plomp, 2008). DBR is a design science research methodology, applied in an educational context (de Villiers, 2012; Reeves, 2006).

DBR terminology includes many differing yet related labels, indicating its foundations and predecessors:

- Design studies (Shavelson, Phillips, Towne and J., 2003);
- Design experiments (Brown, 1992; Cobb, Confrey, diSessa, Lehrer and Schauble, 2003);

- Development research (Reeves *et al.*, 2004); and
- Design research (van den Akker *et al.*, 2007).

DBR is characterised by the existence of a complex real-world problem which must be solved in context by the iterative development of an artefact. The DBR approach is addressed in detail in Chapter 5, Design Research and Methodology. Quantitative or qualitative research approaches can be used, or both together, with mixed-methods data generation, involving the collection of quantitative and qualitative data by different methods (Creswell, 2009; Roto, Obrist and Väänänen-Vainio-Mattila, 2009). Evaluation of the innovative evolving technology-oriented solutions occurs, so as to refine the resulting artefact/s. DBR occurs in complex learning environments and frequently involves collaboration between researchers and practitioners (Barab and Squire, 2004; The Design-Based Research Collective, 2003; Wang and Hannafin, 2005).

Design-based research in the present work

The present research comprises six successive DBR studies and was undertaken between 2010 and 2012 in a dynamic tertiary educational context across two different campus environments, Campus 1 (C1) and Campus 2 (C2). A mixed-methods data generation approach was used, as both HEs and questionnaires were used to gather data. Participants included expert evaluators and end-users (learners), while the researcher filled the dual role of educator and researcher. Table 1-1 below lists the six studies.

Table 1-1: DBR iterations

Study	DBR Iteration	Date	Versions of *m-LR*		Purpose of the Study
			Pre-evaluation	Post-evaluation	
0	BSc Honours Project	May 2010	-	-	Development of $m\text{-}LR_1$, an initial version of *m-LR*
1	Pre-Study	Nov 2010	$m\text{-}LR_1$	$m\text{-}LR_{pre}$	Preliminary evaluation of the usability of $m\text{-}LR_1$, leading to $m\text{-}LR_{pre}$
2	Mobile Usage Study	Sept 2011	-	-	Collection of data to establish the mobile profile of learners
3	Pilot Study	Oct 2011	$m\text{-}LR_{pre}$	$m\text{-}LR_{ps}$	Testing of evaluation procedure, tasks, documentation, instruments and the evaluation of usability and UX of $m\text{-}LR_{pre}$, leading to $m\text{-}LR_{ps}$
4	Main Study 1	Nov 2011	$m\text{-}LR_{ps}$	$m\text{-}LR_{m1}$	Evaluation of usability and UX of $m\text{-}LR_{ps}$, leading to $m\text{-}LR_{m1}$
5	Mobile Learning Digital Divide Study	Mar 2012	-	-	Exploration of an emergent digital divide
6	Main Study 2	Apr 2012	$m\text{-}LR_{m1}$	$m\text{-}LR_{m2}$	Evaluation of the usability and UX of $m\text{-}LR_{m1}$, leading to the development of a fully-functional $m\text{-}LR_{m2}$ in future work

Study 0: BSc Honours Project

This study, Study 0, falls outside the scope of the research design but has been included in Table 1-1 to indicate the development of the initial version of *m-LR*, namely $m\text{-}LR_1$, which was evaluated in Study 1, Pre-Study.

Study 1: Pre-Study

After establishing an initial set of categories and criteria for the evaluation of usability, this study aimed to evaluate $m\text{-}LR_1$ for usability. Evaluation methods included heuristic evaluation by three experts and the completion of questionnaires by ten undergraduate project management learners. Subsequent unstructured focus group interviews with a selected group of participants extended the findings of the surveys. Quantitative and qualitative data was processed by statistical and thematic analysis respectively. The findings resulted in the evolution of $m\text{-}LR_1$ to $m\text{-}LR_{pre}$.

Study 2: Mobile Usage Study

The Mobile Usage Study was not part of the iterative development and evaluation of *m-LR*, but was undertaken to establish the learners' patterns of technology usage, enabling a purposive selection of participants for the Pilot Study and to provide information regarding the mobile technology environment of the users. The survey gathered demographic data as well as quantitative and qualitative data relating to the use of mobile technology. Participants were 36 software engineering learners in two cohort groups from two separate campuses. Quantitative and qualitative data was processed by statistical and thematic analysis respectively.

Study 3: Pilot Study

The Pilot Study verified and validated the research procedure, activities and instruments designed for Main Study 1. Participants in the Pilot Study included one expert and a pre-selected group of four software engineering learners on one campus. The pilot study incorporated an exploratory evaluation of usability and UX of the target system, *m-LR*, based on the framework of categories and criteria, synthesized for the Pre-Study but extended by further concepts from the literature.

As a consequence of the Pilot Study, minor adjustments were made to the research procedure and to $m\text{-}LR_{pre}$, resulting in the $m\text{-}LR_{ps}$ version.

Study 4: Main Study 1

Main Study 1 involved heuristic evaluation by five experts and completion of questionnaires by seventeen learners from one campus to investigate the usability and

UX of *m-LR*. The quantitative data was processed by statistical analysis and the qualitative data by thematic analysis.

Findings of Main Study 1 informed minor modifications to $m\text{-}LR_{ps}$, resulting in the $m\text{-}LR_{m1}$ version.

Study 5: Mobile Learning Digital Divide Study

As was the case with Study 2, the Mobile Usage Study, the Mobile Learning Digital Divide Study was not part of the iterative development and evaluation of *m-LR.* Instead it was undertaken to collect in-depth data regarding patterns of mobile technology use from learners on the two different campuses, C1 and C2, to determine the extent of an emergent digital divide between them. In addition, the study explored the capability of an m-learning environment to bridge the digital divide. A total of 35 learners participated in the study. Once again, the quantitative data was processed by statistical analysis and the qualitative data by thematic analysis.

Study 6: Main Study 2

The purpose of the final study, Main Study 2 was to evaluate *m-LR* for usability and UX, in a similar fashion to Main Study 1. This study, however, was more extensive in that it involved participants from campus C1 and campus C2. Participants were five experts and 32 learners. Again, the quantitative data was processed by statistical analysis and the qualitative data by thematic analysis.

The findings can be used in future research to produce a new version, $m\text{-}LR_{m2}$.

1.7.3 Research Methods and Instruments

As has been mentioned, the research instruments were questionnaires.

There were separate questionnaires for experts and for end-users, i.e. learners. They included open-ended (qualitative) questions for spontaneous participant feedback and closed (quantitative) five-point Likert scale items. In addition, the Mobile Usage and Mobile Learning Digital Divide surveys included nominal scale items such as Yes/No questions to formulate profiles for users of mobile technologies. The satisfaction or dissatisfaction that users experience with an m-learning environment is strongly related to the occurrence of problems in the system. User satisfaction or dissatisfaction, which was incorporated in various questionnaire categories, was investigated due to the major role it plays in both usability and UX. Questionnaires were used in all six studies.

1.7.4 Ethical Aspects

The necessary permission was acquired from the university where the studies were undertaken, and ethical clearance was obtained from Unisa, where the researcher is a registered learner. All participants signed informed consent. Further details are provided in Section 5.8 of the chapter on the research design.

1.8 Scope of the Study

This section reports on the domain of the research and its underlying assumptions, and also sets out the limitations and delimiters.

1.8.1 Domain

This research study incorporates aspects of information and computing technology for development (ICT4D); human computer interaction (HCI); the technology of mobile handheld devices; web-based learning; m-learning; and, finally, the evaluation of usability and UX of mobile learning environments. Expert evaluators and end-users (learners) participated in evaluations using custom-designed evaluation instruments in natural contexts of use, not in experimental or controlled evaluation environments.

The research was undertaken in the discipline of SE, and used the cohorts taught by the researcher as the target groups. Practical hands-on teamwork forms part of the coursework and assessment requirements, and this lent itself to the implementation of an m-learning component.

1.8.2 Underlying Assumptions

The following assumptions were made about the participants:

- They would input accurate data in response to questionnaire items;
- They would have adequate digital capabilities and mobile device experience;
- They would have satisfactory skills in the use of the English language, enabling an understanding of the wording of evaluation tasks and questionnaire items; and
- The data provided would honestly reflect their opinions.

It was further assumed that:

- The completion of the HEs and questionnaire surveys would be easy and cost-effective to administer and would be completed by participants within two hours;

- The research instruments would yield accurate data and that the analysis of data would be correct, leading to feasible recommendations;
- The data would be a realistic reflection of the population being surveyed; and
- Although bandwidth strength and the cost of connectivity would not be estimated as part of the study, bandwidth would be adequate during evaluations and the cost of connectivity would be affordable.

1.8.3 Limitations and Delimiters

It is difficult to accurately measure the extent and nature of anywhere-and-anytime communication and collaboration for a mobile learning environment. The findings of the research into m-learning could limit the potential to draw conclusions. For example, it was not possible to ascertain who actually used a particular phone to communicate and collaborate in chat rooms, to take part in a discussion forum, or to post on a wiki, as learners have the habit of sharing mobile devices. Due to personally unique contexts, the experience of the same m-learning activity might be different, dependent on whether learners are off-campus, at home or in a formal classroom environment.

Moreover, factors that could constrain participation and outcomes include the availability of bandwidth; the type and capability of devices used by expert and learner evaluators; the cost and quality of connectivity; and a lack of interest in m-learning on the part of some learners.

A blended learning environment is defined as one where the delivery of learning and training material occurs via varying media for improved learning effectiveness (Chilcott and Hadfield, 2009; Shepherd, 2008). In practice, the usual meaning of blended learning is the combination of traditional contact teaching with some form of e-learning. Books and paper-based journals can be supplemented by training material in digital format which is accessible through ubiquitous smartphones and tablets. The present research is situated within a mobile blended learning environment, which provides supplementary learning opportunities via the system, *Mobile Learning Research* (*m-LR),* where and when convenient, using mobile handheld devices to extend but not replace face-to-face classroom interactivity. Instead, an anytime-anywhere, ubiquitous, learning environment was provided.

The study addresses the facilitation of learning, communication and collaboration by means of m-learning, but does not determine whether the m-learning environment could

replace other forms of learning, for example, face-to-face interaction and PC-based learning or web-based learning.

A range of mobile handheld devices, such as smartphones and tablets from a spectrum of device brands and capabilities, was utilised in the study. This was appropriate to the context, and represented the variety of devices used within the learner body.

It is not the purpose of this study to demonstrate generalizability. However, data triangulation and method triangulation, discussed in Chapter 5, Section 5.7 on the research design and methodology, are incorporated into the research design to support validity of the findings.

It is not the intention of this study to establish whether any relationships exist between the usability and UX of the m-learning environment and the academic performance of the learners, i.e. the study did not attempt to determine whether learning had occurred in the SE discipline.

Finally, it was not the aim to develop *m-LR* as a complete and fully operational system. Rather, the study set out to demonstrate the extent of conformance of the prototype *m-LR* to criteria within a single evaluation framework, which contains both usability criteria and UX criteria for evaluating m-learning environments.

1.9 Structure of the Dissertation

1.9.1 Layout and Interrelationships of the Chapters

Figure 1-2 depicts the layout of the chapters and interrelationships between them.

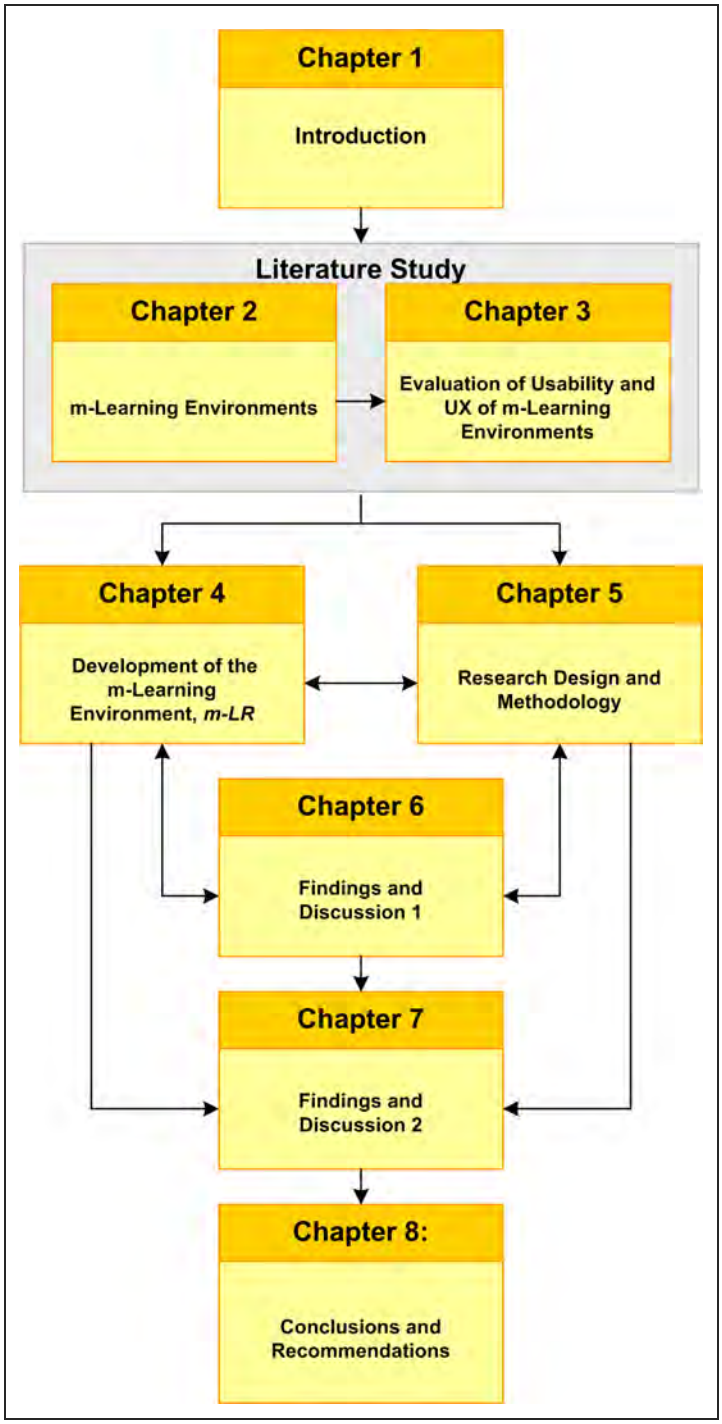

Figure 1-2: Chapter layout and interrelationships

1.9.2 Contents of the Chapters

The dissertation comprises the following chapters:

- *Chapter 1* – Introduction;
- *Chapter 2* – m-Learning Environments;
- *Chapter 3* – Evaluation of Usability and UX of m-Learning Environments;
- *Chapter 4* – Development of the m-Learning Environment, *m-LR*;
- *Chapter 5* – Research Design and Methodology;
- *Chapter 6* – Findings and Discussion 1;
- *Chapter 7* – Findings and Discussion 2; and
- *Chapter 8* – Conclusions and Recommendations.

Chapter 1 introduces the study, outlining the research approaches and the context of the dissertation. Two literature review chapters, Chapter 2 and Chapter 3, provide theoretical foundations for m-learning environments and the usability and UX evaluation of m-learning environments, respectively, using the existing body of knowledge as secondary data. In Chapter 4, the *m-LR* environment, which underlies the study, and provides the practical component, is briefly described. The theoretical background contained in Chapters 2 and 3 and the practical environment described in Chapter 4, inform the synthesis within Chapter 5 of a proposed framework of criteria for the evaluation of m-learning environments. Chapter 5 details the research design and methodology. The findings of the study are analysed and discussed in Chapter 6 (Main Study 1) and Chapter 7 (Main Study 2), addressing both the theoretical aspects emanating from Chapters 2 and 3 and the practical content of Chapter 4. Chapter 8 concludes the study with recommendations that emerge from the findings.

1.10 Conclusion

This chapter provided an introduction to the study. Initially, the underlying real-world problem was discussed as a background to the study. This was followed by a brief outline of m-learning environments in general. The specific research objectives and research questions were presented. Concise mention of the proposed contribution of the study was followed by an explanation of the research design and methodology. The scope, domain, assumptions and limitations of the study were discussed. The chapter concluded with a presentation of the structure of the dissertation, together with interrelationships and contents of the chapters.

CHAPTER 2: m-Learning Environments

2.1 Introduction

The traditional face-to-face, instructor-led higher education experience is no longer sufficient and satisfying for the digital age learner (Prensky, 2004). While e-learning complements the educational scene, m-learning is increasingly playing a role (Brown, 2008). Learning experiences in a digital era are dynamic and complex (O'Neil and Carr, 2008). They are influenced by numerous factors, such as the advent of mobile handheld devices and new information communication and technology (ICT) capabilities, with a major dependency on Internet connectivity. (Beaudoin, 2013).

Based on the literature, this chapter presents a view of m-learning based both on the foundational concepts of e-learning and on the uniquely mobile attributes of m-learning. Factors associated with the context of m-learning are introduced and opportunities offered by an m-learning environment are suggested. This chapter contributes to answering ***RQ2***, which formulates the evaluation criteria specific to m-learning environments. In addition, background information is provided to ***RQ4***, which explores the potential of m-learning to reduce the digital divide.

Background information is presented in Section 2.2 while Section 2.3 defines m-learning. Section 2.4 explains the view that mobile handheld devices can be used as m-learning environments. Section 2.5 discusses uses of such devices for educational purposes, followed in Section 2.6 with an outline of the transition to m-learning from e-learning. The context, complexities and challenges of an m-learning environment are considered in Section 2.7. Section 2.8 concludes and summarises the chapter.

2.2 Background

Several perspectives create a backdrop for the m-learning context of the present study, namely:

- Blended learning;
- Formal and informal learning;
- Problem-based learning; and
- The digital divide.

2.2.1 Blended Learning

Blended learning incorporates different modes of learning, combined to offer the learner an effective learning environment. It consists of components such as face-to-face classroom engagement and e-learning methodologies, such as webinars, CD ROM course content, web-based training, electronic tutorials and simulations. An example of research in a blended mobile learning context, is provided by Pieri and Diamantini (2009) who investigated a face-to-face classroom experience, supplemented by the delivery of a learning unit with a specific purpose, and delivered via Pocket PC.

The design of blended learning combinations is determined by the nature of the learning objectives, course content and learner-audience factors. This includes the location, competencies and personalised styles of learning (Chilcott and Hadfield, 2009). Besides offering opportunities for improved and personalised learning styles so that learners are able to watch, read, speak, listen and think within their learning experiences, blended learning introduces a move towards active involvement and interactivity. The learner participates beyond the confines of a passive, presentation-format classroom (Nash, 2011). Learners work together and separately through classroom engagement and by using online components. The development of communication and collaboration skills is facilitated.

The nature of blended learning environments varies. Critical design factors for each particular environment could include:

- The nature of the interactive content;
- Appropriate online learning platforms; and
- Training in blended learning for educators (Cheung, Lam, Lau and Shim, 2010b).

These aspects of blended learning are important, leading potentially to increased interest in course content. In higher education, evolving technologies and Web 2.0 create possibilities for new blended strategies with the inclusion of virtual worlds, social learning, augmented reality and mobile learning. Research has shown that blended learning environments can contribute to improved outcomes (Wyllie, 2009). A successful blended learning strategy depends on factors such as an effective and integrated learning management system, institutional facilitation and transformation by higher education faculties to support and expedite the learning process (Cheung *et al.*, 2010b).

Informal learning can play a motivational role in a blended learning environment, contributing to positive attitudes to learning (Jones, Issroff, Scanlon, Clough and McAndrew, 2006). An informal mobile phone learning environment could:

- Facilitate a motivating learning experience;
- Give control and ownership to the learner;
- Allow communication between learners;
- Capitalise on the view that the phone is seen as a gadget of entertainment;
- Make Internet communication feasible where there is no Internet connectivity, enabling sharing between learners; and
- Support portability, so that information may be captured in one location and transported to another for later use – this is valuable where small relevant chunks are gathered

  (Ally, 2009; Cobcraft *et al.*, 2006; Cochrane, 2010; Ebner and Schiefner, 2008; Herrington and Herrington, 2006; Naismith *et al.*, 2004; Sharples, Arnedillo-Sanchez, Mildrad and Vavoula, 2009a; Traxler, 2007b).

2.2.2 Formal and Informal Learning

Sharples, Taylor and Vavoula (2007) suggest that m-learning should include both formal and informal aspects. Vavoula, Scanlon, Lonsdale, Sharples and Jones (2005) make a distinction between formal and informal learning (Figure 2-1), namely:

- *Formal learning* – intentional learning processes and goals directed by teachers and the curriculum; and
- *Informal learning* – comprising intentional dimensions directed by the learner, and unintentional, coincidental dimensions.

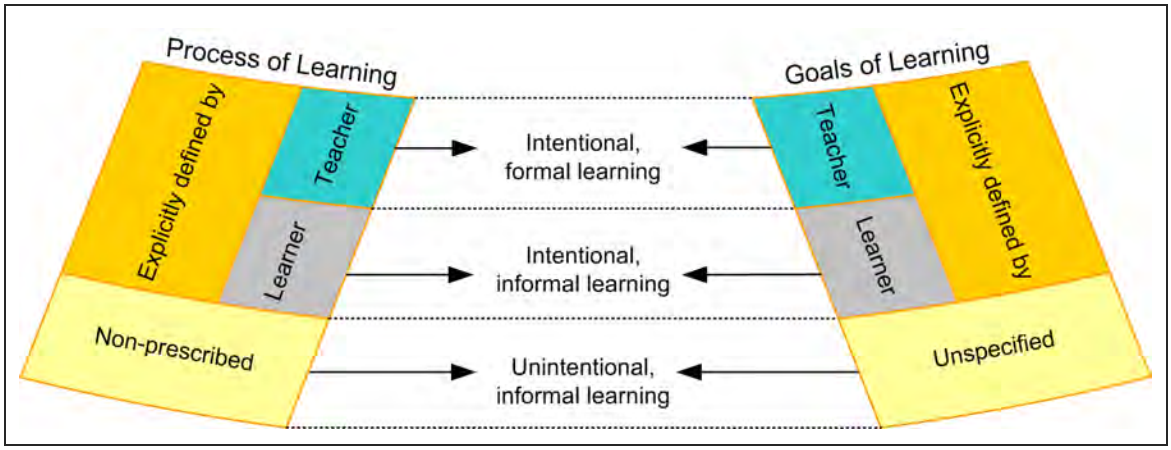

Figure 2-1: Typology of formal and informal learning (Adapted from Vavoula et al., 2005)

Survey findings by Clough, McAndrew and Scanlon (2008) indicate that informal m-learning incorporates various categories of activities:

- *Referential* – accessing e-books, dictionaries, and the Internet;
- *Location-aware* – using tools such as GPS to ascertain physical context associated with a location, which could be a classroom, an outing or a journey;
- *Reflective* – visiting blogs, discussion forums, wikis;
- *Data collection* – creating audio notes and doing online research; and
- *Administrative* – calendar and contacts.

2.2.3 Problem-Based Learning

In problem-based learning (PBL) scenarios, learners are exposed to practical problem-solving situations. They are provided with resources and engage in group-oriented tasks to resolve realistic problems. By experiencing the problems, they are able to identify the skills they need for a particular subject area (Ellis, Carswell, Bernat, Deveaux, Frison, Meisalo, Nulden, Rugelj and Tarhio, 1998). In this form of learning, the educator is more than an teacher, filling instead the role of a facilitator (Hmelo-Silver and Barrows, 2006).

Hakkarainen (2009) implemented a PBL environment within a design-based research (DBR) strategy. The PBL model supported formal learning within a collaborative environment. The teamwork was undertaken in tutorial sessions and learners responded positively to it. Findings of Qiu and Chen (2010) indicate that learner collaboration on PBL projects can produce a positive attitude to the relevance of project work and interactivity.

Linge and Parsons (2006) found that problem-based learning was an effective method in the teaching and learning of computer network design. Learners filled the role of network design consultants, while participating in conventional, face-to-face, lecture-based learning. PBL provided a practical, real-world environment. The approach was generally supported by learner groups.

2.2.4 The Digital Divide

The digital divide, is described as the gap that emerges between those who are able to efficiently and effectively access digital information via the Internet and those who remain disadvantaged, either with poor access, or no access, to the global information society (Ruth, 2012). It is experienced by individuals, by communities, within and between diverse nations, and across continents. Hilbert (2011) highlights the complexity of the digital divide, which impacts on:

- *People* – learners, teams, academic and administrative staff and campuses;

- *Characteristics* – age, culture and home languages;
- *Devices* – smartphones, laptops, netbooks, and tablets; and
- *Connectivity methods* – dial-up, ADSL, wireless, GSM, and 3G.

Laouris and Eteokleous (2005) suggest that digital technology has the potential to bridge the digital divide, simultaneously accelerating development in under-privileged communities. Mobile technology could improve Internet access for learners who do not have facilities for Internet connectivity via computers, thus contributing to a reduction in the gap between the ICT "haves" and "have-nots".

National factors affect the prevalence of the digital divide. Typically, people from developed nations experience the impact of the digital divide to a lesser extent that citizens of developing nations. However, Ruth (2012: p. 82) suggests that despite poor bandwidth and connectivity, "many examples exist of developing nations succeeding under difficult conditions." Constraints of digital technology may include lagging infrastructure and power supply problems, as experienced by Nigerian citizens (Urien, 2011). In addition, urban and rural communities do not experience the same quality of connectivity. For example, major regional disparities are reported in Botswana (Oladokun and Aina, 2011).

According to Brown, Campbell and Ling (2011), the exponential proliferation of mobile phones has facilitated Internet connectivity "on-the-move" among US teenagers, suggesting the emergence of a new bridge across the digital divide. Their findings indicated that young people in poorer communities seemed more likely to spend their money on mobile technology. This introduces a paradox: some poorer teenagers are prepared to, and actually do, pay more for connectivity than some young people from more affluent environments.

A comparison of active mobile-broadband subscription trends for developed and developing countries throughout the world clearly illustrates discrepancies associated with mobile phones (ITU World Telecommunications, 2012). Africa, with 3.79 subscriptions per 100 inhabitants, trails behind Europe and the Americas with 54.10 and 30.49 subscriptions per 100 inhabitants respectively. There is an increase in the uptake of mobile-broadband subscriptions in Africa. Statistics indicate that in 2013, the total number of fixed-broadband subscriptions in developing countries surpasses those in developed countries. But there is still a wide gap when it comes to fixed-broadband penetration rates, with 6.1% in developing countries (and less than 1% in Sub-Saharan Africa), compared with 27.2% in developed countries" (*The World in 2013 ICT Facts and Figures*, 2013).

Nevertheless, researchers emphasize the role of education and the value, in the African context, of competence in digital skills and positive attitudes of both learners and teachers. University education supports efforts to bridge the digital divide (Otuonye, 2011; Yusuf and Balogen, 2011). In a bid to uplift ICT education, educational initiatives in Africa aim to narrow the divide both for impoverished learner communities and for privileged learner groups adversely affected by the digital divide in their local areas (Oneya and Gitau, 2011). One such initiative, named BADILIKO, which means "change" in Swahili, is being sponsored by Microsoft and the British Council (Yussif, 2012). The project will finance digital infrastructure and technology training across the African continent.

Similar ICT4D 2.0 projects aim to find ways to reduce the divide in developing countries, for example, by incorporating aspects of Web 2.0.

2.3 Definition of m-Learning

2.3.1 Various Perspectives

Various authors define m-learning in different ways. Some definitions are basic, viewing m-learning as:

- *A subset of e-learning* – m-learning is viewed as a combination of both e-learning and mobile computing (Holzinger, Nischelwitzer and Meisenberger, 2005);
- *A learning experience* – e-learning is blended together with wireless and mobile technology (Wains and Mahmood, 2008); and
- *Supported learning* – traditional face-to-face learning is extended by the use of mobile devices (Deegan and Rothwell, 2010).

m-Learning may thus be defined as:

- A subset of e-learning;
- A transition from e-learning; or
- A unique and independent concept.

Each of these is briefly explained in this section, while the relationship between e-learning and m-learning is addressed in detail in Section 2.6.

A subset of e-learning

Quinn (2000) suggests that m-learning forms a subset of e-learning. He highlights the role of mobile device technology, as well as specific attributes of m-learning, namely, it is

location-independent and irrespective of time. Similarly, Pinkwart, Hoppe, Milrad and Perez (2003) propose a device-centric view of mobile learning.

Transition from e-learning

According to Georgiev, Georgieva and Smrikarov (2004), m-learning is an extension of e-learning – a new stage of distance-learning and e-learning. The learners are free from physical and wired desktop connections associated with e-learning, yet are still able to access forms of information exchange associated with conventional e-learning. Mostakhdemin-Hosseini and Tuimala (2005) point out that the transition of e-learning to m-learning is facilitated by three different mobile learning domains, namely mobile usability, wireless technology and the e-learning system.

Sharples, Taylor and Vavoula (2005) accentuate the role of the learner in an m-learning context, whilst formulating a theoretical framework for m-learning and outlining an understanding of m-learning. They suggest that the mobile learner gains knowledge in contexts that are supplementary to the classroom, commenting that the learners, and not only the technology, are seen as being mobile.

Unique and independent form of learning

Laouris and Eteokleous (2005) reject a basic definition of m-learning as learning occurring whilst the learner is on the move. Instead, they formulate a definition of m-learning as an independent concept, suggesting a shift away from the concept of m-learning associated with the device to a concept based on the inclusion of people. m-Learning is a unique function of many variables including time, space, environment, content, technology, mental capacity of the learner, and pedagogical aspects.

A multi-perspective view of m-learning therefore considers it as an environment that incorporates the user in a fuller way than e-learning does. Mobile technologies include certain aspects of e-learning, as well as features and facilities that are particularly relevant for m-learning. Mobile learners use their devices in many differing contexts suggesting that m-learning offers certain distinguishing features that are not components of e-learning. In particular, the m-learning environment offers higher education learners opportunities to communicate and collaborate digitally with greater flexibility and speed than can be done via e-mail contact.

2.3.2 Features of m-Learning

In contrast to traditional PC-based e-learning which is seen as being wired and “tethered” or locked down, wireless m-learning is “free” (Traxler, 2007a: p. 14). Besides learning in

the classroom, mobile learners use their devices to learn in various unique and personal ways, at any time, and in diverse places, for example, on the bus, in a car, in the train, whilst sitting in front of the television, as well as for focussed academic purposes.

Mobile handheld devices as m-learning environments provide the necessary conduit for learning by means of digital technology. This is elaborated in the next section.

2.4 Mobile Handheld Devices as m-Learning Environments

Most higher education learners have a mobile phone, which in many cases, is a smartphone – a combination of cell phone and PDA, enabling sophisticated 24-7 connectivity, and PC-like functionality. This is frequently the case among the learners in South Africa encountered by the researcher.

The ubiquitous mobile phone, used increasingly for many purposes other than telephony, provides opportunities to extend the traditional face-to-face classroom to many contexts of learning, as well as varying strategies of collaborative and communicative learning. Communication and collaboration between learners, and between learners and educators, is required to be both synchronous, instantaneously "on the fly", and asynchronous for access at the user's convenience (Georgieva, Smrikarov and Georgiev, 2005). Whenever opportunities are available to access the Internet, learners increasingly rely on rapid snippets of communication in the form of text messages and on quick searches for online information. Mobile phones may be used to facilitate such access via an m-learning application, thus enhancing the learning experience.

Various aspects of mobile devices as m-learning environments will be considered, namely:

- The meaning of 'mobility';
- Mobile technology; and
- Device attributes.

The meaning of 'mobility'

Whilst the term 'mobile' is currently primarily associated with devices, telephony and technology, it is also associated with education on-the-move. Learners and educators are mobile and this mobility is of more significance in higher education than the actual devices and technology (Serrano-Santoyo and Organista-Sandoval, 2010). Stakeholders are mobile and contextual learning is associated with mobility. Mobile devices support

this distinctive m-learning process (Sharples *et al.*, 2007). Ultimately, mobility means mobile individuals, mobile devices, and wireless Internet access in unique contexts.

Mobile technology

Sharp, Rogers and Preece (2007) suggest that mobile technologies that support mobile interfaces are ubiquitous. Requirements and expectations of mobile technology include high portability, adaptability to support the individual, unobtrusiveness, availability, adaptability to context, persistence across changing technologies, usefulness, and ease of use (Sharples, 2000). Besides the development of mobile devices and the availability of appropriate technologies, facilitation of learning via mobile devices has been made possible by innovation in communication technologies such as GPRS, GSM, IEEE 802.11, Bluetooth and IrDA (Rodrigues, Sousa and de la Torre, 2012):

- *GPRS* – General Packet Radio Service, a wireless communication technology that facilities data transfer between wireless devices;
- *GSM* – Global System for Mobile Communications, a digital system for cellular use;
- *IEEE 802.11* – a group of a specifications relevant for wireless networks;
- *Bluetoot* – wireless technology suited to short-range communications; and
- *IrDa* – Infrared Data Association, a consortium of companies responsible for the establishment of guidelines for the transmission of infra-red light waves (ITBusinessEdge, 2012).

Handheld devices, which might previously have been cellphones and smartphones only and always carried by the user, are now more likely to include tablets. Mobile handheld devices for learning extend beyond the cellphone to include smartphones, e-book readers, tablet PCs, and netbooks (Hanson, 2011).

An overview by the researcher of mobile handheld device types (m-devices), both in terms of physical size and functionalities, is presented in Figure 2-2 and Table 2–1 respectively.

Mobile Handheld Device Types

Type 1: Cellphones

Nokia 100

Type 2: Smartphones

BlackBerry Bold 9790

htc One X

Type 3: Tablet PCs

SAMSUNG Galaxy TAB 10.1

Figure 2-2: Mobile handheld device types
(Synthesized by the researcher from BlackBerry, 2012;
htc quietly brilliant, 2012; Nokia, 2012; SAMSUNG, 2012)

In Figure 2-2, cellphones are classified as Type 1, whilst smartphones and tablet PCs are Type 2 and Type 3 respectively. A representative selection of diverse brands are presented, namely Nokia, BlackBerry, htc and SAMSUNG (*Compare*, 2012). Nokia 100 (Type 1) is a cellphone model without smartphone capabilities. It is a cost-effective device which offers only direct cellphone communication and SMS facilities (short messages in text format). This device would not support an m-learning environment. BlackBerry Bold 9790 and htc One X (Type 2) are classified as smartphones. Smartphone features include PC-like capability with larger, multi-touch screens, QWERTY keyboards, larger memory capacity and advanced wireless technology achieving Internet connectivity. Mobile handheld devices of Type 3, tablet PCs, are represented here by SAMSUNG Galaxy Tab 10.1, which incorporates smartphone

technology together with a much larger, touch-screen interface with advanced mobile capabilities.

Device attributes

Educational institutions are challenged to makes choices regarding device type, functionality and device ownership (Traxler, 2009). Figure 2-2 and

Table 2-1 highlight these challenges, demonstrating advancements in handheld device technology that have led to a broad range of mobile device models – a major leap from cellphone to smartphone to tablet.

Mobile handheld devices have diverse attributes including shape and size, keyboard type, applications, operating system, and network connectivity.

Table 2-1 (Compare, 2012) illustrates the diversity of attributes such as connectivity, size and weight, input mechanism, operating system, RAM, and screen type and size that are apparent in the three selected device types – cellphone, smartphone and tablet. Connectivity determines the ability to access the Internet. Connectivity functionality varies from cellphones with 2G connectivity that offer no Internet access, to tablets, that have several connectivity options, including Bluetooth, Wi-Fi, 2G, 3G and even 4G. Size and weight comparisons emphasize the change from the pocket-sized Nokia 100 to the bag-sized SAMSUNG Galaxy Tab 10.1.

Input mechanisms may influence device usability. At one end of the device spectrum, the keyboard is in alphanumeric format, whilst at the other end, enhanced input options include QWERTY and virtual keyboard layouts together with touchscreen technology. Unique operating systems which differ between and within brands are not necessarily equally compatible with all m-learning applications. Interactivity is affected by screen type and size, both of which are considered critical usability aspects associated with m-learning.

Users select and customise mobile handheld devices according to personal preferences. It is challenging to design mobile content with a delivery format suited to a range of device types. Figure 2-2 above presented three device types: cellphones (Type 1), smartphones (Type 2) and tablet PCs (Type 3).

Table 2-1 extends this introduction by summarizing key digital technology features and illustrating the variability of devices available for use in an educational capacity with respect to brands, models, device types and capabilities.

Table 2-1: Specific attributes for a selection of mobile device brands (Synthesized by the researcher from Compare, 2012)

Device Type	Type 1 Cellphones	Type 2 Smartphones		Type 3 Tablet PCs
Brand	Nokia	BlackBerry®	HTC	Samsung
Model	100	Bold™ 9790	One X	Galaxy Tab 10.1
Camera	No	Yes	Yes	Yes
Connectivity	GSM 2G	GSM, HSDPA, GPRS, EDGE Bluetooth, Wi-Fi, 2G, 3G	GSM, HSDPA, GPRS, EDGE Bluetooth, Wi-Fi, 3G	GSM, HSDPA, GPRS, EDGE Bluetooth, Wi-Fi, 2G, 3G
Height	110mm	110mm	134mm	256.6mm
Width	45.4mm	60mm	70mm	175.3mm
Thickness	14.9mm	11.4mm	8.9mm	9.7mm
Weight	75g	107g	130g	588g
GPS	Yes	Yes	Yes	Yes
Input	Alpha-numeric keypad	QWERTY keyboard	Multi-touch	Multi-touch
Battery life	7.2h	5h	6h	10h
Browser	None	HTML	HTML, Adobe Flash	HTML, Adobe Flash
Memory	No card slot	8GB, microSD to 32GB	32GB, 25GB microUSB	32GB, microSD to 32GB
Operating System	Nokia OS	OS 7	Android 4.0	Android 3.1
Processor	-	1 GHz	1.5 GHz Quad Core	1 GHz Dual Core
RAM	Limited	768MB	1GB	1GB
Screen	TFT, 65K colours 128x160 pixels	TFT, 16M colours, 480x360 pixels	Multi-touch TFT 65M colours, 720x1280 pixels	Multi-touch TFT 16M colours, 800x1280 pixels
Screen Size	1.8” (4.6cm)	2.5” (6.2cm)	4.7” (14.5cm)	10.1” (25.7cm)

Device	Capabilities	Device	Capabilities
Basic mobile phone	*Network services, including:*	Smartphone	*As Featurephone plus:*
	Voice telephony and voice mail		Video camera
	SMS (short message service)		Web browser
	USSD (unstructured supplementary service data)		GPS (global positioning system)
			3G+ internet access
	SMS-based services, such as mobile money		Mobile operating "platform" (such as iOS, Android, Blackberry)
	USSD services, such as instant messaging		Ability to download and manage applications
			VoIP (Voice over Internet Protocol)
			Mobile TV (if available)
			Removable memory card
Featurephone	*As basic mobile phone plus:*	Tablet	*As smartphone plus:*
	Multimedia Messaging Service (MMS)		Front and rear-facing video cameras (for video calls)
	Still picture camera		Larger screen and memory capability
	MP3 music player		Faster processor, enabling video playback
	2.5G data access		Touchscreen with virtual keyboard
			USB (universal serial bus) port

Figure 2-3: A general classification of device types and capabilities (ICT4D: Maximizing Mobile, 2012)

Table 2-1 (specific attributes) and Figure 2-3 (general capabilities) above emphasize the many m-device challenges that occur in the context of educational technology, including:

- Platform varieties;
- Differences in screen size;
- Variations in capabilities and functionalities;
- Incompatible productivity applications;
- Competitive social networking tools;
- Connectivity costs;
- Slow interactivity speed;
- Browsing frustrations; and
- Content design for mobile environments.

While acknowledging that the e-book capabilities of tablet devices can enrich learning opportunities by providing all learners with electronic textbooks, Lee, Lee and Kweon (2011) suggest that the use of standard commercially-available devices for this purpose

is inappropriate. They propose that educational technologists and policy makers in higher education could consider custom–designing devices specifically for education.

Internet access factors that are device-driven include the quality and cost of connectivity, bandwidth capacity and download speed – all of which depend on device functionality and capability. The complexities and challenges associated with m-learning environments are revisited in Sections 2.7.2 and 2.7.3 respectively.

2.5 Use of Mobile Devices for Educational Purposes

The mobile phone used traditionally for phone calls and text messages, is now used for many diverse activities, sometimes causing concern to educators who do not approve of interruptions during classroom activities (Oksman, 2010). Most devices are portable, small, lightweight, and easy to use (Naismith *et al.*, 2004), whilst providing instant Internet functionality. This portability and simplicity of use holds both advantages and disadvantages in the context of education. This section considers some of the positive applications of mobile devices in the context of teaching and learning.

Figure 2-4 presents a generic example of wireless interactions via a user-centred, m-learning environment providing links to course content, communications, and multimedia materials, such as video, audio and images.

Figure 2-4: Generic wireless interaction in a typical m-learning environment (Synthesized by the researcher)

As described in an online article, entitled 'From e-learning to m-learning' (Landers, 2002), such an environment could:

- Provide learners with social networking and support services;
- Connect learners to Internet information; and
- Transfer information from educators to learners and between learners.

Over and above telephone functionality, the capabilities of mobile handheld devices include:

- *Digital connectivity* – e-mail, SMS, web browsing, Internet access;
- *Social networking* – Facebook, LinkedIn, Delicious, Word Press (blog), Twitter (micro blog);
- *Multimedia management* – videos, audio, images, photos;
- *Productivity* – letters, spread sheets, presentations;

- *e-Book reading* – Amazon Kindle; and
- *Business transactions* – banking, e-portal access, online shopping.

The above capabilities provide connectivity opportunities, which include social learning, communication and collaboration, the management of multimedia tools; and the delivery of conventional learning content. The first three of these dimensions are discussed further.

2.5.1 Social Learning

Social networking sites (SNSs) are online web-based platforms where groups of people meet, interact and work together digitally (Kelsey, 2010). SNSs that provide communication and collaboration opportunities and that can be used to facilitate social learning, include:

- *Facebook* – a social networking website, connecting friends, family, online communities, business associations and colleagues;
- *LinkedIn* – a platform for business connections and professionals;
- *Delicious* – a social bookmarking service, storing and sharing website bookmarks;
- *Word Press* – open source blogging software; and
- *Twitter* – an instant micro blog and messaging system, designed for short bursts of text communication

(Delicious, 2012; Facebook, 2012; LinkedIn, 2012; Twitter, 2012; WordPress.com, 2012).

Ebner (2007) points out that these sites can serve as interactive platforms for informal social learning, facilitated by mobile handheld devices equipped with Internet capabilities.

2.5.2 Communication and Collaboration

Mobile communication, previously regarded as a social and business activity, may be used to serve educational purposes via synchronous or asynchronous communication or both (Georgieva *et al.*, 2005).

Collaborative learning is described by Rodrigues *et al.* (2012: p. 23) as "… a set of learning activities that enables the group members to enjoy the learning scenario and reach common goals through affective and cognitive comprehension, cooperative work-sharing and social interaction … ".

Traxler (2010c) points out that m-devices provide personal and private contexts where communication and collaboration can occur at any time and in many different places,

reducing the limitations of the context of use that occur with traditional desktop and laptop technology. Several options become possible:

- Learners multitask, gathering information and acquiring knowledge in parallel to their normal life activities rather than in place of them;
- New ways are used to connect conveniently with other learners to share ideas and information;
- Mobile technologies simultaneously enable information consumption, content production, communication and collaboration; and
- Technology facilitates new media for learning and innovative education strategies.

Furthermore, educators can post announcements and instructions that will be received instantly.

2.5.3 Multimedia Tools

Digital and cloud technology tools are available to store, manage, share and view online multimedia files such as video and audio files, presentations, photos and images (DropBox, 2012; Flickr, 2012; SlideShare Inc, 2012; YouTube, 2012).

The mobile phone, initially designed for messages and calls, has become a ubiquitous, sophisticated and almost compulsory multimedia tool (Ji *et al.*, 2006), introducing new patterns of technology usage. Mobile users need different ways to adopt the technology and access the Internet (Serrano-Santoyo and Organista-Sandoval, 2010).

2.6 Transition from e-Learning to m-Learning

This aspect, which was briefly mentioned in Section 2.3.1, is now discussed in more detail. To enable a deeper, richer understanding of m-learning, a brief outline of e-learning is provided. This is followed by a review of the relationship between e-learning and m-learning, referring to selected literature sources. Finally, m-learning is explored in and of itself.

2.6.1 e-Learning Environments

e-Learning is a broad term, incorporating means of learning supported by technology and implemented in many different interactive formats. From the perspective of the researcher, traditional forms of e-learning include electronic tutorials, hypermedia, drills, simulations, educational games, open-ended learning environments and online learning.

These forms may be delivered by CD-ROM, Internet or Intranet (Alessi and Trollip, 2001; de Villiers, 2005a). Key methodologies associated with e-learning include environments for computer-aided instruction (CAI); web-based learning (WBL); and more recently, Web 2.0. According to Ebner (2007), e-learning has evolved from e-Learning 1.0 to e-Learning 2.0 in the milieu of Web 2.0 technologies, which enable learners to personally contribute micro-content. Social networking technologies can play an important role in this process in the context of higher education (Ebner, Holzinger and Maurer, 2007; Richardson, 2006) and include:

- *Weblogs* – e.g. Word Press (2012);
- *Wikis* – e.g. Wikipedia (2012);
- *Social networking sites (SNSs)* – e.g. Facebook (2012), LinkedIn (2012);
- *Podcasts* – RSS feeds; and
- *Applications that share data over the Internet* – e.g. videos (YouTube, 2012), pictures (Flickr, 2012); and bookmarks (Delicious, 2012).

A current trend in e-learning is the use of online discussion forums (ODFs) which support learning by discourse, communication and by collaboration mechanisms. These can be implemented in formal environments such as institutional learning management systems or in group discussions via SNSs.

Several of these types of e-learning environments are now described.

Virtual learning environments

Virtual learning environments (VLEs) may also be called course management systems (CMSs) or learning management systems (LMSs) (Cobcraft, 2006). The terms 'VLE', 'CMS' and 'LMS' are erroneously used interchangeably in the literature while, in fact, they reflect different concepts. A distinction between these terms is provided in Section 4.4.1, Table 4-2.

In brief, VLEs may provide:

- Offline and online learning services for teachers, learners and administrators;
- Internet or intranet services, including learning content; communication and collaboration tools; secure and personalized access to assessment; and library systems; and
- Record keeping facilities and support for administration.

WebCT, Blackboard and Moodle are examples of VLEs (Paulsen, 2002) and are explored in greater detail in Chapter 4, Section 4.4.

Computer-aided instruction

In traditional computer-aided instruction (CAI), learners access instructional content, which is delivered by personal computer (PC). The content can include multimedia such as text, images, sound, audio, video, examples, and exercises. CAI may be presented in various formats such as drills, interactive tutorials, games and simulations (Alessi and Trollip, 2001; de Villiers, 2005a).

Web-based learning

The 'web' and Internet aspects of web-based learning (WBL) incorporate:

- *Network standards* – these guidelines prescribe criteria for websites that consist of collections of files, hosted on the World Wide Web;
- *Platform independence* – the browser application ensures seamless Internet access, independent of the underlying operating system;
- *Medium for delivery* – this feature provides transparent access to the latest version of an application;
- *Communication* – the platform creates opportunities for synchronous communication (chat rooms, audio, and video teleconferencing) and asynchronous communication (email, discussion forums);
- *Methodology for learning* – virtual learning environments (VLEs) facilitate the delivery of learning material;
- *Integration* – the web-based context supports the co-ordination of learning, teaching, and administrative functions;
- *Research purposes* – online databases and search engines establish opportunities to search for and evaluate academic content;
- *Co-ordination* – the system stores, organises and manages learning resources;
- *Collaboration:* social learning and problem-based learning in groups are enabled;
- *Assessment* – a variety of web-based assessments can be scheduled in convenient, secure and private ways. One purpose of assessment is to facilitate revision by multiple choice quizzes. In addition, text-based deliverables can be uploaded for manual marking; and
- *Learning support* – learners are encouraged and motivated (Alessi and Trollip, 2001).

Alessi and Trollip suggest that a quality-oriented WBL experience is measured by critical success factors, such as:

- An ability to navigate with ease;
- Satisfactory use of hyperlinked text;
- Learners' sense of orientation; and
- The presentation of learning content in acceptable, pleasing and appropriate hypermedia and multimedia formats.

Web 2.0

The Web 2.0 era originated from the emergence of Internet technologies that support online collaboration by the sharing of images, documents, text and video. This contributes to the creation of content by participants themselves. Without Web 2.0 participants, there would be no Web 2.0. This more sociable Internet environment includes various digital formats, facilitated by Web 2.0 platforms, such as Facebook. Ebner, Holzinger and Maurer (2007) envisage a future of Web 2.0 learning, characterised by both technological and social change. They highlight Web 2.0 stumbling blocks, calling for applications that are easier to use and a greater acceptance of Web 2.0 tools within teaching and learning. Ebner *et al.* suggest further that there are inherent limitations in Web 2.0. Appropriate didactic design is needed, such as adjustments in curricula and assessment factors. Moreover, they propose that a re-alignment of educational systems could be far-reaching, resulting in changes to institutional policies, practices and governance.

The Web 2.0 revolution offers the learner:

- Improved accessibility;
- Facilitation of teamwork using communication and collaboration tools familiar to the users due to their existing social networking skills;
- Enhanced learning; and
- Opportunities for active involvement and participation (Ebner *et al.*, 2007).

A selection of Web 2.0 tools are available to support web-based interactivity where learners, as collaborative developers, participate in the creation of web content. Whereas Web 1.0 users browse websites to acquire information, Web 2.0 users personally contribute content to the website, interacting via wikis, blogs, online discussion forums (ODFs), social networking, virtual communities of practice, and a collection of platforms and technologies.

According to Jashapara (2011), the dimensions of Web 2.0 technology range from extreme and dynamic meta-data and technology to a people-centred view. This view is associated with engagement and interactivity by users who may have little or no technical ability. Web 2.0 technologies relevant to this study are classified as blogs (e.g. WordPress, Twitter) and social networks (e.g. Facebook, LinkedIn and Delicious).

A current trend in e-learning is to employ a constructivist approach to learning whereby learners personally construct and interpret their own learning and knowledge (Alessi and Trollip, 2001; de Villiers, 2005a). Constructivist learning frequently occurs within the social constructivist paradigm, whereby learners collaboratively share their findings and work in teams. This approach is characterised by flexibility, exploration, learner-centricity, influence of context, and scaffolded education. Constructivism has been facilitated by the emergence of Web 2.0.

Communication and collaboration

e-Learning environments which enable learners to actively construct content themselves by using blogs, wikis and social networking technologies, as described in the previous subsection, have led to motivational and collaborative benefits for both learners and educators who work in teams and construct learning content (Giannoukos, Lykourentzou, Mpardis, Nikolopoulos, Loumos and Kayafas, 2008). Communication and collaboration in teams is implemented by synchronous contact and by asynchronous approaches.

2.6.2 From e-Learning to m-Learning

Various perceptions exist on the relationship between e-learning and m-learning. These perspectives were briefly overviewed in Section 2.3.1, but are discussed here in more detail and presented graphically.

m-Learning may be simplistically defined as a transition from e-learning (Georgiev *et al.*, 2004; Laouris and Eteokleous, 2005; Sharma and Kitchens, 2004). However, this view is controversial and disputed.

For the purposes of this study, the researcher identified various views on the relationship between e-learning and m-learning and synthesized five models, A to E respectively, representing differing relationships. These are:

- **A** *Transformation* (Figure 2-5) – e-learning is extended to provide m-learning capabilities;
- **B** *Loose Association* (Figure 2-6) – a weak connection exists between e-learning and m-learning, each of which retains unique attributes;
- **C** *e-Learning Superset* (Figure 2-7) – m-learning is viewed as a subset of e-learning;
- **D** *m-Learning Superset* (Figure 2-8) – m-learning incorporates all aspects of e-learning, amounting to a more comprehensive discipline; and
- **E** *Intersection* (Figure 2-9) – e-learning and m-learning demonstrate common, shared aspects, as well as independence from each other.

A Transformation

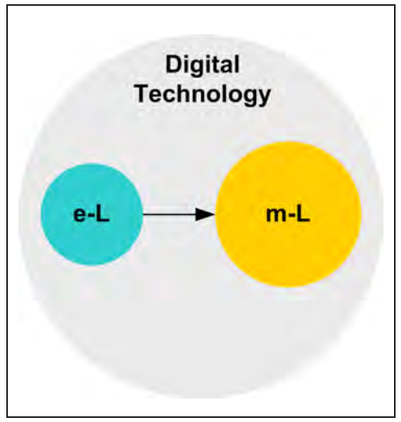

Figure 2-5: Aspects of e-learning contribute to a new m-learning paradigm, facilitated by digital technology

m-Learning emerges as a new paradigm, an extension, a transition from e-learning, inheriting aspects of web-based technologies as well as capabilities and features directly from e-learning but applying them on a different platform. Digital technology establishes the environment for each learning framework.

m-Learning is seen as a new set of shifts that are occurring in pedagogy, communications, feedback and assessment, made possible by digital technology (Deegan and Rothwell, 2010; Mostakhdemin-Hosseini and Tuimala, 2005; Sharma and Kitchens, 2004; Traxler, 2008).

B Loose Association

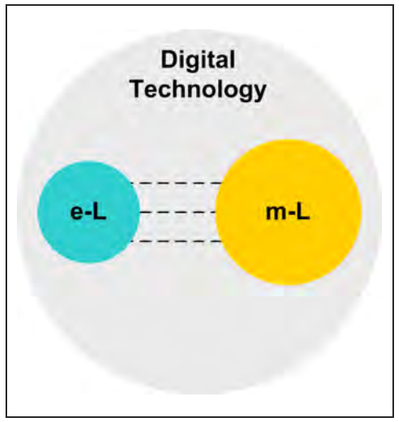

Figure 2-6: m-Learning is characterised as a complex, social environment, independent of e-learning

e-Learning and m-learning environments retain their unique identities yet are weakly associated with each other via digital technology. Deegan and Rothwell (2010), who define m-learning as learning with the aid of mobile devices, propose a classification of m-learning into categories based on use.

Laouris and Eteokleous (2005) describe m-learning as a complex concept where the mobility is associated with the learner. There are many facets to consider with much contextual interactivity between them. They provide a complex, mathematical and abstract formulation for m-learning, independent from e-learning. The view of m-learning as a complex interactive approach, independent of e-learning, is shared by Koole (2007). Sharples, Taylor and Vavoula (2007) view m-learning as a socio-cultural system.

C e-Learning Superset

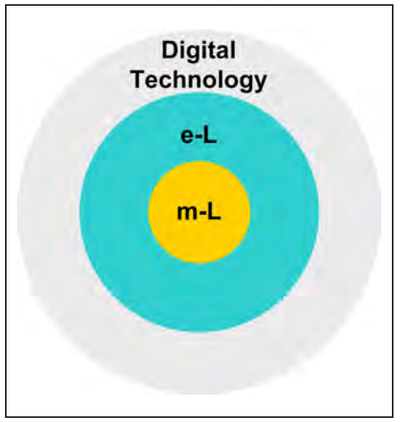

Figure 2-7: m-Learning is a part of e-learning, differentiated by delivery medium

e-Learning encompasses m-learning, suggesting that m-learning is a subset of e-learning (Cobcraft, 2006). m-Learning is the progeny, an offspring, a new stage of e-learning with the difference being the delivery by mobile devices and wireless transmission technology (Georgiev *et al.*, 2004; Pinkwart *et al.*, 2003). The focus of this view is on devices, which extend desktop e-learning applications to PDAs, creating collaborative mobile interaction via a wireless network.

According to Quinn (2000) m-learning is e-learning, but accomplished via a pocket-sized device such as a cellphone.

D m-Learning Superset

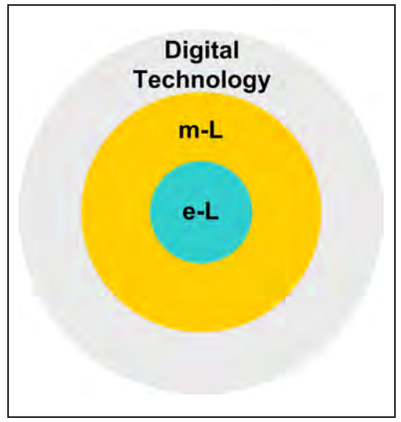

Figure 2-8: m-Learning is more than e-learning, though e-learning maintains its role as the core set of concepts

Although, as he did in 2000, Quinn holds the role of the device as central, he currently intimates that m-learning encompasses e-learning and extends beyond it (Quinn, 2012). Quinn acknowledges the need for an explicit m-learning strategy.

Sharples (2009b) describes this occurrence as the emergence of a new paradigm, viewing m-learning as too complex to be interpreted as a simple variant of e-learning. More importantly, he distinguishes between classroom-based e-learning using PCs and a variety of m-learning formats, and highlights issues associated with evaluating whether learning actually has occurred.

E Intersection

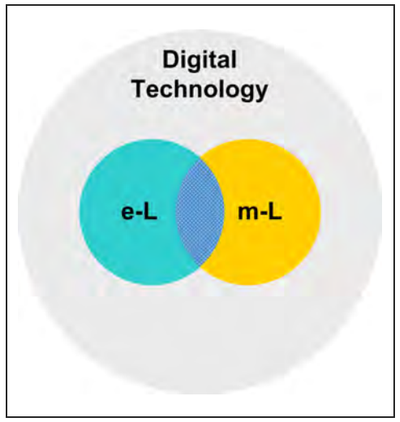

Figure 2-9: e-Learning intersects m-learning in a digital technology context

Proponents of this model suggest that e-learning and m-learning share web-based learning technologies, capabilities and features (Moczarny *et al.*, 2012). Each learning environment retains its own unique attributes whilst sharing some of those of the other.

Traxler (2005a) describes attributes of e-learning and m-learning that indicate an overlap between them.

Figure 2-9 represents the view of the present researcher.

2.6.3 Terminological and Pedagogical Differences between e-Learning and m-Learning

According to Sharma and Kitchens (2004), the transition from e-learning to m-learning is also characterised by different sets of terminology, which are listed in Table 2-2, as well as pedagogical differences, provided in Table 2-3.

Terminological differences

In the context of terminology, Sharma and Kitchens suggest that a new mobile vocabulary is emerging. Table 2-2 illustrates this notion.

Table 2-2: Terminological differences between e-learning and m-learning (Adapted from Sharma and Kitchens, 2004)

From e-Learning	To m-Learning
Computer	Mobile
Bandwidth	Bluetooth
Usually pre-planned	Often spontaneous
Collaborative	Networked
Distance learning	Situated learning
More formal	Informal
Hyperlinked	Connected
Simulated situation	Realistic situation
Multimedia	Learning objects

For example, whereas e-learning experts might speak of multimedia, m-learning specialists refer to learning objects. Simulated e-learning activities are being replaced by learning in realistic situations. Whilst both e-learning and m-learning are interactive, Sharma and Kitchens indicate that m-learning is frequently characterized by spontaneous and on-the-fly experiences while many e-learning experiences are pre-planned. e-Learning activities are more formal, being situated and tied to desktop computers.

Pedagogical differences

Sharma and Kitchens point out that there are also pedagogical changes, which are highlighted in Table 2-3.

Table 2-3: Pedagogical differences between e-learning and m-learning (Adapted from Sharma and Kitchens, 2004)

From e-Learning	To m-Learning
Instruction is based mainly on text and graphics	Instruction is based more on voice, graphics and animation
Classroom, labs, home, workplace	In the field, mobile

Whereas e-learning is suited to classroom, laboratory, and home experiences, m-learning has the advantage of being generally available in multiple locations and during periods whilst learners are on the move. It could, however, be stated that laptop computers are also mobile. This is indeed the case, but they cannot be used as effectively as mobile handheld devices while learners are actually moving from one location or venue to another or travelling.

Despite this viewpoint of Sharma and Kitchens, the researcher is aware of excellent examples of interactivity and animation in e-learning tutorials and simulations. The researcher also acknowledges that handheld devices have limitations, in that it is not easy to view animations and complex graphical representations on the small screens of an m-device.

m-Learning is now explored in and of itself, incorporating:

- Specific features of an m-learning environment;
- Current m-learning strategies; and
- A classification of m-learning environments.

2.6.4 Specific Features of an m-Learning Environment

An exploration of differences between e-learning and m-learning therefore highlights the unique features of m-learning. The models presented in Figures 2-4 to 2-8 illustrate the complexity of establishing a fixed definition of m-learning.

However, seven pertinent and inter-related themes contribute to the view of m-learning environments as understood by the present researcher:

- Extensions to e-learning;
- Perspectives on m-learning;
- m-Learning environments as new technological learning paradigms;
- Device-centric concepts;
- Impact of context;
- Association with the mobile user; and
- Conduits for informal, social learning.

These seven themes are addressed in the next subsections.

Extensions to e-learning

The extension of e-learning to m-learning was addressed in Section 2.6.2, but is concisely outlined here as well. The evolution of digital technology and the availability of mobile handheld devices have facilitated the emergence of m-learning. m-Learning may be described simplistically as a transition from e-learning to m-learning (Georgiev *et al.*, 2004; Laouris and Eteokleous, 2005) or be viewed as an extension to e-learning, differentiated by the fact that the user is able to move around during the learning experience (Cobcraft, 2006; Deegan and Rothwell, 2010). m-Learning is facilitated by ubiquitous mobile devices, which support the transition from e-learning to m-learning (Georgiev *et al.*, 2004).

However, the notion of a mobile device serving both as a delivery medium and a learning environment, introduces complexities (Section 2.7.2) and challenges (Section 2.7.3).

Perspectives on m-learning

Different researchers emphasize different aspects of m-learning. For example, Motiwalla (2007) stresses the pedagogical and technological aspects of m-learning. Mostakdemin-Hosseini and Tuimala (2005) adopt a system-oriented approach focusing on the infrastructure, usability and learning system. Ayoola, McGovern, Mangina and Collier (2008) focus on the benefit of access to learning resources, independent of time and place. Wireless technology provides a means of presenting m-learning environments which complement, but do not replace, face-to-face classroom instruction.

Motiwalla (2007) proposes a framework for the development of m-learning environments, incorporating:

- *Mobile and connected learners* – benefit is achieved from personalised anywhere, anytime interactivity (i.e. practical infrastructural issues); and
- *Electronic learning* – m-learning offers opportunities and methods to incorporate constructivist learning theory within learning experiences (i.e. pedagogical issues).

According to Mostakhdemin-Hosseini and Tuimala (2005), three intersecting factors provide m-learning services:

- *Mobile usability* – the device itself must comply with usability guidelines;
- *Wireless technology* – network infrastructure and cost factors are relevant; and
- *An e-learning system* – a virtual learning system creates an underlying educational platform and includes e-learning components.

m-Learning environments as new technological learning paradigms

Sharples (2009b) points out that m-learning is not merely a variant of e-learning, where delivery of course material occurs by means of portable devices. He proposes that m-learning is more than a simple classroom extension, in that a new human-centred societal paradigm is evolving. Interactions between people, technologies and contexts are creating a new mobile society, resulting in social change and different ways of learning.

Device-centric concepts

In e-learning the technology should be the medium and not the message (de Villiers, 2005a). This is not always the case in m-learning, where a variety of mobile devices, such as notebook computers, tablet PCs, PDAs, mobile and smart phones, play key roles. These devices are distinct; they fulfil differing roles and their functionalities vary according to their capabilities and features. Hence, in m-learning there is a closer connection between the technology and the message it conveys.

Impact of context

Learning may take place away from home, away from the workplace, and away from a formal educational institution. This ubiquitous learning approach marks a paradigm shift to new places of learning, beyond PC-based and desk-oriented e-learning. Whereas e-learning could be viewed as a delivery method for distance learning, m-learning entails a

broader learning environment, encompassing many contextual factors (Cobcraft, 2006; Cobcraft *et al.*, 2006; Georgiev *et al.*, 2004; Laouris and Eteokleous, 2005).

Association with the mobile user

Laouris and Eteokleous (2005) state that no adequate definition could be found for m-learning. The learner, not the device, learning material or learning experience, must be seen as the mobile feature in a mobile learning scenario (Deegan and Rothwell, 2010; Mostakhdemin-Hosseini and Tuimala, 2005). From this perspective, the focus is placed on the learner's multi-location situation, rather than on mobile technology.

Conduits for informal, social learning

m-Learning introduces the notion of informal learning, which is casual, accidental, self-motivated, and social (Lonsdale and Vavoula, 2004).

2.6.5 Current m-Learning Strategies

Cobcraft (2006) views m-learning as a subset of e-learning (Figure 2-7), so in the same way that blended learning includes various delivery strategies, educators now consider strategies of m-learning as an important aspect of the delivery of learning. m-Learning as a delivery medium can be associated either with traditional face-to-face learning or with e-learning.

Koole (2007) proposes a model for the framing of mobile learning, depicted in Figure 2-10.

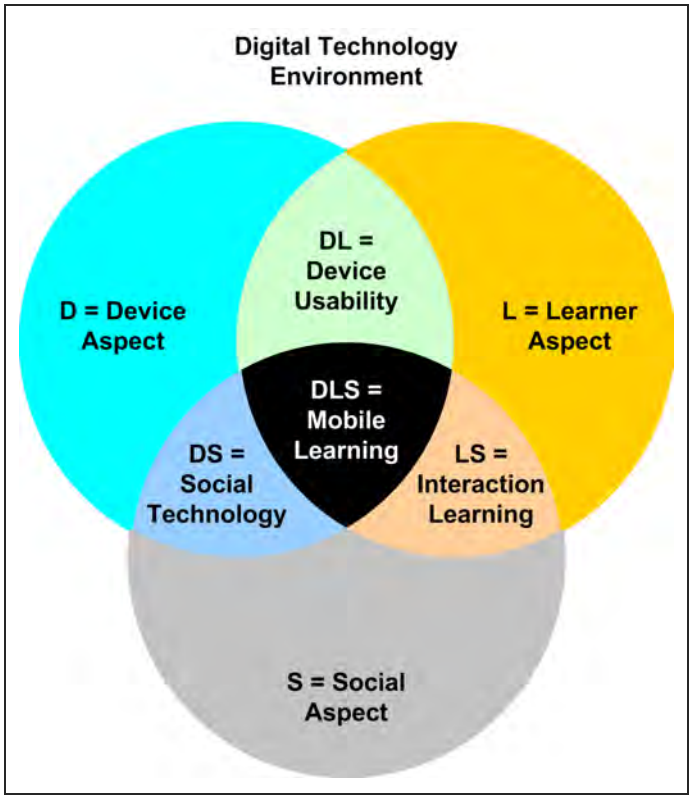

Figure 2-10: Model for framing m-learning (Adapted from Koole, 2007)

Figure 2-10 proposes a context in which three aspects intersect, namely:

- *L* – the learner;
- *D* – the device; and
- *S* – the social aspect.

This creates three intersecting zones:

- *LS* – interaction learning;
- *DL* – device usability; and
- *DS* – social technology.

The core aspect, DLS, which reflects m-learning, is central and comprises aspects of all three intersecting aspects, namely the learner, the device and the social.

2.6.6 A Classification of m-Learning Environments

Kukulska-Hulme and Traxler (2005) provide a basic, but useful, classification of m-learning environments founded on technology, portability, connectedness, situatedness (context), training and support, and purpose. These concepts are briefly explained.

Technology-driven mobile learning

Innovative thinking is applied in the development of mobile environments. In the light of these new technologies, ongoing research is conducted on the structure and characteristics of mobile learning to determine how to optimize these technology-driven shifts within digital education.

Miniature, but portable, e-learning

The desktop is replaced with mobile objects, providing a dynamism as new versions continuously appear.

Connected classrooms and learning

Support is provided for collaboration, for example, interactive whiteboards can be connected to mobile phones within the classroom situation.

Informal personalised, situated learning

The mobile learning context fosters authentic constructivist fieldwork, such as learners conducting research within authentic real-world environments, for example, in museums or computing environments, or making videos and taking photographs as part of project work.

Mobile training and support

Training managers are able to deliver just-in-time mobile training that is context-specific and delivered dynamically. In this way, on-the-spot support is provided for field workers via mobile handheld devices.

Purpose

The purpose and context of use of mobile technology are interrelated. For example, many rural or remote African communities live and learn in a context of a digital divide. Consequently, their access to advanced educational material requires Internet connectivity. Mobile technology has the potential to alleviate this issue and to reduce the digital divide. The digital divide context thus establishes a purpose for the implementation of m-learning environments.

A study on the tools for education, education providers, and learners (Attewell, 2005) identified certain benefits of m-learning, namely:

- Literacy and numeracy can be improved;
- Independent and collaborative learning experiences are encouraged;
- Resistance to ICT is combated;
- A more informal learning experience occurs;
- Longer periods of subject-focus can be achieved; and
- Self-esteem and self-confidence can be improved through non-threatening, personalized learning, supported by peers.

The discussion of the relationship between e-learning and m-learning in this section aimed to provide a deeper understanding of m-learning. Specific factors are worthy of further discussion, including the nature of the m-learning context, and the complexities and challenges of m-learning environments.

2.7 Context, Complexities and Challenges of m-Learning Environments

There are barriers to m-learning and integral restrictions, including capacity of the bandwidth; limitations in network infrastructure; cost of connectivity; diversity of device types and variations in their on-board applications; traditional attitudes to pedagogical device-related issues, such as screen size; difficulties related to navigation objects, such as buttons and keyboard input; and a lack of alignment of educational institutions with respect to new technology.

These barriers are associated with three issues: the context in which m-learning occurs; complexities that originate from the devices; and challenges emanating from the m-learning environment. The three issues are now considered.

2.7.1 Context

Sharp *et al.* (2007) refer to four dimensions of context which are environmental factors inherent to interaction design, namely:

- *Physical* – spatial circumstances such as ambience, lighting, audibility;
- *Social* – collaboration and coordination;
- *Organizational* – support, facilities, resources, infrastructure; and
- *Technical* – compatibility and limitations of technologies.

Traxler (2010a) draws attention to contextualization as a mobile reality, namely, that people can stay connected irrespective of distance and travel. Information is continuously available in, and as part of, real-world experiences and situations. The time, locations, and ways of learning are constantly changing and learners are adapting to the changes.

Learning may occur in a variety of locations, with the venue and time unrelated to conventional learning situations. Ubiquitous learning marks a move away from PC-based and desk-oriented e-learning, leading to m-learning in dynamic contexts that add new dimensions to the learning experience.

Figure 2-11 graphically illustrates some of the locations and contexts of m-learning encounters.

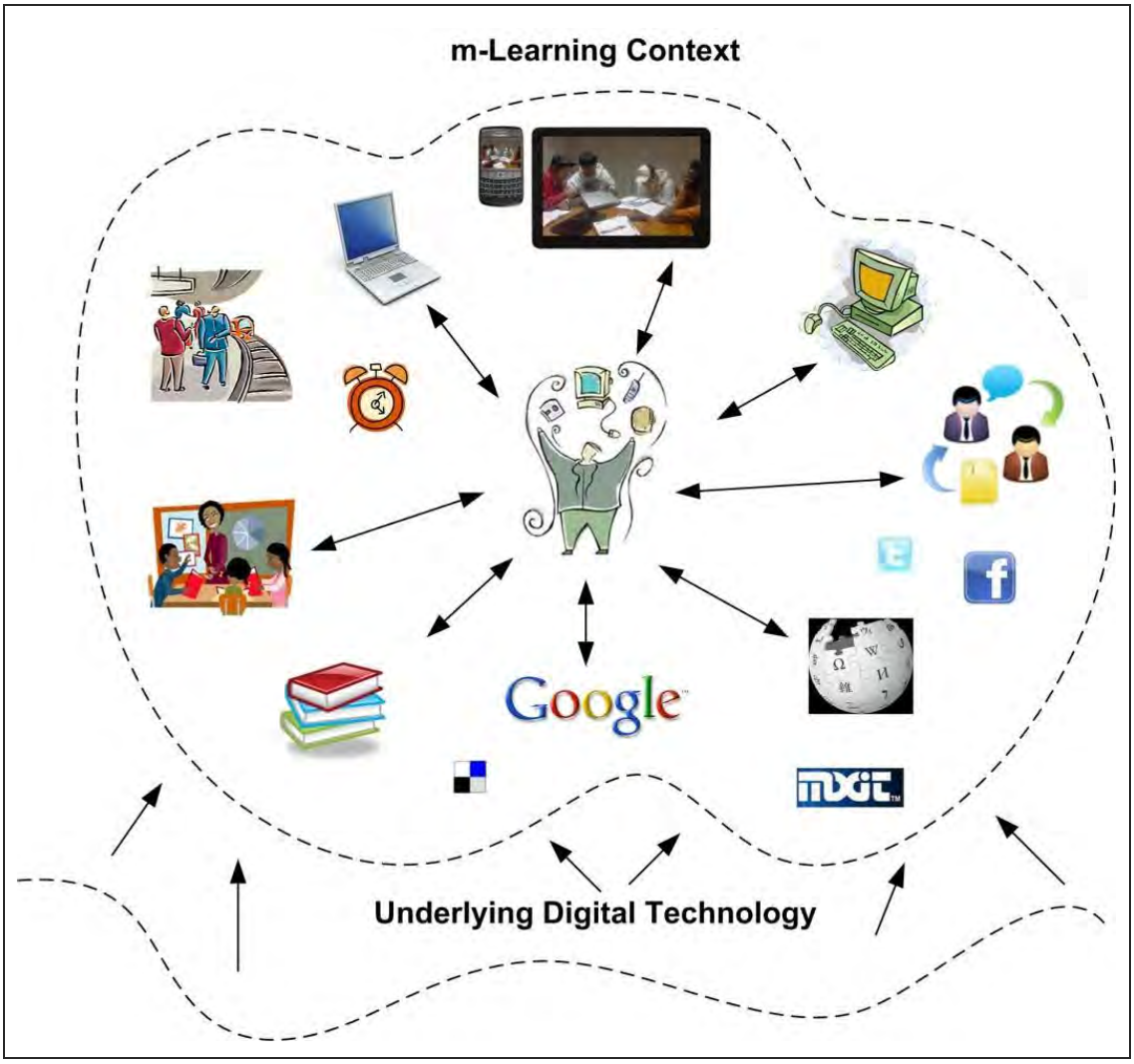

Figure 2-11: Complex m-learning context
(Synthesized by the researcher)

The higher-education learner portrayed centrally in Figure 2-11 learns from, makes discoveries within, and contributes to his or her m-learning context. The context is rich, dynamic and personal, comprising:

- *A diversity of devices* – laptops, cell phones, smartphones, tablets, and PCs;
- *Learning opportunities* – in any location and at any chosen and convenient time, such as in a noisy classroom, in a media centre, while travelling or whilst watching television;
- *The opportunity for learners to personally contribute content in a Web 2.0 environment* – for example, using social networking with online storage; and

- *Synchronous or asynchronous communication* – with others and collaboratively in groups.

As a result of this context, particular complexities and challenges become evident, and are discussed in Sections 2.7.2 and 2.7.3 respectively.

2.7.2 Complexities

Besides the m-learning context outlined in Section 2.7.1, Koole (2007) suggests that an m-learning environment comprises a complex, situated learning context.

Various factors contribute to this complexity, namely:

- *The variety of devices* – comprising many diverse models, operating platforms, interface challenges, and functionality options;
- *Personal preferences* – including traditional ways of thinking and conventional learning environments, limiting the ability to accept new ways of learning;
- *Bandwidth* – relating to availability and prohibitive costs of connectivity;
- *Quality of connectivity* – causing learner frustrations resulting from efforts to stay connected 24-7;
- *The mobile context* – which does not resemble a learning space due to the absence of a formal classroom, colleagues and library;
- *The delivery medium* – where learners perceive the mobile device as an instrument of fun and convenience, relating to social communication, games, music, videos, and text messaging, rather than as a learning and educational collaborative tool; and
- *Web 2.0 applications* – presenting distracting social networking sites such as Facebook, Twitter and MXIT
  (Attewell and Webster, 2005; Boja and Batagan; Frohberg, 2006; Koole, 2007; Lee *et al.*, 2011; Lin and Tatar, 2010; Roschelle, 2003; Serrano-Santoyo and Organista-Sandoval, 2010; Traxler and Kukulska-Hulme, 2005).

Complexities give rise to challenges associated with an m-learning environment.

2.7.3 Challenges

Challenges associated with m-learning have been synthesized by the researcher from literature sources. Initially, a brief outline is given of each of the ten categories of m-learning challenges (A to J). Thereafter, greater detail regarding each category is provided in Table 2-4, citing the contributory literature sources.

Categories of challenges include:

- **A** *Devices* – device challenges incorporate the existence of multiple platforms, differing types of operating systems, out-dated devices, limited battery life, slow processor speed and small screen size;
- **B** *Design and development* – m-learning applications must be compatible with all devices. This presents challenges for design and development, including the development of applications appropriate for smartphones;
- **C** *Content* – content developed for PC delivery is not directly transferrable to m-devices due to limitations of screen and input mechanisms. Course content must be customized and presented in 'nugget' format, designed specifically for an m-learning experience;
- **D** *Context of use* – challenges arise where the context of use of delivered content involves complex combinations of stakeholders, times and locations;
- **E** *Technology* – technology impacts on the way that the set of stakeholders, namely administrators, educators and learners share, reflect, and gain new skills. Moreover, it requires flexibility and adaptation to change;
- **F** *Educational institution* – the m-learning curriculum content and m-learning activities need to blend into the overall educational policies and practices;
- **G** *Security capabilities* – user authentication and secure connectivity should be prioritized for desktop applications. For a mobile network, authentication procedures and secure administration might not be on par with desktop environments;
- **H** *Ethics* – in certain situations, user rights include privacy, confidentiality and anonymity, which are at risk over the Internet;
- **I** *Evaluation* – evaluation of the m-learning environment relates to factors such as usability, network connectivity, varying contexts of use, uncertainty regarding the achievement of learning, and the influence of attributes and capabilities of the various devices; and
- **J** *User Experience* – literature sources advocate that various hedonistic and subjective UX factors, which are difficult to quantify objectively, should be incorporated in computing environments and addressed in UX evaluation. In addition, there is interdependence between factors.

These m-learning challenges (A to J) are now elaborated in Table 2-4, including references to the literature sources from which certain criteria were extracted. At the end of each category in the table, relevant literature sources are cited in substantiation of the

criteria. In some cases, sources are named which, although relevant, have not been previously cited in this chapter.

The synthesis of a detailed framework of evaluation categories and criteria for evaluating mobile learning environments is set out in Section 5.6 in Chapter 5, Research Design and Methodology.

Table 2-4: Challenges associated with m-learning environments (Synthesized by the researcher from literature sources)

	Categories	m-Learning Challenges
A	**Devices**	• Bandwidth of wireless networks is limited. • There are limitations to memory capacity. • Keyboard data entry via small buttons is complex, especially if the user is walking around. • Screen size is small with potential impact on usability. The impact of a small screen is not easy to measure. • Many differing operating systems are in use. • Various types of mobile devices may be used, e.g. smartphones, laptops, tablet PCs. • Each device type has its own disparate capabilities and specifications. • Processing capability and battery power durations are device-dependent. • Graphical display resolution differs, thus affecting multimedia experiences. • Cost of connectivity may be prohibitive. • Internet connectivity strength may be inconsistent and irregular. (Berri *et al.*, 2006; Georgiev *et al.*, 2004; Rodrigues *et al.*, 2012; Zhang and Adipat, 2009)
B	**Design and development**	• Principles of instructional design should guide the design of m-learning applications to ensure that users experience deep and relevant learning. • Principles of interaction design should incorporate awareness of the user, learning management, support requirements, content and context of use. • The design of presentation methods, menus, links and mobile activities must be compatible with the devices used by the target group. • The design should include features that enhance flow such as feedback, clear rules and goals, sufficient complexity and dynamic challenge. • Learning material should be available to all users at all times. • Mobile friendliness can be fostered by minimising scrolling on a small screen and by provision for variability of browsers. • Content and format of multimedia, e.g. MP3 (audio) and MP4 (video), can create user frustration. • From a campus perspective, the faculty is challenged to embed

	Categories	m-Learning Challenges
		mobile education into campus structures, taking cognizance of potential user problems. Support of campus management is required for the achievement of a successful m-learning initiative. • Management of the LMS is dependent on the attainment of new skills by system administrators and educators. • Applications suited to smartphones. (Ally, 2009; Berri *et al.*, 2006; Cheung *et al.*, 2010a; Cochrane and Bateman, 2010; Deegan and Rothwell, 2010; Georgiev *et al.*, 2004; Herrington *et al.*, 2009; Hussain and Aslam, 2009; Mileva *et al.*, 2008; Orna, 1999; Pilke, 2004; Sharp *et al.*, 2007; Traxler, 2004; White, Gray and Porter, 2011; Zhang and Adipat, 2009)
C	**Content**	• Content cannot be directly transposed from PC-based WBL resources to m-learning environments. • Content should be presented in bite-sized nugget format. • Some learning content is unsuitable for m-learning, implying that a blended learning environment is preferable. • The adaptation of content to suit viewing on a small screen is advisable. (Costabile *et al.*, 2008)
D	**Context of use**	• Both formal and informal learning influence the m-learning experience. • Each learning experience is personal and unique, occurring in a social learning setting, at flexible times, in varying locations, and involving different combinations of stakeholders. • m-Learning comprises both technical and pedagogical perspectives creating various contexts. • Real-world situations and problems can be investigated. • Support is provided for interactive activities which are authentic. (Mandula, Meda, Jain and Kambham, 2011; Mileva *et al.*, 2008; Naismith *et al.*, 2004; Nie, 2006)
E	**Technology**	• Users should be motivated by the m-learning experience, take ownership of the approach, and personally control features of application. • Mobile technology must support specific learning activities including exploration, investigation, discussion, data capturing, building, sharing and reflection. • New pedagogical forms, rather than existing ones, must be supported by m-learning tools. • The experience of a technology-centric tool, e.g. an application based on a Moodle platform, can be either positively or negatively influenced by the learning environment. • Users can have differing initial levels of mobile skills and technology experience. • Flexible attitudes are required to assessment and content delivery. • Both users and educators would need to adapt to mobile technology.

	Categories	m-Learning Challenges
		(Cobcraft *et al.*, 2006; Corbeil and Valdes-Corbeil, 2007; Laurillard, 2007; Najafabadi and Mirdamadi, 2011; Park, 2011)
F	**Educational institution**	• The design of the curriculum, controlled traditionally by the educational institution, must incorporate mobile technology. • m-Learning activities must blend into current formal education. • The m-learning content and activities should comply with institutional policies and practices. • The activities of individual educators are likely to be influential. (Kukulska-Hulme *et al.*, 2011)
G	**Security capabilities**	• User authentication is a routine procedure for PC-based learning, however, it is not guaranteed with m-learning, and should be prioritised. • It is difficult to ensure secure Internet connectivity. (Botha *et al.*, 2009)
H	**Ethics**	• Individuals' rights to privacy and private data should be safeguarded over the Internet. • The m-learning researcher is challenged to guarantee confidentiality and anonymity. • Participants must have the right to withdraw at any stage. (Traxler, 2005b)
I	**Evaluation**	• It is difficult to consider all network conditions, as connectivity might be slow and unreliable, impacting in turn on data transfer and signal strength for a mobile user. • Usability may be poor, influencing uptake of m-learning concepts. • During evaluation, device attributes, such as battery life, intermittent connectivity and rapidly changing technology may interfere with outcomes. • The researcher is challenged by a need to capture and analyse learning within contexts and across varying contexts, e.g. physical, social, learning objectives, activities and progress, and tools. • It is challenging to measure whether learning is occurring. • Evaluation should occur in a socio-cultural environment where a "big picture" prevails, which includes both formal and informal learning opportunities. • m-Learning evaluation is complex and context-aware, calling for diverse evaluation methodologies, which could include pedagogical aspects, usability, technological feasibility (which could relate to aspects of user experience) and compatibility dimensions. • Evaluation challenges may include consideration of individual differences and a need for longitudinal studies exploring performance over time. (Orna, 1999; Park *et al.*, 2010; Semiawan and Middleton, 1999; Vavoula and Sharples, 2009; Zhang and Adipat, 2009)

J	**User Experience**	• UX evaluation measures user attitude and user experience of m-learning and should include subjective user perceptions, thus involving aspects different from traditional objective usability evaluation. Furthermore, mobile experiences can be difficult to quantify objectively. • Due to a mobile context where the user is mobile, it may not always be possible to evaluate every experience. • It should incorporate evaluation of complex hedonic factors, e.g. fun, pleasure, frustration, negativity and the measurement of more than the usefulness of pragmatic factors, i.e. more than the usual aspects of efficiency and effectiveness investigated in usability studies. • UX should be evaluated in an authentic context of use. • From an UX perspective, m-learning acceptance can be dependent on at least four factors: enhanced user satisfaction, system functionality, enriched interaction, and communication. • The context of mobile user experience (MEX), indicates that different UX evaluation factors should be considered from those considered in evaluating the UX of e-learning environments. (Botha *et al.*, 2010a; Hildreth and Kimble, 2002; Najafabadi and Mirdamadi, 2011; Väänänen-Vainio-Mattila *et al.*, 2009)

2.8 Conclusion

This chapter presented information from the literature applicable to m-learning environments.

An investigation of blended learning, formal and informal learning, problem-based learning and the digital divide created a background for m-learning and associated devices. Definitions of m-learning from various perspectives were presented and set the scene for a study of the role of mobile handheld devices in m-learning environments.

The transition of e-learning to m-learning and the relationships between them were explored, supported by the literature.

The final section of the chapter provided a deeper, richer understanding of m-learning in the context of this study, exploring contextual factors, emergent complexities and associated challenges.

This chapter played a role in answering research questions ***RQ2*** and ***RQ5*** and sets the context for Chapter 3 on the evaluation of usability and UX of m-learning environments.

CHAPTER 3: Evaluation of Usability and User Experience of m-Learning Environments

3.1. Introduction

This chapter provides introductory material for evaluating the usability and user experience of m-learning environments. Interactive, web-based m-learning environments are of limited value if they extend the face-to-face classroom through the digital delivery of content, yet do so without efficiency and effectiveness. Consequently, the expectations of learners are not matched, resulting in user experiences that are unsatisfactory.

Usability and UX are defined and discussed in Section 3.2. In the same section, a brief analysis of the relationship between usability and UX provides a basis for the evaluation of m-learning environments. The evaluation of usability and UX is discussed in general in Section 3.3, leading to Section 3.4 where the usability and UX of m-learning in particular, are outlined. Section 3.5 introduces guidelines for the evaluation of both usability and UX, culminating in the synthesis in Section 3.6 of a single framework for the evaluation of usability and UX of m-learning environments which is termed MUUX,. Section 3.7 concludes the chapter.

3.2. Usability and UX

In this section, definitions are provided for usability and UX, followed by the formulation of a relationship between usability and UX. Finally, the usability and UX of m-learning environments are discussed.

3.2.1. Usability

Conventional usability is defined by the International Organisation for Standards (ISO 9241-11, 1998) as "… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

From a technology-in-education perspective, the conventional definition of usability might not be appropriate, since the environment that is being evaluated, aims to support learning rather than task-oriented functions (Masemola and de Villiers, 2006). The

evaluation of educational environments is different from the evaluation of conventional systems because:

- Learning is a process rather than a product;
- An e-learning system is both a product (an application) and course material (the learning content);
- Efficiency cannot be assessed by rapid progress through content or activities, because learners have different learning styles.
- Cognitive errors occur as part of the learning process and, as such, are acceptable. Usability errors should be identified and eliminated, but cognitive errors cannot be regarded as instances of poor usability.

Various researchers have addressed usability of different types of e-learning applications and environments. For example, Ssemugabi and de Villiers (2010) considered web-based learning (WBL). The usability of an e-learning application, such as an educational website, includes effectiveness and satisfaction. The learner should be able to achieve learning tasks (satisfaction) and educational goals (effectiveness). The interface of the website should support, rather than hinder, learning and learning activities. Usability of a WBL environment involves the general usability of the interface; website-specific aspects, and its educational usability (Ssemugabi and de Villiers, 2010). Furthermore, the interface should be a conduit for efficient interactivity and should be transparent to the learner (Ardito *et al.*, 2005).

In addition to the conventional understanding of usability in a specific context of use, the design of interactive systems should take cognizance of the manner in which users experience the learning environment (Sharp *et al.*, 2007). This leads to the concept termed 'user experience'.

3.2.2. User Experience

Diverse views of user experience (UX) are presented in the literature, indicating that researchers have difficulty defining UX on the basis of common, conceptual foundations. According to Hassenzahl (2008: p. 1), "… a widely accepted, shared understanding of UX is still lacking".

In order to clarify what UX is, it seems prudent firstly to address what UX is not. UX is not:

- *Oriented towards technology* – UX is people-centric;
- *About isolated individual experiences* – UX is focused more on the user in context;
- *Mental analysis of task-related aspects* – UX is associated with hedonic factors;
- *Usability and associated usability metrics* – usability contributes to UX;
- *User interface design* – UX is more than designing a user-friendly interface; and
- *A focus solely on marketing concepts* – UX includes both brand awareness and overall customer experience (Roto, Law, Vermeeren and Hoonhout, 2011).

User experience is defined by the International Organisation for Standardisation in ISO FDIS 9241-210 (2010) as "… a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service".

On a basic level, UX comprises residual impressions retained by users after a sequence of interactive experiences with products and services (Reiss, 2009). Similarly, Law et al. (2009: p. 727) who propose a limited view of UX, suggest: " … according to our views, user experience focuses on interaction between a person and something that has a user interface".

Bevan (2009: p. 3), expands the conventional definition of UX, indicating that "… user experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use". The user requires more than a merely basic experience and anticipates feelings of pleasure in addition to essential UX attributes (Nielsen and Norman, 2011). Hassenzahl and Tractinsky (2006) also hold a broader view, representing UX as a combination of several aspects, including:

- Holistic, aesthetic and hedonic characteristics in addition to practical features;
- Subjective factors such as user's emotions before and after the experience; and
- Dynamic, complex, unique, situated, and transient components.

A survey of the views on UX of 275 academic and industrial researchers and practitioners indicated the complexity of UX. Survey findings showed that it was difficult to compose unambiguous lists of UX attributes and, furthermore, that the formulation of a single-phrase definition for UX was equally challenging (Law *et al.*, 2009).

In summary, findings of the survey revealed that UX:

- Aligns with ISO 9241-210:2008 providing “ requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems …”;
- Is dynamic, contextual and subjective;
- Includes everything being experienced;
- Relates to perceived benefits from a product;
- Depends on socio-cultural differences in participant attitudes;
- Involves all factors occurring before, during and after the experience;
- Links to user expectations; and
- Is characterised by system design and evaluation requirements.

Sharp *et al.* (2007) suggest that UX of interactive systems involves a user’s experiences, emotions and perception of aesthetics, together with dynamic and indefinable concepts such as satisfaction, fun, reward, frustration, motivation, and creativity support. UX may incorporate sensual gratification linked to aesthetic appeal (Desmet and Hekkert, 2007). In this way, users derive meaning from the interaction which includes the experience itself and some form of emotional response. UX is associated with products and service, the supporting team members, contextual factors such as time and location, as well as the attitude of the user (Sward and MacArthur, 2007).

3.2.3. The Relationship between Usability and UX

The relationship between usability and UX is a subject of debate. Researchers reject the notion that usability and UX are synonyms or different ways of expressing the same idea. In particular, they emphasize the subjective and dynamic nature of UX (Hassenzahl, 2008; Hassenzahl and Tractinsky, 2006). Hassenzahl and Tractinsky differentiate between a focus on product – the pragmatic quality of usability, and a focus on the user – the hedonic quality of UX. Going beyond usability, UX comprises a greater holistic overview of user interactivity with technology to encompass both pragmatic and hedonic qualities (Botha *et al.*, 2010a).

In contrast to the view of usability as a measurable, practical aspect of interactivity, Law *et al.* (2009: p. 727) suggest that UX is “ … dynamic, context-dependent and subjective … something new”.

The literature presents the relationship between usability and UX from differing yet inter-related, perspectives, as listed below. Each perspective is then elaborated in a subsection of its own:

- Usability and UX are characterized by different attributes (Hassenzahl, 2008);
- UX includes the measurable attributes of usability (Law *et al.*, 2009; Tullis and Albert, 2008);
- UX is related to usability (Botha *et al.*, 2010a; Hassenzahl and Tractinsky, 2006; Law, Vermeeren, Hassenzahl and Blythe, 2007; Moczarny *et al.*, 2012);
- UX is more than usability (Bargas-Avila and Hornbæk, 2011; Botha *et al.*, 2010a; Hassenzahl, 2008; Väänänen-Vainio-Mattila *et al.*, 2009; van Greunen, 2010);
- Usability includes UX (Bevan, 2008a); and
- UX intersects with usability (Moczarny *et al.*, 2012; Nielsen, 2011).

Usability and UX are characterized by different attributes

Hassenzahl (2008) indicates the differences that exist between the attributes of usability and UX, illustrated in Table 3–1.

Table 3–1: Comparison of usability and UX attributes (Hassenzahl, 2008)

	Usability	**UX**
A	*Pragmatic features* – includes a practical dimension which supports easier task completion.	*Hedonic features* – has an affective dimension, which contributes to positive experiences.
B	*Do-goals* – are associated with task achievement, providing a basis for traditional usability.	*Be-goals* – reflect a learner's needs.
C	*Objective qualities* – have a connection to external attributes and defined measurements.	*Subjective qualities* – associated with feelings, personal preferences, and interpretations.
D	*Persistence* – remains constant over time.	*Dynamic change* – is characterised by dynamic change that is context-dependent.
E	*Usability metrics* – are used to quantify efficiency, effectiveness and user satisfaction.	*UX metrics* – include usability criteria that are applied to evaluate hedonic and subjective aspects of UX.

UX includes the measurable attributes of usability

UX is a measure of a user's satisfaction associated with the achievement of hedonic factors such as pleasure, likeability, comfort, and trust. These attributes are difficult to measure, however, several attributes of UX can be adequately measured using usability metrics (Tullis and Albert, 2008). The quantifiable responses reflecting the performance of tasks by users are traditional usability metrics and described by Law et al. (2009) as the measurable aspects of UX.

UX is related to usability

The findings of a study by Moczarny, de Villiers and van Biljon (2012) suggest that desirable attributes of UX are supported by conformance to various usability principles such as sound navigation, good information architecture, valuable content, and functionality. The findings suggest that meaningful UX depends on pre-existing usability.

The UX Manifesto in Figure 3-1, proposed by Law, Vermeeren, Hassenzahl and Blythe (2007), illustrates UX from three perspectives, namely:

- *Principles* – defining UX;
- *Policies* – incorporating usability and UX; and
- *Planning* – evaluating UX for both academic and practical purposes.

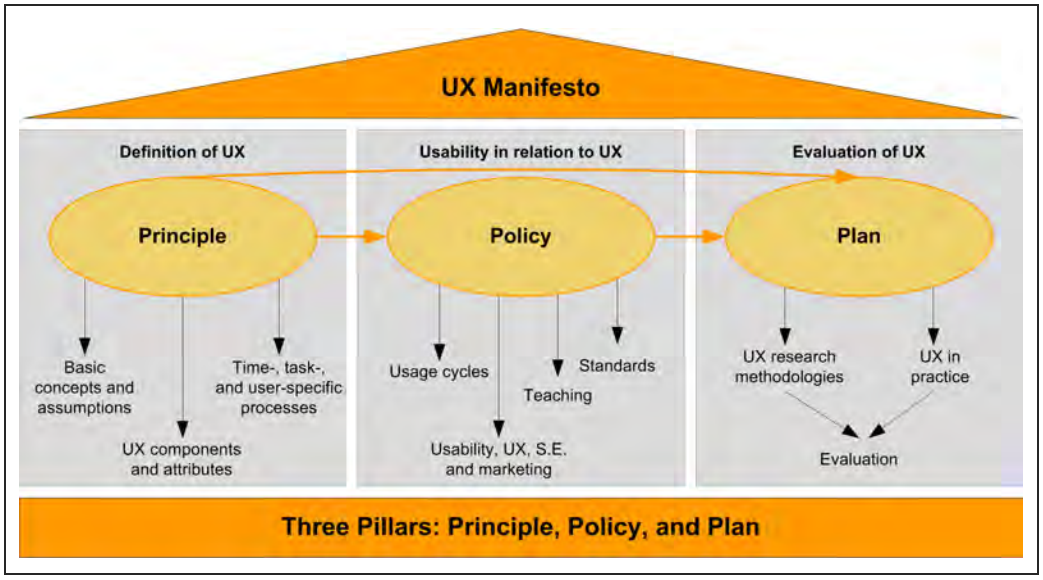

Figure 3-1: The three pillars of the UX Manifesto (Adapted from Law et al., 2007: p. 1)

From the perspective of 'Policy', Figure 3-1 depicts usability as a supportive component of UX in general, fulfilling the role of the central pillar comprising the UX Manifesto. UX features as a constituent of underlying principles, policy-making and planning.

Three high-level factors influence UX, namely, the user, the system and the context (Botha *et al.*, 2010a; Hassenzahl and Tractinsky, 2006). More specifically, UX includes the consequences of end-user interactivity, technology, and the context in which interactivity occurs. UX is an all-inclusive concept, comprising more than the practical, task-oriented interactions associated with usability. Botha *et al.* (2010a: p. 31) comment that "User Experience proposes a more holistic view of the user's engagement with interactive computing devices than what is usually taken in the evaluation of usability".

Furthermore, and particularly relevant to this study, Botha *et al.* acknowledge that for mobile interactions, usability factors do influence the mobile experience (MEX).

UX is more than usability

After an extensive review of empirical research on UX, Bargas-Avila and Hornbæk (2011) concluded that UX builds on a foundation of HCI and usability. Various other sources suggest that UX goes beyond usability and comprises more than usability (Bevan, 2008a; Botha *et al.*, 2010a; Väänänen-Vainio-Mattila *et al.*, 2009).

Hassenzahl (2008) comments that usability does not feature prominently in the definition of UX. Instead, the expansion of usability to include perceptions, needs, and feelings that are experienced by users in various changing contexts, suggests that UX is more than usability (van Greunen, 2010).

Usability includes UX

Bevan (2008b) views UX as a facet of usability and suggests that satisfaction and UX are synonymous concepts. From this perspective, UX is a subset of usability, relating to the concept of 'satisfaction' at the point of containment. Satisfaction, in this context, comprises:

- *Pragmatic satisfaction* – practical education goals, utility, functionality; and
- *Hedonic satisfaction* – personal goals, pleasure, fun, cognitive likeability, achievements, motivation and trust.

UX intersects with usability

This study adopts the approach that, whilst usability and UX share characteristics and intersect at the dimension of satisfaction, they also exhibit separate and unique features (Moczarny *et al.*, 2012; Nielsen, 2011).

3.2.4. Usability and UX of m-Learning Environments

m-Learning and Usability

Several contextual factors contribute to satisfactory usability of m-learning environments. In addition to usability of the interface of the m-learning system, a collection of contextual factors impacts usability, namely:

- *Technology* – the mobile device itself;
- *Tasks and activities* – web-based learning and pedagogical issues;
- *Environment* – contextual influences within a diverse and changing mobile environment*;* and
- *The user* – characteristics of the user culture (Coursaris and Kim, 2011).

The efficiency and effectiveness of m-learning depend on the outcome of the learner's performance of tasks using a choice of mobile handheld device within a variety of contexts. However, mobile usability is more likely to be linked to user satisfaction than to efficiency and effectiveness due to the complex nature of users' mobile experiences within unique contexts where both formal and informal learning occurs (Ji *et al.*, 2006; Jokela, 2004).

The challenges of the learning context and mobility that were introduced in Section 2.7.3, highlight that the m-learning process is dependent on the usability of the device being used by the learner (Ally, 2009; Koole, McQuilkin and Ally, 2010). The learner should be able to focus on interactive cognitive tasks, freed from the limitations of navigation, learnability, memorability, and portability.

Nielsen (2011) interchanges the terms 'usability' and 'UX', according to contexts of use. He refers to the *usability of devices* and the *UX of environments*. Satisfaction forms part of general interface usability but implies more than a checklist of easy-to-use features, incorporating instead "... a seamless merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design …". UX must ensure that the needs of clients are satisfied.

A brief view of usability of WBL sets the scene for a view of usability of m-learning. WBL, mentioned in Section 2.6.1, is distinguished from other e-learning systems since it is accessed by users via the Internet (Alessi and Trollip, 2001; de Villiers, 2005a). Websites designed for usage on PCs, should be equally viewable and usable on mobile devices.

This requirement incorporates the following challenges to users and designers of m-learning environments:

- Small screens with a variety of screen resolutions;
- Input difficulties;
- Connectivity problems;
- Delays during download efforts; and
- The context of mobile interactivity (Zhang and Adipat, 2009).

m-Learning and UX

Law *et al*. (2009) suggest that UX is characterised as an aggregate of all interactions with the user interface, namely with the product, system, services, and objects. In the context of learning, user experience comprises all experiences relating to actual learning, including associated factors such as product brands, activities, and face-to-face interaction.

Figure 3-2 provides a diagrammatic definition of UX in the context of an m-learning environment as a collection of complex interface-interactions comprising all learning experiences (Law *et al.*, 2009).

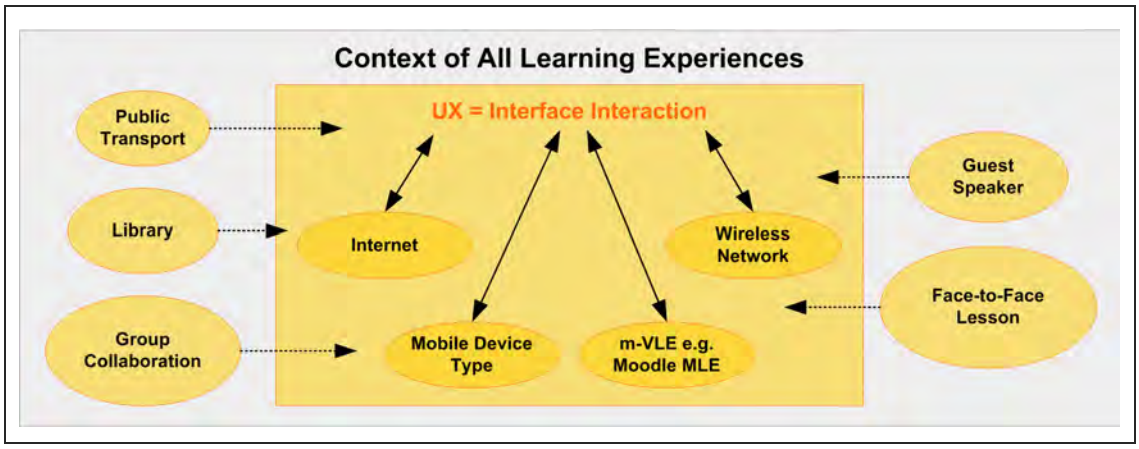

Figure 3-2: UX as interface interaction in the context of all learning experiences (Adapted from Law et al., 2009: p. 727)

The learner accesses the Internet via a mobile network, using a specific type of device. Mobile interaction is facilitated by a mobile virtual learning environment (m-VLE). External learning experiences include:

- *Learning whilst travelling* – using public or private transport;
- *Learning influenced by group activities* – collaborating in groups; and
- *Learning within the classroom environment* – experiencing face-to-face lessons.

Figure 3-2 above borrows from Law *et al.*, and applies their model of user experiences to the context of m-learning underlying this study, where a synthesized, multi-dimensional view of UX in an m-learning context is adopted. This view incorporates:

- A focus on the user and their experiences of the m-learning environment;
- The impact of both the system's characteristics and the context of use; and
- An evaluation perspective based on a post-interaction, affective response.

In summary, UX in an m-learning environment is defined by the present researcher as:

- A user's affective responses;
- A consequence of interacting with an m-learning system and evaluated after system interaction;
- Inclusive of the characteristics of the environment, devices, and context of use which are major contributors to the user's experience of the system; and
- A reflection of the user's experience and perceptions.

3.3. Evaluation of Usability and UX

In this section, the evaluation of general interactive environments is first discussed, highlighting the purpose and goals of evaluation. Thereafter, the evaluation of usability and the evaluation of UX are explored. The discussions on the evaluation of usability and UX in Sections 3.3.2 and 3.3.3 respectively address:

- Challenges of evaluation;
- Evaluation criteria; and
- Evaluation methods.

3.3.1. Evaluation of Interactive Environments

Evaluation is a process undertaken to establish whether the design of the system meets the requirements of the users. The behaviour of the system is investigated, comparing feedback from actual users against expected performance standards (Dix *et al.*, 2004).

Sharp, Rogers and Preece (2007) suggest that four factors guide evaluation, namely:

- Purpose and goals of the evaluation;
- Evaluation strategy;
- Evaluation methodology; and
- Lifecycle considerations.

Purpose and goals of evaluation

According to Dix *et al*. (2004), evaluation has a three-fold purpose:

- *The assessment of system functionality* – the extent to which the system meets users' requirements;
- *The evaluation of user experience* – the manner in which users interact with and respond to the system; and
- *Proactive troubleshooting* – the identification of potential problems users might have with the system.

Evaluation remains an important process throughout the design lifecycle, encompassing the following goals:

- To guide development and delivery of improved solutions;
- To determine potential problems and issues that need to be fixed; and
- To establish whether or not satisfactory outcomes have been achieved.

Evaluation of interactive environments is necessary to resolve problems and improve the quality of learning artefacts, enabling developers to build applications that offer greater efficiency and effectiveness and increase the likelihood of improved user experiences (Sharp *et al.*, 2007).

Evaluation strategy

Evaluation may be:

- A process of measurement – involving experts and actual users;
- Formative – on an evolving system, comprising problem solving and refinement of requirements; and
- Summative – on a functioning system, incorporating user task performance, satisfaction metrics, hedonic aspects, and assessing conformance to standards (Bevan, 2008a).

Evaluation metrics aim to predict and determine several measures, including:

- Quantified measurement of product use and feedback from the experience;
- Match to a reference standard or benchmark;
- Conformance to a set of criteria and goals associated with a model; and
- A structured design process, verifying ongoing improvement (Law, 2011).

Evaluation methodology

Evaluation may be implemented in the laboratory or as field studies in naturalistic contexts, or where real-world contexts are simulated (Dix *et al.*, 2004; Sharp *et al.*, 2007). Evaluation strategies may be based on frameworks of criteria customized in the light of the evaluation context. The selection of suitable evaluation methods plays an important part in the quality of the evaluation. Observation, surveys, interviews and formal testing in laboratories are examples of user-based methods, while inspection, cognitive walkthrough and heuristic evaluation are expert methods.

Lifecycle considerations

Sharp *et al*. (2007) indicate that evaluation should occur iteratively throughout the design process. The process starts with the formation of an initial idea, which is followed by the design of a conceptual prototype, and culminates in implementation of the final application.

Early evaluation of prototype versions may involve designers and experts or may include users in the evaluation of actual implementations. Ideally both expert analysis and user participation methods should be implemented throughout the life cycle phases (Dix *et al.*, 2004).

3.3.2. Evaluation of Usability

Interactive learning systems are evaluated for usability, investigating conformance to the standard ISO definition of usability by which efficiency, effectiveness and users' satisfaction are measured (ISO 9241-11, 1998).

This section:

- Reviews the challenges associated with the evaluation of usability;
- Proposes generic usability evaluation criteria, synthesized from the literature; and
- Describes a selection of usability evaluation methods (UEMs).

Challenges of the evaluation of usability

According to Shneiderman and Plaisant (2005), usability evaluation is challenged by several factors:

- Life cycle phases and the evaluation plan;
- The nature of the application;
- Novelty of the project;

- The expected number of users;
- A need for designers and evaluators with experience in usability evaluation strategies;
- Critical role of the interface in interactive processes;
- The budget allocated to evaluation; and
- Time constraints.

Usability evaluation should be an integral activity within the design process. Instead, it is often overlooked in the development life cycle as developers experience budget and time pressures, requiring earlier and faster delivery of products and systems. It is not uncommon for colleagues, rather than users, to perform evaluation activities (Sharp *et al.*, 2007). In this way, the full benefits associated with evaluation are not realized.

Usability evaluation is not a once-off activity. It should be performed iteratively at key milestones, applying various appropriate methods throughout the phases of an application's development life cycle (Ardito *et al.*, 2005). Effective evaluation should be cyclic and, in particular, should involve users in a multi-layered evaluation design (Taylor, 2006).

Design problems are cheaper and easier to resolve early in the development life cycle. The design of an effective usability evaluation strategy is dependent on design principles that take cognizance of context (*UX Nuggets: Thoughts and advice on usability and user experience*, 2011).

Usability evaluation criteria

Researchers use varying terminology to describe usability criteria, namely:

- Heuristics (Karoulis and Pombortsis, 2003);
- General rules of thumb (Nielsen, 1994);
- Golden rules (Shneiderman and Plaisant, 2005);
- Design rules (Dix *et al.*, 2004); and
- Guidelines and design principles (Bevan, 2005; Ji *et al.*, 2006).

Criteria for the evaluation of usability emerge from the purpose, goals and challenges of usability evaluation. They provide a framework for good design and guide development, focusing attention on a limited, yet consolidated, list of vitally important usability factors. In an educational context, Diaz (2003) suggests that evaluation criteria should:

- Establish a basis for formative evaluation to determine if the system is satisfactory, highlighting whether or not changes need to be made; and

- Provide guidance for software developers who are addressing educational requirements, i.e., the evaluation criteria can serve as design guidelines as well.

Lists of usability criteria guide the planning, design and development of learning artefacts, relative to specific contexts of use and learning outcomes. Appropriate frameworks of usability criteria may be applied with various evaluation methods at differing development stages (Ji *et al.*, 2006). Teachers and learners are consulted and their requirements are incorporated into criteria (Herrington *et al.*, 2009). Lists of criteria that are customized to suit the application being evaluated, often incorporate Nielsen's ten general interface criteria as a foundation:

- Visibility of system status;
- Match between system and the real world;
- User control and freedom;
- Consistency and standards;
- Error prevention;
- Recognition rather than recall;
- Flexibility and efficiency of use;
- Aesthetic and minimalist design;
- Help users recognise, diagnose and recover from errors; and
- Help and documentation (Nielsen, 1994).

Evaluation criteria for e-learning

In moving from the general to the particular, usability evaluation criteria must be customised or newly-generated for e-learning environments. Different kinds of e-learning applications require different evaluation criteria. This section mentions the evaluation of traditional computer-aided instruction (CAI) and web-based learning (WBL) to set the tone for establishing a platform in Sections 3.4 to 3.6 for evaluating m-learning environments.

For example, in pioneering work on evaluating CAI, Squires and Preece (1999) referred to 'learning with software' heuristics, indicating that usability cannot be divorced from learning issues. They extended Nielsen's list of criteria for general interface usability to incorporate the learning context. They adapted Nielsen's heuristics by incorporating cognitive authenticity – by which an individual develops a personal cognitive perception of concepts, and contextual authenticity – learning which takes place in specific contexts and with specific content. This led to a set of heuristics for evaluating early CAI systems,

which had formerly been evaluated by simple checklists. Squires and Preece therefore proposed the following heuristics for evaluating educational software:

- Match between designer and learner models;
- Navigational fidelity;
- Appropriate levels of learner controls;
- Prevention of peripheral cognitive errors;
- Understandable and meaningful symbolic representation;
- Support for personally significant approaches to learning;
- Strategies for the cognitive error recognition, diagnosis and recovery cycle; and
- Match with the curriculum.

The evaluation of interactive WBL environments has been investigated. This requires the formulation of web-specific criteria founded on a sound learning theory foundation. In response to this need, Ssemugabi and de Villiers (2007a, 2010) set up a framework comprising categories of criteria for evaluating WBL environments, suggesting that usability of a WBL environment can be viewed from three perspectives:

- General interface usability;
- Website-specific usability; and
- Learner-centred educational usability (Ssemugabi and de Villiers, 2010)

The present study relates to evaluation of an m-learning environment and hence needs a set of criteria that are custom-designed for m-learning. This development commences in Section 3.4 and continues in Sections 3.5 and 3.6.

Usability evaluation methods

Usability evaluation methods (UEMs) are classified in different, yet overlapping, ways.

A usability evaluation strategy depends on the planning and choice of one or more usability evaluation methods (UEMs), based on factors such as the life cycle stages of the application development (Petrie and Bevan, 2009).

According to Sharp *et al.*, (2007) UEMs fall into three categories:

- *User-based methods* – methods that involve target users, such as experiments, performance-based measurements, and user surveys via questionnaires and interviews;
- *Field studies* – for example, unobtrusive observation in a natural environment and informal interviews in users' customary activity space; and

- *Analytical techniques* – inspections by experts such as prediction-based models and the application of guidelines and principles in heuristic evaluation. These approaches also lead to the identification of usability problems.

Dix *et al.* (2004) also differentiate between UEMs designed for expert analysis and those for user participation. Expert analysis comprises analytic techniques such as cognitive walkthrough; heuristic evaluation; model-based evaluation; and the use of previous studies. User participation studies may be conducted in the field or laboratory, including techniques for observation; query; and the monitoring of physiological responses. Examples of observational techniques include "think aloud"; protocol analysis and walkthroughs. User satisfaction interviews and questionnaires are query techniques. Eye tracking and physiological measurements are achieved with specialized equipment in a HCI laboratory designed to monitor physiological responses. Remote usability involves laboratory monitoring of remotely-logged interactions. Experimental studies incorporate methods such as usability engineering and the observations of groups using video equipment.

Table 3–2 provides a categorization of UEMs, differentiating between user-based and expert-based methods, followed by descriptions of some of the methods.

Table 3–2: Categorization of usability evaluation methods
(Synthesized by the researcher from literature sources)

	Categories				
	Users				**Experts**
	Experimental evaluation *in lab*	**Query evaluation** *in lab or field*	**Observational evaluation** *in lab or field*	**Monitoring evaluation** *in lab*	**Analytic evaluation** *in lab*
Methods	• Experiment • Usability engineering • Video observations in groups	• User satisfaction questionnaire • Interviews	• "Think aloud" • Protocol analysis • Post-task-walkthrough • Usability testing in HCI lab • User testing via mobile usability testing equipment	• Videos of live interactions and re-viewing of such videos • Eye tracking • Physiological measurement • Remote usability testing with monitoring of logged interactions	• Cognitive walkthrough • Heuristic evaluation • Model-based evaluation • Review-based
	(Dix *et al.*, 2004; Moczarny *et al.*, 2012; Sharp *et al.*, 2007)				

A selection of the methods listed in Table 3–2 is outlined below:

User satisfaction questionnaires are survey instruments which are administered to participants, with little input from the researcher. The questionnaire has a structured format so as to obtain uniform data from participants. A large number of responses may be gathered and analysed effectively and efficiently (Shneiderman and Plaisant, 2005). Commercial, off-the-shelf questionnaires provide a reliable and professional solution to the design of questionnaire. However, Dix *et al.* (2004) recommend that custom-designed questionnaires should be styled to match data collection requirements:

- *General* – ethnographic data such as age, gender, and personal preferences is required;
- *Open-ended* – data incorporates loosely structured, qualitative information, for example, attitudes and opinions;
- *Scalar* – data is rated quantitatively on a Likert-type scale, where selection options may include strongly agree, agree, undecided, disagree, and strongly disagree;
- *Multiple choice* – choices are made from a list of restricted options; and
- *Ranked* – data is arranged into some form of preferential order.

Interviews may be direct and structured, where a rigid script is followed, or semi-structured, where core questions are asked, but the interviewer can also investigate interesting and unanticipated angles. Interviews can also be unstructured, open and free. Interviews are valuable in evaluation, but are also useful in early developmental phases when user preferences and requirements are gathered. Subjective responses, such as feelings, opinions and attitudes, may be explored on a deeper level, resulting in the collection of rich data. This can also be combined with observational techniques. The interview presents drawbacks as an effective UEM, because experienced interviewers are required; only qualitative data is collected; and the interview process is time-consuming. However, interviews are suitable for all phases of development and evaluation and for all types of interactive experience from snapshot studies to longitudinal studies.

Usability testing in a HCI laboratory evaluates participants' responses within a controlled setting, away from their workplace or natural environment (Dix *et al.*, 2004). Usability testing is conducted by usability specialists in laboratories that are usually equipped with sophisticated observation equipment such as audio-visual recording facilities and one-way glass. No attempt is made to establish a work-based situation,

which results in the problem of an artificial evaluation context. Specialised equipment can be used to conduct eye-tracking and to gather physiological measurements. The equipment is expensive, specialist skills are required, and the process is time-consuming (Moczarny *et al.*, 2012).

Cognitive walkthrough involves evaluators working through a sequence of steps likely to be followed by users when they interact with the system. Expert evaluators do a mental step-through of expected actions of users, providing insight into the ease with which the system is learned and used (Dix *et al.*, 2004; Shneiderman and Plaisant, 2005).

Heuristic evaluation is an inspection technique, in which expert evaluators are given a set of criteria or 'golden rules' and asked to consider how users would operate within the environment. The experts use their skills to evaluate its effectiveness and to identify deficiencies and problems (Dix *et al.*, 2004; Karoulis and Pombortsis, 2003; Nielsen, 1994; Zaibon and Shiratuddin, 2010). Heuristic evaluation (HE) is viewed as flexible, cost-effective, and relatively easy to execute. Customised lists of heuristics can be structured and applied. HE is appropriate to various development phases from initial prototype to early design evaluations (Nielsen, 2005; Shneiderman and Plaisant, 2005; Ssemugabi and de Villiers, 2010). Several expert evaluators evaluate a system, and determine violations of listed heuristics. In this way, a combined set of issues is established from a group of independent evaluations. Nielsen (2000, 2005) suggests that as few as three experts may uncover usability problems and that about 75% of all issues may be highlighted by just five expert evaluators.

UEMs that are implemented as part of this study include user satisfaction questionnaires and heuristic evaluation by experts.

3.3.3. Evaluation of UX

The evaluation of UX involves determining users' level of satisfaction in their experience with a system. This is closely related to, yet more than, the attainment of their practical goals and tasks, since it incorporates the measurement of emotional factors such as joy. It is aimed at achieving a better end product (Bevan, 2008a). UX evaluation should measure how users feel about the use of a system (Obrist, Roto and Väänänen-Vainio-Mattila, 2009).

This section describes the challenges associated with the evaluation of UX; proposes generic evaluation criteria synthesized from literature sources; and surveys a selection of UX evaluation methods (UXEMs).

Challenges of the evaluation of UX

Evaluation of UX incorporates challenges based on:

- The many and varying definitions of UX;
- Subjective attributes of UX which are difficult to measure;
- The inadequacy of checklists of subjective UX factors;
- A need for awareness by designers of users' requirements;
- The inclusion of both anticipation and actuality of users' experiences; and
- The diversity of attributes of UX requiring measurement

(Bevan, 2009; Law, 2011; Law *et al.*, 2009; Obrist *et al.*, 2009; Väänänen-Vainio-Mattila *et al.*, 2009).

The differing definitions of UX introduced in Section 3.2.2 complicate efforts to achieve the evaluation of UX. In addition, it is challenging to measure hedonic and 'fuzzy' factors, such as emotions, pleasure and joy (Law, 2011; Obrist *et al.*, 2009), occurring side-by-side in interactive applications (Law *et al.*, 2009). Whereas a list of usability metrics may be used to evaluate certain attributes of UX (Hassenzahl, 2008), lists of subjective UX criteria are aimed at user needs and wants, providing inadequate measures of UX (Law *et al.*, 2009). The improvement of users' experiences requires that designers are aware of and able to design for users' needs and values (Väänänen-Vainio-Mattila *et al.*, 2009). Additionally, both the expectation of the experience and the actual experience need to be evaluated for UX, differentiating between the evaluation of usability and UX (Bevan, 2009).

Bevan (2008a) indicates that the attributes of UX that should be prioritized and measured are diverse, including:

- The goals of users;
- Criteria considered important to the users;
- Risks associated with not meeting goals of a particular learning context;
- Validation requirements of the evaluation strategy;
- The establishment of baseline measures;
- Goals aligned to the design of the interface, evaluated early in the development life cycle by experts; and

- Monitoring requirements in context after implementation and during use.

Criteria for the evaluation of UX

A review of literature sources highlights various criteria for the evaluation of UX. The numerous aspects addressed, have been consolidated by the researcher into seven categories of criteria:

- Emotional issues;
- Contextual factors;
- User-centricity;
- Social value;
- Needs;
- Appeal, engagement and hedonism; and
- Satisfaction

(Beccari and Oliveira, 2011; Hassenzahl, 2008; Jones *et al.*, 2006; Law *et al.*, 2009; MacCallum and Kinshuk, 2008; Pirker and Bernhaupt, 2011; Sharples, Arnedillo-Sanchez, Mildrad and Vavoula, 2009b; Smith and Cook, 2009; Väänänen-Vainio-Mattila *et al.*, 2009; Zaibon and Shiratuddin, 2010).

UX evaluation methods

A conventional UEM may be appropriate for measuring a quality of UX. However, a toolkit of evaluation methods for UX differs from a collection of UEMs, because subjective data is being gathered. Roto *et al.* (2011: p. 12) suggest that user experience methods (UXEMs) measure specific qualities of UX, commenting that "… the choice of an evaluation instrument or method depends on the experiential qualities at which the system is targeted, as well as the purpose of the evaluation …".

A review of UXEMs, collected from academia and industry, indicates the existence of more than 101 UXEMs (Law, 2011). Despite the repertoire of methods described by Law, the choice of methods must reflect the nature and context of the particular study. In order to measure UX in a persuasive manner, Law (2011) indicates that UXEMs must measure both quantitative and qualitative parameters, providing meaningful outcomes.

Roto *et al.* (2009) indicate that categorization of UXEMs provides a convenient and efficient way to match the best method to the purpose of the evaluation. A selection of UXEMs is categorized in Table 3–3, in a similar way that usability evaluation methods were categorized in Table 3-2. The table is followed by descriptions of some of the methods.

Table 3–3: Categorization of UX evaluation methods
(Synthesized by the researcher from literature sources)

	Categories			
	Users			Experts
	Field Studies	Lab Studies	Surveys	
Methods	• Affective diaries • Differential Emotions Scale	• Psychophysiological measurements of affect • Emocards • Observation	• AttrakDiff™ • User satisfaction questionnaires • Interviews • Self-Assessment Scale	• Group-based expert walkthrough • Heuristic evaluation • Perspective-based inspection
	(*All About UX*, 2012; Bargas-Avila and Hornbæk, 2011; Bevan, 2009; Hassenzahl, Burmester, Koller, Ziegler and Szwillus, 2003; Law, 2011; Vermeeren, Law, Roto, Obrist, Hoonhout and Väänen-Vainio-Mattila, 2010)			

The UEMs in Section 3.3.2 include user questionnaires, interviews, and heuristic evaluation, all of which are suited to the evaluation of UX as well and are relevant to evaluating more than one category. They are also included in Table 3-3 as UXEMs.

Methods with a narrow scope have been omitted from Table 3–3. A limited selection of the methods listed in Table 3–3 is now discussed:

Affective diaries are implemented in field studies where participants wear sensors that monitor their physical responses such as heart rate. Participants also write notes on mobile devices. Such logging of activities requires expensive equipment and intensive, time-consuming post-evaluation analysis of both quantitative and qualitative data (*All About UX*, 2012).

Differential Emotions Scale (DES) may be implemented as a field, laboratory or survey method for snapshot or episode evaluations.

Psychophysiological measurements of affect record emotional responses to fleeting experiences of the system being evaluated. Responses include skin perspiration levels and heart rate. This UXEM has drawbacks. It is not suited to longitudinal studies; it requires trained evaluators and expensive equipment; and only reports quantitative data (*All About UX*, 2012).

Emocards provide a non-verbal report in the form of flash cards on which participants match emotional responses to pictures. This UXEM is suitable for laboratory, field or online studies. The method is not in questionnaire format so must be administered one at a time, gathering qualitative data only (*All About UX*, 2012).

AttrakDiff™ is a semantic differential method including both pragmatic and hedonic questionnaire items. Participants evaluate features of UX by indicating a response along

a continuum to pairs of words situated at two extremes from each other, for example "Interesting" versus "Boring". The method is suitable for snapshot or longitudinal studies; field or laboratory; and online survey or questionnaire. It is a reflective technique producing only quantitative data. Actual experiences are not evaluated, however post experience feedback is provided. Highly trained evaluators are not required (Bargas-Avila and Hornbæk, 2011; Hassenzahl *et al.*, 2003).

Self-assessment scale (SAM) has a questionnaire format, suited to all study types and to snapshots and episodes of evaluation. The questionnaire records emotional responses triggered by events. The method is easy and quick to implement and may suit differing contexts. SAM has limitations, including the subjectivity of the scale and the fact that it only measures quantitative data (Bevan, 2009).

Group-based expert walkthrough is implemented prior to the actual usage of a system. An evaluation is performed in a laboratory setting by groups of expert users. Experts walk through the system, endeavouring to uncover potential problems, highlighted by 'what-if' questions. Only qualitative data is gathered. Effectiveness of this UXEM depends on the choice of participants. However, it is easy and inexpensive to administer and requires no technical skills or expensive equipment (*All About UX*, 2012).

Perspective-based inspection is conducted in a laboratory by a team of experts during a single evaluation episode. The method gathers many qualitative perspectives, but requires the expertise of trained UX experts (*All About UX*, 2012).

Whilst the UXEMs discussed here provide a background, they were not implemented as part of the research design and methodology of this study. However, some of the features influenced the design and format of the heuristic evaluation by experts and user satisfaction questionnaires, described in Section 3.3.2.

3.4. Evaluation of the Usability and UX of m-Learning Environments

This section examines the challenges and complexities associated with evaluation of m-learning contexts, after which various approaches to the evaluation of usability and UX of m-learning are explored.

An m-learning system which delivers excellent educational content, but which is unusable, is unlikely to culminate in satisfactory UX responses. Similarly, an interactive m-learning environment that is engaging and exciting, but which does not result in

meaningful learning, does not achieve its purpose. Evaluation of the usability and user experience of m-learning environments aims to uncover and measure these attributes and to remedy barriers to user acceptance of technology-enhanced learning, delivered by mobile handheld devices.

A satisfactory m-learning evaluation should be rigorous; efficient in terms of cost, time and resources; ethical; proportionate; appropriate; consistent; authentic and aligned (Traxler, 2007b). However, literature sources indicate that evaluating m-learning environments can be challenging and complex. The vagueness of an m-learning environment contrasts with the clarity of a face-to-face classroom learning engagement (Vavoula and Sharples, 2009).

An m-learning context is unpredictable and changing. Numerous inherent factors, such as physical setting, social setting, learning objects and outcomes, learning methods, learning activities, and learning tools, are likely to influence strategies for the evaluation of m-learning.

Although there are several approaches to the relationship between evaluating usability and evaluating UX, this dissertation adopts the strategy – supported by the literature – that a single holistic framework for the evaluation of m-learning environments can comprise both usability and UX dimensions.

3.4.1. Challenges and Complexities of the Context of m-Learning Evaluation

Challenges

In addition to the challenges associated with the evaluation of usability and UX in general (Sections 3.3.2 and 3.3.3, respectively), the evaluation of m-learning in particular may be challenging, due to:

- The difficulty of differentiating the many varying contexts of m-learning;
- The challenge of discerning whether or not learning has occurred;
- The emergence of new and undefined research ethics associated with m-learning;
- The limitations of mobile devices together with a shift of focus from m-learning to the mobile learner;
- A need for incorporation of m-learning at several levels: personally, socially and institutionally; and
- The characterization of m-learning as being both formal and informal (Vavoula and Sharples, 2009).

Coursaris and Kim (2006) emphasize that the contextual factors associated with mobile usability and shown in Figure 3-3, namely, the user, the actual environment, aspects of technology, and the nature of the task being evaluated, present challenges for evaluation.

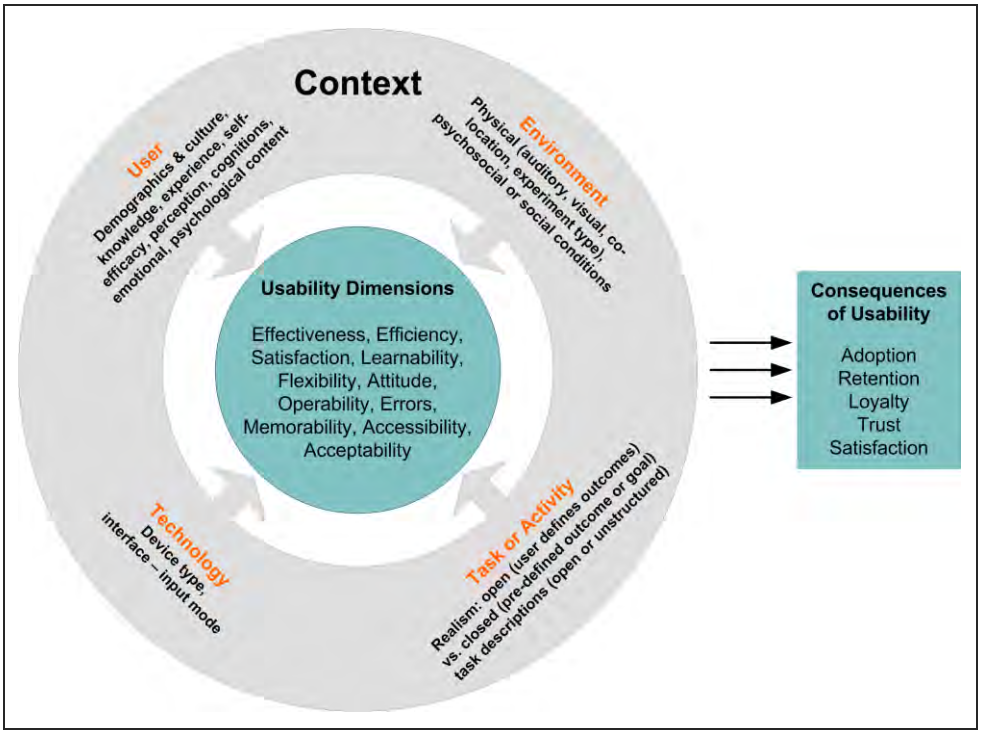

Figure 3-3: Usability, context dimensions and m-learning (Adapted from Coursaris and Kim, 2006: p. 3)

Complexities

Evaluation of usability of m-learning environments is likely to be complex for several reasons. Firstly, there is no ready-made approach that fits every m-learning scenario. For example, Coursaris and Kim (2011) note the absence of a usability evaluation framework for mobile computing environments, calling for urgent attention to this gap. Secondly, there cannot be absolute assurance that the identity of the learner interacting with the m-learning environment is valid. Thirdly, each interaction context is unique. An evaluation framework would need to be customizable for every type of interaction. Finally, traditional usability evaluation falls short of m-learning evaluation requirements which include the user's personal perception and experience of the application environment.

3.4.2. Approaches to the Evaluation of Usability and UX of m-Learning Environments

The relationship between usability and UX was addressed earlier in Section 3.2.3, where the perspectives of various researchers were presented. The diverse approaches to the evaluation of usability and UX of m-learning environments are impacted by these differing, yet inter-related views. Literature sources provide a variety of approaches, suggesting that:

- Evaluation of usability and of UX occur in parallel to each other;
- The evaluation of UX incorporates usability factors;
- Usability and UX require separate evaluations;
- Aspects of usability and UX are evaluated as combined attributes; and
- Evaluation of usability and of UX is achieved by the application of a single framework of selected criteria

(Bevan, 2008a, 2009; Botha, Herselman and van Greunen, 2010b; Law *et al.*, 2009; Petrie and Bevan, 2009; Roto *et al.*, 2009; Sharp *et al.*, 2007; Tullis and Albert, 2008).

These approaches are discussed in greater detail in the sections that follow.

Evaluation of usability and of UX occur in parallel to each other

Whilst acknowledging the commonality of satisfaction to usability and UX, Petrie and Bevan (2009) introduce criteria suited to usability and to UX, treated as separate concepts, and evaluated in parallel. They suggest the use of separate psychometrically-designed questionnaires, based on rating scales and designed for goal-oriented purposes. Bevan (2009) suggests that evaluation of usability and UX are concerned with different criteria. However, he acknowledges that in some circles, the two sets of concerns may be combined as UX factors.

The evaluation of UX incorporates usability factors

Law *et al.* (2009) include the traditional usability metrics as measurable aspects of UX. Similarly, Botha *et al.* (2010b) suggest that UX subsumes pragmatic usability issues, incorporating usability factors into a goal-oriented, evaluation strategy for UX.

Usability and UX require separate evaluations

From this perspective, an evaluation strategy is dependent on what needs to be evaluated. For example, the evaluation requirements for the evaluation of usability of

functional tasks within a web browser differ from the evaluation needs for UX-associated motivation to complete a task. Usability evaluation seeks to highlight problems from an objective and functional perspective, focusing on pragmatic goals such as efficiency and effectiveness (Shneiderman and Plaisant, 2005). On the contrary, UX evaluation focuses on the measurement of satisfaction and of subjective experiences like fun, perception, enjoyment, frustration, and beliefs (Bevan, 2008a). For this reason, Sharp *et al.* (2007) propose a two-fold approach to the evaluation of interactive systems, suggesting separate usability evaluations and UX evaluations.

Aspects of usability and UX are evaluated as combined attributes

Findings by Roto *et al.* (2009) suggest that methods for evaluation of usability and UX are different as dissimilar parameters are being evaluated. However, they express interest in the emergence of mixed methods evaluations where both pragmatic and hedonic aspects are combined.

Evaluation of usability and of UX is achieved by the application of a single framework of selected criteria

According to Tullis and Albert (2008), it is neither practical nor feasible to list and detail all the categories and criteria that might be relevant for every usability and UX evaluation. This view suggests a requirement for the customization of categories of criteria, designed in accordance with the m-learning system being evaluated.

The present researcher adopts the view that it is preferable in this study to construct a single, holistic evaluation framework, where categories of criteria for usability and UX are specifically formulated for the evaluation of an m-learning context.

3.5. Foundations for the Construction of the Evaluation Framework

Various approaches to the evaluation of usability and UX were outlined in the previous section, which addressed the challenges and complexities associated with the evaluation of usability and UX. In this study, the evaluation of usability and UX is achieved by the application of a single framework of selected categories of criteria for the evaluation of usability and UX of m-learning environments (MUUX). The relationship between usability and UX evaluation factors is depicted diagrammatically in Figure 3-4.

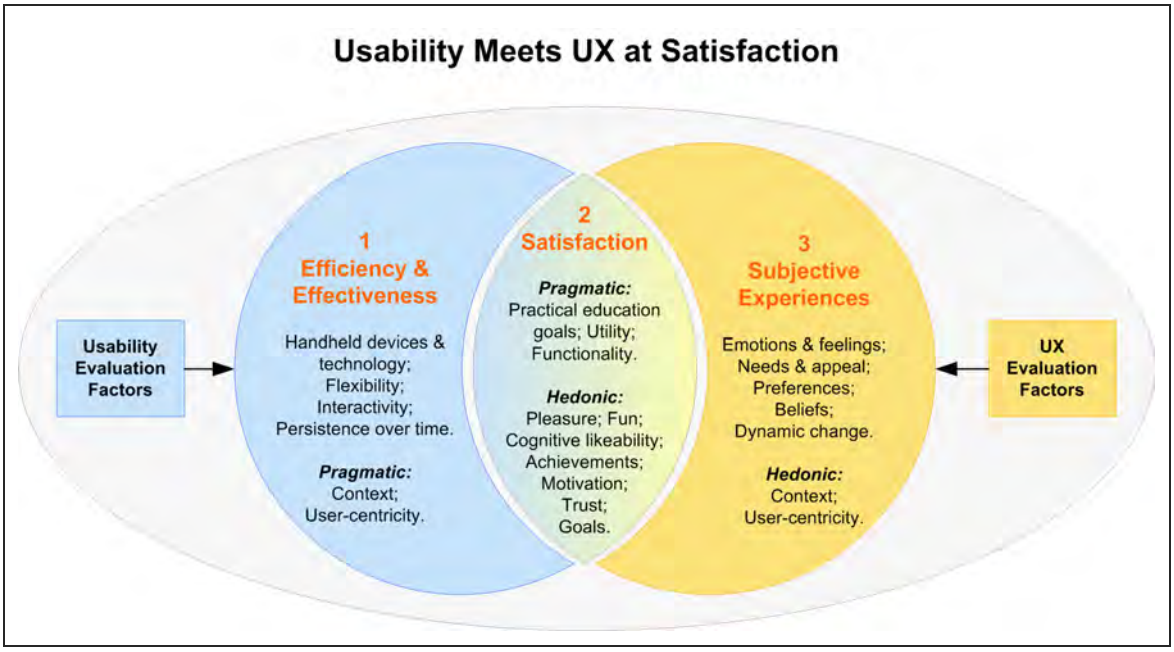

Figure 3-4: Perceived relationship between usability and UX evaluation factors (Synthesized by the researcher)

Three mutually exclusive groups of attributes emerge, comprising: 1 – effectiveness and efficiency, 2 – satisfaction, and 3 – subjective experiences. In addition, Figure 3-4 exhibits three dimensions which influence the evaluation strategy and hence the structure of MUUX. These dimensions are:

- *Interdependence* – good usability is likely to manifest as positive UX and conversely, poor usability could translate into unacceptable UX;
- *Intersection* – context, user-centricity and satisfaction are common to usability (pragmatic) and UX (hedonic); and
- *Independence* – independent and unique factors exist for usability and UX, respectively.

The upcoming sections show the development of the MUUX Framework, which incorporates the dimensions illustrated in Figure 3-4. To establish a reference point upfront and to set the overall scene, all the categories and criteria of MUUX are listed in Table 3-4, prior to the actual explanation of their development. This also contributes to answering ***RQ2***:

What categories and criteria should be included in a usability and UX evaluation framework for m-learning environments?

Table 3–4: Synthesized framework of criteria for the evaluation of usability and UX

MUUX: A Framework of Categories and Criteria for the Evaluation of Usability and UX of m-Learning Environments
Category 1: General Interface Criteria 1 Visibility of system status 2 Match between the system and the real world 3 Learner control and freedom 4 Consistency and adherence to standards 5 Error prevention, in particular, prevention of peripheral usability-related errors 6 Recognition rather than recall 7 Aesthetics and minimalism in design 8 Recognition, diagnosis and recovery from errors 9 Help and documentation
Category 2: Website-specific Criteria 10 Simplicity of site navigation, organisation and structure 11 Relevance of site content to the learner and the learning process 12 Easy to access information 13 Content is both suitable and of a high quality 14 System is simple and easy to use, called easiness 15 Material is of a high quality, i.e. videos and digitisation
Category 3: Educational Criteria 16 Clarity of goals, objectives and outcomes 17 Effectiveness of collaborative learning 18 Cognitive error recognition, diagnosis and recovery 19 Feedback, guidance and assessment
Category 4: m-Learning Criteria 20 Handheld devices and technology 21 Contextual factors (pragmatic) 22 User-centricity (pragmatic) 23 Flexibility 24 Interactivity
Category 5: UX Criteria 25 Emotional issues 26 Contextual factors (hedonic) 27 User-centricity (hedonic) 28 Social value 29 Needs 30 Appeal 31 Satisfaction

Table 3–4 indicates that MUUX comprises five categories, including a total of 31 criteria for evaluating interface, website-specific, educational, m-learning and UX factors, respectively. The format of this framework was influenced by several issues, which are explained in Section 3.6. Figure 3-5 at the end of the chapter, provides a diagrammatic synopsis of the construction of MUUX.

3.6. Construction of the MUUX Framework

The construction of the MUUX Framework of categories of criteria for the evaluation of usability and UX of m-learning environments was influenced by several issues, including:

- Justification for a single framework;
- Shared evaluation guidelines;
- Generic framework as a suitable starting point;
- Criteria for the evaluation of usability of m-learning environments;
- Evaluating user satisfaction;
- Criteria for the evaluation of UX of m-learning environments; and
- Adjustments to the generic model.

These issues are discussed in the seven subsections that follow.

3.6.1 Justification for a Single Framework

The decision to incorporate both usability and UX into one holistic, evaluation framework was informed by literature sources, introduced in Section 3.4.2.

3.6.2 Shared Evaluation Guidelines

The premise in this research study suggests that e-learning and m-learning have factors in common. Hence, this study on evaluating m-learning contexts takes cognizance of guidelines for the evaluation of usability of interactive, web-based learning environments which are also suitable for m-learning, as both types of environments are enabled by browser-based digital technology. These guidelines include:

- *General interface factors* – usability of interactive interfaces of e-learning and m-learning environments may be determined on the basis of the heuristics formulated by Nielsen (2005, 2011);
- *Website-specific issues* – both types of environment are dependent on effective use of browser-based technology (MacCallum and Kinshuk, 2008; Ssemugabi, 2006); and
- *Pedagogical considerations* – education and the transmission of knowledge should be grounded in sound learning theory (de Villiers, 2005a; Kukulska-Hulme, Sharples, Milrad, Armedillo-Sanchex and Vavoula, 2009; Squires and Preece, 1999).

Since many criteria are common to both WBL and m-learning, the guidelines above led the researcher to select the Ssemugabi and de Villiers (2010) model for evaluating the usability of WBL environments as a starting point for certain categories of the present evaluation framework. The next sections show, category by category, how the MUUX Framework was generated.

3.6.3 Generic Framework as a Suitable Starting Point

The categories of criteria for evaluating usability of web-based learning environments synthesized by Ssemugabi and de Villiers (2007a; 2007b; 2010), comprises three categories of general interface, website-specific, and educational criteria, as illustrated in Table 3–5.

Table 3–5: Summary of categories and sub-categories for the evaluation of usability of WBL environments (Ssemugabi and de Villiers, 2010)

Model of Categories and Criteria for the Evaluation of Usability of WBL Environments
Category 1: General Interface Criteria • Visibility of system status • Match between the system and the real world • Learner control and freedom • Consistency and adherence to standards • Error prevention, in particular, prevention of peripheral usability-related errors • Recognition rather than recall • Flexibility and efficiency of use • Aesthetics and minimalism in design • Recognition, diagnosis and recovery from errors • Help and documentation
Category 2: Website-specific Criteria • Simplicity of site navigation, organisation and structure • Relevance of site content to the learner and the learning process
Category 3: Educational Criteria • Clarity of goals, objectives and outcomes • Effectiveness of collaborative learning • Level of learner control • Support for personally significant approaches to learning • Cognitive error recognition, diagnosis and recovery • Feedback, guidance and assessment • Context meaningful to domain and learner • Learner motivation, creativity and active learning

3.6.4 Criteria for Usability of m-Learning Environments

It is essential that evaluation guidelines specific to the evaluation of m-learning environments should be included. Although Sharples (2009a) suggests that Nielsen's ten heuristics are adequate for evaluating mobile device usability, Nielsen asserts that the number of individual criteria emerging for mobile usability has risen from 86 to 210 (Nielsen, 2011). Furthermore, Vavoula and Sharples (2009) recommend that specific m-learning criteria be combined with general guidelines for mobile device usability and foundational learning factors into a customised list of usability criteria.

In addition to the three categories for evaluating usability introduced in Table 3–5, literature sources provide specific guidelines for the usability of m-learning applications. These are given in Table 3–6.

Table 3–6: Criteria for Category 4: m-Learning Criteria
(Synthesized by the researcher from literature sources)

Category 4: m-Learning Criteria
• ***Handheld devices and technology*** The technology, the device capability, interface, input mode, and system capabilities are optimally used; and communication channels are provided (Cochrane, 2006; Coursaris and Kim, 2006; Karoulis and Pombortsis, 2003).
• ***Contextual (pragmatic)*** Physical, visual, and auditory environment; nature of the task or activity; fixed or adjustable goals; characteristics of the working environment; context awareness (Coursaris and Kim, 2006; Göker and Myrhaug, 2008; Herrington *et al.*, 2009; Kroeker and Ally, 2005; Kukulska-Hulme and Traxler, 2007; Savolainen, 2010; Sharples *et al.*, 2005; Smith and Cook, 2009; Traxler, 2010b; Zaibon and Shiratuddin, 2010).
• ***User-centricity (pragmatic)*** Information is easily accessible; experimentation and exploration are possible; user requirements have been specified; self-sufficiency is supported; material is presented in clear learner-centred format; the system is open to everybody; online access is available to all learners, focus is enhanced - learners spend longer times doing tasks, learning content is suitable and of high quality (Coursaris and Kim, 2006; Göker and Myrhaug, 2008; Herrington *et al.*, 2009; Karoulis and Pombortsis, 2003; Savolainen, 2010; Smith and Cook, 2009).
• ***Flexibility*** An adaptable environment has been created; lesson information can be viewed in any order; the system conforms to ubiquity requirements – can be used anytime and anywhere (Coursaris and Kim, 2006; Smith and Cook, 2009; Storey, Phillips, Maczewski and Wang, 2002).
• ***Interactivity*** Navigational fidelity; multimedia components are appropriate' multiple kinds of exercises have been provided; both synchronous and asynchronous communication is provided; system is simple and easy to use – called easiness; collaboration with others occurs; happens in varying ways; lesson material is of a high quality application (Karoulis and Pombortsis, 2003; Kroeker and Ally, 2005; Smith and Cook, 2009; Zaibon and Shiratuddin, 2010).

The criteria outlined in Table 3–6, are categorised as:

- Handheld devices and technology;
- Contextual factors (pragmatic);
- User-centricity (pragmatic);
- Flexibility; and
- Interactivity

(Cochrane, 2006; Coursaris and Kim, 2006; Göker and Myrhaug, 2008; Herrington *et al.*, 2009; Karoulis and Pombortsis, 2003; Kroeker and Ally, 2005; Kukulska-Hulme and Traxler, 2007; Savolainen, 2010; Sharples *et al.*, 2005; Smith and Cook, 2009; Storey *et al.*, 2002; Traxler, 2010b; Zaibon and Shiratuddin, 2010).

Sub-criteria of "*Category 4: m-Learning Criteria*" are detailed in Chapter 5, Research Design and Methodology.

3.6.5 Accommodating User Satisfaction

Although the ISO 9241 (1998) definition of usability includes satisfaction as a factor to be evaluated in a specified context of use, Bevan (2009) suggests that improved user satisfaction implies the achievement of both pragmatic and hedonic goals, thus equating user satisfaction to UX. In addition, UX includes the anticipation of the experience, the experience itself and post-experience perceptions. In this way, 'user satisfaction' encompasses a much wider concept than the satisfaction associated with usability, which results from task completion.

This study adopts the approach of Bevan, incorporating criteria for the evaluation of pragmatic satisfaction throughout the usability evaluation categories. Although usability and UX do overlap at the aspect of satisfaction, MUUX makes provision for hedonic criteria within its UX category i.e. hedonic aspects of satisfaction are included in the '*Satisfaction*' criterion of Category 5: UX Criteria, which is detailed in Section 3.6.6.

3.6.6 Criteria for UX of m-Learning Environments

In addition to presenting criteria for evaluating the usability of m-learning environments, literature sources provide guidelines for evaluating the UX of m-learning environments.

These criteria contribute to Category 5, UX Criteria and are summarised in Table 3–7.

Table 3–7: Criteria for Category 5: UX Criteria
(Synthesized by the researcher from literature sources)

Category 5: UX Criteria
• ***Emotional issues*** Affect, emotive factors, excitement, interest, attitude, fun, joy, well-being, beliefs. (Beccari and Oliveira, 2011; Jones *et al.*, 2006; MacCallum and Kinshuk, 2008; Sharples *et al.*, 2009b; Smith and Cook, 2009; Zaibon and Shiratuddin, 2010)
• ***Contextual (hedonic)*** User knowledge, user experience and goals, flexibility, time, situation, individual needs. (Law *et al.*, 2009; Pirker and Bernhaupt, 2011; Sharples *et al.*, 2009b)
• ***User-centricity (hedonic)*** Support for personal approaches to learning, personalised learning format, ability to personally customise material, personal growth potential. (Sharples *et al.*, 2009b)
• ***Social value*** Social self-expression, media sharing, synchronous and asynchronous interaction. (Väänänen-Vainio-Mattila *et al.*, 2009)
• ***Needs*** Autonomy, competence, relatedness, stimulation, security, competition. (Hassenzahl, 2008; Sharples *et al.*, 2009b; Väänänen-Vainio-Mattila *et al.*, 2009)
• ***Appeal*** New impressions, curiosity, insights, visual power, audio interactivity, aesthetic factors. (Pirker and Bernhaupt, 2011)
• ***Satisfaction*** Pleasure, fun, cognitive likeability, trust, achievements, motivation, goals. (Beccari and Oliveira, 2011; Bevan, 2009; Law *et al.*, 2009; Roschelle, 2003; Sharples *et al.*, 2009b)

Table 3–7, lists several criteria for the evaluation of UX, incorporating:

- Emotional issues;
- Context (hedonic);
- User-centricity (hedonic);
- Social value;
- Needs;
- Appeal; and
- Satisfaction

(Beccari and Oliveira, 2011; Bevan, 2009; Hassenzahl, 2008; Jones *et al.*, 2006; Law *et al.*, 2009; MacCallum and Kinshuk, 2008; Pirker and Bernhaupt, 2011; Sharples *et al.*, 2009b; Smith and Cook, 2009; Väänänen-Vainio-Mattila *et al.*, 2009; Zaibon and Shiratuddin, 2010).

3.6.7 Adjustments to the Generic Model

General interface factors, browser technology and pedagogical issues underlie interactive WBL environments and are relevant to m-learning. However, some customization for the m-learning context was needed to extend the two criteria in Category 2 of Table 3-5 to the six criteria in Category 2 of MUUX, as shown in Table 3-4.

Four additional criteria were added to Category 2, Website-specific Criteria, namely:

- Easily accessible information
- Content is both suitable and of a high quality;
- System is simple and easy to use, called easiness; and
- Digitised multimedia material, such as videos and podcasts, is of a high quality

(Coursaris and Kim, 2006; Herrington *et al.*, 2009; Karoulis and Pombortsis, 2003; Smith and Cook, 2009; Storey *et al.*, 2002; Zaibon and Shiratuddin, 2010).

Several other adjustments made to the generic WBL evaluation model (the Ssemugabi and de Villiers Model in Table 3–5), are reflected below in Table 3–8.

Table 3–8: Adjustments to the model of Ssemugabi and de Villiers, 2010

WBL Model Ssemugabi and de Villiers (2010) Table 3–5	**MUUX Framework Figure 3-5**
From Category 1	**To Category 4**
• Flexibility and efficiency of use	• Flexibility
Flexibility is a key factor for m-learning environments, not just for the usability of interactive web-based interfaces (Coursaris and Kim, 2006; Smith and Cook, 2009; Storey *et al.*, 2002).	
From Category 3	**To Category 4 and 5**
• Level of learner control • Support for personally significant approaches to learning	• User centricity (pragmatic) • User centricity (hedonic)
The success of m-learning depends to a large extent on the attitude to learning; practical involvement; and the personal perceptions of users (Coursaris and Kim, 2006; Göker and Myrhaug, 2008; Herrington *et al.*, 2009; Karoulis and Pombortsis, 2003; Law *et al.*, 2009; Pirker and Bernhaupt, 2011; Savolainen, 2010; Sharples *et al.*, 2009b; Smith and Cook, 2009).	
• Context meaningful to domain and learner	• Contextual factors (pragmatic) • Contextual factors (hedonic)
The influence of context is complex and specifically relevant for m-learning (Coursaris and Kim, 2006; Göker and Myrhaug, 2008; Herrington *et al.*, 2009; Kroeker and Ally, 2005; Kukulska-Hulme and Traxler, 2007; Savolainen, 2010; Sharples *et al.*, 2005; Smith and Cook, 2009; Traxler, 2010b; Zaibon and Shiratuddin, 2010).	
• Learner motivation, creativity and active learning	• Satisfaction
User experience reflects levels of satisfaction with the m-learning environment, attainment of goals and sense of achievement (Beccari and Oliveira, 2011; Law *et al.*, 2009; Roschelle, 2003; Sharples *et al.*, 2009b; Väänänen-Vainio-Mattila *et al.*, 2009).	

Table 3–8 demonstrates how certain items from the WBL Model on the left were renamed and moved to two new categories in the MUUX Framework on the right, namely, Category 4, m-Learning Criteria and Category 5, UX. Justification for each adjustment, based on literature, is provided.

3.6.8 Final MUUX Framework

Figure 3-5 below provides the culmination of the construction of the MUUX Framework, based on Tables 3-4 to 3-7. Dotted orange lines and arrows illustrate the manner in which criteria from the Ssemugabi and de Villiers Model (on the left hand side) were renamed and merged into the MUUX framework (centre). Teal-coloured arrows highlight the incorporation of the two new categories, Category 4: m-Learning Criteria and Category 5: UX Criteria and the additional website-site specific criteria.

MUUX does not cover all the factors/aspects presented in Table 2.4., but focuses on those most appropriate to m-LR. The MUUX evaluation framework is presented in Section 5.6 of Chapter 5. It is an appropriate component of the Research Design and Methodology Chapter, because it served as the enabling mechanism of the DBR research design that facilitated the iterative evolution of m-LR through its various stages.

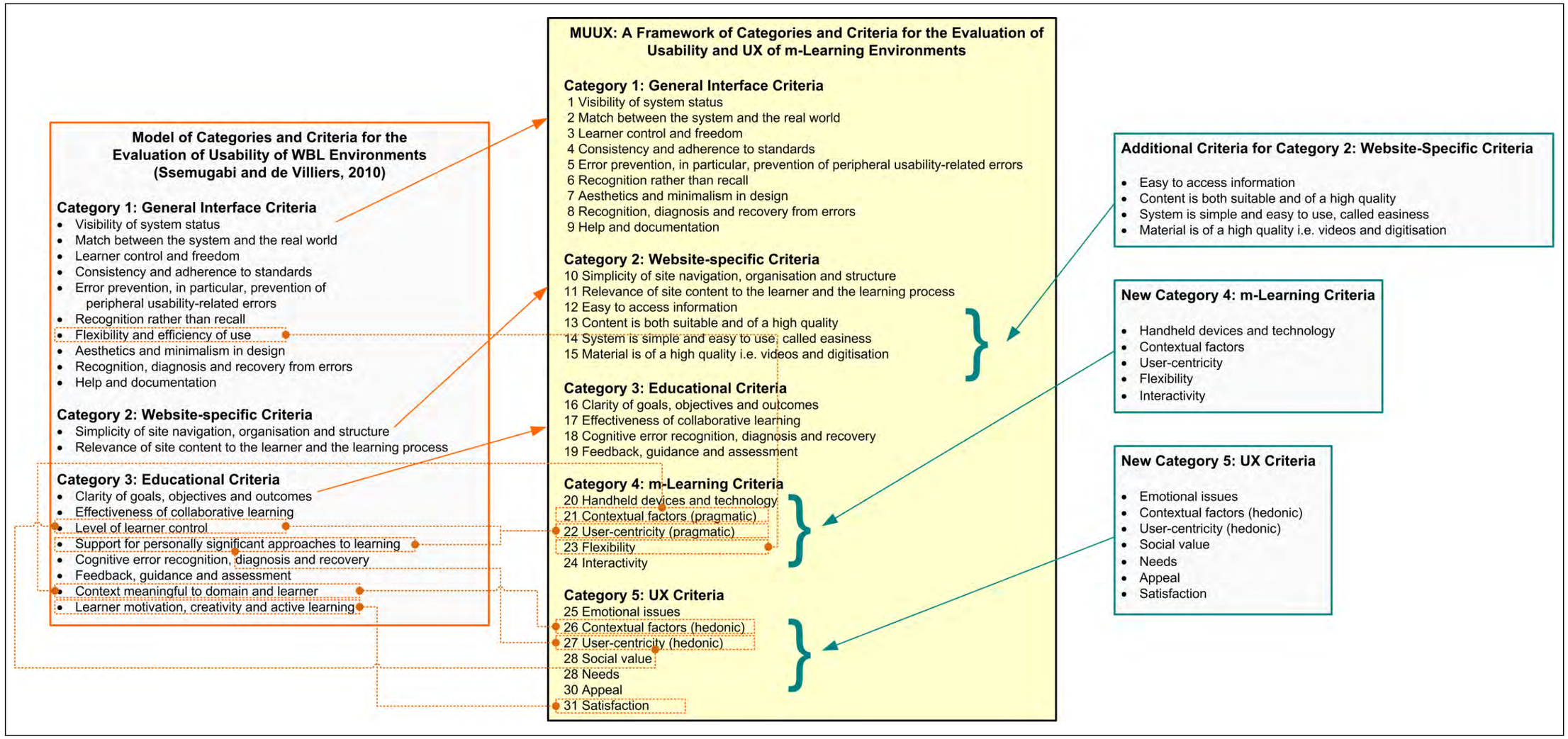

Figure 3-5: Finalised MUUX Framework
(Synthesized by the researcher from literature sources)

3.7. Conclusion

This chapter introduced concepts associated with the evaluation of usability and user experience for m-learning environments. On the basis of the literature, initial generic definitions for usability and UX were proposed, establishing common, as well as unique, features. This discussion culminated in the present researcher's definition of UX in an m-learning environment.

A brief and general analysis of the relationship between usability and UX provided a basis for the evaluation of m-learning environments in particular. Challenges, criteria, and methods associated with the evaluation of usability and UX, together with an outline of various approaches to the evaluation of usability and UX, formed the background for the synthesis and finalisation of a single framework of criteria for the evaluation of usability and UX of m-learning environments (MUUX).

CHAPTER 4: Development of the m-Learning Environment, *m-LR*

4.1 Introduction

This chapter explains the development of the custom-designed prototype m-learning environment, *Mobile Learning Research, m-LR*, the application that underlies the study. Section 4.2 provides background information together with justification and requirements for developing *m-LR*. In Section 4.3, aspects of the planning, design and development strategy for interactive, blended learning environments are discussed, including guidelines for the development of m-learning environments. The general outline for virtual learning environments in Section 4.4 incorporates a specific comparison of Moodle 1.9 and Blackboard 7.0. Finally, Section 4.5 describes the development and features of *m-LR*. The chapter concludes with Section 4.6.

4.2 Background

A real-world problem was outlined in Section 1.1, namely, that learners in an undergraduate software engineering (SE) class were required to work together in teams on specific tasks associated with group projects. The researcher observed a lack of interest in, and boredom with, traditional face-to-face SE lessons; curriculum content; and the prescribed textbook.

Whilst some learners in one of the cohort groups had both laptops and smartphones, all the learners in both cohort groups associated with this study, owned mobile devices. Several learners also used tablet PCs in class. The researcher observed that some learners, who travelled lengthy distances to reach the campus, seemed to be very dependent on their mobile devices and proficient in the use of mobile technology. At times they did not attend lectures but worked on their collaborative projects, communicating with each other via their mobile devices.

It seemed feasible to the researcher that an informal, goal-specific m-learning environment could extend the classroom to the learners' mobile devices. An interactive and participatory m-learning environment could serve two important purposes. Firstly, achievement of practical activities and project work could be enhanced. Secondly, a

better attitude might be realised towards the theoretical aspects of the software engineering curriculum.

4.2.1 Justification

Goal-driven mobile applications focus on providing mobile services and solutions for specific purposes (Oinas-Kukkonen and Kurkela, 2003). By introducing a focused, yet informal, aspect of m-learning to an existing classroom, a more satisfying and motivating learning experience could result, leading to improved learner attitude (Jones *et al.*, 2006). Jones *et al*. offer possible reasons why a more positive learning experience can be achieved after introduction of m-learning into a classroom, namely:

- The appeal of informal learning activities;
- Control and ownership of the use of a personal mobile device;
- Support for interactive communication and collaboration between learners;
- Association by the learner of the device as a fun-filled experience;
- Contextual and timeous access to relevant information; and
- Portability.

These observations guided the decision to custom-design a prototype m-learning environment for delivery by mobile devices.

4.2.2 Requirements

The mobile environment aimed to extend the face-to-face learning environment to an informal, blended learning model. Learners should be able to access the m-learning environment via any laptop or mobile device with Internet connectivity. Learner-oriented services for anywhere-anytime completion of specific activities associated with the SE curriculum should support the following activities:

- Finding definitions in a SE glossary;
- Doing a revision quiz;
- Accessing and downloading course content in PDF, video or audio file format;
- Interacting on SE project requirements via social networking sites;
- Researching SE topics on the Internet; and
- Communicating and collaborating both synchronously and asynchronously on group project deliverables via a chat room, discussion forum and wiki.

Section 4.3 outlines planning, design and development processes.

4.3 Planning, Design and Development

The success of a blended learning model depends on several factors, including:

- Planning;
- Design and development processes;
- Educational technology;
- An effective VLE;
- Appropriate online material; and
- Reflection and interactivity by learners; and
- Ability of both teachers and learners to adapt to a new way of teaching and learning (Cheung *et al.*, 2010b).

The first two factors are particularly relevant to this section and are now dealt with in detail.

4.3.1 Planning

According to Cheung *et al.* (2010b), guidelines for the planning of an interactive, blended learning environment incorporate:

- An initial course overview;
- A plan for a re-designed view of lessons that are delivered via m-device;
- Creation of lesson content;
- Preparation of resources, e.g. video, audio, and slide shows;
- Customisation of a learning management system; and
- Ongoing evaluation of the environment.

Planning improves the quality of interactive, technology-enhanced, multimedia environments (Alessi and Trollip, 2001). The planning process includes the establishment of requirements; the analysis of issues that might materialise; and consideration of likely interactive activities (Dix *et al.*, 2004).

An m-learning environment is complex and incorporates a variety of challenges, which have been highlighted and detailed in Section 2.7.3, Table 2-4.

In the context of the design and development of *m-LR*, the envisaged m-learning environment needed to make provision for the following issues:

- *Devices* – implement the environment for desktop PC and for all mobile device types; mobile platforms and operating systems;
- *Design and development* – focus on learner-centred design and development associated with specific SE activities;
- *Content* – customize a selection of SE instructional components for m-learning use;
- *Context of use* – anticipate both tethered-to-desktop and on-the-move requirements;
- *Technology* – include informal Web 2.0 features with access to relevant SE websites via the Internet;
- *Educational institution* – provide optional and unofficial learner support in a blended learning environment which extends the classroom;
- *Security capabilities* – include secure username and password login functionality;
- *Ethics* – establish hierarchical user rights and privileges for learners, experts, and the researcher; and
- *Evaluation* – design and develop the environment in an iterative and cyclical manner, enabling corrections and amendments to *m-LR* resulting from feedback by learner and expert evaluation.

The planning of a technology enhanced learning (TEL) environment is not an isolated stage in a software engineering lifecycle strategy, such as the waterfall methodology (Sommerville, 2011). Planning is also an important feature of a design and development methodology which is iterative, formative and ultimately summative.

4.3.2 Design and Development

The quality of the solution is related to the extent to which developers follow recommended design and development guidelines. In addition, ongoing evaluation of the environment during planning, design and development phases, supports review, adjustment and improvement of the designed artefacts (Dix *et al.*, 2004).

This section addresses:

- User-centred design (UCD);
- Learner-centred design and development processes (LCD); and
- Guidelines for the design and development of m-learning environments.

User-centred design

A UCD approach to development of interactive environments is advocated by Sharp, Rogers and Preece (2007), who suggest that soliciting users' feedback during early iterations of interaction design of any product ensures a more usable end-result. The focus of UCD is traditionally the typical user of the system being designed and developed. The success of interactive systems depends on iterative cycles of formative design and development, centred on the user and the users' needs.

UCD is characterized by three principles, namely:

- Users are active components within the design process, which incorporates both the user and the tasks the user conducts in a particular domain of expertise;
- The design process is iterative, basing the ultimate design on the evolution of preceding designs; and
- Effective usefulness and usability is a final goal of the design strategy, indicating the significance of ongoing evaluation throughout the iterations

(Mao, Vredenburg, Smith and Carey, 2005; Sharp *et al.*, 2007).

Life cycle models aim to provide the discipline and structure needed for the development of interactive software products so that they are usable (Sharp *et al.*, 2007). Oinas-Kukkonen and Kurkela (2003) emphasize the importance of evaluation with real users (who in the present research are learners) throughout the design and development cycles. They indicate that the level of satisfaction expressed by users when they interact with the system may reflect perceived effectiveness and quality of navigating through the system, leading to positive user experience of the system.

The cycle for human-centred design processes (ISO 9241-210:2010, 2010) is based on explicit understanding of users, their tasks and the environments in which they operate. It further states that users should be involved throughout the processes of design and development.

Learner-centred design and development processes

In an educational technology domain, the user of the learning environment may be the administrator, the educator, the designer, the developer or the learner.

According to Zaharias and Poulymenakou (2006), learner-centred design borrows from and extends human-centred design concepts, and has as its focus the aim of improving the effectiveness of learning. This section emphasizes and extends several of the points in the preceding section on UCD, but does so in the context of e-learning systems, based

explicitly on learner-centred design (McLoughlin and Luca, 2002; Quintana, Krajcik and Soloway, 2000).

The learner-centred design model applied in this research, is illustrated in Figure 4-1 below, and has been adapted from the ISO (2010) model. It includes the following four processes (**P1** – **P4**):

P1 *The analysis and specification of learner context* – characteristics, goals and tasks;

P2 *Specification of requirements* – from the learners' perspective;

P3 *Achievement of formative solutions* – on the basis of preceding iterations; and

P4 *Evaluation of designs* – testing by learners and experts against design criteria.

Figure 4-1 below illustrates design and development processes for interactive learning systems.

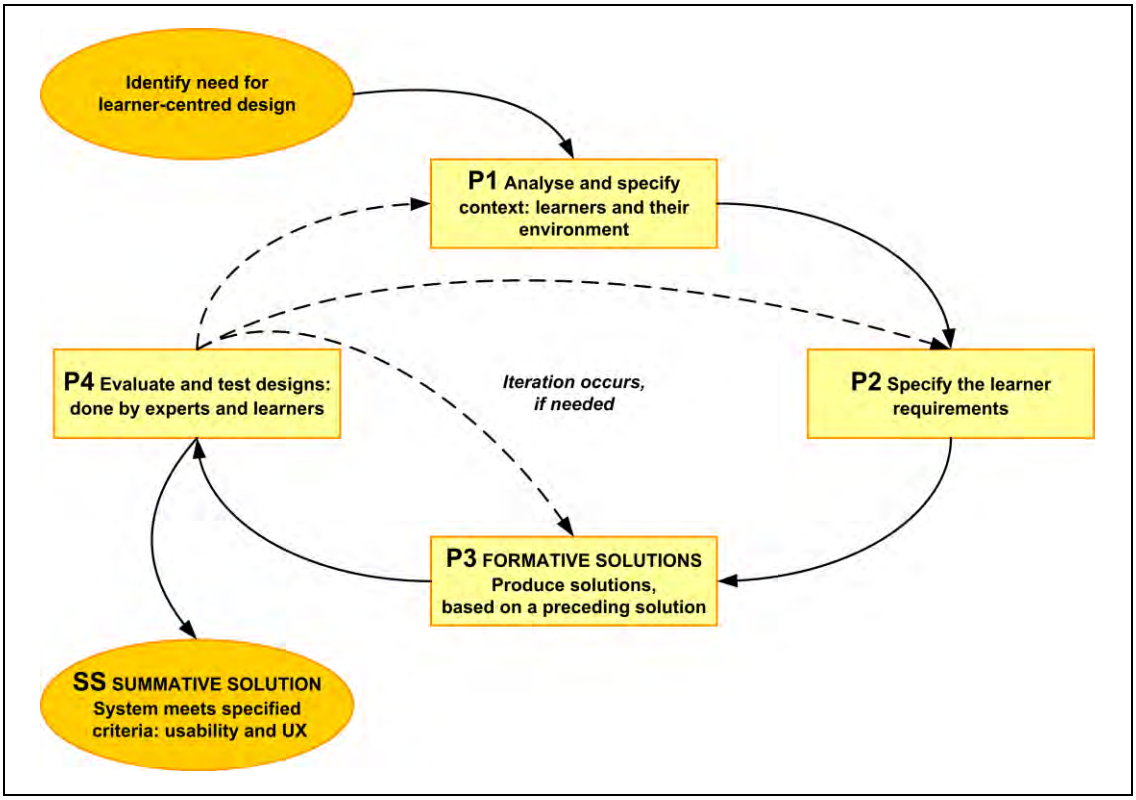

Figure 4-1: Learner-centred design and development processes for interactive systems (Adapted from ISO 9241-210, 2010)

The iterative design and development cycle in Figure 4-1, starts with identifying the needs of learners. The context of a real-world problem is analysed and specified, considering both the learners and their environment (**P1**). Requirements are determined

in process **P2**. In **P3**, a formative solution is developed, considering any previous solution. Thereafter, experts and learners test and evaluate designs (**P4**).

When specified evaluation criteria are met, the designer may conclude that satisfactory levels of usability and UX have been reached. The cycle culminates when a final summative version of the application has been achieved, namely **SS** in Figure 4-1, which suggests that iterations involving additional formative solutions may be undertaken, if necessary.

Guidelines for the design and development of m-learning environments

Usability and UX of an m-learning environment may improve if developers take cognizance of key guidelines for design and development. Oinas-Kukkonen and Kurkela (2003: p. 5) suggest that, in addition to usability and functionality, several design principles contribute to good mobile applications, suggesting that: " … a good mobile service provides additional value for the user and is fast and natural to use".

From the literature sources provided, as included in Table 4-1, the researcher synthesized a generic framework of guidelines for the design and development of m-learning environments, eight categories (A – H) of guidelines are presented, namely:

- **A** Design and development strategy;
- **B** Mobile specifications;
- **C** User-centricity;
- **D** Ease of use;
- **E** Content;
- **F** Context;
- **G** Virtual learning environments; and
- **H** Web 2.0 tools.

Table 4-1: Design and development guidelines for an m-learning environment (Synthesized by the researcher from literature sources)

Guidelines	Literature Sources
A: Design and development strategy	
• Provide interactivity via UCD;	Göker and Myrhaug (2008)
• Involve a contribution to the design by experts;	Bri, Garcia, Coll and Lloret (2009)
• Improve the environment by implementing iterative design phases;	Göker and Myrhaug (2008)
• Include specifications for the design of mobile environment, course content, resources, pages, fonts, and graphics.	Low and O'Connell (2006)

B: Mobile specifications	
• Provide accessible information whilst moving to and from campus, around campus, in the classroom, and from the outside world; • Focus more on classroom content and m-learning processes than on technology; • Link tasks and activities to course content;	Oinas-Kukkonen and Kurkela (2003) Sharma and Kitchens (2004) Landers (2002) Pinkwart, Hoppe, Milrad and Perez (2003) Parsons, Ryu and Cranshaw (2006)
• Ensure support for networked learning, seamlessness, and social networking;	Landers (2002) Parsons, Ryu and Cranshaw (2006) Sharma and Kitchens (2004)
• Include accessibility via all devices, especially all mobile options; • Aim for compatibility with a wide range of media, e.g. file formats, video, and audio; • Incorporate security and privacy features.	Low and O'Connell (2006) Landers (2002) Parsons *et al.*(2006) Naismith, Lonsdale, Vavoula and Sharples (2004) Pinkwart *et al.* (2003)
C: User-centricity	
• Guide the design of the interface, involving users; • Consider users' use and understanding of terminology and ways in which they like to navigate; • Incorporate usefulness and simplified experiences from a user's perspective; • Allow customisation and adaptability for each user's preferences, needs and abilities; • Include features that enhance motivation.	Sharp *et al*. (2007) Oinas-Kukkonen and Kurkela (2003) Oinas-Kukkonen and Kurkela (2003) Oinas-Kukkonen and Kurkela (2003) Botha, van Greunen and Herselman (2010c)
D: Ease of use	
• Focus on simplicity and flexibility; • Aim for easy assimilation on the part of the learner; • Present only the essential data and information, applying consistency and using short words; • Make provision for evaluation of the attributes of usability; • Implement fluent navigation; • Facilitate access to important information.	Oinas-Kukkonen and Kurkela (2003) Sharma and Kitchens (2004) Bri *et al.* (2009) Low and O'Connell (2006) Low and O'Connell (2006) Low and O'Connell (2006) Bri *et al.* (2009)
E: Content	
• Include self-contained 'chunks' of educational material; • Provide content in accessible and compact formats, presented in multiple ways; • Accommodate communication and collaboration needs and capabilities of learners; • Ground the content in teaching and learning.	Low and O'Connell (2006) Low and O'Connell (2006) Sharma and Kitchens (2004) Bri *et al.*(2009) Botha, van Greunen and Herselman (2010c) Bri *et al.*(2009) Cheung (2009)

F: Context	
• Take cognizance of mobility levels, usage mode, time and place of learning, budget, and network connectivity factors; • Plan for *in-situ* learning associated with new, individual and team skills with social interaction; • Incorporate a selection of screen and keyboard/touch options, operating systems, device types, network configurations, and learner characteristics.	Botha *et al.* (2010c) Oinas-Kukkonen and Kurkela (2003) Parsons *et al.* (2006) Botha *et al.* (2010c)
G: Virtual learning environments	
• Ensure that the environment reflects academic vision and offers relevant curriculum content, providing training and support for staff and learners; • Resolve copyright and intellectual property issues;	Cheung (2009) Levy (2003)
• Provide value to the learner in a rapid and natural way via successful mobile services;	Bri *et al.* (2009) Oinas-Kukkonen and Kurkela (2003)
• Consider that digital technology has changed learner views of writing the "old-fashioned" way, differing from "pencil and paper" lessons; • Offer uniform access to a variety of information sources, e.g. websites, glossaries, reading material, relevant YouTube videos, other learner opinions.	Lai, Yang, Ho and Chant (2007) Pinkwart *et al.* (2003) Bri *et al.* (2009) Pinkwart *et al.* (2003)
H: Web 2.0 tools	
• Extend the learner's classroom experience; • Include podcasts, blogs, microblogs, wikis, and social networking sites (SNSs); • Emphasize the need for planning due to the technical nature of implementing of aspects of Web 2.0 social networking applications within an online educational technology program; • Facilitate communication and collaboration via various synchronous (chat rooms) and asynchronous interactivity (discussion forums).	Ebner (2009) Ebner (2009) Ebner and Schiefner (2008) Lockyer and Patterson (2008) Minocha and Thomas (2007) Safran (2008) Lockyer and Patterson (2008) Jones (2010) MacCallum and Kinshuk (2008) Minocha and Thomas (2007)

Planning, design and development concepts associated with interactive learning environments, have been discussed in this section, leading to Section 4.4 where virtual learning environments (VLEs) are introduced.

4.4 Virtual Learning Environments

4.4.1 Terminology

Communication and collaboration tools are widely used in higher and university education environments to extend the face-to-face classroom experience, giving rise to

the increased popularity of web-based education systems (Romero, Ventura and Garcia, 2007). Various terms are used in the literature for electronic learning systems. The terminology conveys subtle differences between them. Some of the forms are:

- *VLE* – virtual learning environment;
- *CMS* – content management system;
- *LMS* – learning management system; and
- *LCMS* – learning content management system (Denev, Totkov, Doneva and Kasakliev, 2007; Giroux, 2011).

Table 4-2 reflects distinctions between these four kinds of environment, highlighting selected attributes, namely: purpose; target users; role in training and classroom management; collaboration; event scheduling; content creation; customization of test questions; and delivery of learning material.

Table 4-2: Comparison of VLE, CMS, LMS and LCMS
(Synthesized by the researcher from Denev et al., 2007; Giroux, 2011)

	VLE	CMS	LMS	LCMS
Purpose	Software tools that facilitate learning experiences, aimed at course delivery via a website, e.g. Blackboard, Moodle, Sakai, Blackboard Vision (formerly WebCT)	Administration of online content, publication of webzine and blog e.g. Dotclear, Drupal, Joomla, Moodle, WordPress	Supervision of learners: enrolment, tracking records of performance, provision of learning material, e.g. Blackboard Vision (formerly WebCT), Moodle, Sakai	Suite of software applications that enable many developers to collaborate, co-develop and deliver course content and reusable learning objects, e.g. Claroline, Ganesha, Moodle
Target users	University and college tutors, lecturers, teachers, learners	Online authors, publishers, content developers	Administrators, educators, learners	Content developers, educational technology project managers
Role played in training and classroom management	Support for a blended learning context	Concerned with content management	Focused on activity management	Specialising mostly in course content and structure manipulation
Collaboration	Between lecturers, tutors, teachers, learners	Between authors, publishers, developers	Between learners and administrators	Between developers and project managers

Event scheduling	Yes	No	Yes	No
Content creation	Functionality for novice developers	Resource specialization	Activity management	Focus on teamwork
Customization of test questions	Yes	Yes	No	Yes
Delivery of learning material	Yes	Yes	No	Yes

Whether the digital learning platform is referred to as a VLE, CMS, LMS or LCMS, the terminology implies the same concept, namely, a platform enabling electronic access to an e-learning environment.

4.4.2 Comparison of Moodle 1.9 and Blackboard 7.0

Moodle, Blackboard, and WebCT are regarded as comparable examples of VLEs implemented in higher education environments (Cheung, 2006). WebCT (now known as Blackboard Vision) was acquired by Blackboard in 2006, with an understanding that the WebCT brand would be gradually phased out. For this reason, WebCT has been excluded from the comparison of LMSs and VLEs incorporated in this study.

According to Unal and Unal (2011), Moodle is implemented within higher education and university environments in over 100 countries, with more than 45,000 deployments in over 45 languages. More than 60% of colleges and universities in the USA, listed by Forbes.com, are using Blackboard (Athanassopoulos, Katsikarelis and Papaioannou, 2012).

Moodle 1.9 and Blackboard 7.0 have similar features, including:

- Restricted access;
- Customizability;
- Synchronous and asynchronous communication;
- Discussion forums;
- Quizzes and tests; and
- The ability to link to external websites (Skillspark eLearning Ignited, 2009).

However, differences are also apparent. Blackboard is commercially available; distributed as reputable, proprietary closed system software; licensed by annual fees; and utilised by higher education institutions, world-wide. Moodle, on the other hand, is Free Open Source Software (FOSS), which is a web-based learning and course

management system available under the GNU Public License. Relative to Blackboard, Moodle is reputed to offer superior pedagogical capabilities and functionality (Cato, 2009).

Bri et al (2009) indicate that whilst Blackboard consists of a suite of products for e-learning, transactional processing and e-commerce, certain features of Moodle are not readily available via Blackboard, namely:

- Creation of content in online mode using HTML;
- Learner peer reviews;
- Self-assessment of submitted activities;
- Learner journals; and
- Embedded glossary.

Table 4 3 compares the two citing literature sources that contribute to the comparison of the strengths and weaknesses of Moodle 1.9 and Blackboard 7.0. Several strengths are highlighted, namely:

- *For Moodle 1.9* – platform compatibility; content management; total cost of ownership; flexibility; customization; maintenance; hosting; reputation; and
- *For Blackboard 7.0* – platform compatibility; mobile capability; user database; product support; reputation.

In addition, several weaknesses emerged, including:

- *For Moodle 1.9* – mobile capability; product support; customization and maintenance; and
- *For Blackboard 7.0* – content management; total costs of ownership; customization; maintenance; flexibility; adaptability.

Table 4-3: Comparison of Moodle 1.9 and Blackboard 7.0, illustrating strengths and weaknesses (Synthesized by the researcher from literature sources)

VLE	Strengths	Weaknesses
Moodle 1.9	• *Platform compatibility*: suited to Windows, Mac, Linux environments; • *Content management*: provision for course developer, teacher as well as learner creation and control; • *Total cost of ownership*: limited due to the benefit of FOSS software; • *Flexibility*: associated with adaptability and ease of use; • *Customization*: controlled by teachers, developers and learners; • *Maintenance*: provided iteratively by learner involvement of many online Moodle partners and contributors; • *Hosting*: supported by many FOSS suppliers of hosting services at no or minimal cost; and • *Reputation*: a worldwide community of developers and users.	• *Mobile capability*: limited to third party plugins such as Mobile Moodle (MOMO) and Mobile Learning Engine (MLE); • *Product support*: dependent on limited and dispersed program support; • *Customization and maintenance*: requires prioritization and co-ordination of modifications by faculty; suggests necessary processes for the evaluation of additional customisation; and calls for additional technical training of skilled personnel for installation and maintenance.
Blackboard 7.0	• *Platform compatibility*: created for desktop and virtual PC, enterprise-wide requirements; • *Mobile capability*: incorporated with suite of product offerings; • *User database*: implemented within international, higher education and university environments; • *Product support*: based on licence agreements; and • *Reputation*: established by international credibility.	• *Content management*: geared for teacher maintenance; • *Total cost of ownership*: increased by expense of licence fees with negative financial implications; • *Customization*: controlled by Blackboard Inc. developers; • *Maintenance*: linked to annual licence fees based on new product features and modifications; and • *Flexibility and adaptability*: limited by contractual agreements.
(Blackboard, 2012; Bri *et al.*, 2009; Cheung, 2006; Costa, Alvelos and Teixeira, 2012; Dougiamas, 2010; Kaya, 2012; Kumar, Gankotiya and Dutta, 2011; Lam and Duan, 2012; Machado and Tao, 2007; Skillspark eLearning Ignited, 2009)		

4.4.3 Evaluation of Usability and UX of Moodle

This section pays particular attention to Moodle, which is the underlying platform for *m-LR*. Reasons for the choice of Moodle are outlined in the next section.

According to Savolainen (2010), Moodle has been built on the basis of sound usability principles and has been evaluated for usability and UX by rigorous application of heuristics. Furthermore, the e-learning platform Moodle is learner-centric and benefits from heuristic evaluation by both experts and users to ascertain conformance to criteria for usability and UX. An expert heuristic evaluation of Moodle was conducted by investigating compliance to Nielsen's ten heuristics by Martin, Martinez, Revilla, Aguilar, Santos and Boticario (2008) who represented the ten heuristics for general interface design by 300 usability checkpoints and found that Moodle had several non-compliant dimensions. They pointed out that conducting usability evaluation of the Moodle environment is challenging for several reasons:

- It is required to be highly flexible to enable customization;
- Users are diverse, including developers, administrators, authors, learners and tutors;
- Moodle is implemented for many different purposes; and
- It is difficult to capture pedagogical effectiveness, the main functionality of a VLE.

In a study conducted by Machado and Tao (2007) the usability and UX of Moodle were surveyed in parallel by instructors and learners. Moodle was found to satisfy the following criteria: high availability, usability, scalability, and interoperability. Learners indicated a preference for Moodle when comparing it to Blackboard.

Savolainen (2010) suggests that the evaluation of usability and UX is an issue in OSS communities as: resources are seldom allocated to it; ownership is not taken for it; and there is a limited availability of documentation. Contrarily, designers and developers get feedback from real users in the OSS community thus supporting UCD. The iterative nature of OS design and development is likely to be founded on sound usability and UX principles.

4.4.4 A Custom-designed m-Learning Environment based on Moodle 1.9

After comparing the strengths and weaknesses of Moodle 1.9 and Blackboard 7.0, a decision was made by the researcher to custom-design an m-learning environment for this study, based on Moodle 1.9.

Key factors from Table 4 3 support this decision, including:

- *Platform compatibility* – facilitating mobile technology via mobile add-ons for Moodle;
- *Total cost of ownership* – supporting the development of the research environment on a limited budget;
- *FOSS technologies* – providing hosting services, Moodle software; and XAMP (XML, Apache, MySQL and PHP); and
- *A community of developers for Moodle implementation* – enabling easy customization and maintenance with online support.

The decision to implement Moodle was strengthened by a brief review of some recent studies of implementations of the Moodle platform in university and higher education environments, namely:

- Academics from USA, Malaysia, Turkey, Cyprus, Portugal, Spain and Nigeria, reported a preference for the implementation of Moodle in university contexts (Ahmad, BawaChinade, Gambaki, Ibrahim and Ala, 2012; Bri *et al.*, 2009; Costa *et al.*, 2012; Fola-Adebayo, 2010; Kaya, 2012; Unal and Unal, 2011); and
- Researchers from Greece, Hong Kong and Mauritius suggested favourable support for Moodle in higher education environments (Athanassopoulos *et al.*, 2012; Lam and Duan, 2012; Pudaruth, Moloo, Mantaye and Nbibi, 2010).

4.4.5 Moodle VLE and Mobile Capability

Moodle VLE

Moodle is a free, e-learning platform (Ayoola *et al.*, 2008), developed by Martin Dougiamas at Curtin University, Australia. The acronym 'Moodle' is reputed to stand for Modular Object-Oriented Dynamic Learning Environment. The word 'moodle' also describes a lazy movement. The process represents enjoyment whilst browsing around lazily, with the possibility of achieving insight and creativity (*AllWords.com*, 2012).

Moodle was developed primarily for a Linux environment, but is also frequently customized for Windows operating systems. It is installed within a web browser, along with a prerequisite bundle of technologies, commonly referred to as XAMP, comprising:

- *Extensible Markup Language (XML)* – provides a format for encoding human- and machine-readable documents for the Internet;

- *Apache web server software* – supports language interfaces such as PHP (*The Apache Software*, 2012);
- *MySQL* – provides open source, database functionality with Structured Query Language (SQL) features (*MySQL*, 2012); and
- *PHP, a server-side scripting language* – facilitates development of dynamic web pages (The PHP Group, 2012).

Moodle is accessible over the Internet and may be hosted in several ways. Firstly, it may be hosted on the web server of the educational institution. However, this option may be infeasible due to policy and security restrictions of the institution's web server. An alternative hosting opportunity is provided by companies offering subscription-based web hosting services. However, research projects connected to the development of prototypes for emerging educational technology may experience budgetary constraints. A free hosting service might be preferable for research purposes. Limited webhosting functionality is offered at no charge by FOSS distributors of Moodle software. Figure 4-2 depicts *GoToNames (2012)*, formerly known as LimeDomains (2010), which provides this free webhosting service; the Moodle software; and access to XAMP.

Figure 4-2: GotoNames - free webhosting service, Moodle software, access to XAMP
Available at http://apps.gotonames.com/moodle-hosting

Figure 4-2 provides the Moodle hosting page of the GoToNames website which includes the *Install Moodle* option. Moodle is categorised as a content management application, within the *Application Categories* menu.

Moodle supports the creation of online learning sites by educators enabling effective communities of learners to be created (Dougiamas, 2010). A basic Moodle instance includes:

- *A welcoming front page* – offering customizable login options;
- *Categorized courses* – associated with enrolment options;
- *Course content* – consisting of topics, resources, and activities;
- *Role allocation with designated privileges* – based on customizable requirements for administrators, developers, educators, and learners; and
- *Navigation tools* – facilitating web-based browsing.

Although Moodle is accessible via mobile devices, it has primarily been used for the development of computer- and web-based learning environments. It has not been used to provide infrastructure suitable for m-learning. Customization of the application is required, in order to:

- Facilitate a fully-fledged m-learning environment; and
- Enable the viewing of the application on any mobile device.

Mobile Capability

Naismith *et al.* (2004) suggest that learners should be able to access the m-learning interface via desktop PCs and mobile devices. In this way, ease of use of the m-learning environment is supported by transferability of skills from prior experience with traditional e-learning platforms.

Moodle may be extended by third party plugins that provide mobile capability, such as:

- *Mobile Moodle* – the MOMO plugin (Sourceforge.net, 2011); and
- *Mobile Learning Engine* – the MLE-Moodle plugin (Moodle, 2011).

MOMO provides Moodle tools and methodologies for developers with limited skill in the development and publishing of web-based, m-learning material. However, MOMO is inappropriate as a mobile extension to Moodle for this study for the following reasons:

- MOMO must be installed on each learner's phone resulting in impracticalities, inconvenience and complications; and

- MOMO does not render the Moodle environment equally available for PC-based access.

For the reasons listed above, MOMO would not provide an adequate solution to the real-world problem outlined in Chapter 1 Section 1.1 and was therefore not implemented or evaluated as part of this study.

MLE-Moodle ensures that the m-learning environment is complete and is accessible via desktop PC, laptop, and mobile handheld devices (Moodle, 2011). Three operational alternatives are provided, namely:

- A PC-based WBL application in e-learning format;
- The opportunity for users to download a phone-specific browser environment; and
- The opportunity to view the application without adjusting the mobile phone's browser settings.

The development of the m-learning environment, *m-LR*, associated with this study, incorporated the MLE-Moodle plugin. The implementation of Moodle and MLE-Moodle is detailed in Section 4.5.

4.5 The Development of Mobile Learning Research (*m-LR*)

The researcher required an m-learning application to support her teaching of a software engineering course to 3rd level higher education learners at a tertiary education institution. Due to limited resources and the absence of any pre-existing software engineering environment in m-learning format, Mobile Learning Research (*m-LR*) was developed by the researcher as a customised Moodle (Version 1.9) environment.

The blended learning environment associated with this study comprises a face-to-face classroom experience, which remains the official medium of instruction, but is extended by the VLE. The web-based application *m-LR*, underlying the research study, was developed by the researcher by iteratively building a Moodle (Version 1.9) VLE (Dougiamas, 2010).

There was a series of versions of *m-LR*, namely $m\text{-}LR_1$, $m\text{-}LR_{pre}$, $m\text{-}LR_{ps}$ and $m\text{-}LR_{m1}$, as indicated in Table 1.1, Chapter 1. These versions were part of the evolution of *m-LR* following the iterative evaluations and refinements within the DBR process introduced in Section 1.7.2. The versions are mentioned again under the findings of the empirical studies presented in Chapters 6 and 7. The ultimate intention for future research and

development, after completion of the present study, is the production of a final operational version, *m-LR*$_{m2}$.

Table 4-4 depicts the four versions of *m-LR* associated with the study.

Table 4-4: The four versions of m-LR, associated with the study

Version	Year	Study	Course Content
m-LR$_{pre}$	2010	Pre-Study	Project Management
m-LR$_{ps}$	2011	Pilot Study	Software Engineering
m-LR$_{m1}$	2012	Main Study 1	Software Engineering
m-LR$_{m2}$	Operational version	Main Study 2	Software Engineering

An early customisation of Moodle, *m-LR*$_{1}$, provided just enough functionality to commence iterative development in line with the approach of Diaz *et al.* (2008). They suggest that the initial version should offer minimal, high-level capabilities, sufficient merely for users to browse through and interact with essential content, enabling an initial evaluation by users of a first prototype version.

Table 4-4 indicates that *m-LR*$_{pre}$, was implemented during 2010 and supported a course in Project Management. Further iterations between 2010 and 2012 evolved as part of the DBR design and development strategy, through two additional versions, named *m-LR*$_{ps,}$ and *m-LR*$_{m1}$. Recommendations for adjustments to *m-LR*$_{m1}$ would lead to the development of a final version, *m-LR*$_{m2}$.

Whereas *m-LR*$_{pre}$ was customised for compatibility with a BlackBerry 9730 smartphone, the ultimate aim of the customisation was to achieve compatibility with multiple mobile device types and platforms. For this purpose, the add-on, MLE-Moodle outlined in Section 4.4.5, was implemented as part of *m-LR*$_{ps}$ and *m-LR*$_{m1}$. In keeping with the design-based research strategy (DBR) associated with the study and discussed in Sections 5.3.1 and 5.3.2 of Chapter 5, the chapter on the research design and methodology, reflections on the outcomes of each study provide input for the development of subsequent versions.

4.5.1 Development Objectives

m-LR was custom-designed to resolve a real-world problem, to achieve the objectives ***O1*** and ***O3*** and to enable the answering of research questions, ***RQ1*** and ***RQ3*** (Sections 1.4 and 1.5 in Chapter 1):

O1: To develop an m-learning environment, for scaffolding and fostering interactive team-based activities involving communication and collaboration between learners, as well as to present learning material and assessments.

The primary research question associated with ***O1*** is:

RQ1: To what extent does the m-learning environment, *m-LR*, custom-designed for a tertiary educational institution, conform to the criteria of the synthesized usability and UX evaluation framework?

O3: To determine the extent of usability and UX conformance of the m-learning environment to the MUUX Framework of criteria;

***RQ3*:** What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?

4.5.2 Requirements for *m-LR*

m-LR is thus a goal-oriented, m-learning environment, designed and developed for the delivery of software engineering course content by mobile devices to third year undergraduate BSc Computer Studies learners. The curriculum consists of ten topics, presented weekly:

- *Topic 1* – Introduction to Software Engineering;
- *Topic 2* – Requirements;
- *Topic 3* – Requirements Engineering;
- *Topic 4* – Group Work;
- *Topic 5* – Risk Management;
- *Topic 6* – Software Processes;
- *Topic 7* – Introduction to Project Planning;
- *Topic 8* – Introduction to Project Costing;
- *Topic 9* – Patterns and Model, View, Controller; and
- *Topic 10* – UML and Version Control.

For each topic, course content is presented in Microsoft PowerPoint slide format. Subject matter is augmented by a selection of downloadable lessons in Microsoft Word and PDF format; relevant YouTube videos; and links to software engineering material on the Internet.

The following features of Moodle were identified as necessary capabilities of *m-LR*:

- *Glossary* – search for SE definitions related to coursework;
- *Quiz* – opportunities to revise coursework topics, developing general knowledge in readiness for examinations;
- *Multimedia* – access to downloadable course content in various file formats, suitable for mobile viewing;
- *Social networking* – participation by teams of learners on activities associated with project deliverables via smartphones and tablet PCs;
- *Internet research* – links to the Internet and specific websites enabling research (SE curriculum topics);
- *Discussion forum* – creation of a project diary by group members;
- *Chat room* – synchronous and asynchronous communication by team members; and
- *Wiki* – collaboration of team members on group project deliverables.

4.5.3 Sitemap and Description of *m-LR*

Figure 4-3 below provides a diagrammatic map of the website links in *m-LR.*

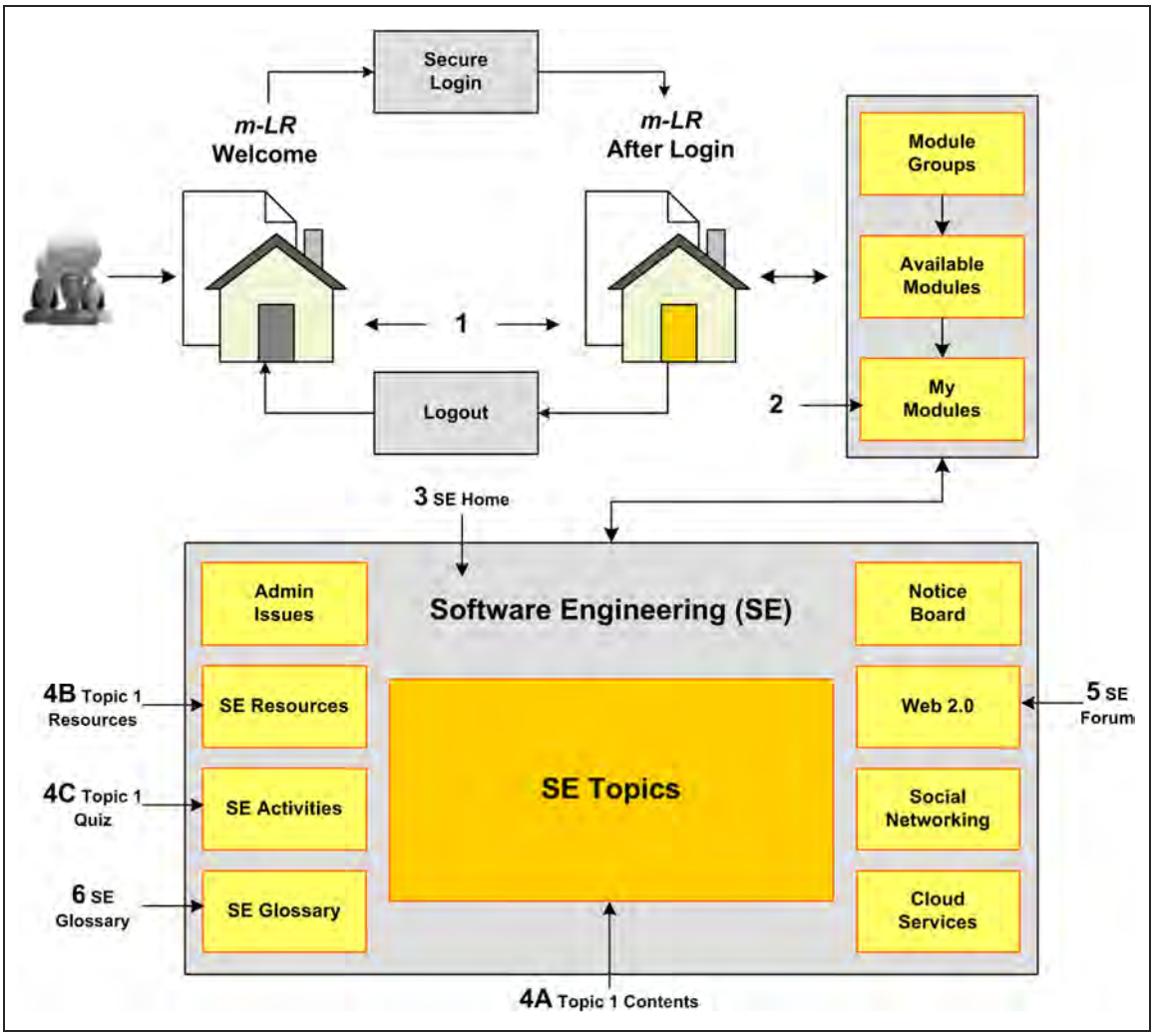

Figure 4-3: Diagrammatic view of the sitemap for m-LR (Synthesized by the researcher)

Eight of the key features of *m-LR* depicted in Figure 4-3, have been selected by the researcher for discussion in this study. Although, as already stated, *m-LR* runs on multiple mobile telephone platforms, a BlackBerry 9730 smartphone was used to capture selected features included in the *m-LR* sitemap. These features are illustrated in the screenshots in Figure 4-4 to Figure 4-11:

1 *Secure login screens* – a generic 'learner' login (Figure 4-4);

2 *My Modules* – a link to the module entitled Software Engineering 2012 (Figure 4-5);

3 *SE Home* – after the selection of the link to Software Engineering 2012 (Figure 4-6);

4A *Topic 1 Contents* – introduction to the Lessons (Figure 4-7);

4B *Topic 1 Resources* – lessons, quiz, PDFs, slides, video, URLs (Figure 4-8);

4C *Topic 1 Quiz* – a selection of sample questions (Figure 4-9);

5 *SE Forum* – a selection of contributions to a discussion forum entitled 'Project Sniplets' (Figure 4-10); and

6 *SE Glossary* – a search in the SE Glossary for 'Project Manager' (Figure 4-11).

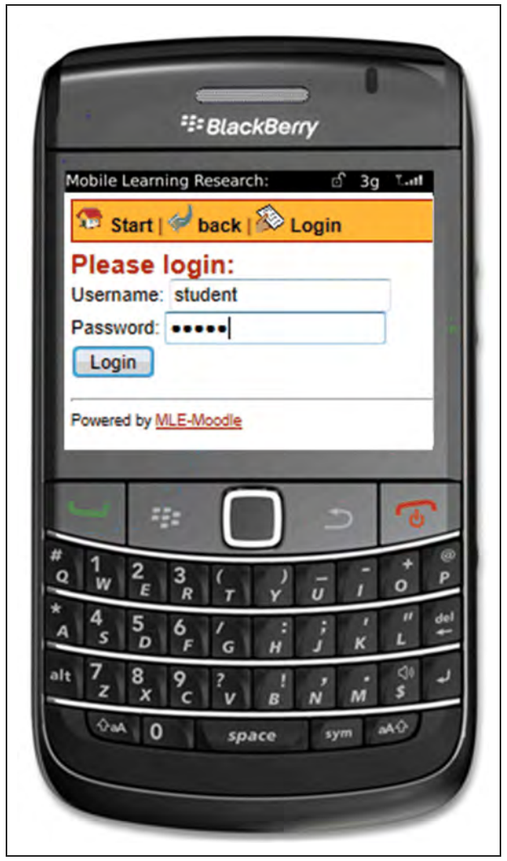

Figure 4-4: 1 Secure login screen

Figure 4-5: 2 My Modules

Figure 4-6: 3 SE Home

Figure 4-7: 4A Topic 1 Contents

An initial login screen requests that a username and secure password are submitted, prior to the user being able to access *m-LR*. Username authentication depends on pre-determined hierarchical roles, including: learner, designer, tutor, and administrator. Figure 4-4 demonstrates the login of a generic 'learner'.

Once authentication has been verified for 'learner', the user gains access to the modules for which he/she has been enrolled, e.g. My Modules – Software Engineering 2012. Breadcrumbs at the top of the screen make provision for browsing back a level or directly to the Start. An easy 'Exit' option is also available.

The user is able to browse to SE Home – the homepage for Software Engineering 2012, by selecting the hyperlink 'Software Engineering 2012'. Onscreen options include: Tasks, Upcoming Events, Details, SE Glossary, SE Forum and SE Wiki. Course Topics are reached intuitively by clicking on the 'Topics'.

In Figure 4-7, Topic 1 – Introduction to Lessons, has been selected. Learners are able to browse the topics in any chosen sequence. Contents of Topic 1 are displayed under the heading: 'This chapter covers …'.

Users are able to conveniently access email and the Inbox on any screen visited.

Figure 4-8: 4B Topic 1 Resources

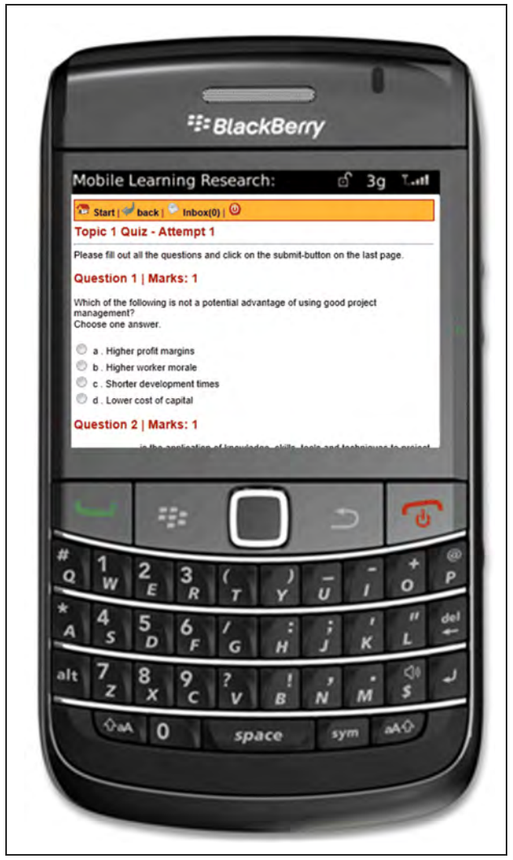

Figure 4-9: 4C Topic 1 Quiz

Figure 4-10: 5 SE Forum Discussion

Figure 4-11: 6 SE Glossary

Links to resources are illustrated in Figure 4-8. The links are associated with Topic 1 and include topics such as: 'The Project Life Cycle'. These additional resources include MS WORD and PDFS, video and PowerPoint files. A link to Topic 1, Quiz, is visible. URLs that are appropriate to Topic 1 are provided.

A snapshot view of a question from a quiz the first multiple choice question of Topic 1 Quiz is depicted in Figure 4-9. The learner is able to select the option that reflects the chosen answer. The quiz makes the correct answer available, thus providing self-assessment opportunities. The quiz may be retaken at a later time, and used for revision purposes.

Figure 4-10 illustrates the potential of the SE Forum Discussion feature. Members of a collaborating group may communicate asynchronously on project activities in this way. All members with group membership privileges may read and contribute to all posted threads.

The customizable SE Glossary provides learners with opportunities to contribute to the contents of the glossary as well as to access software engineering terminology whilst on-the-move. Search features are powerful and include: Alphabetic, Browse by Category, Date and Author options.

4.6 Conclusion

The iterative development of the custom-designed m-learning environment, *m-LR*, was the subject of Chapter 4. Background information was provided, together with justification for the need for the *m-LR* m-learning environment and requirements for its development.

Aspects of the planning, design and development strategy for interactive blended learning environments were discussed. The literature was used to synthesis a set of guidelines for the design and development of m-learning environments. Thereafter, virtual learning environments were briefly introduced, considering the terminology; presenting a comparison of Moodle 1.9 and Blackboard 7.0; and giving details of the custom-designed Moodle, *m-LR*. An outline of the mobile features of MLE-Moodle was followed by development objectives and requirements for *m-LR*. The chapter includes a sitemap and key features of *m-LR*, along with screen prints of *m-LR*.

Whilst Chapter 4 did not directly provide answers to the research questions, it did describe the design and development of *m-LR*, which contributed to the answering of research questions ***RQ1*** and ***RQ3***. *m-LR* facilitated the determination of the outcomes of the evaluation of the usability and UX of an m-learning environment, supporting ***RQ3***. In addition, *m-LR* played a part in establishing the extent of the conformance of an m-learning environment to the MUUX framework of criteria synthesized in Section 3.6 and illustrated in Figure 3-5, and to the answering of ***RQ1***.

The research design and methodology of the study is the subject of the next chapter, Chapter 5.

CHAPTER 5: Research Design and Methodology

5.1 Introduction

The primary goal of this research, comprising a series of six iterative studies, is to investigate the conformance of an m-learning environment to the usability and UX criteria within a synthesized evaluation framework. The work was undertaken in a dynamic and evolving learning environment, impacted by a changing societal milieu. This chapter aims to communicate the research design and methodology of the study.

The *philosophical paradigm* influencing the research practice within this study is *interpretivism* (Oates, 2008), which involves:

- Having several truths with no single subjective reality;
- Changing meaning within various contexts;
- Involving the researcher's actions, involvement and influence;
- Studying phenomena in natural surroundings; and
- Interpreting findings reflexively from multiple views.

In this research, interpretivism is applied by a hybrid, multi-method approach to data collection and analysis, involving both quantitative and qualitative methods (Botha *et al.*, 2009; Creswell, 2009; de Villiers, 2005b).

In the quest for an appropriate *research design* to address the complex nature of the context and the need for an m-learning environment, the researcher consulted various literature sources and decided to use *design-based research* (DBR) (Barab and Squire, 2004; van den Akker *et al.*, 2007; Wang and Hannafin, 2005). DBR is described in more detail in Section 5.3.

The m-learning environment, *m-LR*, is a goal-oriented, prototype application used in a blended learning situation. It extends classroom-based face-to-face learning by providing anytime, anywhere access to software engineering (SE) course material and communications via mobile handheld devices to undergraduate, software engineering learners. The study thus complies with a DBR situation in that it explores a real-world issue. The target system, *m-LR,* was custom-designed and iteratively evaluated by DBR processes to facilitate learning within the SE module.

The evaluation focused on investigating usability and UX, as explained in Chapter 3. The evaluation methods were heuristic evaluation (HE) by expert evaluators and

questionnaire surveys among learner users, based on the evaluation criteria in the MUUX Framework. In addition, a mobile-usage survey and a digital-divide survey were conducted to better inform the researcher about the mobile technology environment of the users. The research design incorporated data-, method- and evaluator triangulation.

Section 5.2 revisits the research questions while design-based research is discussed in Section 5.3. The research methods are outlined in Section 5.4. The DBR iterations are explained in Section 5.5, leading to the framework of criteria for the evaluation of usability and UX of m-learning environments (MUUX) presented in Section 5.6. This is followed by Section 5.7 which briefly addresses validity, reliability and triangulation. Section 5.8 overviews research ethics and informed consent procedures used, while the chapter is summarised and conclusions are drawn in Section 5.9.

5.2 Research Questions in the Context of the Study

The five research questions, ***RQ1*** to ***RQ5***, which were introduced in Section 1.5, are repeated and contextualised in Table 5-1, indicating whether primary and/or secondary data sources were used in answering the research questions. The answer to ***RQ1*** emerges from ***RQ2*** and ***RQ3***. ***RQ1*** to ***RQ4*** provide the practical contribution of the study, while ***RQ5*** delivers the theoretical contribution by contributing to meta-evaluative knowledge relating to mobile learning.

Table 5-1: Research questions in the context of the study

#	Research Question	Data Source		Mapping of Research Questions to Sections in the Study
		Primary	Secondary	
RQ1	To what extent does the m-learning environment, *m-LR*, custom-designed for a tertiary educational context, conform to the criteria of a usability and UX evaluation framework?	**X**	**X**	8.2.3
RQ2	What categories and criteria should be included in a usability and UX evaluation framework for m-learning environments?		**X**	2.6, 2.7, 3.5, 3.6, 4.2, 4.4, 5.6, and 8.2.1
RQ3	What are the outcomes of using the MUUX Framework to evaluate *m-LR* for usability and UX?	**X**		6.2, 6.4, 6.5, 7.3, and 8.2.2
RQ4	Can mobile technology reduce the digital divide in a tertiary educational context?	**X**	**X**	7.2 and 8.2.4
RQ5	How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?	**X**	**X**	2.6, 2.7, 3.5, 3.6, 5.6, 6.5, 7.3, and 8.2.5

The research questions were answered by consulting both primary and secondary data sources, as indicated in Table 5-1.

5.3 Research Design: Design-Based Research

This section provides a generic view of design-based research as well as the design-based research approach adopted for this study.

5.3.1 Generic Design-Based Research

Design-based research (DBR) is design science research in an educational technology context. It comprises iterative studies, undertaken to solve complex real-world problems in dynamic learning environments and to produce both a practical and a theoretical outcome (de Villiers, 2005b; de Villiers, 2012). This approach of impacting on real-world practice and also generating theoretical principles is evident in both the definitions following.

According to Wang and Hannafin (2005, p. 6) design-based research is characterised as "… a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories … ".

Barab and Squire (2004, p. 2) more succinctly describe the DBR methodology as "… a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings … ".

The DBR paradigm has several characteristic attributes, including:

- Grounding in a real-world context addressed by collaboration between researchers and practitioners (Reeves *et al.*, 2004);
- Exploration of a real-world learning problem (The Design-Based Research Collective, 2003);
- Investigation of innovative, technology-enhanced learning solutions (Wang and Hannafin, 2005);
- Connection between the designed product, contextual research environment and research findings (Wang and Hannafin, 2005);
- A research process involving interactivity, iteration and flexibility (Cobb *et al.*, 2003);

- An association between complex research situations and multiple, dependent output variables (Barab and Squire, 2004);
- Data collection and analysis methods which can be both qualitative and quantitative (de Villiers, 2012; Wang and Hannafin, 2005);
- Formative and summative evaluation (de Villiers, 2012); and
- A synergistic relationship between design and research; and between theory and practice (de Villiers, 2012).

De Villiers (2012) developed a representation of design-based research, which is depicted in Figure 5-1.

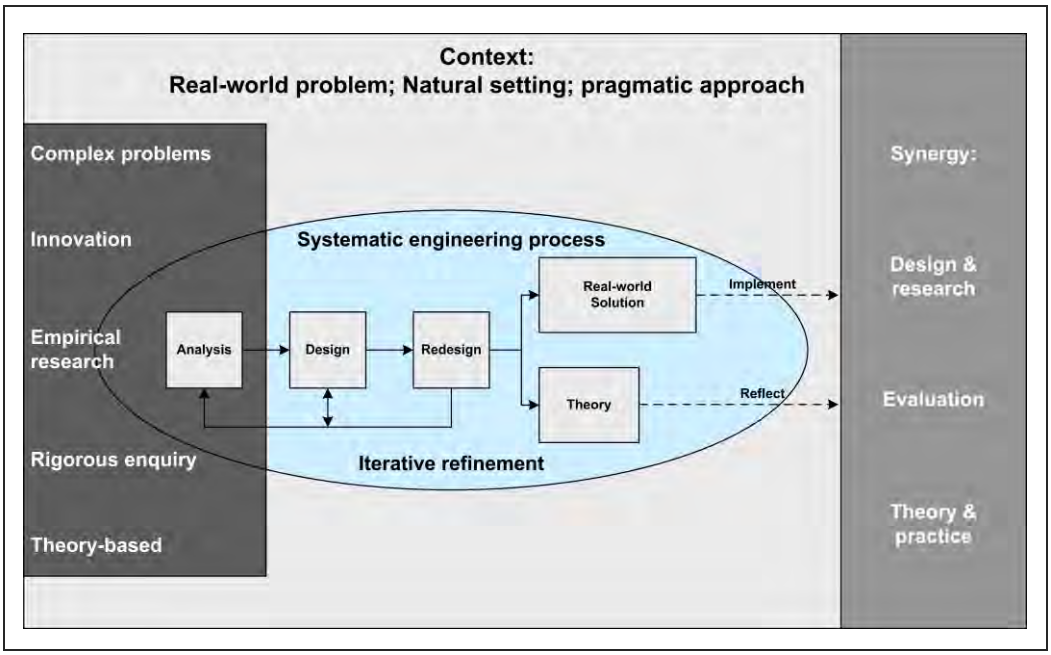

Figure 5-1: Model of design-based research (de Villiers, 2012)

The generic DBR model depicted in Figure 5-1 illustrates that systematic, logical steps are incorporated. These pragmatic activities include both sequential and iterative concepts such as analysis, design and redesign. Reflection, a key aspect of DBR, occurs after each iteration, when the researcher evaluates and interprets results. The outcomes of this interpretive approach feed decisions and actions taken in subsequent cycles of the design and development of artifacts (de Villiers, 2012). De Villiers' diagram incorporates the characteristic features of the DBR paradigm described above: a real-world context; innovative approaches to complex learning problems; an iterative and systematic empirical research methodology; theoretical foundations; research in the natural setting; synergy between design, research, evaluation, theory and practice; and a dual outcome, namely a practical outcome relating to the design of a real-world solution and a theoretical contribution.

5.3.2 Design-Based Research for the m-Learning Context of the Study

The features of DBR that were introduced in Section 5.3.1 are mapped to facets of the present study and tabulated in Table 5-2. This mapping suggests that a DBR strategy is an appropriate research design for this research.

Table 5-2: Features of a DBR paradigm in the context of the study (Synthesized from by the researcher from literature sources)

Features of a DBR Paradigm	Context of the Study
Real-world problem	The problem relates to learning and assessment in the context of a diverse learner body, with an inherent digital divide and a need for meaningful learning experiences.
Complex learning problem	Complexity arises from the fact that there are two different campuses and variations in all of the following: learner profiles; cultural and socio-economic factors; digital technology skills; device types and capabilities; academic capabilities; personal preferences and attitudes to technology-enhanced learning environments.
Innovative, technology-enhanced learning solutions	A face-to-face classroom environment is extended by the development of an innovative prototype m-learning environment called *m-LR*. *m-LR* is delivered by mobile handheld devices and custom-designed for a tertiary educational context.
Iteration	Refinement is achieved by repeated interactive evaluations of *m-LR* conducted by experts and learner users.
Connection between designed product, context and findings	The findings of the usability- and UX evaluations of *m-LR* by expert evaluators and learner end-users, are reported.
Formative and summative evaluations	The research involves formative evaluation studies, providing recommendations for a summative evaluation of the final post-prototype fully-functional version, which is outside the scope of the study.
Quantitative and qualitative methods	Research methods incorporate the collection and analysis of numerical data and descriptive data.
Dual outcome	The aim is to achieve both practical and scientific outcomes – the practical being an effective *m-LR* mobile learning environment and the theoretical being guidelines for the evaluation of m-learning environments.
(Barab and Squire, 2004; Cobb *et al.*, 2003; de Villiers, 2012; Reeves *et al.*, 2004; The Design-Based Research Collective, 2003; Wang and Hannafin, 2005)	

5.4 Research Methods

Ubiquitous mobile devices are increasingly impacting on the rapidly-changing university environment, where learners are digitally aware and connected, on- and off-campus (Traxler, 2010b). In this research, contextual and social differences were envisaged between groups of cohorts, further contributing to the dynamism of the environment.

This section provides an outline of the research methodology of the study, describing:

- Data collection;
- Research instruments;
- Sampling and participants; and
- Data analysis.

5.4.1 Data Collection

The two data generation methods used are:

- Heuristic evaluation by experts (HE) – an inspection method (analytical evaluation); and
- End-user (learner) questionnaire surveys (query evaluation)

(Dix *et al.*, 2004; Sharp *et al.*, 2007).

These methods were introduced in Sections 3.3.2 and 3.3.3 in Table 3-2 and Table 3-3, respectively.

HE by experts was selected, due to its ease of implementation; cost effectiveness; and economical time aspects (Dix *et al.*, 2004; Nielsen and Molich, 1990). Furthermore, HE lends itself to evaluation that takes place in a mobile context (Ji *et al.*, 2006).

End users are central to the development of a learning solution and should be involved in the associated evaluation of evolving artefacts. This approach is in line with the ethos of user feedback (Sharp *et al.*, 2007). Usability and UX evaluation of the m-learning environment included data generation by a questionnaire survey among the learners themselves. This method of generating data was selected for various reasons:

- Administration is fast and efficient;
- Rigorous analysis of data is possible, due to the uniformity of the data; and
- A staged approach to design and development is adopted, hence the method is relevant for DBR, which encompasses different stages of the development of *m-LR.*

Controlled usability testing (UT) would have been a preferred alternative data collection method, but the researcher was unable to access a human computer interface laboratory (HCI Lab) for this purpose.

As stated, data was collected using questionnaire surveys. Questionnaires were administered to the learners and to the experts, as part of their HE. A survey collects demographic, numerical and descriptive data in an easy, economical, systematic and consistent manner (Oates, 2008). Surveys are traditionally conducted to gather quantitative data, but can simultaneously collect qualitative data. The same type of data can be obtained from different groups of participants (Creswell, 2009; Oates, 2008). Creswell (2009) indicates that the concurrent collection of quantitative and qualitative data is advantageous because:

- The time taken to collect data is reduced;
- A deeper understanding is achieved of the research problem;
- The weaknesses of either quantitative or qualitative data collection are minimised; and
- It incorporates the advantages of both quantitative and qualitative data.

The research instruments in this research contained both questions and statements as evaluation items, eliciting quantitative and qualitative data for analysis and interpretation. For quantitative data, questions were closed and numerical values assigned to responses of participants. The descriptive qualitative data was obtained from open-ended questions. Thematic analysis of descriptive data generated themes; produced a synthesis of issues; informed remedial recommendations; and provided deeper insight into participants' experiences (Creswell, 2009). Some of the qualitative data was quantified according to type or theme.

Experts and learner user evaluators familiarised themselves with the *m-LR* environment and completed a few prescribed tasks. With the exception of Study 1: the Pre-Study, the completion of the questionnaires was unsupervised. In general, location and time decisions were made for the convenience of the evaluators, and, as is appropriate for m-learning applications, the researcher did not specify when and where mobile activities should occur (Traxler, 2010a).

Details of the data collection procedures are presented in Section 5.5, separately for each of the six studies.

5.4.2 Research Instruments

The questionnaires for both experts and learners were custom-designed to gather quantitative and qualitative data during each of the six studies and comprised general, open-ended, scalar, and multi-choice items.

General items were used to obtain data relating to participants' mobile profiles. Scalar items were five-point Likert scale statements where 1=Strongly Disagree; 2=Disagree; 3=Undecided; 4=Agree; and 5=Strongly Agree. The numerical responses enabled basic statistical analysis. In some instances, scalar items were combined with open-ended questions to enhance analysis. Open-ended items gave participants the opportunity to report their experiences and to express options and frustrations. Suggestions offered by evaluators could highlight issues, offer solutions and provide deeper insight for the researcher. Multiple choice items required respondents to select an option from a set of explicit items, providing specific answers to particular questions.

Two kinds of questionnaire surveys

In the six studies, there were two types of questionnaire surveys, namely, four evaluation studies and two studies to obtain information regarding the users' mobile technology environment:

1. *Evaluation studies*

Four evaluation studies were conducted as part of the iterative evaluation-and-refinement process. In longitudinal research, Studies 1, 3, 4 and 6 (each comprising an HE and a user survey) were undertaken to evaluate versions of the *m-LR* prototype.

The experts' questionnaires and the learners' questionnaires had similar structures, consisting of the same categories and criteria. The wording of questionnaire items was adjusted to suit the style and usage requirements of the type of participant, with heuristics for experts and personalised statements for learner users. In places, additional statements were included in the SU instrument to improve data triangulation.

Table 5-4 tabulates the purpose of each study, but this section briefly indicates the nature of each questionnaire survey. *Study 1*: The *Pre-Study* comprised a questionnaire of four categories of criteria for the evaluation of usability. *Study 3*: The *Pilot Study* evolved from the Pre-Study and included a fifth category of criteria related to UX. *Study 4*: *Main Study 1* involved minor adjustments to the Pilot Study, mainly the correction of typographical errors and the elimination of ambiguity. *Study 6*: *Main Study 2* required slight changes to the research instruments, based on feedback from evaluators, which

indicated that insufficient space had been allocated to open-ended items in the instrument used for Main Study 1.

Complete versions of the final HE survey and end-user (learner) questionnaire are included in Appendices A-5 and A-6, respectively.

2. Studies for obtaining rich data regarding the users' mobile technology

Further data and enriched information about the mobile devices used by the learners, was generated by two additional questionnaire instruments among learners, namely, *Study 2*: *Mobile Usage Survey* – usage data associated with the profile of the mobile learner; and *Study 5*: *Mobile Learning Digital Divide Survey* which investigated an emergent digital divide between the learners. The questionnaires consisted of general, open-ended, scalar and multiple choice items which provided quantitative and qualitative feedback.

Appendix A-7 contains the Mobile Usage Survey whilst the Mobile Learning Digital Divide Survey is found in Appendix A-8.

5.4.3 Sampling and Participants

As mentioned in Section 1.2, the researcher is an educator at the two campuses in the Western Cape. Among others, she teaches the SE module. For the heuristic evaluation component, experts were selected from a pool of available, suitably qualified, and willing colleagues.

The learner sampling frame consisted of fulltime 3rd year undergraduate learners in the years 2010, 2011 and 2012 enrolled for the same undergraduate BSc Computer Systems program, offered at twelve national campuses of the same university, of which the researcher teaches at two. Participants were selected by purposive samples of convenience (Oates, 2008):

- *Purposive* – responses from selected cohorts; and
- *Convenience* – cohorts from two Western Cape campuses only.

Table 5-3 provides a breakdown of BSc Computer Systems cohorts enrolled during 2011 and 2012 at the twelve nationwide campuses, labelled C1 to C12. Potential respondents were both fulltime and part-time learners from the two campuses in the Western Cape, which are C1 and C2 in the table, and are recorded in the first row. Cohorts of learners enrolled at C1 in 2010 and who participated in earlier evaluation studies of the researcher's BSc Honours project have been excluded from Table 5-3.

In total, learners from four different groups of cohorts contributed to the study in various ways. Cohort Group 1 (CG1) comprises the 2011 learners who attended classes on the C1 campus in Cape Town, whilst CG2 refers to Cohort Group 2 consisting of learners from C2 during 2011. C1 and C2 cohort groups during 2012 are represented by CG3 (Cohort Group 3) and CG4 (Cohort Group 4), respectively.

Table 5-3: Breakdown of fulltime B.Sc Computer Systems learners in cohort groups at 12 national campuses

Campus	Learners 2011	% of Total	Learners 2012	% of Total
C1	CG1=22	6.5%	CG3=13	4.0%
C2	CG2=40	11.8%	CG4=36	11.1%
C3	30	8.9%	8	2.5%
C4	14	4.1%	48	14.8%
C5	21	6.2%	8	2.5%
C6	9	2.7%	6	1.9%
C7	7	2.1%	13	4.0%
C8	14	4.1%	11	3.4%
C9	20	5.9%	21	6.5%
C10	135	39.9%	108	33.3%
C11	20	5.9%	45	13.9%
C12	6	1.8%	7	2.2%
Total	338	100.0%	324	100.0%

The 'n' values in Table 5-3 give the numbers of learners in a cohort. The figures in Table 5-3 do not reflect the number of learners who actually participated in the studies, however, actual numbers of participants are shown in Tables 5-5 to 5-10, for Studies 1 to 6, respectively.

5.4.4 Data Analysis

The questionnaires were custom-designed to produce both quantitative and qualitative data leading to statistical analysis and thematic analysis, respectively.

Quantitative data

Responses to the closed, Likert scale items, which had been rated by experts and learner users according to a five-point scale, produced numerical measures for usability and UX criteria. Likert scale responses were collated and processed by small-scale statistical analysis.

Qualitative data

Responses and problems reported in the open-ended questionnaire items by experts and learner users were categorised, establishing the major issues by thematic analysis.

Quantitative values from qualitative data

Problems were itemised and consolidated for experts and for learner user evaluations. Thereafter, a count was made of issues uncovered by experts (HE) and learner users, facilitating a comparison of the findings of the two methods of evaluation.

A description of the design-based research and the six studies follows in Section 5.5, along with a summary table of each study.

5.5 Design-based Research: the Series of Studies

The artefact developed iteratively in the DBR process is the mobile learning environment, *m-LR*. It evolved through four successive prototype versions during the course of the research with a fourth envisaged for future research and development. As indicated in Section 5.4.2, there were six studies, conducted between 2010 and 2012.

The series of sequential iterative studies was introduced in Table 1-1 in Section 1.7.2, and is repeated here as Table 5-4.

Table 5-4: DBR iterations

Study	DBR Iteration	Date	Versions of *m-LR*		Purpose of the Study
			Pre-evaluation	Post-evaluation	
0	B.Sc Honours Project	May 2010	-	-	Development of $m\text{-}LR_1$, an initial version of *m-LR*
1	Pre-Study	Nov 2010	$m\text{-}LR_1$	$m\text{-}LR_{pre}$	Preliminary evaluation of the usability of $m\text{-}LR_1$, leading to $m\text{-}LR_{pre}$
2	Mobile Usage Study	Sept 2011	-	-	Collection of data to establish the mobile profile of learners
3	Pilot Study	Oct 2011	$m\text{-}LR_{pre}$	$m\text{-}LR_{ps}$	Testing of evaluation procedure, tasks, documentation, instruments and the evaluation of usability and UX of $m\text{-}LR_{pre}$, leading to $m\text{-}LR_{ps}$
4	Main Study 1	Nov 2011	$m\text{-}LR_{ps}$	$m\text{-}LR_{m1}$	Evaluation of usability and UX of $m\text{-}LR_{ps}$, leading to $m\text{-}LR_{m1}$
5	Mobile Learning Digital Divide Study	Mar 2012	-	-	Exploration of an emergent digital divide
6	Main Study 2	Apr 2012	$m\text{-}LR_{m1}$	$m\text{-}LR_{m2}$	Evaluation of the usability and UX of $m\text{-}LR_{m1}$, leading to the development of a fully-functional $m\text{-}LR_{m2}$ in future work

Table 5-4 above includes a preliminary study, Study 0 (the first line, outside the scope of the study), and reflects the six sequential DBR studies introduced in Section 5.4.1, comprising four evaluation studies – Studies 1, 3, 4, and 6 and two further questionnaire surveys – Studies 2 and 5. The difference between these two kinds of studies was explained in Section 5.4.2. For each evaluation study the preceding and resultant *m-LR* prototypes were incorporated, the former as input and the latter as the resultant output after evaluation and refinements. In addition, Table 5-4 indicates the completion date and a brief description of the purpose of each study. Study 0, excluded from this research study, was part of the researcher's previous B.Sc Honours Project, which resulted in $m\text{-}LR_1$, the preliminary prototype of *m-LR*.

The iterations are illustrated below in Figure 5-2 which presents the design-based research model of this work on the evaluation of an m-learning environment. Study 1, the Pre-Study is green; Studies 2, 3 and 4 are orange; and Studies 5 and 6 are turquoise.

The top row shows versions of *m-LR*, shaded in grey. The central row represents the evaluation studies. Each of the four sequential evaluations (Study 1, Study 3, Study 4, and Study 6) is associated with a preceding and a resultant version of *m-LR*. The size of the blocks represents the relative extent of the studies. The bottom row comprises the two questionnaire surveys, which respectively provide mobile profile and digital divide data.

The evaluation studies and versions of *m-LR*, are linked as follows:

- *Study 1* – Pre-Study, $m\text{-}LR_{pre}$;
- *Study 3* – Pilot Study, $m\text{-}LR_{ps}$;
- *Study 4* – Main Study 1, $m\text{-}LR_{m1}$; and
- *Study 6* – Main Study 2, $m\text{-}LR_{m2}$.

Each of the six studies is briefly described in Sections 5.5.1 to 5.5.6 respectively.

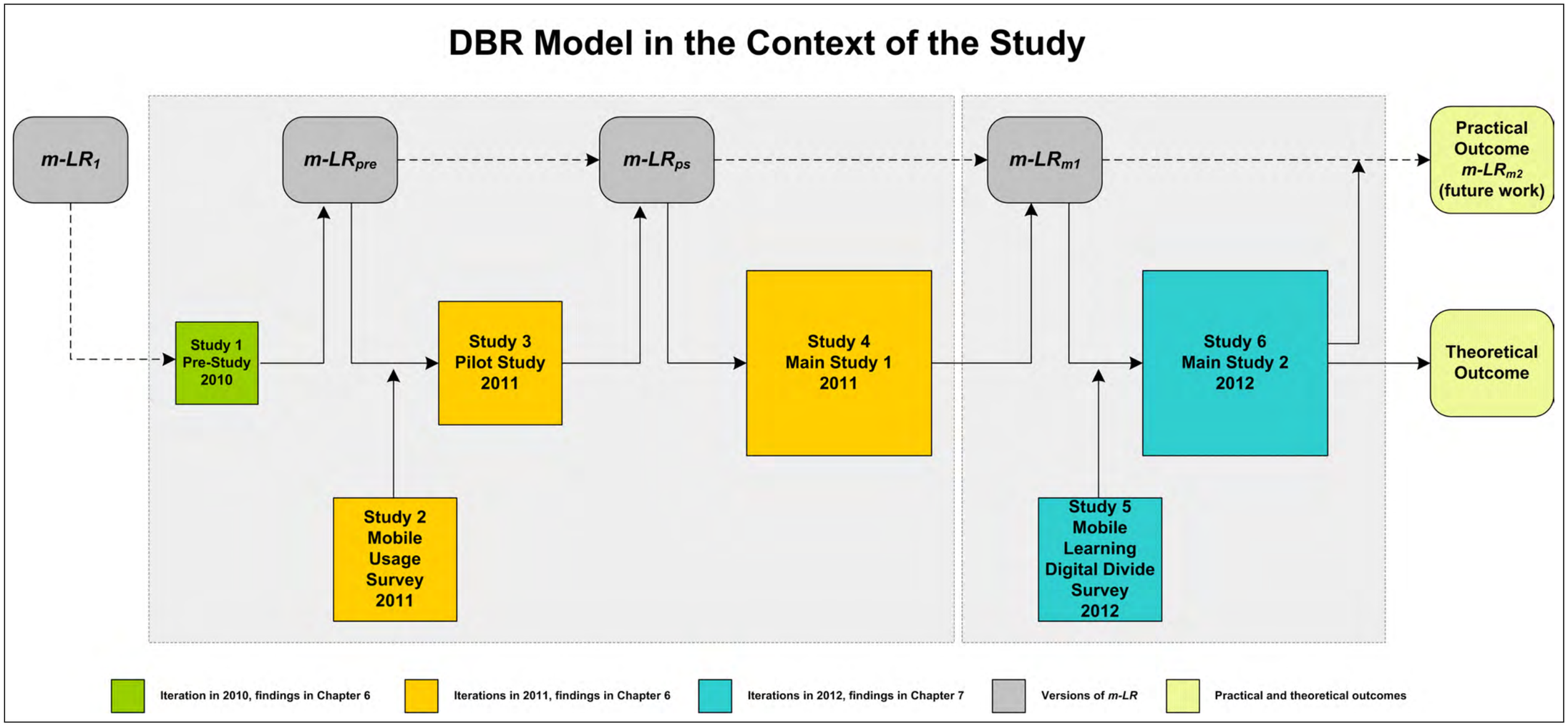

Figure 5-2: DBR iterations illustrating the six sequential studies and the versions of m-LR resulting in practical and theoretical outcomes

5.5.1 Study 1: Pre-Study

Study 1, the Pre-Study was part of the researcher's unpublished B.Sc (Honours) project (Harpur, 2010), in which the first prototype of *m-LR*, *m-LR*$_1$ was subjected to usability evaluation. This evaluation study is outlined in Table 5-5, while its findings are presented in Chapter 6, Section 6.2.2. This initial work served as a platform for the rest of this research. It highlighted the need for Study 2, Mobile Usage Survey.

Table 5-5: Study 1 – Pre-Study

Pre-Study 2010		
Participants	Single campus	Heuristic evaluation: three experts
	Sample of convenience of a 2010 cohort on campus C1	Questionnaire survey: ten learners
Delivery device	Blackberry 9700, supplied by the researcher	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Preliminary evaluation of usability of the m-learning environment version, *m-LR*$_1$ resulting in *m-LR*$_{pre}$	

5.5.2 Study 2: Mobile Usage Survey

The survey was designed to gather information concerning mobile phone technology and profile data from learner user respondents. Four of these respondents were selected to participate in Study 3, the Pilot Study. An outline of Study 2 is provided in Table 5-6 and the findings are reported in Section 6.3.2.

Table 5-6: Study 2 – Mobile Usage Survey

Mobile Usage Survey 2011		
Participants	Single campus	Questionnaire surveys: seventeen learners
	Population of a 2011 cohort of fulltime learners on campus C1	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Collection of data to establish mobile profile of learners	

5.5.3 Study 3: Pilot Study

The purpose of the Pilot Study, Study 3, was to try out the research method and instruments to identify misconceptions, confusion or poor design in instruments and documentation (Olivier, 2009). The instructions for the evaluation tasks were also reviewed, resulting in minor adjustments to the documentation and to the research instrument. Table 5-7 summarises Study 3, which is detailed in Section 6.4.2.

Table 5-7: Study 3 – Pilot Study

Pilot Study 2011		
Participants	Single campus	Heuristic evaluation: one expert
	Sample of convenience of a 2011 cohort of fulltime learners on campus C1	Questionnaire surveys: four learners
Delivery device	Blackberry 9700, supplied by the researcher	
Data Collection	Paper-based HE and learner questionnaire survey	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – analysis of reported issues and suggestions	
Purpose	Testing of research procedure, tasks, and instrument and evaluation of usability and UX of the m-learning prototype, $m\text{-}LR_{pre}$ resulting in $m\text{-}LR_{ps}$	

5.5.4 Study 4: Main Study 1

The findings of Study 3, the Pilot Study, informed the minor modifications required for Main Study 1, which is summarised below in Table 5 8. Study 4, Main Study 1, aimed to determine the conformance of the prototype $m\text{-}LR_{ps}$ to MUUX, the synthesized framework of criteria for the evaluation of usability and UX. The findings are presented in Section 6.5.2.

Table 5-8: Study 4 – Main Study 1

Main Study 1 2011		
Participants	Single campus	Heuristic evaluation: five experts
	Population of a 2011 cohort of fulltime learners on campus C1	Questionnaire surveys: seventeen learners
Delivery device	A range of device types, used in a classroom setting	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Evaluation of usability and UX of the m-learning environment version, $m\text{-}LR_{ps}$ resulting in $m\text{-}LR_{m1}$	

5.5.5 Study 5: Mobile Learning Digital Divide Survey

Study 5, the Mobile Learning Digital Divide Survey, summarised in Table 5-9, aimed to establish digital profiles for the two cohort groups participating in Study 6, Main Study 2. In addition, the study explored the nature of a latent digital divide that was emerging and the role of mobile technology in the reduction of this divide in the context of tertiary education. The findings of this study are detailed in Section 7.2.2.

Table 5-9: Study 5 – Mobile Learning Digital Divide Survey

Mobile Learning Digital Divide Survey 2012		
Participants	Two campuses	Questionnaire surveys: 13 learners from C1 and 22 learners from C2
	Population of 2012 cohorts of fulltime learners on campuses C1 and C2	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Exploration of a latent digital divide	

5.5.6 Study 6: Main Study 2

Study 6, Main Study 2, was the 2012 successor to Study 4, Main Study 1 of 2011. It was also informed by the findings of Study 5, the Mobile Learning and Digital Divide Survey. Study 6 is summarised in Table 5-10, and its findings are given in Section 7.3.2. This study determined the conformance of *m-LR* to MUUX, for the evaluation of usability and UX.

Table 5-10: Study 6 – Main Study 2

Main Study 2 2012		
Participants	Two campuses	Heuristic evaluation: five experts
	Population of 2012 cohorts of fulltime learners on campuses C1 and C2	Questionnaire surveys: thirteen learners from C1; nineteen learners from C2
Delivery device	A range of device types, used in natural settings	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Evaluation of usability and UX of the final prototype m-learning environment, $m\text{-}LRm_1$ resulting in recommendations for future adjustments to produce a fully operational system $m\text{-}LR_{m2}$	

5.6 MUUX, A Framework of Categories and Criteria

An evaluation requires both an evaluation method/s and evaluation criteria. As part of this research, MUUX, a framework of criteria for evaluating usability and UX of m-learning environments, was synthesized and implemented for the evaluation of *m-LR*.

Its development was described in Chapter 3, Section 3.5. It is given again here in Table 5-11, then consolidated category by category in Tables 5-12 to 5-16.

Table 5-11: Final MUUX Framework

MUUX: A Framework of Categories and Criteria for the Evaluation of Usability and UX of m-Learning Environments
Category 1: General Interface Criteria 1. Visibility of system status 2. Match between the system and the real world 3. Learner control and freedom 4. Consistency and adherence to standards 5. Error prevention, in particular, prevention of peripheral usability-related errors 6. Recognition rather than recall 7. Aesthetics and minimalism in design 8. Recognition, diagnosis and recovery from errors 9. Help and documentation
Category 2: Website-specific Criteria 10. Simplicity of site navigation, organisation and structure 11. Relevance of site content to the learner and the learning process 12. Easy to access information 13. Content is both suitable and of a high quality 14. System is simple and easy to use, called easiness 15. Material is of a high quality, i.e. videos and digitisation
Category 3: Educational Criteria 16. Clarity of goals, objectives and outcomes 17. Effectiveness of collaborative learning 18. Cognitive error recognition, diagnosis and recovery 19. Feedback, guidance and assessment
Category 4: m-Learning Criteria 20. Handheld devices and technology 21. Contextual factors (pragmatic) 22. User-centricity (pragmatic) 23. Flexibility 24. Interactivity
Category 5: UX Criteria 25. Emotional issues 26. Contextual factors (hedonic) 27. User-centricity (hedonic) 28. Social value 29. Needs 30. Appeal 31. Satisfaction

This section outlines the structure of MUUX and presents the final framework of categories, criteria and sub-criteria, supported by relevant literature sources. MUUX comprises five evaluation categories (Tables 5-12 to 5-16) and 31 criteria with an overall total of 117 sub-criteria, summarised as follows:

- *Category 1* – General interface usability criteria, nine criteria and 27 sub-criteria;
- *Category 2* – Website specific criteria, six criteria and nineteen sub-criteria;
- *Category 3* – Educational criteria, four criteria and eleven sub-criteria;
- *Category 4* – m-Learning criteria, five criteria and 39 sub-criteria; and
- *Category 5* – UX criteria, seven criteria and 21 sub-criteria.

Table 5-12 sets out criteria for Category 1: General interface usability criteria, whilst Table 5-13 shows Category 2: Website specific criteria. Table 5-14 outlines the Category 3 criteria used to evaluate aspects of educational technology. Table 5-15 lists the criteria for m-learning in Category 4. Finally, in Category 5, Table 5-16 presents the criteria which were used to assess the user experience of *m-LR*. The tables also indicate the literature sources from which the criteria were derived.

Table 5-12: Category 1: General interface criteria and sub-criteria

Category 1: General interface criteria and sub-criteria; modified for an m-learning environment		**References**
1	*Visibility of system status, provide feedback* • Feedback is provided by the application. • The system is responsive to user actions without odd and unexplained events. • Visible feedback icons communicate what is happening.	Dix et al. (2004) Nielsen (1994) Shneiderman and Plaisant (2005) Squires and Preece (1999)
2	*Match between system and the real world* • Clear, everyday, understandable language has been used in the application. • Where metaphors are used they represent real-world objects, ideas and concepts. • Symbols and icons follow an intuitive pattern in line with tasks. • Information is seen as sequential, logical and as naturally arranged.	Dix et al. (2004) Nielsen (1994) Squires and Preece (1999)
3	*Learner controls* • Users are able to exert control on the system. • It is possible to exit at any time even though mistakes might have been made. • Undo and Redo options exist.	Dix et al. (2004) Nielsen (1994) Shneiderman and Plaisant (2005) Squires and Preece (1999)
4	*Consistency and adherence to standards* • Patterns of words, symbols, icons repeat logically throughout the application. • Platform standards are recognised as similar to	Alessi and Trollip (2001) Dix et al. (2004) Nielsen (1994)

	PC-oriented standards.	Shneiderman and Plaisant (2005) Squires and Preece (1999)
5	*Error prevention, in particular, prevention of peripheral usability-related errors* • Errors are preventable – the system is designed to take care of this. • An appropriate message is shown if a mistake is made.	Nielsen (1994) Dix et al. (2004) Squires and Preece (1999) Shneiderman and Plaisant (2005) Karoulis and Pombortsis (2003)
6	*Recognition rather than recall, memory use* • Objects are visible and familiar; scrolling is needed occasionally. • The screen is manipulated to view any information without needing to remember. • Advice on system use is visible and able to be used whenever needed. • Simple displays are presented with few or no multiple page display options. • The zoom feature enables easy enlargement of text for improved reading.	Dix et al. (2004) Nielsen (1994) Shneiderman and Plaisant (2005) Squires and Preece (1999)
7	*Aesthetics and minimalism in design* • Distracting material of minimal relevance has been excluded. • Graphics are used to illustrate a point rather than to decorate the page.	Dix et al. (2004) Nielsen (1994) Squires and Preece (1999) Storey et al. (2002)
8	*Recognition, diagnosis and recovery from errors* • Error messages are easy to follow being presented in straight forward language. • Quick and simple solutions are offered if errors are made. • Recovery is achieved after constructive help.	Dix et al. (2004) Karoulis and Pombortsis (2003) Nielsen (1994) Shneiderman and Plaisant (2005) Squires and Preece (1999)
9	*Help and documentation* • A help facility exists, it is easy to find and support the users' needs. • A search facility makes it easy to find information. • Support documentation is provided on each page.	Dix et al. (2004) Nielsen (1994) Shneiderman and Plaisant (2005) Squires and Preece (1999)

Table 5-13: Category 2: Website-specific criteria and sub-criteria

	Category 2: Website-specific criteria and sub-criteria; relevant for delivery by mobile handheld devices	**References**
10	*Simplicity of site navigation, organisation and structure* • The application is easy to navigate on a mobile phone. • There are several paths to and from a chosen destination. • Related information has been grouped into obvious categories. • Information is organised hierarchically. • Links and buttons support navigation throughout the site without cluttering it.	Squires and Preece (1999)
11	*Relevance of site content to the learner and the learning process, content meaningful to domain and learner* • The site is interesting and keeps the user's attention focused. • Site information is clear and relevant. • No racial or gender biases are noted. • If material has been copyrighted, this has been made clear.	Alessi and Trollip (2001)
12	*Easy to access information* • Any lesson material or downloadable documents can be reached. • The videos open with ease. • All links to external sites provide the required connections to additional information.	Coursaris and Kim (2006) Karoulis and Pombortsis (2003) Storey, Phillips, Maczewski and Wang (2002)
13	*Content is both suitable and of a high quality* • Additional website links provide suitable content. • The content is of a high standard.	Herrington, Herrington and Mantei (2009) Karoulis and Pombortsis (2003) Zaibon and Shiratudin (2010)
14	*System is simple and easy to use, called easiness* • No difficulties are experienced reaching site material via the mobile interface. • It is just as easy to scroll or browse back to the site after visiting another site. • It is easy to browse back and forth through the many learning options offered.	Storey, Phillips, Maczewski and Wang (2002) Zaibon and Shiratudin (2010)
15	*Material is of a high quality, i.e. videos and digitisation* • Text is presented in a legible easy to read format. • Digital material is of a high quality, no difficulty is experienced during viewing.	Smith and Cook (2009)

Table 5-14: Category 3: Educational criteria and sub-criteria

Category 3: Educational criteria and sub-criteria; based on learner-centred instructional design, grounded in learning theory		References
16	*Clarity of goals, objectives and outcomes* • Goals are clearly set out, objectives and expected outcomes for learning are clear too. • There is a good reason for the inclusion of each page and this reason is obvious.	Albion (1999) Alessi and Trollip (2001) Ardito et al. (2005) Squires and Preece (1999)
17	*Effectiveness of collaborative learning* • Activities are experienced encouraging collaborative learning in several different ways. • The discussion forum is fun and operational. • Chat room facilities are found.	Alessi and Trollip (2001) Ardito et al. (2005) Squires and Preece (1999)
18	*Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle* • Problem-based learning strategies have been implemented. • Mistakes can be made affording users the chance to learn from them. • Help is provided to recover from cognitive errors.	Karoulis and Pombortsis (2003) Squires and Preece (1999)
19	*Feedback, guidance and assessment* • Users receive prompt feedback from the application on assessment and progress. • Guidance is provided about the tasks and construction of knowledge going on. • Activities are graded with grades providing instant feedback and correction.	Alessi and Trollip (2001) Squires and Preece (1999)

Table 5-15: Category 4: m-Learning criteria and sub-criteria

Category 4: m-Learning criteria and sub-criteria; customised for mobility and mobile handheld devices in a learning context		References
20	*Mobile phones and technology* • Technology has made mobile learning feasible. • The mobile phone has adequate capabilities to support mobile learning. • The mobile interface does not hamper working with the application. • Inserting text and numbers is feasible and achievable. • The mobile phone system is used to its fullest capability. • Mobile communication channels are provided.	Cochrane (2006) Coursaris and Kim (2006) Karoulis and Pombortsis (2003)
21	*Contextual factors (pragmatic)* • A physical environment is noted but it does not	Coursaris and Kim (2006)

	hinder the lesson experience. • The lessons are followed where noise and audible interference is experienced. • Prior mobile phone knowledge and exposure makes the task easy. • User characteristics have been considered as part of the exercise. • Goals are set and not adjustable. • The application feels and behaves like a normal working environment. • During the lesson, awareness of surroundings is evident. • Users are exposed to rich and complex environments, not limited by the mobile.	Göker and Myrhaug (2008) Herrington, Herrington and Mantei (2009) Kroeker and Ally (2005) Kukulska-Hulme and Traxler (2007) Savolainen (2010) Sharples, Taylor and Vavoula (2005) Smith and Cook (2009) Traxler (2010b) Zaibon and Shiratuddin (2010)
22	*User-centricity (pragmatic)* • Support for personal approaches to learning is offered. • Experimentation and exploration is possible. • User requirements have been specified. • Self-sufficiency is observed. • Material is presented in a clear, learner-centred format. • Focus is enhanced in that learners spend longer times doing tasks. • Personalised learning format has been provided. • Learners are personally aware of all content with control being given to users. • Learners can customise, applying their own preferences. • Active learning promotes critical thinking: users compare, analyse, classify, deduce. • Users are able to direct their own learning with a sense of ownership.	Coursaris and Kim (2006) Göker and Myrhaug (2008) Herrington, Herrington and Mantei (2009) Karoulis and Pombortsis (2003) Savolainen (2010) Smith and Cook (2009)
23	*Flexibility* • The lesson may be done at any personal moment in time. • An adaptable environment has been created. • Lesson information may be viewed in any order. • The system can be adjusted to individual needs. • The systems can be used anytime and anywhere.	Coursaris and Kim (2006) Smith and Cook (2009) Storey, Phillips, Maczewski and Wang (2002)
24	*Interactivity* • Navigational fidelity is experienced. • Multimedia components are appropriate. • Multiple kinds of exercises have been provided. • Synchronous communication is possible. • Asynchronous communication is possible. • Interaction happens in varying ways. • Interaction with the application is smooth. • Support is provided for interactivity with the application. • Interactivity has been encouraged in creative ways.	Karoulis and Pombortsis (2003) Kroeker and Ally (2005) Smith and Cook (2009) Zaibon and Shiratuddin (2010)

Table 5-16: Category 5: UX criteria and sub-criteria

	Category 5: UX criteria and sub-criteria	References
25	*Emotional issues* • The lessons are motivating and fun. • The application encourages participation with a longer time trying to process the lesson. • The experience is enjoyable. • It is new technology yet it is interesting and an acceptable form of learning. • This way of learning software engineering is exciting.	Beccari and Oliveira (2011) Jones, Issroff, Scanlon, Clough and McAndrew (2006) MacCallum and Kinshuk (2008) Sharples, Arnedillo-Sanchez, Mildrad and Vavoula (2009b) Smith and Cook (2009) Zaibon and Shiratuddin (2010)
26	*Contextual factors (hedonic)* • Knowledge of mobile technology makes this way of learning a pleasure. • The need for this type of learning suits the current mobile learner environment.	Law et al. (2009) Oppenheim et al. (2001) Pirker and Bernhaupt (2011) Sharples et al. (2009b)
27	*User-centricity (hedonic)* • Personalised learning is encouraged. • The learner is able to customise the learning environment.	Sharples et al. (2009b)
28	*Social value* • The application is social, encouraging media sharing. • The m-learning approach provides both synchronous and asynchronous interaction.	Väänänen-Vainio-Mattila et al. (2009)
29	*Needs* • The learner is encouraged to express personal opinions. • The learning environment is stimulating. • A sense of security is achieved.	Hassenzahl (2008) Sharples et al. (2009b) Väänänen-Vainio-Mattila et al. (2009)
30	*Appeal* • New impressions of the learning content create an appealing space. • The learner is motivated to explore. • The experience is visually appealing.	Pirker and Bernhaupt (2011)
31	*Satisfaction* • The experience adds fun to the learning opportunity. • This way of learning is motivating. • A satisfying sense of achievement is felt. • The learner is encouraged to engage with the course material.	Beccari and Oliveira (2011) Law et al. (2009) Oppenheim et al. (2001) Roschelle (2003) Sharples et al. (2009b)

5.7 Validity and Reliability

The inclusion of more than one data generation method is termed method triangulation (Oates, 2008). In this research, method triangulation was achieved by incorporating two survey research methods namely, heuristic evaluation by experts as well as evaluations by learner users.

Data triangulation enables the researcher to explore the research questions in different ways, using various forms of data such as quantitative and qualitative data that corroborate each other. Findings from quantitative and qualitative analysis can then be compared, improving reliability and validity (Creswell, 2009). The collection of data from various sources indicates an effort to achieve triangulation (Attewell and Webster, 2005). Primary empirical data as well as secondary literature study data was collected.

Data triangulation was implemented in questionnaires, where similar questions were asked, but statements were expressed in varying ways. Data was triangulated as follows:

- Surveys were piloted to ensure appropriate wording of the heuristics;
- Quantitative and qualitative data items were embedded in the same research instrument and placed in proximity to the criterion being evaluated;
- Expert evaluators and learner user evaluators provided evaluation feedback from diverse perspectives;
- Each of the four evaluation studies incorporated a new 'set' of evaluators; and
- Different cohorts from ethnographically divergent learner communities and campuses participated in the evaluations.

In addition to method and data validation discussed above, efforts to achieve research validity included:

- *Evaluator triangulation* – HEs included a selection of education practitioners and experts in technology-enhanced learning, while questionnaires were administered to learner cohorts from two different campuses between 2010 and 2012;
- *An iterative, design-based research strategy* – user-centred design was informed by feedback from four DBR evaluation study cycles based on MUUX, namely, evaluations of an early prototype, a pilot, and two formative versions of the m-learning environment;
- *Data analysis* – the data collected for quantitative and qualitative purposes was analysed statistically and thematically (de Villiers, 2005b).

Reliability of findings was measured by comparing the findings of Main Study 1 and Main Study 2. In addition, the extent of the conformance of the application to the set of MUUX criteria was determined.

5.8 Ethical Aspects and Informed Consent

Ethical clearance was requested from and provided by CTI Head Office Johannesburg and the Ethical Clearance Subcommittee of Unisa's College of Science, Engineering and Technology.

Prior to commencing the evaluations, a covering letter was given to each participant guaranteeing the right to withdraw or refuse to participate at any stage. Assurance of anonymity and confidentiality was provided. Participants were asked to sign informed consent, also acknowledging that findings might be published in academic publications. The informed consent document is given in Appendix A-3.

A clear explanation of the research purpose and procedure was provided prior to the evaluations. Contact details of the researcher were supplied. Evaluations were conducted in a professional manner in a safe and secure research environment.

After completion of the evaluations and unstructured interviews, participants were debriefed and thanked for their support and time.

The researcher declared her intention to avoid plagiarism and to adhere to correct citation principles.

5.9 Conclusion

In this chapter, the design-based research strategy associated with this study was outlined from several perspectives.

Firstly, the research questions underlying the study were revisited. This was followed by an introduction to a generic view of DBR including a mapping of DBR concepts to the context of this study. A discussion of data generation methods, sampling frame and techniques, research instruments, data collection, and data analysis, provided an understanding of the research methods associated with the study. A tabular summary of the six DBR iterations of the study was set out, indicating the sequence and relationship between them. The DBR research design was portrayed in a key diagram, giving a holistic perspective on the work. This was followed by tabulated summaries of the purpose and participants of each study. The synthesized framework of criteria for the

evaluation of usability and UX of m-learning environments, MUUX, was presented. Finally validity, reliability, ethical aspects and informed consent were briefly discussed.

The research design and methodology discussed in this chapter establishes the evaluation framework and approaches for the detailed empirical studies. Findings and discussion follows in Chapters 6 and 7. Chapter 6 includes Studies 1, 2, 3 and 4 while Studies 5 and 6 are found in Chapter 7.

CHAPTER 6: Findings and Discussion 1

6.1 Introduction

The findings and discussion of this research are presented in two parts as follows:

- *Chapter 6*: Findings and Discussion 1 – which considers a series of four studies in the design-based research process; and
- *Chapter 7*: Findings and Discussion 2 – the further two studies in the design-based research (DBR) process.

This chapter therefore reports on the first four iterative studies, namely Study 1, Pre-Study (Section 6.2), Study 2, Mobile Usage Study (Section 6.3), Study 3, Pilot Study (Section 6.4) and Study 4, Main Study 1 (Section 6.5). Studies 1, 3 and 4 are evaluation studies as explained in Section 5.5 of Chapter 5, Research Design and Methodology, while Study 2 was done to acquire enriched data regarding the mobile phone use of the target users – also set out in Section 5.5. For each study, an initial outline is followed by the presentation and discussion of the findings of the study. In keeping with the DBR methodology discussed in Chapter 5, a brief reflection on the findings of each respective study and its impact on *m-LR*, is conducted at the end of each section. Section 6.6 concludes the chapter.

Figure 6-1 illustrates the first section of the DBR model initially provided as Figure 5-2 in Section 5.5 and included here to contextualise Studies 1, 2, 3 and 4. Figure 7-1 in the next chapter will provide the second section of the DBR model, encompassing Studies 5 and 6.

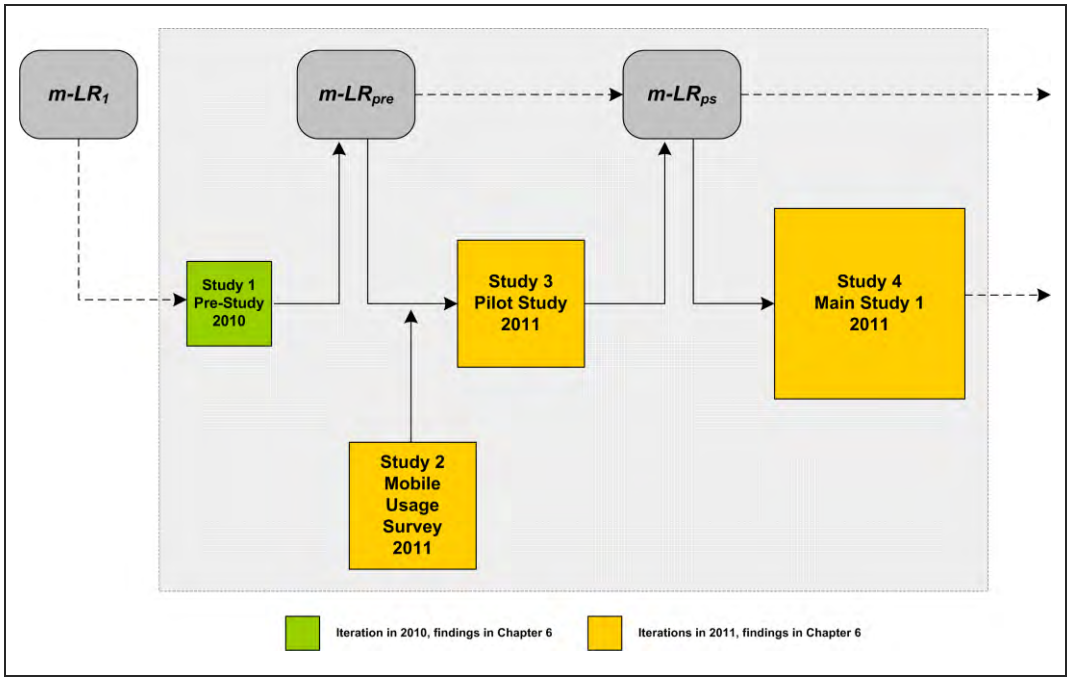

Figure 6-1: Section of the DBR model incorporating Study 1 to Study 4

Figure 6-1 indicates that Study 1, the Pre-Study provided guidelines for the customisation of *m-LR*$_{pre}$ while Study 2, the Mobile Usage Survey established supportive input for Study 3, the Pilot Study. The Main Study 1 in 2011 (Study 4) evaluated *m-LR*$_{ps}$ for usability and UX. The findings of this iteration led to *m-LR*$_{m1}$, evaluated in Main Study 2 in 2012.

Chapter 6 contributes to the answering of research questions ***RQ3*** (practical outcome of the study) and ***RQ5*** (theoretical outcome).

6.2 Study 1: Pre-Study

6.2.1 Outline of the Survey

Study 1, Pre-Study, which appears as the first study in Figure 6-1, formed part of the researcher's unpublished BSc (Honours) project work (Harpur, 2010). An early prototype version of *m-LR*, *m-LR*$_1$ was populated with content for a course in Project Management and subjected to usability evaluation. The outcome of this iteration informed the adjustments to *m-LR*$_1$, resulting in *m-LR*$_{pre}$ as output, which served as a platform for this research.

Table 6–1: Study 1 – Pre-Study, a reproduction of Table 5-5, summarises Study 1.

Table 6–1: Study 1 – Pre-Study

Pre-Study 2010		
Participants	Single campus	Heuristic evaluation: three experts
	Sample of convenience of a 2010 cohort on campus C1	Questionnaire survey: ten learners
Delivery device	Blackberry 9700, supplied by the researcher	
Data Collection	Paper-based survey questionnaires, supervised completion	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Preliminary evaluation of usability of the m-learning environment version, *m-LR*$_1$ resulting in *m-LR*$_{pre}$	

The key features of the Pre-Study are incorporated into Table 6–1 which indicates that the purpose of the study was usability evaluation. The number of participants was small, involving three expert evaluators and ten learners. Completion of the questionnaire was done in the presence of the researcher, meaning that it was supervised, resulting in an evaluation context that was not naturalistic.

6.2.2 Findings and Discussion

The questionnaires used as research instruments, gathered quantitative (five-point Likert scale items) and qualitative (open-ended items) data in four evaluation categories of criteria, namely: general interface, website-specific, pedagogical and m-learning usability.

Quantitative findings

Table 6–2 provides the quantitative findings of Study 1 in tabular format where 'Overall' ratings in the last column indicate the average of all reported values. A more favourable overall evaluation score of 4.0 was reported by experts compared with the rating of 3.5, indicated by learner users.

Table 6–2: Study 1 – Pre-Study, mean Likert scale ratings

		Categories of Criteria				Overall
		1	2	3	4	
Experts (n=3)	**Mean Likert Scale Ratings***	**4.2**	3.6	4.0	4.0	**4.0**
Learner Users (n=10)	**Mean Likert Scale Ratings***	**3.6**	3.4	3.2	3.6	**3.5**

* P(T<=t) = 0.030466, < p=0.05 df=3, indicates that the differences between the means of Experts and Learner Users are statistically significant, demonstrating a greater evaluation rating of *m-LR*$_1$ by Experts (4.0) than by Learner Users (3.5)

The findings of Study 1 are presented graphically in Figure 6-2, which depicts the mean ratings assigned by experts, and Figure 6-3 , which similarly presents the mean ratings assigned by the learner participants. Mean Likert scale ratings are juxtaposed against the number of problems reported by experts and learner users, enabling simultaneous visualization of the findings.

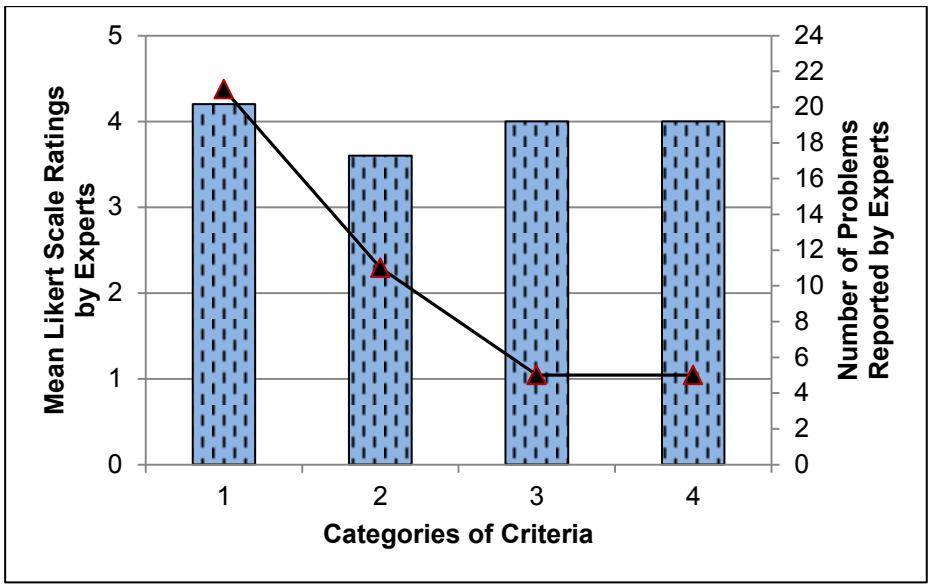

Figure 6-2: Mean Likert scale ratings – Experts

Figure 6-2 shows that the expert evaluators allocated their highest mean rating (4.2) in Category 1, General Interface Usability. Paradoxically, they also listed the highest number of problems (21) in Category 1, equivalent to 50% of all the difficulties reported. In contrast, a mean Likert rating of 4.0 for Category 3 is associated with just five problems (5%).

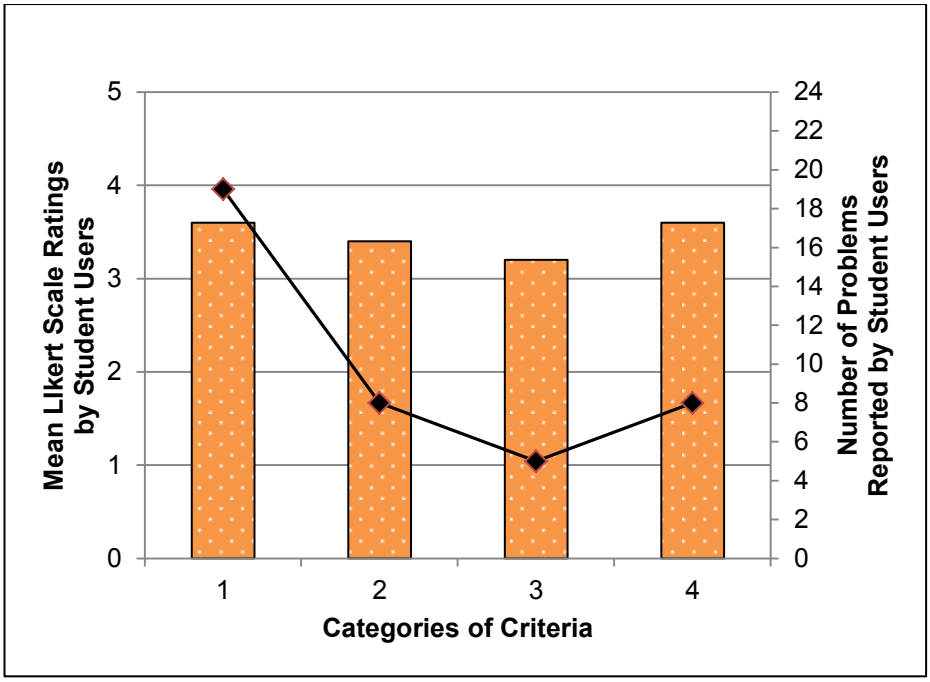

Figure 6-3: Mean Likert scale ratings – Learner Users

Quantitative findings from qualitative data

Table 6–3 indicates the quantitative information elicited from qualitative data, derived by counting the number of problems reported by experts and by learners (Creswell, 2009).

Table 6–3: Study 1 – Pre-Study, number of reported problems

		Categories of Criteria				Overall
		1	2	3	4	
Experts (n=3)	**Number of Problems**	**21 (50%)**	11 (26%)	5 (12%)	5 (5%)	**42 (100%)**
Learner Users (n=10)	**Number of Problems**	**19 (47.5%)**	8 (20%)	5 (12.5%)	8 (20%)	**40 (100%)**

Three experts detected approximately the same number of problems (42), compared with the problems reported by learner users (40). This observation supports Nielsen's suggestion that three to five expert evaluators uncover 75% of all problems (Nielsen, 1994).

Qualitative findings

A total of 42 distinct violations were reported by the three expert evaluators who separately noted 52 problems. Experts reported 50% (21 problems), 26% (11 problems), 12% (5 problems) and 12% (5 problems) for General Interface Usability, Website-specific, Educational and m-Learning criteria respectively. A sample of evaluator comments is provided below where expert observations highlighted navigation:

- *General Interface Usability* – "confusion about no feedback when navigating", "too much scrolling", "Navigation difficulties are distracting";
- *Website-specific usability* – "although breadcrumbs are good at the top, scrolling too much means breadcrumbs are out of sight";
- *Educational Usability* – "lecturers would need to provide plenty of online feedback"; and
- *m-Learning Usability* – "scrolling around is difficult".

A total of 40 distinct problems were reported by the ten learner evaluators with 48% coming from General Interface, 20% from Website, 12% from Educational and 20% from m-Learning Categories. Sixty eight per cent of problems were identified by two evaluators and results are skewed by six evaluators whose contribution was either zero or minimal. The number of problems reported per category relates closely to the number of criteria in the category. As suggested by Nielsen (1994) three experts produced effectively as many problems as a bigger target group of learner users, namely 42 by experts and 40 by learner users in this study. The following remarks constitute a small sample of responses made by learner evaluators in open-ended items:

- *General Interface Usability* – "struggled to locate the video section", "think colour scheme should be more visible on phone browser", "Zoom makes speed reading difficult";
- *Website-specific usability* – "although breadcrumbs are good at the top, scrolling too much means breadcrumbs are out of sight", :chatting doesn't allow for a quick link back to the home page";
- *Educational Usability* – "Just wanted to note that I really like the idea of the chat room function. This would be of great use if implemented 100%"; and
- *m-Learning Usability* – "get frustrated when working with handheld devices".

6.2.3 Reflection

m-LR$_1$ was an e-learning version of *m-LR*, delivered in an m-learning context via a BlackBerry 9700. It is considered an 'e-learning' rather than an 'm-learning' application, as learners accessed a WBL version of Moodle via the Internet using personal computing and laptop devices. The main findings in Study 1 indicate that the experience was unsatisfactory largely due to the limitations of mobile devices such screen size and connectivity difficulties. These findings suggest that the design, development and implementation of *m-LR* should be on the MLE-Moodle platform, and be specifically implemented for an m-learning context, rather than as an e-learning application. Adjustments to *m-LR*$_1$ culminated in *m-LR*$_{pre}$, the subsequent version of *m-LR* that was piloted in Study 3, Pilot Study. The evolutionary adjustments to *m-LR*$_1$ included:

- A complete redesign of the look and feel of the interface;
- The redesign of content to encompass short nuggets rather than textbook versions course material, more suited to delivery by mobile devices;
- The ability to login using a variety of devices;
- Reduction in the amount of information contained within a single frame, opting instead for easier navigation to multiple pages;
- Inclusion of course content in various downloadable formats such as MS Word, PDF, slide shows, and video;
- The inclusion of software engineering module content, increasing the glossary feature to make provision for additional terminology.

Several weaknesses in the research methodology were highlighted as a consequence of Study 1, namely:

- The study excluded the evaluation of UX dimensions;
- The sample size was small and not adequately representative of the cohort groups of 2010;
- All the evaluations were done on the same mobile device – a BlackBerry 9700 supplied by the researcher; and
- The supervised completion of the research activities and use of the instrument meant that the study was not conducted in a natural context of use.

These limitations would be considered in subsequent evaluation iterations – Study 4, Main Study 1 and Study 6, Main Study 2. Despite the shortcomings listed above, Study 1, Pre-Study produced comparable quantitative findings and indicated that heuristic evaluation by experts and the questionnaire surveys by learner users constituted a cost-

and time-effective evaluation strategy. In addition, Study 1 highlighted a need for more detailed information on the nature and extent of the digital profile of mobile learners. This led to Study 2, the Mobile Usage Survey.

6.3 Study 2: Mobile Usage Survey

Study 2 comprised a paper-based survey questionnaire (see Appendix A-7) which aimed to establish the mobile technology and usage profile of 3rd year Software Engineering cohorts on two different campuses, C1 and C2, in the Western Cape in 2011. In addition, the findings of this study, Study 2, informed the selection of a non-probability sample of convenience for Study 3, the Pilot Study. Figure 6-1 shows that Study 2 is not one of the evaluation studies, yet the outcomes of Study 2 do indeed provide input relevant to Study 3.

6.3.1 Outline of the survey

Table 6–4, is a reproduction of Table 5-6, and summarises Study 2, the Mobile Usage Survey.

Table 6–4: Study 2 – Mobile Usage Survey

Mobile Usage Survey 2011		
Participants	Two campuses Population of 2011 cohorts of fulltime learners on campus C1 and C2	Questionnaire surveys: 36 learners
Data Collection	Paper-based survey questionnaires, supervised completion	
Data Analysis	Quantitative – elementary statistical analysis	
Purpose	Collection of data to establish mobile profile of learners	

The survey gathered data regarding the participants' mobile phone usage information and provided feedback relating to their personal feelings and attitudes to the potential of mobile technology as a supplementary medium to support their software engineering studies. The findings of the survey enabled the selection of participants for the upcoming Study 3, Pilot Study by a purposive sample of convenience.

The populations of the two Software Engineering cohorts, 36 participants in total, completed the questionnaire (Appendix A-7) during a knowledge management class when the elicitation of tacit knowledge was being addressed. The research instrument consisted of demographic, multiple choice, five-point Likert scale (1= Not at all, 2= No, not really, 3 = Unsure, 4 = Yes, I do and 5 = Absolutely) and open-ended items. The survey process included an explanation of purpose of the survey; completion

instructions; and assurance of confidentiality and anonymity. The learners were advised that the findings were for academic purposes only and might also be used in research publications. They signed an informed consent document (Appendix A-3).

6.3.2 Findings and Discussion

Study 2 collected both quantitative and qualitative mobile usage data, incorporating time spent travelling and mode of transport; brands and models of mobile ones used; mobile phone activities; feelings and attitudes to the use of mobile devices; and learner attitudes to the prospect of m-learning. A selection of the quantitative data has been analysed in this study.

Quantitative findings

Travelling time and mode of transport

Table 6–5 and Table 6–6 respectively summarise the time learners spend travelling to and from campus on a daily basis and the manner in which they travel.

Table 6–5: Time taken per day to travel to and from campus

Travelling Time	#	%
Less than 1 hour	11	31%
1-2 hours	9	25%
2-3 hours	2	6%
3-4 hours	3	8%
More than 4 hours	11	31%
Totals	**36**	**100%**

Table 6–6: Learners' mode of transport

Mode of Transport	#	%
Bicycle	1	3%
Bus	3	8%
Car	16	44%
On foot	4	11%
Taxi	6	17%
Train	6	17%
Totals	**36**	**100%**

These findings are included to establish whether learners would benefit from learning whilst being on the move. On the one hand, m-learning is a realistic prospect for the 31% of learners who reported spending more than four hours travelling per week. However, an equal number of learners live in close proximity to campus, travelling less than an hour per week. Table 6–6 suggests that travelling by taxi or by train (17% in both cases) provides opportunities for technology enhanced learning.

Brands and models

The challenges of m-learning contexts discussed in Section 2.7, indicate that the variety of mobile devices in use contribute to the complexity of technology-enhanced learning. Study 2 reports that participants used six brands of mobile device type with a collective total of 28 different models. Table 6–7 illustrates that the most popular brand was Nokia (36%), where thirteen learners reported using nine Nokia models.

Brand	#	%	Models
Apple	1	3%	1
BlackBerry	8	22%	4
LG	1	3%	1
Nokia	13	36%	9
Samsung	8	22%	8
Sony Ericsson	5	14%	5
Totals	**36**	**100%**	**28**

Table 6–7: Brands and models of mobile devices

Mobile phone activities

Figure 6-4 demonstrates that participants reported using their mobile phones to perform a variety of activities, ranging from the making of calls and sending of SMSs (100%) to podcasting activities (less than 10%).

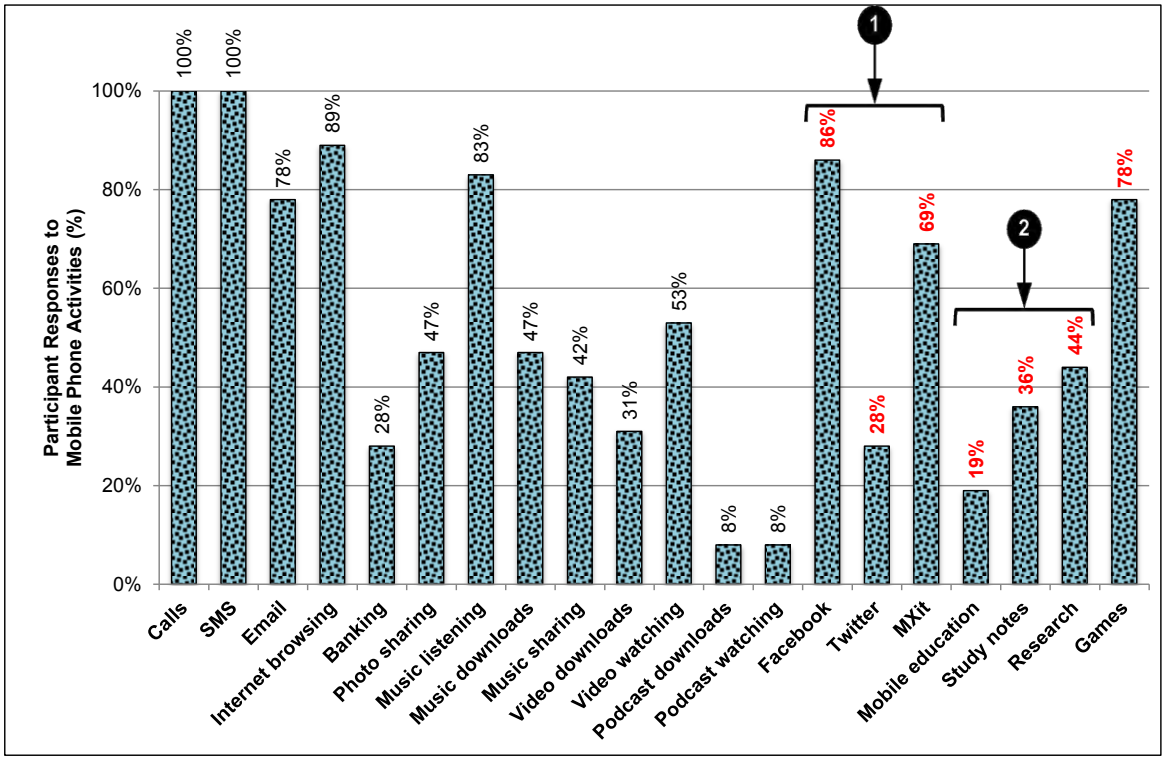

Figure 6-4: Mobile phone activities

Two groups of activities (shown by black arrow placements) are highlighted in Figure 6-4:

❶ Learners use their mobile devices for social networking activities such as Facebook (86%), Twitter (28%) and MXit (69%).

❷ The percentage of participants using their mobile phones for study notes (36%) and research (44%) is indicative of a lack of adequate on-campus computer laboratory facilities and Internet connectivity. Seven participants (19%) indicated the use of their phones for mobile education.

Personal feelings and attitudes to the use of mobile phones

Table 6–8 and Figure 6-5 summarise mean Likert ratings for items from Q21 to Q27 associated with learners' attitudes to the use of their mobile phones.

Table 6–8: Mean Likert scale ratings for learner attitudes to the use of mobile phones

	Feedback on the Use of Mobile Phones	Mean Ratings
Q21	Do you feel self-conscious using your mobile phone in public?	1.9
Q22	Do you feel comfortable installing and operating third party software on a mobile phone?	3.2
Q23	Do you believe that your mobile phone could support learning in groups?	**3.5**
Q24	Would learning by mobile phone motivate you to achieve better study outcomes?	**3.0**
Q25	To what extent do you think using your mobile phone for learning would be frustrating?	**2.9**
Q26	Do you find the idea of submitting quiz answers by mobile phone, trustworthy?	3.2
Q27	Do you regard your cell phone as a fashion item?	2.2
	Overall Mean Rating: Use of Mobile Phones	**2.9**

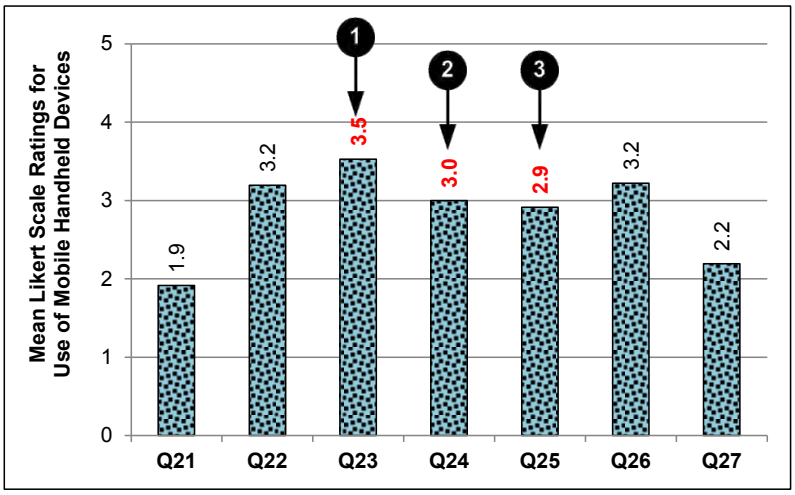

Figure 6-5: Learner attitudes to the use of mobile phones in the context of studying SE

Mean ratings relevant to this study are selected for discussion and highlighted in Table 6–8 (red values) and Figure 6-5 (black arrows):

❶ The mean Likert rating of 3.5 (Q23) suggests that learners can envisage the positive benefit of using their mobile phones when doing group work.

❷ The use of mobile devices is viewed to a lesser extent (3.0 in Q24) as a positive means of achieving better study outcomes.

❸ The participants indicated in Q25 that they did not really feel the m-learning experience would be frustrating (2.9).

Attitudes to the use of an m-learning environment

Table 6–9 and Figure 6-6 present findings from Q29 to Q34 on the potential use of m-learning environments.

Table 6–9: Mean Likert scale ratings for learner attitudes to the use of an m-learning environment

	Feedback on the Use of m-Learning Environments	Mean Ratings
Q29	Would you feel comfortable allowing your lecturers to contact you through your mobile phone?	**3.9**
Q30	Would you feel safe receiving exam and coursework results via SMS?	3.6
Q31	Would you agree that having course materials such as slides, lecture notes and practice quizzes available on your mobile phone would be beneficial to your study process?	**3.8**
Q32	Would you invest personal time learning to use and install software that could make these resources available on a mobile phone?	3.6
Q33	Would you be willing to purchase a new mobile device if you thought it would improve your performance at HWU?	**2.9**
Q34	Do you feel that the use of some kind of mobile learning software would improve overall success in your courses?	3.3
	Overall Mean Rating: Use of an m-Learning Environment	**3.5**

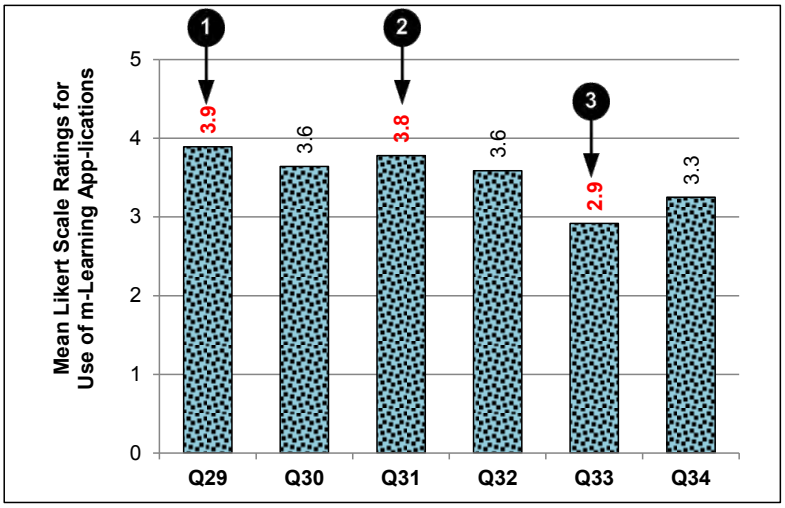

Figure 6-6: Learner attitudes to m-learning in the context of studying SE

In Table 6–9 (red values) and Figure 6-6 (black arrows) items are selected for further discussion:

❶ A positive attitude in Q29 to mobile phone contact with lecturers (3.9) is implied.

❷ In addition, Q31 indicates support for the digital delivery of course materials (3.8) is indicated.

❸ However, a rating of 2.9 for Q33 signals a resistance to personally purchasing new devices specifically to accommodate m-learning.

6.3.3 Reflection

The study collected data from two campuses, C1 and C2. However, no effort was made to compare and contrast the responses from the two cohort groups. The study contributed minimally to the answering of ***RQ4*** in that an emergent digital divide was implicitly noticed, but was not specifically addressed. The nature of this divide was investigated in Study 5, Mobile Learning and Digital Divide Survey in Section 7.3, which answered ***RQ4*** comprehensively.

A profile of the C1 and C2 mobile learners in 2011 indicates that learners travel various distances to and from campus, making use of *differing modes of transport*, revealing that only a few participants would benefit from m-learning whilst travelling. A particularly pertinent finding is that a *range of brands and models of mobile phones* was used by participants, implying that an m-learning environment would need to be accessible by all device types, as participants seemed *unwilling to purchase new mobile devices* specifically for m-learning. *Facebook* was a popular digital communication mechanism and could provide *a collaboration platform* for group work. In contrast, a limited number of participants reported the use of m-learning for educational purposes.

Whilst Study 2 gathered information from both campuses, C1 and C2, learner users from C1 with good academic records were selected as participants for Study 3 the Pilot Study. Four learners were purposively selected to comprise the sample, based on the findings of Study 2 considering travelling time and means of transport; brand and model of mobile phone; attitude to the use of Facebook; and experience with an m-learning environment.

6.4 Study 3: Pilot Study

The main purpose of a pilot study is to try out the research approach and instruments prior to undertaking a main study. In this context, Study 3, the Pilot Study was used to assess the suitability and effectiveness of research approach and methods, criteria and

instruments prior to their inclusion in Study 4, Main Study 1. In addition, however, the Pilot Study gathered primary data in a full-scale evaluation of usability and UX of *m-LR*$_{pre}$ by a small number of participants comprising one double expert and four learner user as evaluators.

Figure 6-1 depicts that Study 3 preceded Study 4. It contributed to the answering of the following research question:

RQ3 *– What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

6.4.1 Outline of the Study

Table 6–10, a reproduction of Table 5-7, summarises Study 3, Pilot Study.

Table 6–10: Study 3 – Pilot Study

Pilot Study 2011		
Participants	Single campus	Heuristic evaluation: one double expert
	Sample of convenience of a 2011 cohort of fulltime learners on campus C1	Questionnaire surveys: four learners
Delivery device	Blackberry 9700 supplied by the researcher	
Data Collection	Paper-based HE and SU questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – analysis of reported issues and suggestions	
Purpose	Testing of research procedure, tasks, and instrument and evaluation of usability and UX of m-learning environment version, *m-LR*$_{pre}$ resulting in *m-LR*$_{ps}$	

Mobile technology is undergoing rapid change. The Pilot Study was conducted in 2011 when no tablet devices were in use by experts or learners. In addition, few students owned smartphones. A decision was made to implement the study using the researcher's BlackBerry 9700, ensuring Internet connectivity and coverage of data costs. This rationale facilitated the evaluation of the m-learning environment whilst excluding complexities of diverse device types. The participants in Study 3 included one double expert and four SE learners from campus C1. The double expert was an educator and online e-learning portal developer with HCI and content development expertise. The learners were selected on the basis of findings of Study 2, Mobile Usage Survey (Section 6.3) and constituted a representative sample. They were willing participants with proven academic achievements in SE and appropriate technological and computer literacy levels.

Research instruments included heuristic evaluation and learner user survey questionnaires (Appendices A-5 and A-6 respectively), derived from the MUUX evaluation framework synthesized by the researcher in Section 3.6.8 and detailed in Section 5.6. Participants signed letters of consent (Appendix A-3) which assured anonymity and confidentiality, then completed a set of prescribed evaluation tasks (Appendix A-4) and the evaluation questionnaire.

Questionnaires elicited quantitative and qualitative findings which provided initial perceptions of the usability and UX of *m-LR*$_{pre}$, which was the input artefact to the Pilot Study.

6.4.2 Findings and Discussion

The evaluation of usability and UX in the Pilot Study reported both quantitative and qualitative findings derived from criteria with five-point Likert scale items and open-ended questions in five categories: Category 1 – General interface criteria; Category 2 – Website-specific criteria; Category 3 – Educational criteria; Category 4 – m-Learning criteria, and Category 5 – UX criteria.

Quantitative findings

The overall ratings in Figure 6-7 by experts (4.1) and learner users (4.0) suggest satisfactory usability and UX of *m-LR*$_{pre}$. Whereas the reported values appear to be consistent for expert and learner users, a higher rating by the expert in Category 1 (4.2) contrasts with the value reported by learner users (3.8). This discrepancy could be ascribed to device-related anomalies and connectivity capabilities. However the validity of this observation is limited due to the small sample size.

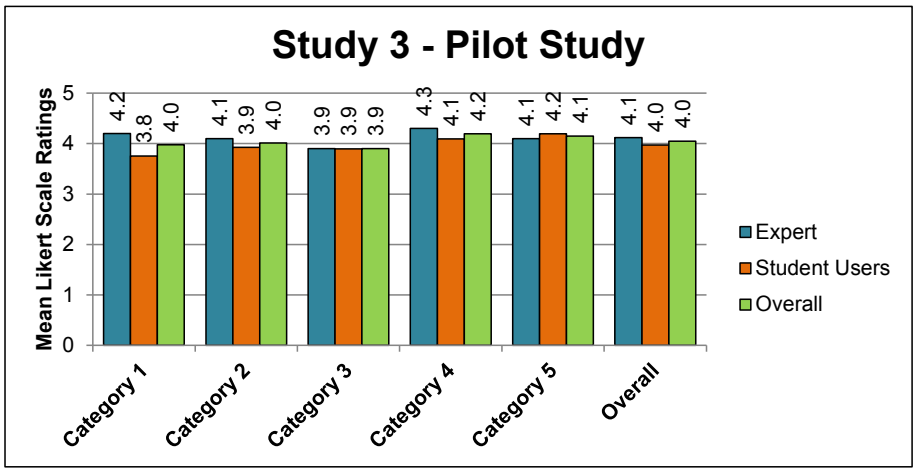

Figure 6-7: Mean Likert scale ratings reported by the Expert and Learners Users

Figure 6-8 presents the number of problems reported by the expert and the four learner users according to the five evaluation categories and collectively as a set of problems for the entire study.

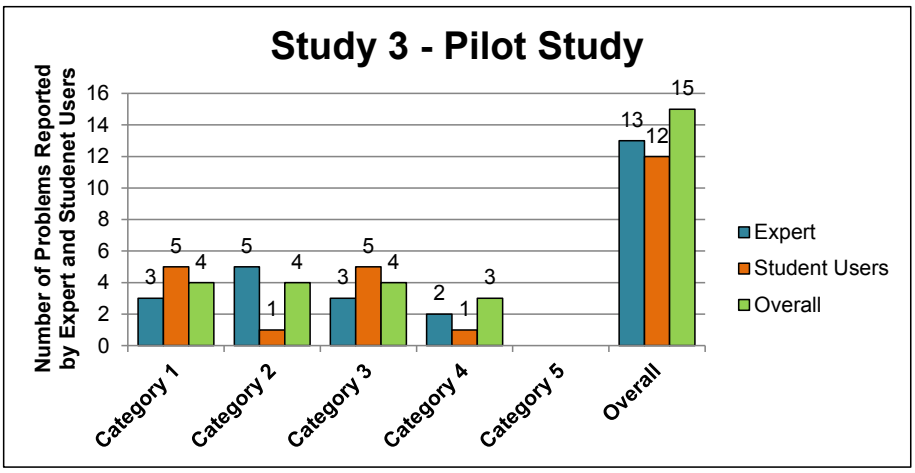

Figure 6-8: Number of problems reported by the Expert and Learner Users

Problems reported by the expert (13) and the learners (12) culminated in a set of fifteen unique issues. Figure 6-8 suggests that although the expert and learners uncovered a similar number of problems, the distribution of these problems across the categories differed, highlighting the benefit of evaluation by different evaluator types. The absence of reported problems in Category 5 revealed a fault in the design of the research instrument as provision had not been made in Category 5, UX for open-ended questions.

Qualitative findings

Table 6–11 portrays that five central themes emerged following an analysis of reported problems: scaffolding; communication; motivation; media; and assessment.

Table 6–11: Themes relating to reported problems with evaluators comments

Theme	Evaluator Comments
Scaffolding	Help not available; unexpected messages; confusing links; error responses caused redirection.
Communication	Interactivity a problem; struggled with blog; found glossary issues.
Motivation	Design not aesthetically pleasing; information not easily available; not quick enough; Internet connectivity frustration.
Media	Video conflicts – cannot view on my phone.
Assessment	Not sure about open-ended quiz questions; have trust issues with assessment process.

A selection of comments made by evaluators is included in Table 6–11.

6.4.3 Reflection

Study 3, Pilot Study, uncovered a few typographical errors in the documentation and instruments. In addition to minor adjustments to the wording of a few criteria and questions, the evaluation of *m-LR*$_{pre}$ highlighted a lack of open-ended statements and questions in Category 5, UX. The adjusted and finalised HE and survey questionnaires for expert and learner user evaluators are respectively found in Appendices A-5 and A-6.

The minor adjustments to *m-LR*$_{pre}$ led to m-*LR*$_{ps}$, the version of *m-LR* evaluated during Study 4, Main Study 1. Refinement to *m-LR*$_{pre}$ resulted from pertinent problems reported by evaluators and included:

- Adjustment to the *privileges settings* for usage of the blog feature;
- Customisation of the *glossary* options;
- Improvement to the *look and feel* of *m-LR*$_{pre}$, was achieved by a change to font styles, size, and colour; and
- Restructuring of the *quiz* to exclude open-ended items.

The perceptions collated in the Pilot Study evaluation ensured a close association with the subsequent usability and UX evaluation in Study 4, Main Study 1 improving validity of the findings.

Finally, a few minor adjustments to the documentation, research instruments and procedures were required. These included:

- Evaluators seemed uncertain about *username and password requirements* contained in the documentation. This was adjusted for Study 4: Main Study 1, where the *login procedure* was simplified;
- Additional space was allocated for evaluators to record contributions in *open-ended sections*; and
- The evaluators experienced *navigation difficulties* when using their mobile phones. The suggestion was made by learner evaluators that it might be easier to navigate *m-LR* using a Samsung Galaxy 10.1 Tablet. However the research strategy was not adjusted to incorporate this idea.

6.5 Study 4: Main Study 1

Figure 6-1 positions Study 4, Main Study 1 of 2011, the third evaluation study which follows Study 3. It indicates that Study 4 marks the end of the first part of the empirical findings. The aim of Study 4 was to subject m-LR_{ps} to a usability and UX evaluation, by applying the MUUX framework of criteria formulated in Section 3.6 and illustrated in Figure 3-5. Study 4 contributed to the answering of two research questions:

RQ3 – W*hat are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX? and*

RQ5 – *How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

These research questions will be addressed in Section 6.5.4 at the end of this section. However, completed answers are contained in Chapter 8, Section 8.2.

6.5.1 Outline of the Study

Table 6–12, a reproduction of Table 5-8, summarises Study 4.

Table 6–12: Study 4 – Main Study 1

Main Study 1 2011		
Participants	Single campus	Heuristic evaluation: five experts
	Population of a 2011 cohort of fulltime learners on campus C1	Questionnaire surveys: seventeen learners from C1
Delivery device	Learners: Blackberry 9700, used in a classroom setting Experts used their own devices	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Evaluation of usability and UX of the m-learning environment version, $m\text{-}LR_{ps}$ resulting in $m\text{-}LR_{m1}$	

The documentation and research instruments for Study 4 are found in Appendix A as follows:

- Informed Consent Form – Appendix A-3;
- Evaluation Task List – Appendix A-4;
- Expert Heuristic Evaluation Questionnaire – Appendix A-5; and
- Learner User Survey Questionnaire – Appendix A-6.

As in Study 3, Study 4 collected data using two evaluation methods (Section 5.4.1), namely HE by experts (n=5) and questionnaire survey by learner users (n=17). However, Study 4 differed from Study 3 in that the sample of participants was larger. Learners used a BlackBerry 9700 smartphone while the evaluators used a range of personal device types to evaluate $m\text{-}LR_{ps}$. Whilst experts completed the evaluation within a time-frame and location of their own choosing, learner user evaluations were supervised by the researcher and formed part of a scheduled SE class on the principles of usability.

Study 1, Pre-Study (Section 6.2) highlighted the need for the inclusion of user experience in the evaluation framework. The inclusion into the MUUX framework of criteria (Section 3.6.6) in Category 5 to evaluate UX factors resulted from this observation. The research instruments elicited quantitative and qualitative data derived respectively from five-point Likert scale and open-ended items in five categories: Category 1 – General interface usability; Category 2 – Website-specific usability; Category 3 – Educational usability; Category 4 – m-Learning usability, and Category 5 – User experience (UX). HE ratings

by experts and survey questionnaire ratings by learner users are respectively included in Appendices B-1.1 and B-2.1.

The problems reported by evaluators in response to the open-ended items were tallied in the five categories defined above, subjected to rudimentary thematic analysis and categorised. This feedback is found in Appendix B-1.2 (for experts) and in Appendix B-2.2 (for learner users).

The findings of the HE by expert evaluators are presented in Section 6.5.2. Thereafter, the findings of the user questionnaire survey conducted among learners are illustrated and discussed in Section 6.5.3. The combined feedback from experts and learner users comprehensively establishes the level of conformance of $m\text{-}LR_{ps}$ to the MUUX framework of criteria. Section 6.5.4 reflects on the findings of the Study 4, Main Study 1, providing recommendations for adjustments to $m\text{-}LR_{ps}$ that led to a subsequent version of *m-LR*, namely $m\text{-}LR_{m1}$.

6.5.2 Findings and Discussion – Heuristic Evaluation by Experts

The sample of five experts, which included one double expert, was selected from colleagues and fellow academics, whose qualifications and expertise are detailed as follows:

- *Expert 1* (double expert) – BComm (Hons) (IS), lecturer, LCMS developer;
- *Expert 2* – MSc (IT), IT forensic analyst;
- *Expert 3* – BSc (Hons) Business IS, manager, facilitator, mentor;
- *Expert 4* – BSc (Hons) Business IS, visual programming instructor, lecturer and developer; and
- *Expert 5* – MBA (Operations Research), business skills lecturer.

The experts completed the evaluations independently of each other.

In the following two subsections, the quantitative findings for heuristic evaluation by experts are reviewed and an analysis of qualitative data leads to additional quantitative findings.

Quantitative findings from heuristic evaluations

Evaluations resulted in the determination of mean Likert ratings based on the items included in the criteria in the HE questionnaire (Appendix A-5). Quantitative findings are detailed in Appendix B-1.1.

General interface usability

Table 6–13 and Figure 6-9 collectively reflect the mean Likert scale ratings by experts, as well as the standard deviations for Category 1, General Interface Usability.

Table 6–13: HE ratings of Category 1 criteria – Experts

Category 1 General Interface Usability		Mean	S.D.
1	Visibility of system status, provide feedback	**3.6**	0.49
2	Match between system and the real world	3.8	0.79
3	Learner control	**3.4**	0.90
4	Consistency and adherence to standards	4.0	0.55
5	Error prevention, in particular, prevention of peripheral usability-related errors	**3.3**	0.40
6	Recognition rather than recall, memory use	**3.2**	0.79
7	Aesthetics and minimalism in design	4.2	0.51
8	Recognition, diagnosis and recovery from error	**3.1**	0.53
9	Help and documentation	**3.0**	0.94
	Overall Rating	**3.5**	**0.80**

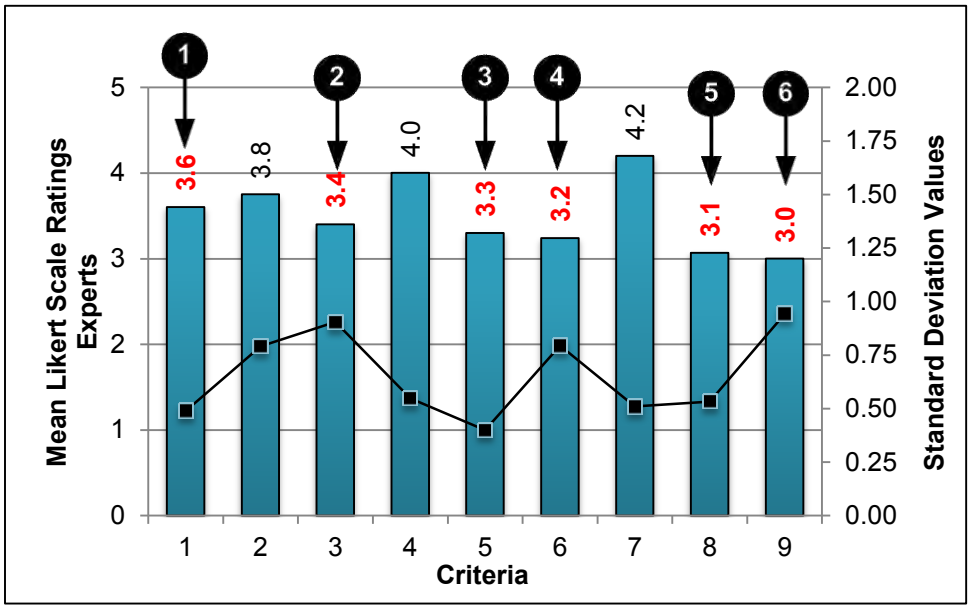

Figure 6-9: Category 1 General Interface Usability – Experts

The standard deviation values (S.D.) in the last column suggest limited scatter of the data. Evaluator ratings recorded in Table 6–13 indicate some dissatisfaction was reported by experts for Category 1 which has an overall rating of 3.0 (S.D. = 0.94). Criteria 1, 3, 5, 6, 8 and 9 (red values) are highlighted as potential areas for improvement.

A selection of notable items in Figure 6-9 has been flagged by black arrows for further discussion:

❶ Experts did not experience the feedback option in a completely satisfactory manner (Criterion 1).

❷ This response suggests that the experts were concerned that learners might not be totally in control of their m-learning activities (Criterion 3).

❸ The previous observation was confirmed by the weak rating of error prevention (Criterion 5).

❹ Interactive clues from the system should support recall in an improved fashion, rather than requiring users to remember each step (Criterion 6).

❺ The rating for this item indicates that, once errors have occurred, users would not easily recover (Criterion 8).

❻ The source of the above less-than-satisfactory ratings is likely to be the problems experienced with the help feature (Criterion 9).

Website-specific usability

Table 6–14 and Figure 6-10 illustrate the feedback from experts in Category 2, website-specific usability with an overall rating of 3.6 (S.D.=0.80).

Table 6–14: HE ratings of Category 2 criteria – Experts

Category 2 Website-specific Usability		**Mean**	**S.D.**
10	Simplicity of site navigation, organisation and structure	**3.5**	0.82
11	Relevance of site content to the learner and the learning process, content meaningful to domain and learner	3.9	0.75
12	Easy to access information	**3.5**	0.45
13	Content is both suitable and of a high quality	**3.5**	0.77
14	System is simple and easy to use, called easiness	3.6	0.65
15	Material is of a high quality i.e. videos and digitisation	3.8	0.93
	Overall Rating	**3.6**	**0.80**

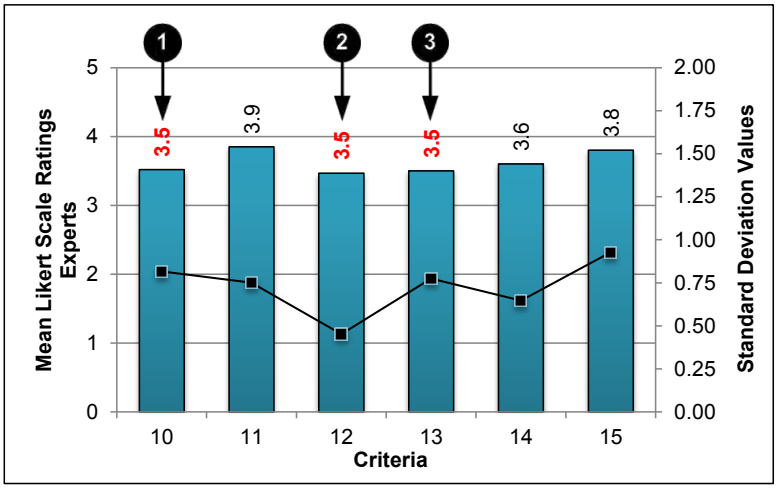

Figure 6-10: Category 2 Website-specific Usability – Experts

Three criteria from Category 2, namely 10, 12 and 13, each with a mean Likert scale rating of 3.5, are highlighted in red in Table 6–15 and flagged in Figure 6-10 for further discussion.

❶ Experts indicated they experienced some difficulty when navigating around *m-LR*$_{ps}$ with their mobile phones (Criterion 10).

❷ On a similar aspect and to a similar extent, information was not easily accessed (Criterion 12).

❸ Furthermore, the suitability and quality of the media content for an m-learning environment was questioned (Criterion 13).

Educational usability

Table 6–15 and Figure 6-11 reflect the evaluation ratings of experts in Category 3, Educational Usability.

Table 6–15: HE ratings of Category 3 criteria – Experts

Category 3 Educational Usability		Mean	S.D.
16	Clarity of goals, objectives and outcomes	3.0	0.71
17	Effectiveness of collaborative learning	3.5	0.86
18	Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle	3.7	0.13
19	Feedback, guidance and assessment	3.8	0.27
	Overall Rating	**3.5**	**0.70**

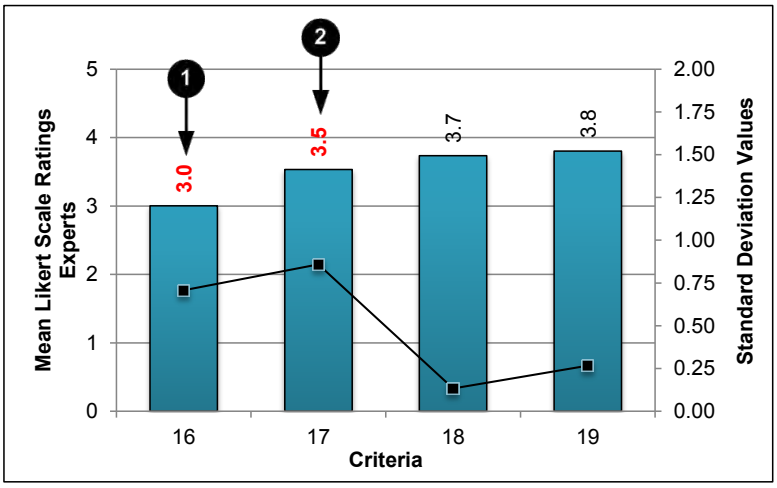

Figure 6-11: Category 3 Educational Usability – Experts

In Table 6–15 an overall rating of 3.5 (S.D.=0.70) suggests a satisfactory usability with regard to educational and pedagogical issues, but analysis of the individual ratings of a few items (red values), such as Criteria 16 and 17 with mean ratings of 3.0 and 3.5 respectively, indicates that some improvement should be made to *m-LR*. Black arrows highlight these items in Figure 6-11.

❶ Experts indicate dissatisfaction with Criterion 16, believing that goals, objectives and outcomes associated with education have not been clearly defined.

❷ In addition, their responses to Criterion 17 report some dissatisfaction. Even though the study did not attempt to evaluate whether collaborative learning had occurred, it was deemed important to evaluate the perception of evaluators to the possibility of collaborative learning. Criterion 17 included the following items: activities are experienced, encouraging collaborative learning in several different ways; the discussion

forum is fun and operational; and chat room facilities are found. This concern is particularly noteworthy, because this item aims to evaluate perception of effectiveness of collaborative learning and working in groups, in which the role of mobile devices can play a key role.

m-Learning usability

The findings of Category 4, m-Learning Usability are reported in Table 6–16 and Figure 6-12 with an overall mean Likert rating of 3.6 (S.D. = 0.50). This value suggests that experts rated the usability of *m-LR*$_{ps}$ as average.

Table 6–16: HE ratings of Category 4 criteria – Experts

Category 4 m-Learning Usability		Mean	S.D.
20	Mobile phones and technology	3.7	0.48
21	Contextual factors (pragmatic)	**3.5**	0.35
22	User-centricity (pragmatic)	**3.2**	0.56
23	Flexibility	4.1	0.32
24	Interactivity	3.6	0.44
	Overall Rating	**3.6**	**0.50**

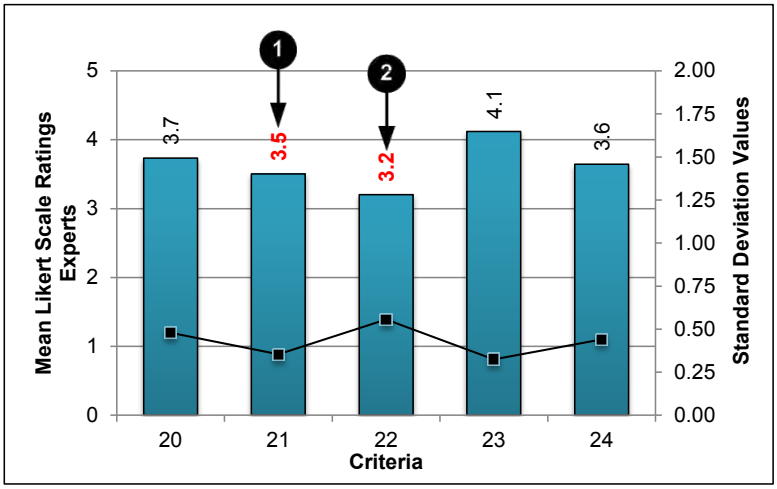

Figure 6-12: m-Learning Usability – Experts

Criterion 21, contextual factors (rated as 3.5) and Criterion 22, user-centricity (rated as 3.2) in Table 6–16 (red values) and Figure 6-12 (black arrows) have been selected for further discussion.

❶ According to the experts, Criterion 21 relates to the context in which users experience m-learning. The context exacerbates the m-learning experience to some extent as the user has to overcome difficulties associated with the context in which they are accessing the m-learning application. These factors have been illustrated in Figure 2-10 in Section 2.7.1 and include environmental factors, the Internet connectivity limitations and

constraints of the device itself. This response was expected as experts completed the evaluation within their chosen natural context of use.

❷ The rating for Criterion 22 suggests that experts felt that the m-learning environment did not adequately address the need for a focus on the user's views and requirements. This rather disappointing response is likely due to a range of personal device types used during the evaluation.

User Experience (UX)

Ratings of the seven items in Category 5, UX are included in Table 6–17 and Figure 6-13 with an overall Likert scale value of 3.2 (S.D.=0.70). The quantitative findings relating to Category 5 represent the lowest mean Likert ratings assigned by the experts. Whereas usability ratings reflect the need for a measure of evolutionary change to m-LR, Criteria 25 to 31 collectively suggest that the user's experience of the environment was unsatisfactory. This finding justifies the inclusion of Category 5 in the MUUX framework of criteria.

Table 6–17: HE ratings of Category 5 criteria – Experts

Category 5 UX		**Mean**	**S.D.**
25	Emotional issues	**3.1**	0.75
26	Contextual factors (hedonic)	**3.2**	0.68
27	User-centricity (hedonic)	**3.1**	0.80
28	Social value	3.7	0.40
29	Needs	**3.3**	0.49
30	Appeal	**3.0**	0.89
31	Satisfaction	**3.1**	0.60
	Overall Rating	**3.2**	**0.70**

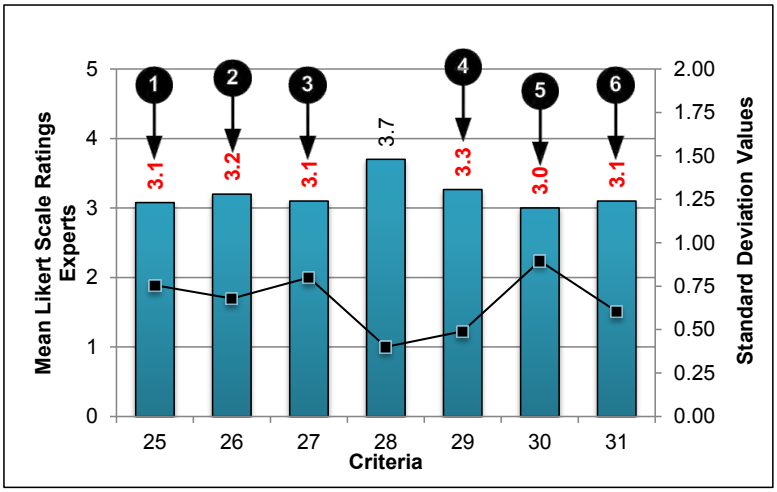

Figure 6-13: UX – Experts

Criterion 28 investigated the potential of social networking tools for the sharing of course information. Experts reported a positive user experience for this criterion. On the contrary, they indicated relatively poor user experiences (red values) in each of the other six items (black arrows). Less than acceptable UX was revealed for these items.

❶ Criterion 25 surveyed emotional responses to *m-LR*$_{ps}$ such as motivation, encouragement and enthusiasm.

❷ A rating of 3.2 for Criterion 26 indicates that experts expressed doubt that familiar tasks could easily be accomplished using their mobile phones.

❸ The learning experience did not necessarily meet the personal needs of the evaluators (Criterion 27).

❹ In a similar way, Criterion 29 expresses doubt that the self-expression needs of learners are not likely to be met when they experience m-LR on their mobile phones.

❺ The experience did not appeal to expert evaluators (Criterion 30).

❻ The experts expressed a level of dissatisfaction (Criterion 31) with the m-learning environment, sharing a disbelief that m-learning would motivate learners to learn.

In summary, Category 5 highlights important hedonic aspects of the user's experience with *m-LR*. These observations suggest that users are unlikely to benefit from *m-LR* even if it meets usability criteria, as in general, the experience was only moderately satisfying.

Quantitative findings from qualitative data elicited from heuristic evaluations

The problems identified by expert evaluators (Appendix B-1.2) were extracted from their unprompted responses to the open-ended items in the questionnaire. Thematic analysis was used to classify problems according to the eight categories of design guidelines that were synthesized by the researcher and presented in Table 4-1, Section 4.3.2. The categories of guidelines comprised: design and development, mobile specifications, learner-centricity, ease of use, content, context, VLEs and Web 2.0 tools. A detailed account of the thematic analysis of all five categories is too comprehensive to be included and has been included in Appendix B-1.2. However a tabular sample of the problems reported by experts in Category1, General Interface Usability, is provided here and serves to illustrate the manner in which the qualitative data was analysed.

Table 6–18: A section from Appendix B-1.2, indicating thematic analysis of the problems reported by experts

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**3**			
	1.1. When I downloaded the PDF it put it into my downloads folder but did not tell me so it appeared it has not worked.	1	20	Feedback	Ease of use
	1.2. The last Q in the test had no place to enter data. Don't use a free form field in a test marked by machine.	1	20	Assessment	Content
	1.3. I think you could add breadcrumbs on the top and a site map or search site box.	1	20	Navigation	Ease of use
2	***Match between system and the real world***	**2**			
	2.1. Tablet version would be easy to use for a PC based user not familiar with mobile phones.	1	20	Device Constraints	Context
	2.2. Couldn't find chat so I assumed a message on the forum. If this is correct then Chat and Forum message was used interchangeably.	1	20	Social Networking: Chat	Web 2.0
3	***Learner control***	**3**			
	3.1. After getting to the last review of my answers to the quiz, the only way back was to use the start button and go right back to the beginning page, rather than returning to the previous level that I was on.	1	20	Navigation	Ease of use
	3.2. I didn't see any undo options other than those inherent on my phone.	1	20	Errors	Ease of Use
	3.3. When I did go to see the SE Glossary to find an answer for the quiz, it did not remember my previous answers.	1	20	Feedback	Ease of use

Table 6–18 represents a view of the outcome of thematic analysis of qualitative data elicited from HE questionnaires completed by experts. The reference numbers of criteria are recorded in the first column, whilst the second column lists the comments made by evaluators. In the third column ***f*** reflects the number of counted problems per criterion. The fourth column indicates the percentage of experts reporting each problem together with a subtotal per criterion. Each identified problem is allocated to a theme in the next column and finally, the relevant design guidelines are suggested in the last column. For example, for Criterion 3 *Learner control*, three problems were identified with one in each of the themes – *Navigation, Errors and Feedback*. All three problems are associated with the design guideline '*Ease of Use'*. Table 6–19 quantifies the qualitative data (Creswell, 2009), suggesting that of a total of 41 problems identified by experts, the highest quantity (16) occurs in Category 1, General Interface Usability, containing 29.3% of the total number of problems reported by experts.

In contrast, the least number of problems (2) was experienced in Category 4, m-Learning Usability (4.9%).

Table 6–19: Problems reported by Experts

	Experts	Number of Problems Reported per Category of Criteria					Total
		1	2	3	4	5	
Themes	Design and Development	1	1	0	0	0	**2**
	Mobile Specifications	0	0	0	1	0	**1**
	Learner-centricity	0	0	0	0	7	**7**
	Ease of Use	12	3	2	1	0	**18**
	Content	1	2	1	0	0	**4**
	Context	1	0	0	0	0	**1**
	VLEs	0	2	2	0	0	**4**
	Web 2.0 Tools	1	1	2	0	0	**4**
	Total	**16**	**9**	**7**	**2**	**7**	**41**

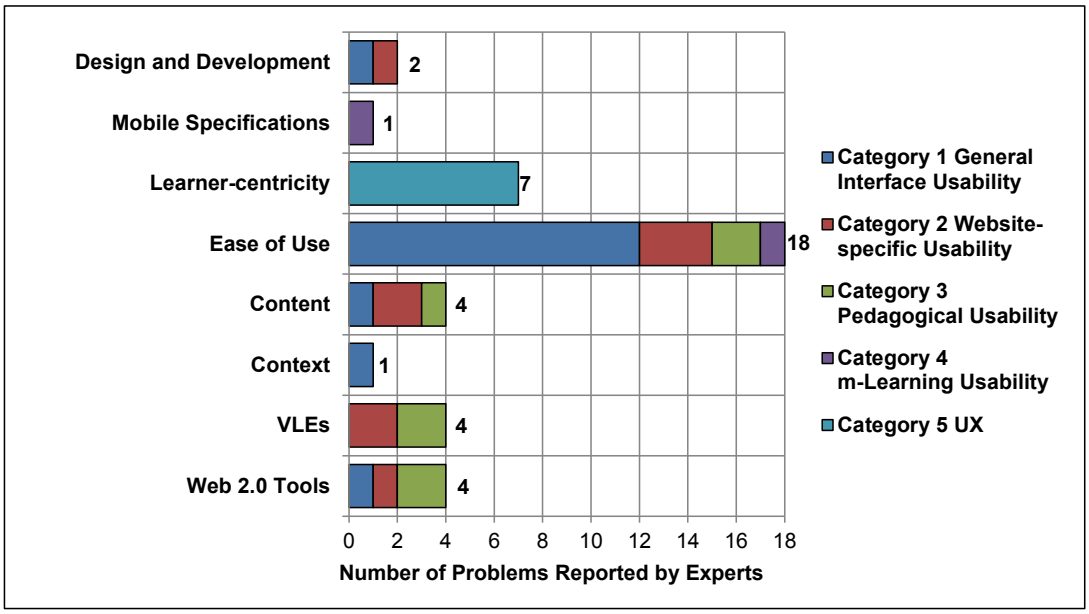

Figure 6-14: Thematic analysis of problems reported across 5 evaluation categories – Experts

Figure 6-14 graphically illustrates the allocation of problems to themes where the largest group of problems (18) was associated with *Ease of Use* and all seven *Learner-centricity* issues were identified in Category 5, UX. This finding complements the quantitative feedback for Category 5, UX in Table 6–17 indicating that content and application developers could improve UX by focusing on the seven problems reported in the 'Ease of Use' theme. In addition, Ease of Use is a usability factor. The findings corroborate the link between usability and UX as either positive or negative satisfaction.

6.5.3 Findings and Discussion – Learner User Survey

The sample of seventeen learners selected as participants for Study 4 comprised the population of the fulltime Software Engineering (SE) cohort, enrolled on campus C1 during 2011. Whilst two Western Cape campuses, C1 and C2, offer the identical course, the researcher was only responsible for the delivery of the SE course to the C1 cohort, facilitating the supervision of the usability and UX evaluation of *m-LR* at C1.

The findings in this section are reported in a similar way to the manner used for the HE by experts in Section 6.5.2. Firstly quantitative data (Appendix B-2.1) gathered from learners who completed survey questionnaires (Appendix A-6) are discussed severally for each of the five categories of criteria used to evaluate *m-LR*. Then, problems are recorded in response to open-ended questions, counted and categorised (Appendix B-2.2) on the basis of the guidelines for the design and development m-learning environments, synthesized earlier in Table 4-1, Section 4.3.2. In this way, qualitative data gives rise to additional quantitative findings.

Quantitative findings from learner survey evaluations

Learner evaluations are reviewed by sequential examination of the reported quantitative ratings in the five categories of criteria contained in the MUUX framework (Section 3.6) comprising: general interface, website-specific, educational and m-learning usability and UX.

General interface usability

The quantitative findings of learners for Category 1, General Interface Usability are provided in tabular and graphical format in Table 6–20 and Figure 6-15, respectively.

Table 6–20: Survey ratings of Category 1 criteria – Learner Users

	Category 1 General Interface Usability	Mean	S.D.
1	Visibility of system status, provide feedback	4.3	0.38
2	Match between system and the real world	4.0	0.46
3	Learner control	3.9	0.57
4	Consistency and adherence to standards	4.2	0.52
5	Error prevention, in particular, prevention of peripheral usability-related errors	4.0	0.47
6	Recognition rather than recall, memory use	4.0	0.38
7	Aesthetics and minimalism in design	4.1	0.81
8	Recognition, diagnosis and recovery from error	4.0	0.68
9	Help and documentation	3.7	0.54
	Overall Rating	**4.0**	**0.72**

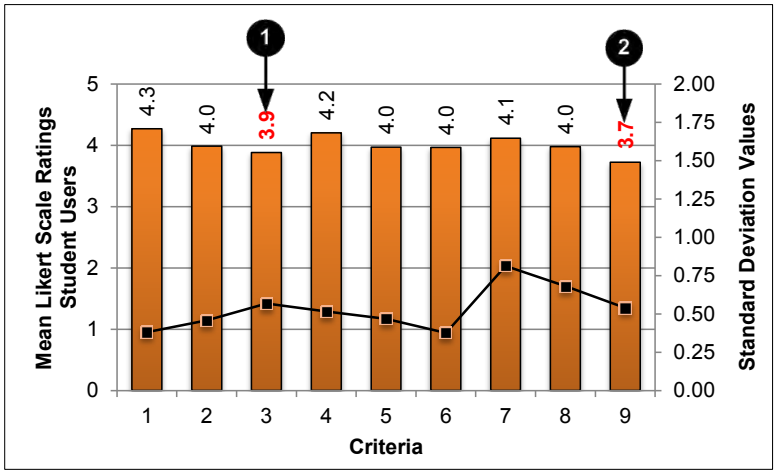

Figure 6-15: Category 1 General Interface Usability – Learner Users

The S.D. values in the last column of Table 6–20 suggest limited scatter of the data relative to Criterion 7 on the aesthetic appeal of *m-LR* where a slightly higher S.D. of 0.81 is noted. Learner ratings recorded in Table 6–20 indicate high levels of satisfaction with the interface indicated by an overall rating of 4.0 (S.D. = 0.72). The overall rating contrasts with two criteria, namely Criterion 3 (rating = 3.9) and Criterion 9 (rating = 3.7), which have been selected for further discussion. These items are highlighted in red in Table 6–20 and with black arrows in Figure 6-15.

❶ Criterion 3 suggests that although learners wanted a greater ability to control their m-learning environment, this requirement seemed like a moderate issue with a rating of 3.9.

❷ The problems encountered by experts (3.0) with the help system were confirmed by learner responses to Criterion 9, albeit to a lesser degree. This observation is likely to be due to the nature of digital learners who easily resolve problems with web-based environments.

Website-specific usability

The mean Likert scale ratings reported learner users in Category 2, website-specific usability, are provided in Table 6–21 and Figure 6-16. The overall rating of 4.0 (S.D. = 0.49) for Category 3 indicates good usability and reflects, once again, the resilience and independence of learners in a web-based environment. The higher S.D. values for Criterion 12 (0.71) and Criterion 15 (0.73) indicate a greater scatter of responses to *ease of access* and ability to evaluate the *digital media*. These responses could result from the use in Study 4 of a variety of mobile devices.

Table 6–21: Survey ratings of Category 2 criteria – Learner Users

Category 2 Website-specific Usability		Mean	S.D.
10	Simplicity of site navigation, organisation and structure	4.0	0.46
11	Relevance of site content to the learner and the learning process, content meaningful to domain and learner	4.1	0.32
12	Easy to access information	4.0	0.71
13	Content is both suitable and of a high quality	4.0	0.27
14	System is simple and easy to use, called easiness	4.0	0.56
15	Material is of a high quality i.e. videos and digitisation	4.0	0.73
	Overall Rating	**4.0**	**0.49**

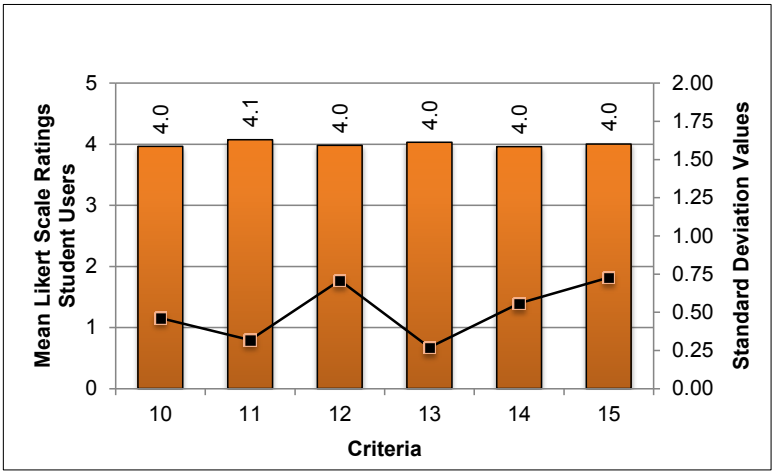

Figure 6-16: Category 2 Website-specific Usability – Learner Users

In contrast to the findings of experts, learner users experienced minimal difficulties with the website environment, reporting an overall mean Likert scale value of 4.0 (S.D. = 0.49). These positive usability findings can be ascribed to the skill set of digital learners.

Educational usability

Table 6–22 and Figure 6-17 reflect the evaluation ratings of learner users for Category 3, Educational Usability.

Table 6–22: Survey ratings of Category 3 criteria – Learner Users

Category 3 Educational Usability		Mean	S.D.
16	Clarity of goals, objectives and outcomes	4.0	0.32
17	Effectiveness of collaborative learning	4.3	0.41
18	Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle	4.0	0.57
19	Feedback, guidance and assessment	4.2	0.47
	Overall	**4.1**	**0.48**

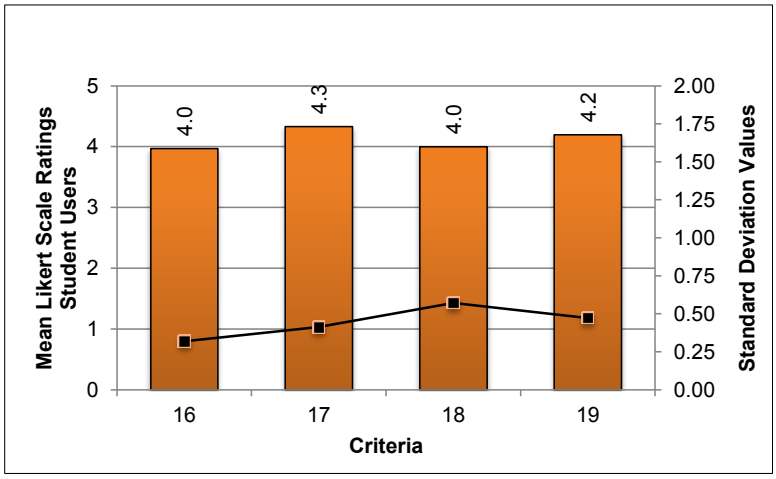

Figure 6-17: Category 3 Educational Usability – Learner Users

Table 6–22 and Figure 6-17 above provide the findings of learner users in Category 3, Educational Usability with an overall rating of 4.1 (S.D.=0.48) in contrast to the mean rating of experts who indicated a mean Likert rating of 3.5 in this category. Learners reported good usability for each of the criteria in this category. The highest mean Likert scale rating of 4.3 was observed for Criterion 17. This value indicates positive feedback for collaborative learning, suggesting encouragement for the use of the m-learning environment to enhance the completion of educational activities. The more positive rating of learners compared with experts, could indicate that a more positive attitude to the capability of m-learning to scaffold educational goals is shown by learners.

m-Learning usability

Table 6–23 and Figure 6-18 portray learner user responses to m-learning criteria with an overall rating of 4.0 (S.D.=0.39).

Table 6–23: Survey ratings of Category 4 criteria – Learner Users

Category 4 m-Learning Usability		Mean	S.D.
20	Mobile phones and technology	**3.9**	0.50
21	Contextual factors (pragmatic)	**3.8**	0.39
22	User-centricity (pragmatic)	**3.8**	0.29
23	Flexibility	4.2	0.33
24	Interactivity	4.1	0.25
	Overall	**4.0**	**0.39**

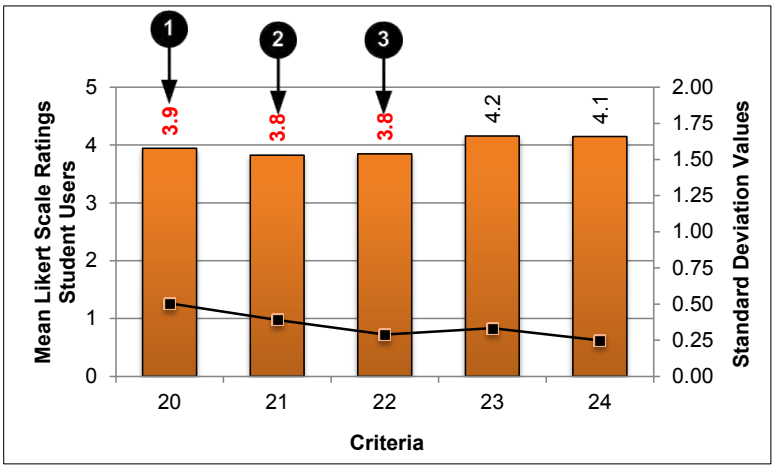

Figure 6-18: Category 4 m-Learning – Learner Users

These findings suggest positive support for the m-learning items listed in Category 4. The less than perfect ratings of Criteria 20 to 22 (red values in Table 6–23) mirror to some extent the findings of experts in that both contextual factors and user-centric requirements could be considered when adjustments are made to *m-LR*$_{ps}$, which was the version of m-LR used as input to Main Study 1. In addition, the mean rating of 3.9 for Criterion 20 is indicative of the constraints experienced by learners when accessing the m-learning environment with their mobile devices. Comments are provided here on the mean ratings for Criteria 20 to 22 (black arrows in Figure 6-18).

❶ The mobile device itself constitutes an aspect of the user's m-learning context, limiting the capabilities of *m-LR* to some extent (Criterion 20).

❷ Learners acknowledge that additional factors in their environment other than idiosyncrasies of their mobile phones could hinder efforts to augment their learning experience via mobile technology (Criterion 21).

❸ The overall rating of Criterion 22 (3.8) suggests that the learners do not adequately relate to learning via *m-LR*, indicating a need for greater focus on the users' requirements.

User Experience

Table 6–24 and Figure 6-19 report the mean Likert scale ratings of the seven items in Category 5, UX by learner users.

Table 6–24: Survey ratings of Category 5 criteria – Learner Users

Category 5 UX		Mean	S.D.
25	Emotional issues	4.3	0.45
26	Contextual factors (hedonic)	4.6	0.46
27	User-centricity (hedonic)	4.1	0.39
28	Social value	4.4	0.50
29	Needs	4.0	0.42
30	Appeal	4.1	0.46
31	Satisfaction	4.1	0.47
	Overall	**4.2**	**0.49**

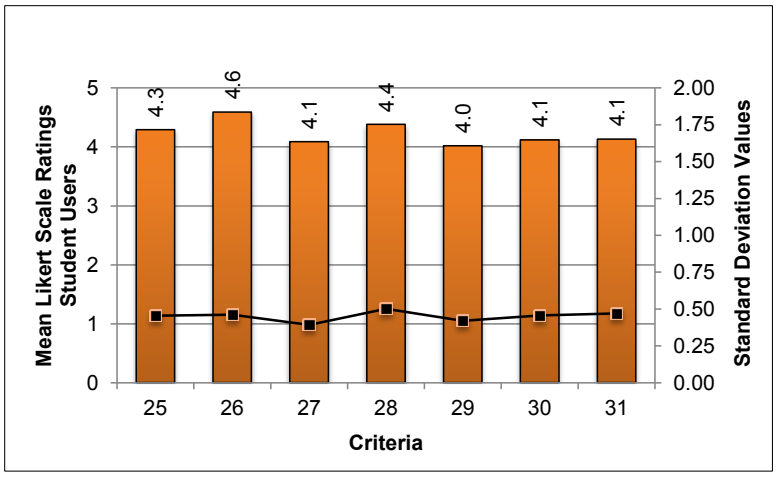

Figure 6-19: Category 5 UX – Learner Users

The pattern of responses elicited in Category 5, UX strongly differentiates the UX reported by the learner from that of the expert evaluator. Whereas Table 6–24 and Figure 6-19 indicate consistently good UX with all Likert scale values shown as greater than 4.0, ratings provided by the experts shown earlier, expressed a more negative picture of UX of *m-LR*$_{ps}$. Learners experience the m-learning environment as a fun-filled and familiar web-based space. Mobile phone technology is a way of life for them and, in many

instances, the only means of digital communication. This is particularly relevant for the C1 learners where the emergence of a digital divide was observed by the researcher. Post-evaluation conversations with a few of the experts reveal a different digital profile manifesting a more conservative attitude to potential of m-learning.

Quantitative findings from qualitative data elicited from the learner surveys

Thematic analysis was approached in the same manner for the textual data provided by the expert evaluators in their responses to open questions and for the data provided by learner users. The problems identified by learner users were therefore also categorised according to the eight design and development themes synthesized in Table 4-1, Section 4.3.2.

As for the experts in the previous section, thematic analysis was used to classify the problems found by learners and listed according to Table 4-1, Section 4.3.2. The problems identified by learner users are detailed in Appendix B-2.2 and summarised in Table 6–25, Table 6–26 and Figure 6-20.

Table 6–25: A section from Appendix B-2.2, indicating thematic analysis of the problems reported by learners

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**4**			
	1.1. Internet is slow, but the app is good.	1	5.9	Device Constraints	Mobile Specifications
	1.2. I couldn't change the glossary wording. 1.3. Problem changing glossary wording.	2	11.8	Design	Content
	1.4. I couldn't see the triple constraint video. 1.5. The video didn't play.	2	11.8	Media	VLEs
	1.6. The blog entry was confusing. 1.7. On Blog page, I clicked on "Turn edit button on" but still was unable to edit the plagiarism and ethics topic.	2	11.8	Social Networking: Blog	Web 2.0
2	***Match between system and the real world***	**2**			
	2.1. There are links that are not displayed nicely.	1	5.9	Navigation	Ease of Use
	2.2. Topic outline - the green letters are too big, the colour does not help when reading and they are too big.	1	5.9	Look and Feel	Design and Development
3	***Learner control***	**1**			
	3.1. There are no short navigation descriptions that tells you where to click - like a short HELP popup message.	1	5.9	Navigation	Ease of Use

Table 6–25 provides a section of Appendix B-2.2, which is too detailed to be included here. An example is used to illustrate the structure and content of Table 6–25:

- Learners indicated that Criterion 1 – Visibility of system status, was associated with seven problems categorised in four themes and four different design guidelines.

- This analysis provides content and environment developers with a structured blueprint for evolutionary adjustments to the m-learning environment.

Table 6–26 provides summary data and indicates that in total, learner users found 46 problems, amounting to 12.2% more than those uncovered by experts. The greatest number of issues (18) was identified in Category 1, General Interface Usability, comprising 39.1% of all problems reported by the learner participants. These findings corroborate the feedback from experts.

Table 6–26: Problems reported by Learner Users

	Learner Users	Number of Problems Reported per Category of Criteria					Total
		1	2	3	4	5	
Themes	Design and Development	7	1	0	2	0	**10**
	Mobile Specifications	1	1	0	3	0	**5**
	Learner-centricity	0	1	0	0	6	**7**
	Ease of Use	7	2	1	1	0	**11**
	Content	2	2	0	0	0	**4**
	Context	0	0	0	1	0	**1**
	VLEs	1	0	4	1	0	**6**
	Web 2.0 Tools	0	0	1	1	0	**2**
	Total	**18**	**7**	**6**	**9**	**6**	**46**

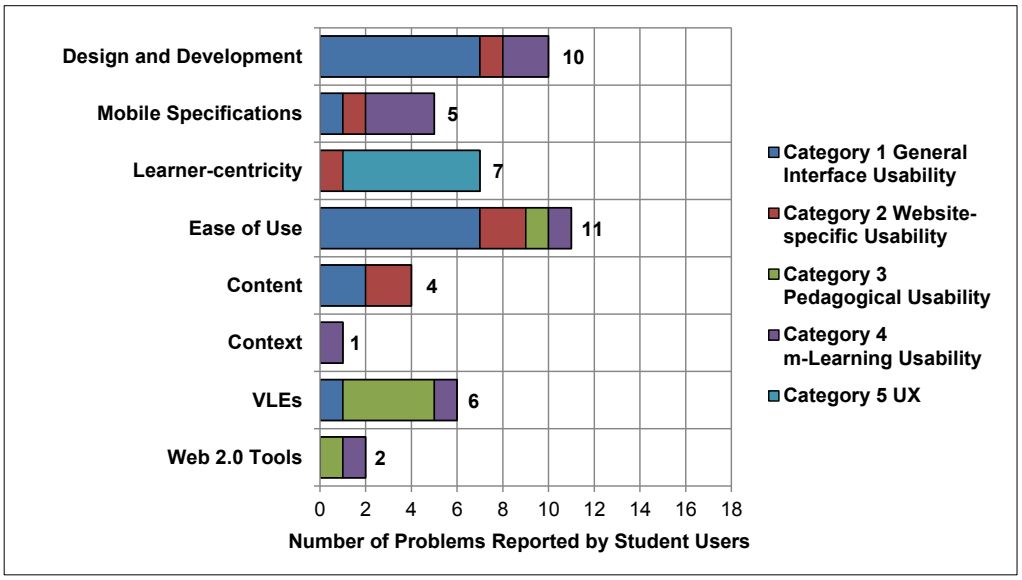

Figure 6-20: Thematic analysis of problems reported across 5 evaluation categories – Learner Users

A similar number of problems were reported by experts (41) and by learners (46). A close inspection of these issues reveals the nature of the identified difficulties (Figure 6-14 and Figure 6-20), illuminating key differences between expert and learner evaluations. This

observation supports the research methodology adopted in this study which conducted the evaluation of usability and UX using two methods, namely HE by experts and questionnaire surveys by learner users.

Figure 6-20 suggests that a similar numbers of problems was reported by learner users for *Design and Development* (10) and for *Ease of Use* (11) amounting to 21.7% and 23.9% respectively, of problems detected by learners. This observation contrasts with the problems in Figure 6-14 listed by experts for *Design and Development* (2) and for *Ease of Use* (18) equalling 4.9% and 43.9% respectively.

6.5.4 Reflection

This section consolidates the findings of Study 4, Main Study 1 which provided conformance metrics and several insights related to the evaluation approach, the evolution of m-LR and the latent digital divide.

Conformance metrics

Table 6–27 provides a side-by-side summary of the quantitative findings of Study 4, Main Study1. Mean Likert scale ratings and the number of problems reported respectively by experts and learners are compared and contrasted.

Table 6–27: Summary of conformance metrics for Study 4, Main Study 1

Category of Criteria	Expert Evaluators		Learner Evaluators	
	Mean Rating	Reported Problems	Mean Rating	Reported Problems
1	3.0	16	4.0	18
2	3.6	9	4.0	7
3	3.5	7	4.1	6
4	3.6	2	4.0	9
5	3.2	7	4.2	6
Overall	**3.4***	**41**	**4.1***	**46**

* t-Value=0.0007, $p<0.05$ indicates mean differences for Experts and Learners are strongly statistically significant

Table 6–27 illustrates that a similar number of problems were reported by experts (41) and by learners (46). A close inspection of these issues reveals the nature of the identified difficulties (Figure 6-14 and Figure 6-20), illuminating key differences between expert and learner evaluations. This observation supports the evaluation strategy adopted in this study which conducted the evaluation of usability and UX using two methods, namely HE by experts and questionnaire surveys by learner users.

Evaluation approach

The outcomes of Study 4 informed adjustments to the evaluation strategy used for Study 6, Main Study 2 in which the usability and UX evaluations were conducted in a more natural context of use. Participants did not make use of their own mobile devices during supervised evaluations of *m-LR* performed in a classroom context in Study 4. Evaluations were conducted in a personally chosen and more naturalistic location in Study 6.

The research instruments and the evaluation procedure (Appendices A-3, A-4, A-5 and A-6) were not adjusted, and remained the same for Study 4 and Study 6. A combination of quantitative and qualitative findings informed the evolution of *m-LR* to a new version named $m\text{-}LR_{m1}$ in the iterative evolution process that characterizes DBR.

Evolution of m-LR

In Study 4, a paper-based usability and UX evaluation study, quantitative and qualitative feedback from experts and learner evaluators provided guidelines for adjustments to *m-LR* enabling its improvement and evolution from $m\text{-}LR_{ps}$ to $m\text{-}LR_{m1}$.

Enhancements and refinements were implemented by the researcher on the basis of the reported Likert scale values and in accordance with the following five categories of criteria:

- Category 1 – General usability interface usability;
- Category 2 – Website-specific usability;
- Category 3 – Educational usability;
- Category 4 – m-Learning usability; and
- Category 5 – UX.

The unsatisfactory rating by experts concerning the *Help* facility in *Category 1* was confirmed by the feedback from learners. This item was identified as a key factor, leading to an adjustment to the *built-in support documentation* provided by Moodle.

In contrast to the ratings by learners who viewed items in *Category 2* for website-specific usability in a favourable manner (4.0), the rating by experts (3.6) indicated a need for *adjustments to links*. Wording in the 'breadcrumbs' was changed in an attempt to improve *navigation*. Several evaluators struggled to view video and slide show content, as some mobile devices were incompatible with the format of *online media*. The method of presentation of media was adjusted to reduce problems with buffering.

Experts indicated in *Category 3* that *goals* and *learning outcomes* needed to be clarified. The content was adjusted to include these items at the beginning of each lesson.

Shortcomings in *Category 4* included insufficient focus on *user-centricity*. This weakness was alleviated when links were provided to course content in PDF format, ensuring the ability to read the data in offline mode. Learners indicated they would appreciate direct access to Facebook and Twitter from the site – these features were incorporated into *m-LR*. In addition, although no participants had indicated in Study 2, Mobile Usage Survey that they used tablet devices, a growing interest in tablet technology stimulated the inclusion of this *device compatibility* option for m-learning environments. To improve the *appeal* of the site, cloud technology was incorporated with a link to Dropbox. This adjustment intended to facilitate communication between project leaders and members of SE groups.

Finally, the pattern of responses in *Category 5*, UX, differentiated between the perceptions of expert and learner evaluators regarding $m\text{-}LR_{ps}$. In contrast to the overall response of experts to this category which was unfavourable (3.2), a far more positive response was elicited from learners (4.2). The most likely reason for this disparity emanates from the acuity and mobile technology skill set of the digital learner together with a positive perception of the value of Web 2.0 tools. In conversation after the evaluation with a couple of experts, a more conservative attitude to mobile technology was observed. Consequently, no adjustments were made to $m\text{-}LR_{ps}$ on the basis of negative feedback from experts in Category 5.

This subsection has detailed the noteworthy improvements to $m\text{-}LR_{ps}$ as it evolved into the $m\text{-}LR_{m1}$ version of *m-LR*, as part of the iterative DBR process.

Digital divide

The researcher became aware during Study 2, Mobile Usage Survey that the digital skills, attitudes, needs and privileges differed between the cohorts of C1 and those of C2, the two Western Cape campuses offering the same B.Sc. degree (Section 6.3.3). The re-emergence of this latent digital divide in Study 4 (Section 6.5.3) prompted the researcher to conduct the next study – Study 5, Mobile Learning Digital Divide Survey, to determine the digital profile of C1 and C2 3rd year SE learners prior to conducting Study 6, Main Study 2. Study 5 also proffered the opportunity to investigate the potential of m-learning to reduce an emergent digital divide between two campuses, C1 and C2 observed during Study 2, Mobile Usage Survey (Section 6.3.3).

Study 5 served several purposes. It established the digital profile of the 2012 cohorts, providing background information for Study 6 and investigated the role that mobile technology could play in reducing the digital divide. It also precipitated the decision to

incorporate all learners from both C1 and C2 as participants in Study 6. Both Study 5 and Study 6 are described and discussed in Chapter 7.

Contribution to the research questions

RQ3 – W*hat are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

Table 6–27 summarises the outcomes of using the MUUX Framework to evaluate *m-LR*$_{ps}$, a version of *m-LR*, for usability and UX.

RQ5 – *How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

The following observations are made:

- The MUUX Framework could be incorporated into two different research instruments, where the wording could be adjusted to suit the evaluating audience;
- In addition to the use of two data collection methods based on one MUUX framework, both expert and learner evaluation questionnaires where minor changes could be made to the wording of statements and questions according to the evaluation audience;
- Four of the categories contributed to an understanding of the usability of the system whilst fifth dealt exclusively with UX;
- Both quantitative and qualitative data could be gathered enabling the analysis of findings and providing conformance metrics on two levels: mean Likert ratings and lists of reported problems; and
- The indices provide benchmark values, demonstrating the extent of the conformance, separately, within each of five evaluation categories.

6.6 Conclusion

Chapter 6 provided the findings and discussion of Main Study1, consisted of the first four iterative studies, namely Study 1, Pre-Study (Section 6.2), Study 2, Mobile Usage Study (Section 6.3), Study 3, Pilot Study (Section 6.4) and Study 4, Main Study 1 (Section 6.5). Studies 1, 3 and 4 were evaluation studies while Study 2 gathered data from learner participants regarding the use of their mobile phone. The composition of Main Study 1 together with an illustration of the relationship between its four studies is reflected in Figure 6-1 at the beginning of the chapter.

The presentation and discussion of each study was structured in a similar fashion comprising an initial outline, the findings themselves and finally culminating in a reflective

section. In particular, the reflection in Study 4 enabled the consolidation of conformance metrics alongside a review of the evaluation approach and an exploration of the impact of the study on the evolution *m-LR*. Both studies discussed aspects of the digital divide emerging during the studies followed by a brief outline of the manner in which the chapter contributed to answers to the research questions. Research questions ***RQ3*** and ***RQ5*** were addressed in this chapter but are fully answered in Chapter 8 in Sections 8.2.2 and 8.2.5 respectively.

In keeping with the iterative nature of the underlying DBR methodology adopted for this research study, Main Study 1 was followed by Main Study 2 which is the subject of the next chapter, Chapter 7, Findings and Discussion 2.

CHAPTER 7: Findings and Discussion 2

7.1 Introduction

This chapter comprises the second part of findings and discussion of the design-based research (DBR) process, completing and complementing the contents of Chapter 6, Findings and Discussion1.

The chapter reports the findings of Study 5, Mobile Learning and Digital Divide Survey and Study 6, Main Study 2 in Sections 7.2 and 7.3, respectively. The previous four iterations, Study 1, Study 2, Study 3 and Study 4 that were included in Chapter 6 and illustrated in Figure 6–1, preceded Study 5 and Study 6. These two studies are contextualised in Figure 7-1 below.

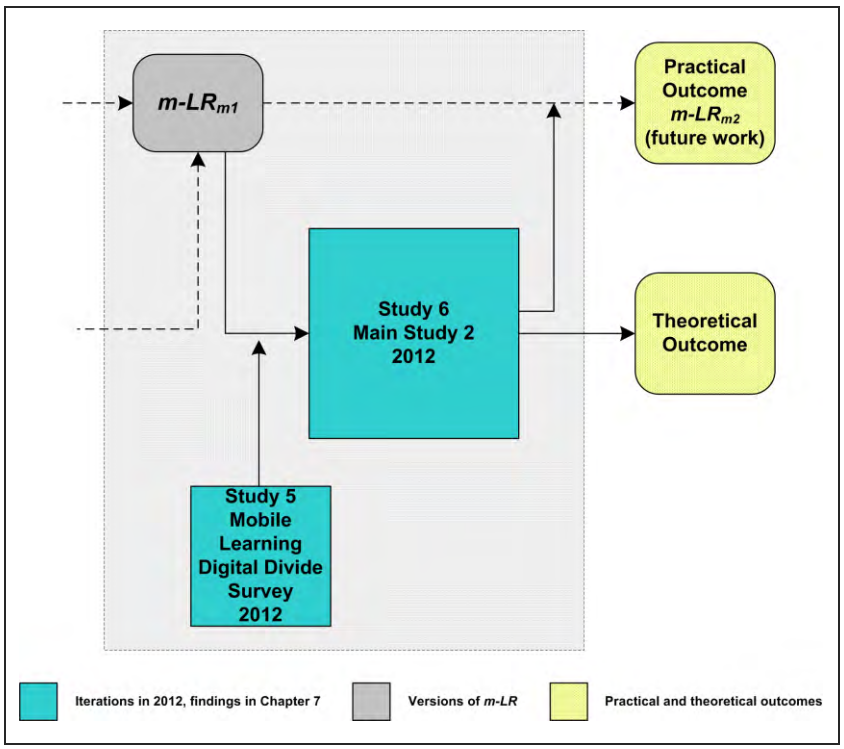

Figure 7-1: Section of the DBR model incorporating Studies 5 and 6

In Figure 7-1, *m-LR*$_{m1}$ is presented as the outcome of Study 4, and is the version of *m-LR* evaluated for usability and UX in Study 6. Study 5 investigated the digital divide, providing rich information on the mobile digital profile of learner participants. As in Chapter 6, each study includes an initial outline followed by an analysis of the quantitative and qualitative findings of the study. A brief reflection on the findings of each

study and its impact on the development of *m-LR*, is presented at the end of each section – this is in keeping with the DBR methodology and process introduced in Chapter 5. The chapter contributes to answering research questions ***RQ3*** and ***RQ4*** (practical outcome of the study) and ***RQ5*** (theoretical outcome).

Section 7.4 concludes the chapter. It draws on the findings of Section 6.5, Main Study 1 and on Section 7.3, Main Study 2, providing comparative findings based on quantitative and qualitative data elicited respectively from the heuristic evaluations and survey questionnaires completed by experts and learners.

7.2 Study 5: Mobile Learning Digital Divide Survey

The discussion on Study 2 in Section 6.3 indicated, but did not investigate, the emergence of a digital divide between the C1 and C2 cohorts of 2011. Study 5, the Mobile Learning Digital Divide Survey, aimed to create a digital profile of participants for Study 6, Main Study 2, so as to investigate the latent digital divide emerging between the 2012 cohorts of C1 and C2. This data would contribute to determining the role of mobile technology in the reduction of this divide.

The study provides answers to research question ***RQ4***: Can mobile technology reduce the digital divide in a tertiary educational context? Survey data was gathered by paper-based questionnaires, based on the instrument designed for the Mobile Usage Survey. The questionnaire is given in Appendix A-8. Most of the material in Sections 7.2.2 and 7.2.3 was included in a conference paper by Harpur and de Villiers (2012), presented at the 6th IDIA Conference in Istanbul, Turkey in 2012 and published in the conference proceedings. Study 5 was conducted by the researcher specifically for the purposes of this masters' degree research to holistically augment the value of its findings, regardless of the conference presentation.

7.2.1 Outline of the Study

Table 5-9 is repeated here as Table 7–1 which summarises Study 5, Mobile Learning Digital Divide Survey.

Table 7–1: Study 5 – Mobile Learning Digital Divide Survey

Mobile Learning Digital Divide Survey 2012		
Participants	Two campuses Population of 2012 cohorts of fulltime learners on campuses C1 and C2	Questionnaire surveys: 13 learners from C1 and 22 learners from C2
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Exploration of an emergent digital divide	

7.2.2 Findings and Discussion

The survey elicited both quantitative and qualitative data. Firstly, quantitative data is presented, discussing mobile devices – brands, usage and location of use and learner attitudes to a mobile technology strategy. Secondly, qualitative data is presented in both tabular and graphical formats.

Quantitative findings

Mobile phone brands, usage location and mobile phone activities

Learners reported owning a variety of mobile phone (m-phone) brands, which they used in various locations. They also indicated the activities most often performed via these phones.

Figure 7-2 and Figure 7-3 respectively compares the mobile phone brands used by C1 and C2 learners and shows the location of their phone usage. Socio-economic differences exist between C1 and C2, where C2 learners tend to come from more affluent families. C1 learners are often from neighbouring states with varying home languages and diverse cultural composition.

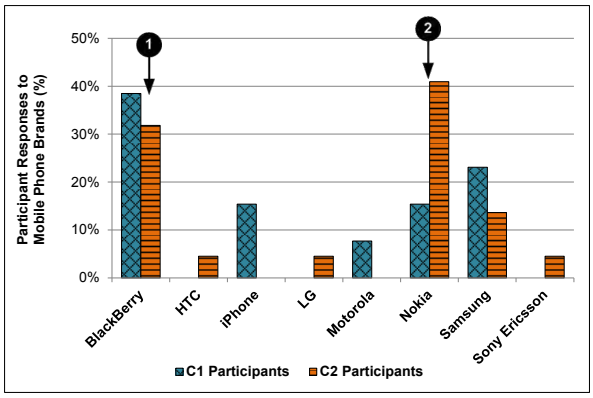

Figure 7-2: Mobile phone brands

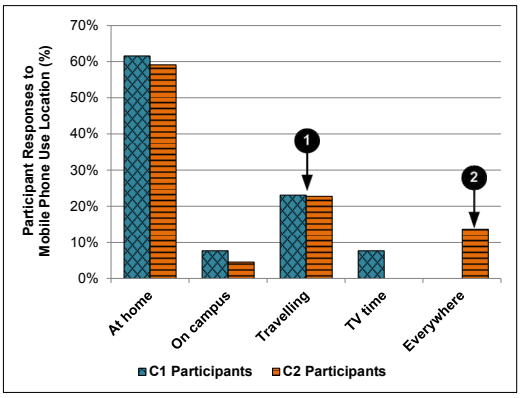

Figure 7-3: Location of mobile phone usage

Figure 7-2 illustrates diverse m-phone brand choices reported by C1 and C2 learners. Key differences are noted for BlackBerry and Nokia brands:

❶ C1 learners (38.5%) indicate a stronger BlackBerry culture than C2 learners (31.8%), reflecting the greater appeal to C1 of the almost-free Internet connectivity offered by BlackBerry. Three C1 learners used iPad tablets regularly, in addition to their smartphones. However, no use of tablets was reported by C2 learners.

❷ On the contrary, more C2 learners (40.9%) used Nokia devices than C1 learners (15.4%). C2 learners indicated a lack of interest in the need for free Internet via telephone, instead choosing a brand which is popular among their peers. This is probably due to the fact that they have easy access to the Internet via laptop computers.

Learners used their mobile phones in many different places. Figure 7-3 reflects the locations of mobile phone use:

❶ C1 learners (23.1%) and C2 learners (22.7%) used their phones to similar extents whilst travelling to and from campus, although C1 learners travelled greater distances for longer periods. The similarity between the two sets of results reflects the characteristic nature of university learners, who tend to use their phones on an ongoing basis. ❷ However, 13.6% of C2 learners claim they use their phones everywhere, compared with 0% of C1 learners. This is likely due to the issue of security; in fact, in a follow-up discussion to completing the questionnaire, C1 learners verbally mentioned the risks inherent in using technology on public transport. The mobile device is regarded as a precious commodity – it is not easily replaceable if it is stolen.

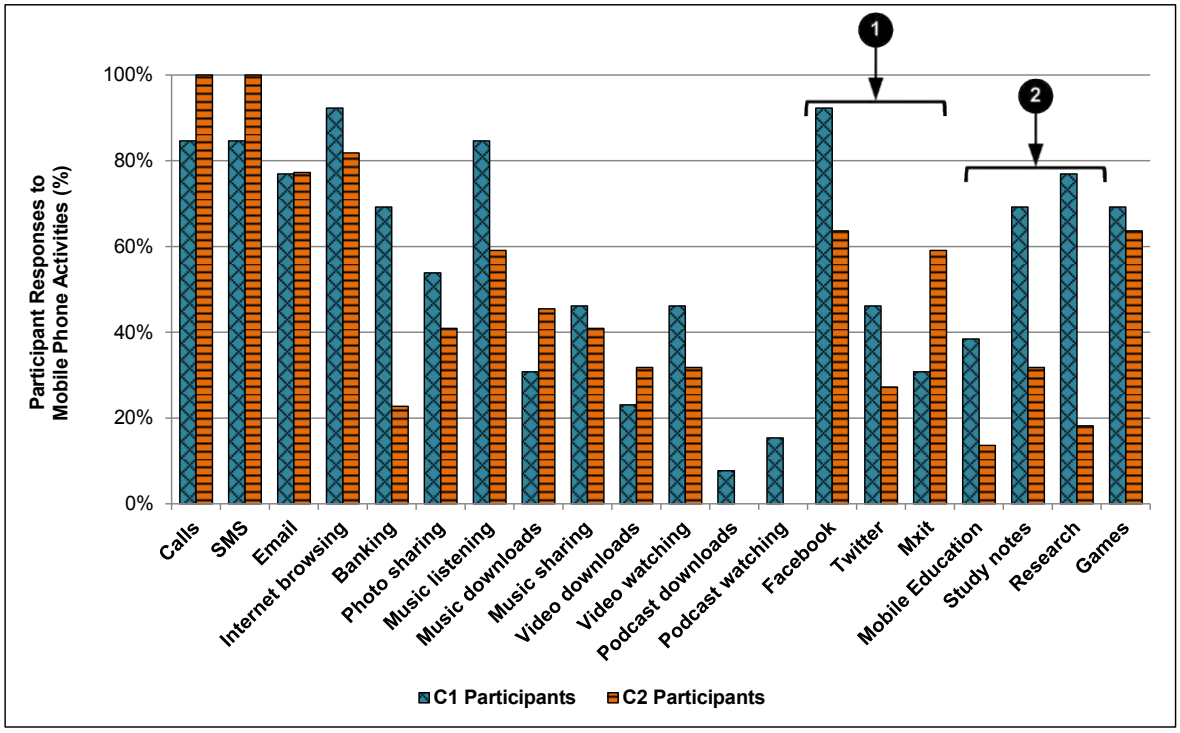

Figure 7-4: Mobile phone activities

Figure 7-4 shows a range of activities performed by learners on their mobile devices. Activities include: calls, SMS, banking, Internet browsing, banking, photo sharing, music listening, music downloads, music sharing, video downloads, video watching, podcast downloads, podcast watching, Facebook, Twitter, MXit, mobile education, study notes, research and games. Two groups of activities shown in Figure 7-3 have been selected for further discussion, namely: Facebook, Twitter and MXit and Mobile Education, Study Notes and Research.

❶ *Facebook, Twitter and MXit*: C1 learners (92.3%) show a greater propensity for Facebook use via m-phone and are more receptive to social networking sites via mobile devices than C2 learners (63.6%). Similarly, C1 learners (46%) make use of Twitter to a greater extent than C2 learners (27%). These differences suggest the likelihood that C1 learners would more easily adapt to a mobile Web 2.0 context, regarding mobile technology as an important means of staying in touch. A greater use is made of the free messenger application MXit by C2 learners (59.1%) than C1 learners (30.8%). This is in line with the findings that fewer C2 learners use BlackBerry smartphones. As stated previously, BlackBerries have certain associated free communication facilities. In order to communicate at no cost, C2 learners therefore need to make use of MXit.

❷ *Mobile Education, Study Notes and Research*: Mobile education, study notes on mobile devices, and research via mobile Internet are more common among C1 learners

(38.5%, 69.2%, 76.9 % respectively) than C2 (13.6%, 31.8% and 18.2% respectively). This supports the notion that m-learning would be more relevant for, and acceptable to, C1 learners.

In summary, C1 learners are Web 2.0 savvy and, due to the digital divide they experience on a daily basis, have developed mobile coping mechanisms based on the use of their mobile phones. On the other hand, C2 learners prefer to send SMSs and make calls with their phones because, for connectivity, they have other options. Whereas C1 learners would find it easier to adapt to an m-learning strategy, C2 learners would likely need to be persuaded to take ownership of the idea. C1 learners have learned to do Internet research via mobile phone, even though they have limited financial resources. C2 learners choose phone brands and activities which show that they regard the mobile phone largely as a means of communication (Harpur and de Villiers, 2012).

Learner Attitudes to a Mobile Technology Strategy

The survey included two sections in which learners' attitudes to mobile phones (findings: Table 7–2 and Figure 7–5) and m-learning (findings: Table 7–3 and Figure 7-6) were investigated. The inclusion of these sections provided the opportunity to explore the perspective of learner users, whilst supporting a central tenet of a design-based research strategy, where real problems are being solved and solutions for the future are developed (de Villiers, 2005b). The findings from ten questions (Q29, Q31, Q32, Q35, Q36, Q37, Q38, Q39, Q40, Q41) selected from the survey, are based on a five-point Likert scale where 1= Not at all, 2= No, not really, 3 = Unsure, 4 = Yes, I do and 5 = Absolutely, presented to participants, are included for discussion in this section.

Six questions targeted learner attitudes to the use of mobile phones whilst the remaining four questions related to learner attitudes to the use of an m-learning environment. Table 7–2 and Figure 7–5 depict the findings on attitudes to the use of mobile phones for C1 and C2.

Table 7–2: Mean Likert scale ratings for learner attitudes to the use of mobile phones

	Feedback on the Use of Mobile Phones	C1	C2	t-Values
Q29	Do you believe that your mobile phone could support your studies?	3.9	3.2	0.034*
Q31	Do you believe that your mobile phone could support learning in groups?	4.2	2.8	0.001*
Q32	Would learning by mobile phone motivate you to achieve better study outcomes?	3.6	3.3	0.381
Q35	Do you think that the submitting of revision test answers to your lecturer by phone mobile is possible?	4.2	3.3	0.004*
Q36	Would you feel comfortable allowing your lecturers to contact you via your mobile phone?	3.8	3.5	0.612
Q37	Would you feel secure receiving SE coursework and exam results by mobile phone?	4.1	3.8	0.548
	Overall Mean Rating: Use of Mobile Phones	**4.0**	**3.3**	**0.013***

* $p < 0.05$ - Mean differences for C1 and C2 is significant; these values are discussed further.

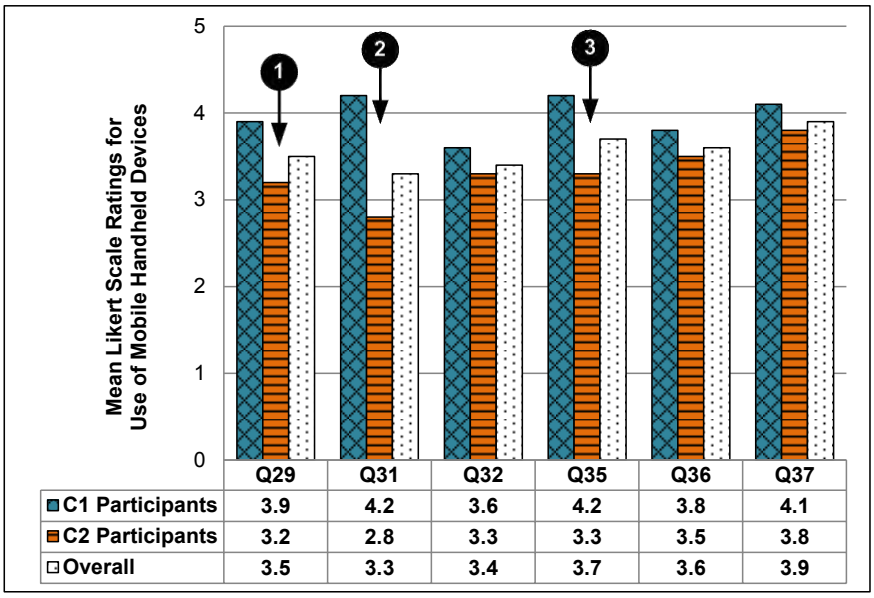

Figure 7-5: Learner attitudes to the use of mobile phones in the context of studying SE

Average responses to Q29, Q31 and Q35 by C1 and C2 have been highlighted in Table 7–2 (red t-values) and Figure 7–5 (black arrows). These questions are discussed further. In comparison with C2 learners, C1 learners strongly agree that: ❶ the use of the mobile phone could contribute to support for studies (3.9) and ❷ group activities (4.2) indicating ❸ comfort about lecturers making mobile phone contact (4.2). The t- values of 0.034, 0.001 and 0.004 for these three questions respectively, indicate a significant difference in attitude between C1 and C2, contributing to an overall t-value of 0.013 for the section.

Table 7–3 and Figure 7-6 illustrate the findings on attitudes to the use of an m-learning environment for C1 and C2. In order to establish whether or not differences between observed Likert scale averages were significant, two-tail two-sample t-test analysis

assuming unequal variances was conducted for each question and for each of the two sections.

Table 7–3: Mean Likert scale ratings for learner attitudes to the use of an m-learning environment

	Feedback on the Use of an m-Learning Environment	C1	C2	t-Values
Q38	Do you think that having course material such as slides, lecture notes and revision quizzes available on your mobile phone would be beneficial to your studies in Software Engineering?	3.5	2.8	0.079
Q39	Would you invest personal time installing and learning to use software applications that could make these resources available on a mobile phone?	4.2	3.9	0.348
Q40	Would you be willing to purchase a new mobile device if you thought it would improve your performance in your studies?	3.9	3.1	0.081
Q41	Do you feel that the use of some kind of mobile learning software would improve success in your Software Engineering module?	3.6	3.2	**0.031***
	Overall Mean Rating: Use of an m-Learning Environment	**3.8**	**3.2**	**0.033***

* $p < 0.05$ - Mean differences for C1 and C2 is significant; these values are discussed further.

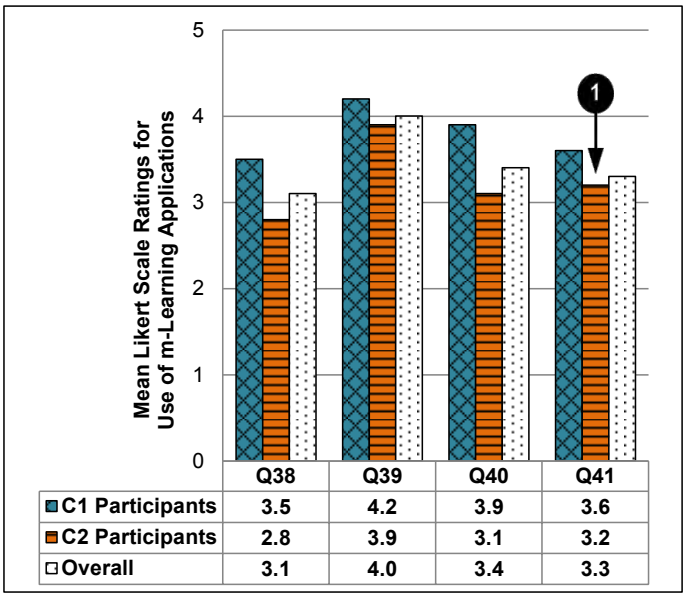

Figure 7-6: Learner attitudes to m-learning in the context of studying SE

Average responses to Q41 by C1 and C2 have been highlighted in Table 7–3 and Figure 7-6 (black arrows). This question is discussed further. Both C1 and C2 agree to some extent that: ❶ an m-learning application could improve course outcomes. A t-value of 0.031 indicates that a significant difference between C1 and C2 learner feedback exists for Q41.

In summary, Table 7–2 and Table 7–3 indicate that significant differences in attitude exist between C1 and C2 learners for both the use of mobile phones (t-Value=0.013, $p<0.05$) and m-learning environments for educational purposes (t-Value=0.033, $p<0.05$). C1 learners have a more positive attitude to the use of their mobile devices for working in groups and to the notion that mobile device use can support their studies. C1 learners see the potential of m-learning environments being able to improve their success on the Software Engineering module to a significantly greater extent than C2 learners (Harpur and de Villiers, 2012).

Qualitative findings

Qualitative textual information was gathered from participants in responses to three open-ended questions in the survey. Participants were explicitly asked about positive ways in which mobile technology can support learning and about negative aspects or limitations associated with using the mobile phone for learning. These unprompted responses were thematically analysed to determine themes and patterns. Comments in both Table 7–4 and Table 7-5 that follow are attributed to the appropriate participants as follows: [P1.X] refers to a comment by Participant X in Cohort 1, while [P2.Y] refers to a comment by Participant Y in Cohort 2.

Positive ways in which mobile phones could support studies

Table 7–4 presents feedback from C1 and C2 participants regarding *positive* ways in which mobile phones might scaffold their studies.

Table 7–4: Learner feedback - ways in which mobile phones could support studies

C1	C2
• ***Course announcements*** Learners can be sent reminder SMS's for deliverables [P1.1]*; Could be notified about readings [P1.1]*; announcements/updates [P1.7]; Specific module info [P1.7]; Forum to answer or ask questions about course subject matter [P1.7].	• ***Course announcements*** Receive notifications, important information [P2.6]; Get tips on course and study work [P2.8].
• ***Academic tasks*** Write study notes [P1.2]; Uploading from YouTube [P1.2]; Load study notes onto phone [P1.2].	• ***Academic tasks*** Download study information [P2.1]; I use my phone as a laptop; phone is my personal device; I use it to do research and upload work [P2.15]**.
• ***Support functions*** Record lectures [P1.3]; Search for info [P1.3]; Make notes [P1.6]; Can open documents e.g. spread sheets; can make PowerPoint shows and PDFs [P1.3]; Typing is less tiring than writing [P1.3]; My phone supports me in my studies because I use the dictionary; open emails, download documents [P1.11].	• ***Support functions*** Record chapters to listen to while doing chores [P2.1]; Can get (previous) exam papers on my phone which will help me to study [P2.17]; Access documents: PDFs, Office docs [P2.21].
• ***Research-related***	• ***Research-related***

When I don't understand something or a word in my studies, I can research it on my mobile, as it is faster than researching it on a computer [P1.10]; Researching online [P1.2]; File sharing with other learners (my team) [P1.8]; Research done easier [P1.8].	Access Internet at any time via Blackberry [P2.10]; Do a lot of mobile research on the Internet access Internet at any time via Blackberry [P2.10]; Do a lot of mobile research on the Internet [P2.14].
• ***Working on-the-go*** Ideal for reading on the go [P1.4]; Use on train, buses [P1.3]; Browse Web for info while travelling [P1.6].	• ***Working on-the-go*** Read on the go [P2.1]; BBM other learners [P2.10].
• ***Communication*** Communicating with teachers [P1.5]; receiving teachers notes [P1.5].	• ***Communication*** An excellent teaching medium between teacher and learner [P2.13]; Exchange SMS's with friends using my phone to ask them about study questions [P2.19].
[P1.X] and [P2.Y] refer to feedback from learner X from C1, and learner Y from C2, respectively. * [P1.1]: this C1 learner is disadvantaged in several ways. He has an old phone which is only capable of sending and receiving SMSs. He travels long distances to campus and has no computer facilities at home. When group work was being done, his team complained bitterly about his lack of delivery on electronic promises causing him to be ostracised. His computer literacy skills are rudimentary compared with other members of his team. ** [P2.15]: this C2 learner is a genuine mobile learner, suffering from digital divide pressures. His words explain: *"I use my phone as a laptop to do assignments because I have to share a computer with my family and use my phone to do research and my work on it. I type and upload my assignments with my phone."* His mobile technology literacy skills are advanced, due to his determination to overcome his heritage.	

Table 7–4 summarises C1 and C2 learner feedback regarding how their mobile phones could be used to support their studies. Comments were grouped into a few themes: course announcements, academic tasks, support functions, research-related aspects, working on-the-go, and communication. [P1.1] is a truly digitally disadvantaged learner, who had no Internet access, neither on a computer nor via a smartphone. Unlike campus peers who had overcome the divide by using their mobile phones to support their studies, 'he' OR 'she' had no connectivity and was embarrassed as indicated by 'his' OR 'her' comments in Table 7–4. [P2.15], on the other hand, was totally and solely connected via m-phone, using it competently, though not rapidly, to type assignments; upload documents; and download PDF's, images and research articles. He/she could be said to be enrolled on the 'wrong' campus, due to living closer to C2 than to C1. 'He' OR 'she' displays many of the attributes of a stereotypical member of the C1 cohort and, similar to [P1.1], though conversely, has different characteristics and abilities from his/her peers and has difficulties settling into the designated C2 team.

Limitations when using mobile phones to learn

Table 7–5 summarises C1 and C2 learner feedback regarding the limitations of using mobile phones to learn. Learner comments were grouped into three categories: mobile handheld devices; connectivity issues; and attitudes. [P1.1], a C1 learner expressed strong feelings about not having the same quality of connectivity as others in his/her class, indicating the divide between his/her capabilities and the requirements of being part of PBL team project. The attitude of [P1.10] whose phone represented the latest technology was one of joy about his/her phone. In contrast, attitudes of [P2.4], [P2.5] and [P2.14] towards their mobile phones, indicated negativity (Harpur and de Villiers, 2012).

summarises various *negative factors*, where learners gave their opinions regarding limitations that occur when one studies via a mobile phone.

Table 7–5: Learner feedback - limitations when using mobile phones to learn

C1	C2
• ***Mobile handheld devices*** Spam, compatibility of software for mobile devices [P1.1]*; RIM (BlackBerry) has a limit on its browser cache and downloads, phone is a bit slow [P1.3]; Phones too small for proper research, phones must also be faster [P1.4]; What about learners who do not have smartphones? [P1.5]; What about those who cannot pay for the Internet? [P1.5]; The small size of the screen [P1.8], [P1.13]; Reading documents from the phone is quite hard, limited screen resolution [P1.9]; Space is limited, meaning I might need to get a device that could store more [P1.12].	• ***Mobile handheld devices*** Some phones are too old to use then cannot connect to Internet, can just make calls and SMS [P2.4]***, [P2.5]****; Most phones do not support all applications - incompatibility e.g. PDFs [P2.10], [P2.16]*****, [P2.21], [P2.22]; Slow response rate [P2.10], [P.21]; Limited battery power; security risks [P2.8], [P2.11], [P2.15]; Screen resolution; small keyboard can be tiring. [P2.10], [P2.13]; Small screen size [P2.14], [P2.18], [P2.20].
• ***Connectivity issues*** Cost of data. Would have to use wireless at home (WiFi) [P1.7]; Absence of an Internet connection; not all files can be opened [P1.11].	• ***Connectivity issues*** Mobile connectivity issues [P2.6]; Connectivity costs and lack of airtime could restrict use for learning purposes [P2.8]; Data is expensive; doing work via a computer is cheaper than mobile phones; no airtime [P2.9], [P2.15], [P2.17]; expensive to download large files [P2.18]; Coverage not always trustworthy, available; difficulty viewing large documents on small screen [P2.2].
• ***Attitudes*** Distractions on your phone such as MXIT, Facebook, BBM, Games, Music which could pull learners away from studies [P1.6], [P1.10]**.	• ***Attitudes*** Distraction from social networking, SMS's, random phone calls [P2.1], [P2.12].

[P1.X] and [P2.Y] refer to feedback from learner X from C1, and learner Y from C2, respectively.
* [P1.1] comments: "You are almost inexistent if you're not on BBM or WhatsApp, if you don't have a smartphone, you appear broke and uncool."
** [P1.10] says: *"I love my phone; I can't stay more than half-an-hour without it."*
*** [P2.4] expresses a general C2 attitude saying: *"I don't have feelings for my phone!"*
****[P2.5] says in disgust: "*You can kill somebody with it, it is a brick!"*

***** [P2.16] is emotive and negative about his phone reporting: *"I find my BlackBerry claustrophobic and terribly incompatible, which is why I am looking for an upgrade to an android-based mobile device"*.

Table 7–5 summarises C1 and C2 learner feedback regarding the limitations of using mobile phones to learn. Learner comments were grouped into three categories: mobile handheld devices; connectivity issues; and attitudes. [P1.1], a C1 learner expressed strong feelings about not having the same quality of connectivity as others in his/her class, indicating the divide between his/her capabilities and the requirements of being part of PBL team project. The attitude of [P1.10] whose phone represented the latest technology was one of joy about his/her phone. In contrast, attitudes of [P2.4], [P2.5] and [P2.14] towards their mobile phones, indicated negativity (Harpur and de Villiers, 2012).

7.2.3 Reflection

The various digital divide factors which materialised in the findings of this study, are summarised. A digital divide of a complex nature and extent emerged, based on differences between learners; shortcomings of campus infrastructures; device-related aspects such as the type of device and the cost of data; Internet connectivity issues; and attitudes to mobile technology.

An intra-campus divide materialised on each campus. For C1, a learner who was ostracised for not being able to use a phone for mobile research expressed disgruntlement with the smartphone 'brigade'. For C2, a mobile-savvy learner who was forced to type assessment reports on a mobile phone, equally suffered conflict with team mates when deliverable deadlines were missed.

It was expected that a digital divide would materialise on C1 due to the cosmopolitan nature of the C1 learners, the sub-standard Internet connectivity and PC facilities offered by the campus. However, feedback from C1 learners indicated that they had happily developed mobile Internet research methods to compensate for shortcomings of campus infrastructure and connectivity gaps due to lack of Internet access at home. This interesting paradox is emphasized by the feedback from C2 learners, who, whilst benefitting from having their own transport, higher income households and powerful on-campus and at-home connectivity, complained about Internet connectivity issues. Several of the C2 learners did not regard their mobile phones as potential tools for learning but instead as tools to keep in touch by calls and SMS's.

Learners revealed the ownership of mobile phone brands with a diversity of capabilities, reporting that they used their phones in a variety of dissimilar locations, carrying out a

range of activities other than telecommunications. C1 learners revealed a mostly positive attitude to their mobile phones whilst several C2 learners seemed negative about the functionality of their mobile phones. Statistical analysis of C1 and C2 learner attitudes to the use of their mobile phones and to the use of an m-learning environment revealed significant campus differences between C1 and C2, providing numerical measures of the divide.

It appears from the feedback received from C1 that learners had already become accustomed to mobile technology through necessity, inadvertently reducing their own digital divides. An m-learning environment could reduce the digital divide in this context. The study reveals several anomalies. Learner devices are so diverse that the m-learning environment would have a small chance of success. Mobile device limitations that emerged from this study suggest that learners would need to be equipped with similar mobile hand-held devices across the board. The wireless network required to support connectivity requirements does not exist at C1 and is inadequate at C2. These infrastructural issues need to be addressed. Attitudes of all the learners on both campuses would need to be aligned positively to a mobile technology strategy.

Finally, this study highlighted the phenomenon of how context – both of personal socio-economic situation and the ethos of the academic institution – impacts on learners. This, in turns results in differences in the types of technologies used, in this case mobile phone devices, and the ways in which learners interact with them.

It should be borne in mind that these findings relate to two particular campuses, early in 2012. They cannot be generalised nor, with the increased usage of smart technologies, can it be taken for granted that they would still be accurate in 2013.

This study provides the answers to ***RQ4***: Can mobile technology reduce the digital divide in a tertiary educational context? ***RQ4*** is briefly revisited in Section 8.2.4.

7.3 Study 6: Main Study 2

Study 6, Main Study 2 of 2012, the fourth and final evaluation study is the final iteration in this design-based research process. The main aim of this study, which extends and complements the findings from the evaluations completed in Studies 1, 3, and 4, was to assess the conformance of $m\text{-}LR_{m1}$ to the MUUX Framework of criteria (Section 3.6) for usability and UX. The study endeavoured to contribute to evolutionary change to *m-LR*, providing guidelines for a fully operational version, $m\text{-}LR_{m2}$.

In Study 6, as in Study 4, HE by experts and questionnaire surveys by learner users were the methods used to gather data (Section 5.4.1 In contrast to Study 4, the learner user participants in Study 6 comprised the 2012 cohorts of SE learners from both campuses in the Western Cape, namely C1 and C2, whereas Study 4 was conducted only on Campus C1. Compared with Study 4, the population of participants in Study 6 thus provided a larger and more diverse selection of participants, covering the same range of learners as Study 5, which addressed the latent digital divide between campuses. Study 6 contributed to the answering of two research questions:

RQ3 *– What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

RQ5 *– How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

These research questions are revisited at the end of the chapter in Section 7.3.4 and will be fully answered in Chapter 8, Section 8.2.

7.3.1 Outline of the Study

Table 7–6, a reproduction of Table 5-10, provides a summary of Study 6.

Table 7–6: Study 6 – Main Study 2

Main Study 2 2012		
Participants	Two campuses	Heuristic evaluation: five experts
	Population of 2012 cohorts of fulltime learners on campuses C1 and C2	Questionnaire surveys: thirteen learners from C1 and nineteen learners from C2
Delivery device	A range of device types, used in natural settings	
Data Collection	Paper-based survey questionnaires	
Data Analysis	Quantitative – elementary statistical analysis Qualitative – thematic analysis	
Purpose	Evaluation of usability and UX of the m-learning environment version, *m-LR*$_{m1}$ resulting in recommendations for adjustments to *m-LR*$_{m2}$ (beyond the scope of the study)	

As in Study 4, expert evaluators (n=5) and learner participants (n=32) completed an Informed Consent Form (Appendix A-3), and conducted a set of m-LR activities, provided in an Evaluation Task List (Appendix A-4). However, Study 6 differed from Study 4 in that all Study 6 participants did the evaluation on their own mobile devices and in a personal and unsupervised context of use.

Study 4 and 6 used identical HE and survey questionnaires provided respectively in Appendices A-5 and A-6. HE ratings by experts and survey questionnaire ratings by learner users are separately included in Appendices C-1.1 and C-2.1.

The problems reported by evaluators in response to the open-ended items were tallied in the five categories defined above, subjected to rudimentary thematic analysis and categorised. This feedback is found in Appendix C-1.2 (for experts) and in Appendix C-2.2 (for learner users).

The findings and discussion associated with Study 6 where both quantitative and qualitative data was elicited are provided in Section 7.3.2 (HE by experts) and Section 7.3.3 (survey questionnaires by learner users). The combined feedback from experts and learner users systematically establishes the level of conformance of $m\text{-}LR_{m1}$ to the MUUX framework of criteria. Section 7.3.4 reflects on the findings of the Study 6, Main Study 2, providing recommendations for adjustments to $m\text{-}LR_{m1}$ leading to fully operational version of *m-LR* namely $m\text{-}LR_{m2}$.

7.3.2 Findings and Discussion – Heuristic Evaluation by Experts

Five willing colleagues and fellow academics agreed to fill the role of expert evaluator. They were selected on the basis of their qualifications and expertise, summarised as follows:

- *Expert 1 (double expert)* – MSc. (in progress) (IS), HCI lecturer, course developer, moderator, wireless network administrator;
- *Expert 2* – MSc. (IT), Senior lecturer, Artificial Intelligence, PhD learner;
- *Expert 3* – MTech (IS), software engineering and knowledge management lecturer, IS project supervisor;
- *Expert 4* – BSc. (Hons), lecturer database design, project manager: digital systems; and
- *Expert 5* – MLM, academic co-ordinator, computer science and information systems facilitator.

Experts completed the HE questionnaires independently of each other. In the two subsections that follow, the quantitative findings for heuristic evaluation by experts is reviewed and then an analysis of qualitative data leading to additional quantitative findings is provided.

Quantitative findings from heuristic evaluations

Evaluations resulted in the determination of mean Likert ratings which are based on the five categories of criteria in the HE questionnaire (Appendix A-5) and are detailed in Appendix C-1.1.

General interface usability

The mean Likert scale ratings and standard deviations in Category 1, General Interface Usability reported by experts is provided in Table 7–7 and Figure 7–7.

Table 7–7: HE ratings of Category 1 criteria – Experts

	Category 1 General Interface Usability	Mean	S.D.
1	Visibility of system status, provide feedback	**3.5**	0.50
2	Match between system and the real world	3.8	0.22
3	Learner control	3.9	0.34
4	Consistency and adherence to standards	3.8	0.51
5	Error prevention, in particular, prevention of peripheral usability-related errors	**3.5**	0.89
6	Recognition rather than recall, memory use	3.6	0.74
7	Aesthetics and minimalism in design	3.8	0.40
8	Recognition, diagnosis and recovery from error	3.7	1.05
9	Help and documentation	**3.3**	0.83
	Overall Rating	**3.6**	**0.70**

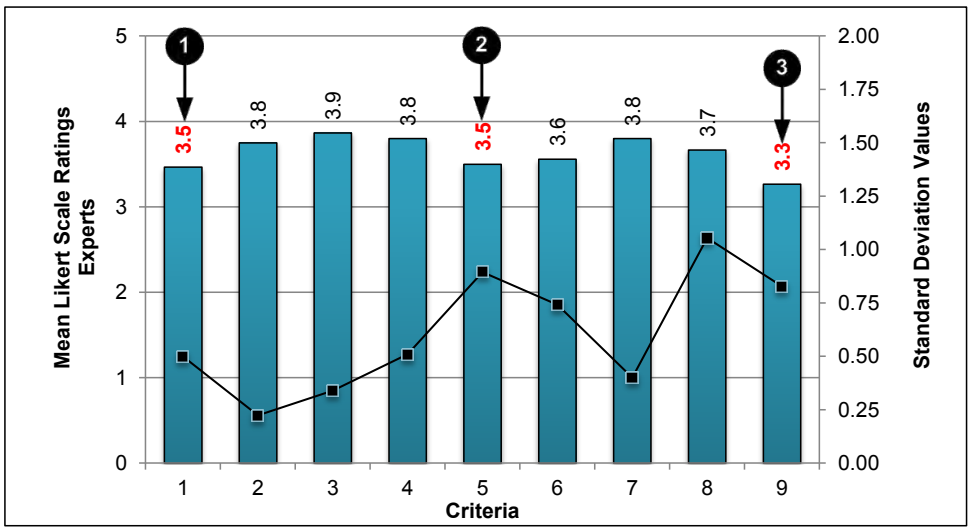

Figure 7-7: Category 1 General Interface Usability – Experts

The standard deviation values (S.D.) in the last column suggest levels of scatter of the data. Evaluator ratings recorded in Table 7–7 and Figure 7–7.

Table 7–7 indicate some dissatisfaction with *m-LR* was reported by experts for Category 1 with an overall rating of 3.6 (S.D.=0.70). Criteria 1, 5 and 9 (red values) are highlighted as potential areas for improvement.

Three items in Figure 7-7 are flagged by black arrows for further comment:

❶ The system needs to offer improved *feedback* mechanisms (mean 3.5) (Criterion 1).

❷ Rating of Criterion 5 (3.5) indicates that errors occur without satisfactory means of preventing the *errors*

❸ Criterion 9 evaluates the ability of the system to provide *help*. The poor rating of 3.3 confirms the ratings of Criteria 1 and 5, providing a possible reason for all three values. The missing help functionality with no feedback could adversely affect the outcome of trying to fix errors.

Website-specific usability

Table 7–8 and Figure 7-8 illustrate the feedback from experts in Category 2, website-specific usability with an overall rating of 3.5 (S.D.=0.75). The quantitative findings relating to Category 2 include the lowest mean Likert rating (2.8) assigned by the experts in Study 6, namely Criterion 12 – Easy to access information.

Table 7–8: HE ratings of Category 2 criteria – Experts

Category 2 Website-specific Usability		**Mean**	**S.D.**
10	Simplicity of site navigation, organisation and structure	**3.4**	0.50
11	Relevance of site content to the learner and the learning process, content meaningful to domain and learner	3.7	0.37
12	Easy to access information	**2.8**	0.62
13	Content is both suitable and of a high quality	4.0	0.55
14	System is simple and easy to use, called easiness	3.7	0.79
15	Material is of a high quality i.e. videos and digitisation	3.6	0.86
	Overall Rating	**3.5**	**0.75**

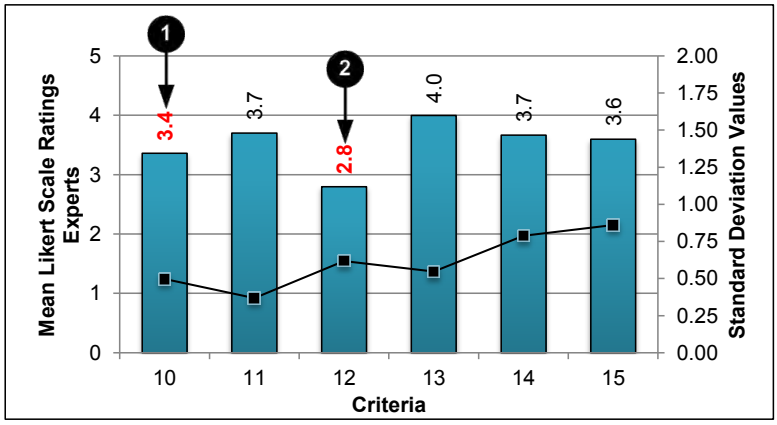

Figure 7-8: Category 2 Website-specific Usability – Experts

Criterion 10 with rating 3.4 (S.D.=0.50) and Criterion 12 with rating 2.8 (S.D.=0.62) are highlighted in red in Table 7–8 and flagged in Figure 7-8 for further discussion.

❶ Experts rate the *ability to navigate* within *m-LR* as unsatisfactory and experience difficulties with its structure (Criterion 10).

❷ According to expert opinion, it is important for learners to be able to *access course material* in an easy manner (Criterion 12). This requirement has not been adequately met.

Educational usability

Table 7–9 and Figure 7-9 reflect the evaluation ratings of experts in Category 3, Educational Usability.

Table 7–9: HE ratings of Category 3 criteria – Experts

Category 3 Educational Usability		Mean	S.D.
16	Clarity of goals, objectives and outcomes	**3.4**	0.73
17	Effectiveness of collaborative learning	4.0	0.56
18	Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle	**3.5**	0.58
19	Feedback, guidance and assessment	**3.5**	0.78
	Overall Rating	**3.6**	**0.73**

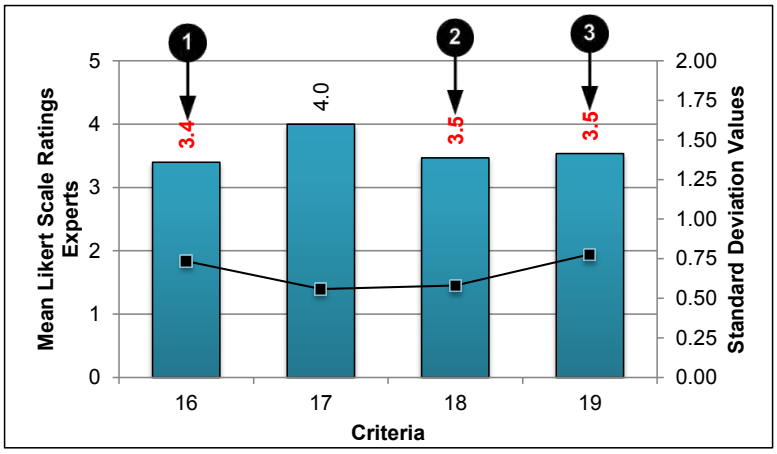

Figure 7-9: Category 3 Educational Usability – Experts

In Table 7–9 an overall rating of 3.6 (S.D.=0.73) suggests less than satisfactory usability with regard to educational and pedagogical issues. Individual ratings of a few items (red values), such as Criteria 16, 18 and 19 with mean ratings of 3.4, 3.5 and 3.5 respectively, highlight that some improvement should be made to *m-LR*. Black arrows highlight these items in Figure 7-9.

❶ *Learning goals* and objectives are not clearly and immediately obvious (Criterion 16).

❷ As with Criterion 5 in Category 1, the *error management* mechanism in *m-LR* and the user's ability to recover from errors when doing course-related activities needs to improve (Criterion 18).

❸ Likewise, the experts were not satisfied with the feedback mechanisms, perceiving a lack of feedback during the assessment activity (Criterion 19).

m-Learning usability

The findings of Category 4, m-Learning Usability are reported in Table 7–10 and Figure 7-10 with an overall mean Likert rating of 3.9 (S.D. = 0.39). This value suggests that experts rated the usability of *m-LR*$_{m1}$ as average.

Table 7–10: HE ratings of Category 4 criteria – Experts

Category 4 m-Learning Usability		Mean	S.D.
20	Mobile phones and technology	4.1	0.47
21	Contextual factors (pragmatic)	**3.7**	0.30
22	User-centricity (pragmatic)	**3.7**	0.27
23	Flexibility	4.2	0.25
24	Interactivity	**3.7**	0.23
	Overall Rating	**3.9**	**0.39**

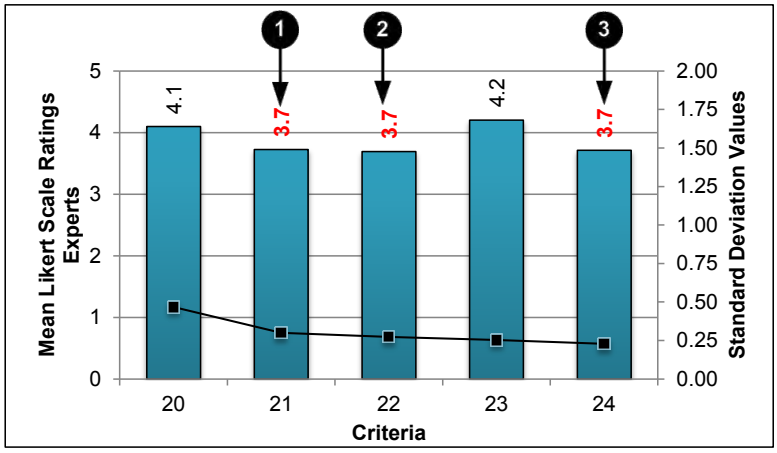

Figure 7-10: m-Learning Usability – Experts

Three criteria have the same rating of 3.7: Criterion 21, contextual factors, Criterion 22, user-centricity and Criterion 24 interactivity in Table 7–10 (red values) and Figure 7-10 (black arrows) have been selected for further discussion.

❶ Criterion 21 – *contextual factors* such as distraction due to the availability of the Internet, as well as aspects of the device type, are likely to interfere with efforts to learn using the mobile phone.

❷ Criterion 22 – a greater attention to *users' requirements* such as instant download of lesson material is indicated.

❸ Criterion 24 – experts would prefer a more *interactive learning* environment.

User Experience (UX)

The overall rating for Category 5, user experience, amounted to 3.7 (S.D.=0.84). Criteria 25 and 27 collectively suggest that the user's experience of the environment was merely satisfactory.

Table 7–11: HE ratings of Category 5 criteria – Experts

Category 5 UX		Mean	S.D.
25	Emotional issues	**3.5**	0.69
26	Contextual factors (hedonic)	4.3	0.75
27	User-centricity (hedonic)	**3.5**	1.00
28	Social value	4.0	0.63
29	Needs	3.8	0.88
30	Appeal	3.6	0.57
31	Satisfaction	3.6	0.80
	Overall Rating	**3.7**	**0.84**

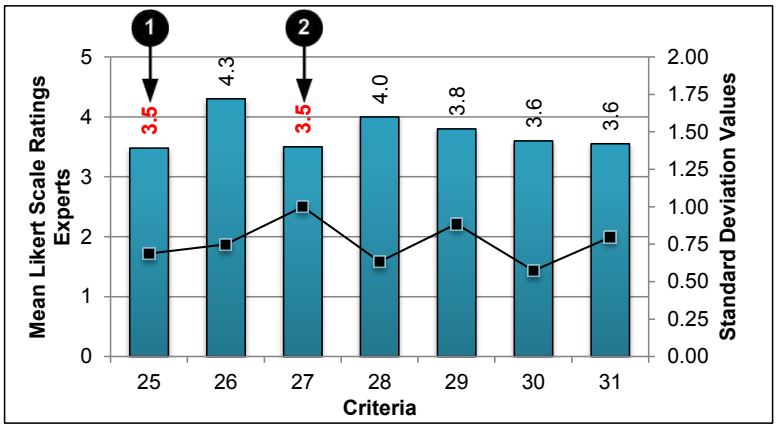

Figure 7-11: UX – Experts

❶ Experts did not report the experience of *m-LR* as thrilling and representative of a *fun*-filled learning environment (Criterion 25).

❷ Similarly, the needs of the *users* require greater focus (Criterion 27).

Quantitative findings from qualitative data elicited from heuristic evaluations

As for Study 4, the problems identified by expert evaluators (Appendix C-1.2) were extracted from their unprompted responses to the open-ended items in the questionnaire. Thematic analysis was used to classify problems according to the eight categories of design guidelines that were synthesized by the researcher and presented in Table 4-1, Section 4.3.2. The categories of guidelines comprised: design and development, mobile specifications, learner-centricity, ease of use, content, context, VLEs and Web 2.0 tools. A detailed account of the thematic analysis of all five categories is too comprehensive to

include; instead, this information is presented in Appendix C-1.2. However a sample of the problems reported by the five experts in Category1, General Interface Usability, is tabulated in Table 7-12. It illustrates the manner in which qualitative data may be analysed quantitatively, (Creswell, 2009) producing valuable guidelines for evolutionary development of m-learning environments.

Table 7–12: A section from Appendix C-1.2, indicating thematic analysis of the problems reported by experts

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**4**			
	1.1. There is little form of interaction between the user and the system.	1	20	Feedback	Ease of Use
	1.2. Server unavailable.	1	20	Device Constraints	Mobile Specifications
	1.3. Cannot find blog or video.	1	20	Media	VLEs
	1.4. The only indicator of the system or its pages loading is in the URL indicator.	1	20	Design	Design and Development
2	***Match between system and the real world***	**2**			
	2.1. Some pages have little or not enough information which shows the importance of the pages.	1	20	Feedback	Ease of Use
	2.2. Got lost in menus.	1	20	Navigation	Ease of Use
3	***Learner control***	**1**			
	3.1. Able to use the 'back' button without having to 'save'.	1	20	Navigation	Ease of Use
4	***Consistency and adherence to standards***	**2**			
	4.1. Inconsistent with PC standards that allow for user friendly message that assists the user to use the application.	1	20	Feedback	Ease of Use
	4.2. Unable to select 'search' without text being added.	1	20	Design	Design and Development

Table 7–12 represents a view of the outcome of thematic analysis of qualitative data elicited from HE questionnaires completed by experts. As described in Study 4, the reference numbers of criteria are recorded in the first column, whilst the second column lists the comments made by evaluators. In the third column ***f*** reflects the number of counted problems per criterion. The fourth column indicates the percentage of experts reporting each problem together with a subtotal per criterion. It is notable that that different expert reported different problems, demonstrating the value of a set of experts with varying perspectives. Each identified problem is allocated to a theme in the next column and finally, relevant design guidelines are suggested in the last column. For example, for Criterion 1 *Visibility of system status, provide feedback*, four problems were identified with one problem allocated to each of the Design Guidelines in column four – *Ease of Use, Mobile Specifications, VLEs and Design and Development* and one classified in each of four themes – *Feedback*, *Device Constraints*, *Media* and *Design*.

Table 7–13 quantifies the qualitative data (Creswell, 2009), suggesting that of a total of 28 problems identified by experts, the highest quantity (14) occurs in Category 1, General Interface Usability, representing 50% of the total number of problems reported by experts. In contrast, no problems were identified in Category 3, Educational Usability.

Table 7–13: Problems reported by Experts

	Experts	Number of Problems Reported per Category of Criteria					Total
		1	2	3	4	5	
Themes	Design and Development	3	1	0	1	0	5
	Mobile Specifications	1	1	0	0	0	2
	Learner-centricity	0	0	0	0	4	4
	Ease of Use	9	1	0	0	0	10
	Content	0	0	0	1	0	1
	Context	0	0	0	1	0	1
	VLEs	1	3	0	1	0	5
	Web 2.0 Tools	0	0	0	0	0	0
	Total	**14**	**6**	**0**	**4**	**4**	**28**

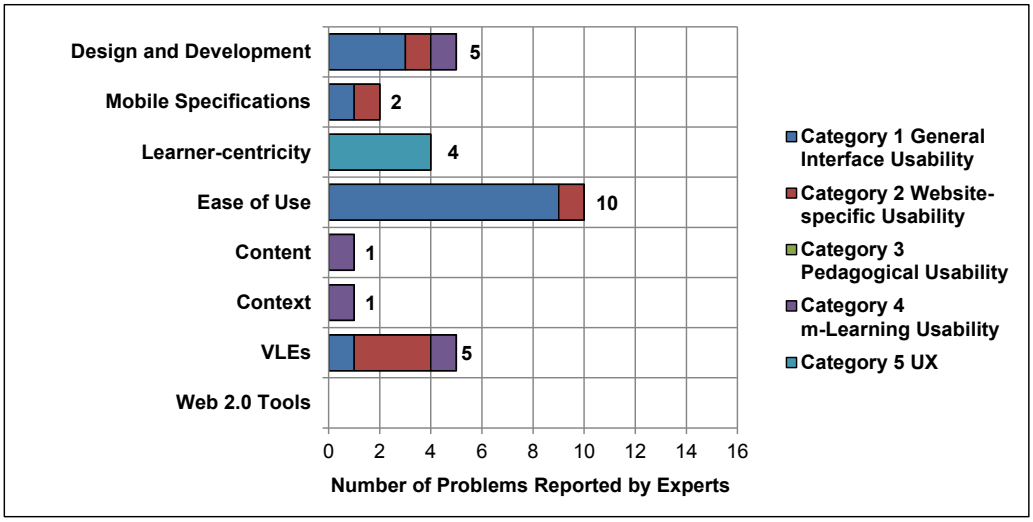

Figure 7-12: Thematic analysis of problems reported across 5 evaluation categories – Experts

Figure 7-12 graphically illustrates that ten problems (36%) were associated with the theme *Ease of Use*. Further analysis of the list of problems indicated that 90% of issues defined by this theme were reported in Category 1, General Interface Usability. This finding corroborates one of the major challenges of m-learning, namely the limitation of the mobile handheld device itself.

7.3.3 Findings and Discussion – Learner User Questionnaires

The sample of 32 learners selected as participants for Study 6 comprised the population of fulltime Software Engineering (SE) cohorts, enrolled on campuses C1 and C2 during 2012. The two Western Cape campuses, C1 and C2, offer the identical course content.

The findings in this section are reported in a similar way to the manner used for the HE by experts in Section 7.3.2. Firstly quantitative data (Appendix C-2.1) gathered from learners who completed survey questionnaires (Appendix A-6) is discussed separately for each of the five categories of criteria used to evaluate *m-LR*. Then, problems are recorded in response to open-ended questions, counted and categorised (Appendix C-2.2) on the basis of the guidelines for the design and development m-learning environments, synthesized earlier in Table 4-1, Section 4.3.2. In this way, qualitative data gives rise to additional quantitative findings.

Quantitative findings from learner survey evaluations

Learner evaluations are reviewed by sequential examination of the reported quantitative ratings in the five categories of criteria contained in the MUUX framework (Section 3.6) comprising: general interface, website-specific, educational and m-learning usability and UX.

General interface usability

The quantitative findings of learners for Category 1, General Interface Usability are provided in tabular and graphical format in Table 7–14 and Figure 7-13, respectively.

Table 7–14: Survey ratings of Category 1 criteria – Learner Users

	Category 1 General Interface Usability	Mean	S.D.
1	Visibility of system status, provide feedback	4.1	0.53
2	Match between system and the real world	4.1	0.44
3	Learner control	3.9	0.60
4	Consistency and adherence to standards	4.0	0.93
5	Error prevention, in particular, prevention of peripheral usability-related errors	**3.8**	0.66
6	Recognition rather than recall, memory use	**3.7**	0.70
7	Aesthetics and minimalism in design	4.1	0.76
8	Recognition, diagnosis and recovery from error	3.9	0.64
9	Help and documentation	**3.6**	0.83
	Overall Rating	**3.9**	**0.70**

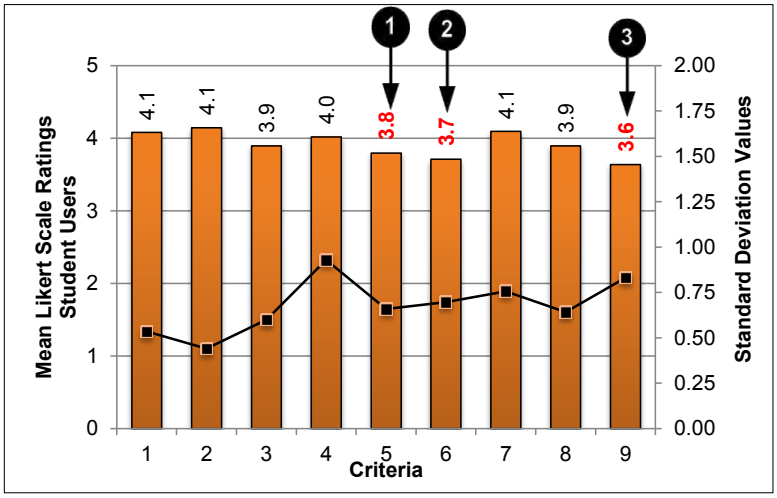

Figure 7-13: Category 1 General Interface Usability – Learner Users

Learner ratings recorded in Table 7–14 indicate a satisfactory interface usability indicated by an overall rating of 3.9 (S.D.=0.70). The overall rating includes the learner responses to three criteria in particular, namely Criterion 5 (rating = 3.8), Criterion 6 (rating = 3.7) and Criterion 9 (rating = 3.6), which have been selected for further comment. These items are highlighted in red in Table 7–14 and with black arrows in Figure 7-13.

❶ Some *errors* occurred and learners were unable to prevent them (Criterion 5).

❷ The m-learning system should *support* the learner's need to be prompted from time to time (Criterion 6).

❸ As with feedback from experts, learners did not easily get support from the *help* function (Criterion 9).

Website-specific usability

The mean Likert scale ratings reported learner users in Category 2, Website-specific Usability, are provided in Table 7–15 and Figure 7-14. The overall rating of 4.0 (S.D. = 0.69) for Category 3 indicates good usability and reflects, once again, the resilience and independence of learners in a web-based environment.

Table 7–15: Survey ratings of Category 2 criteria – Learner Users

Category 2 Website-specific Usability		Mean	S.D.
10	Simplicity of site navigation, organisation and structure	4.0	0.60
11	Relevance of site content to the learner and the learning process, content meaningful to domain and learner	4.1	0.46
12	Easy to access information	**3.6**	0.75
13	Content is both suitable and of a high quality	4.0	0.80
14	System is simple and easy to use, called easiness	4.0	0.72
15	Material is of a high quality i.e. videos and digitisation	4.2	0.61
	Overall Rating	**4.0**	**0.69**

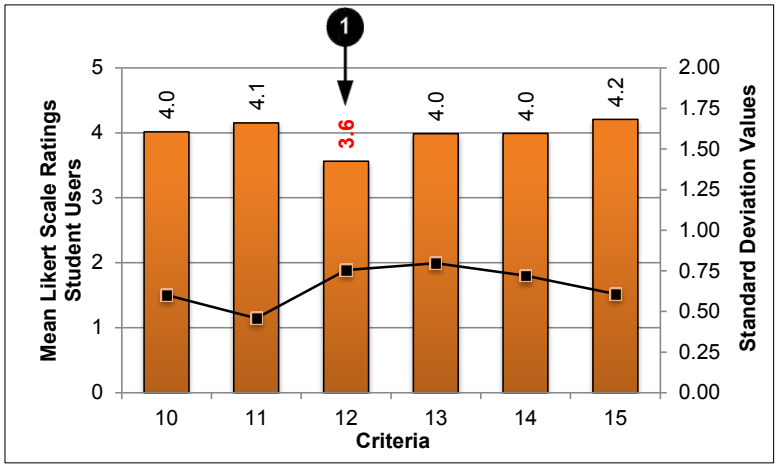

Figure 7-14: Category 2 Website-specific Usability – Learner Users

❶ *Ease of access* (Criterion 12), with a mean Likert rating of 3.6 (S.D.=0.75) remains an issue, due largely to the limitations of digital technology such as data transfer speed and bandwidth constraints.

Educational usability

Table 7–16 and Figure 7-15 reflect the evaluation ratings of learner users for Category 3, Educational Usability.

Table 7–16: Survey ratings of Category 3 criteria – Learner Users

Category 3 Educational Usability		Mean	S.D.
16	Clarity of goals, objectives and outcomes	4.1	0.61
17	Effectiveness of collaborative learning	**3.9**	0.66
18	Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle	**3.9**	0.68
19	Feedback, guidance and assessment	4.0	0.71
	Overall	**4.0**	**0.67**

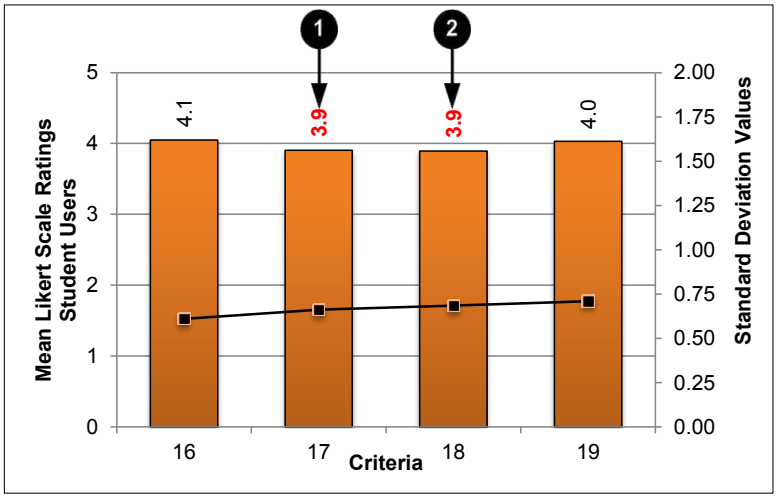

Figure 7-15: Category 3 Educational Usability – Learner Users

Table 7–16 and Figure 7-15 above provide the findings of learner users in Category 3, Educational Usability with a high overall rating of 4.0 (S.D.=0.67) in contrast to the mean rating of experts who indicated a mean Likert rating of 3.6 in this category. Learners reported good usability for each of the criteria in this category, with the two lowest ratings both being 3.9. The higher rating of learners, compared with experts, could indicate that learners have a more positive attitude to the potential of m-learning to scaffold educational goals.

❶ Learners *working collaboratively* on project work express some slight doubt about the benefit of communicating via an m-learning environment such as *m-LR* (Criterion 17).

❷ Some learners made mistakes in the quiz or while browsing the glossary and could not easily recover as prompts and links were not clearly provided (Criterion 18).

m-Learning usability

Table 7–17 and Figure 7-16 portray learner user responses to m-learning criteria with an overall rating of 3.9 (S.D.=0.55).

Table 7–17: Survey ratings of Category 4 criteria – Learner Users

Category 4 m-Learning Usability		Mean	S.D.
20	Mobile phones and technology	4.0	0.39
21	Contextual factors (pragmatic)	**3.7**	0.54
22	User-centricity (pragmatic)	**3.8**	0.56
23	Flexibility	4.1	0.47
24	Interactivity	**3.9**	0.55
	Overall	**3.9**	**0.55**

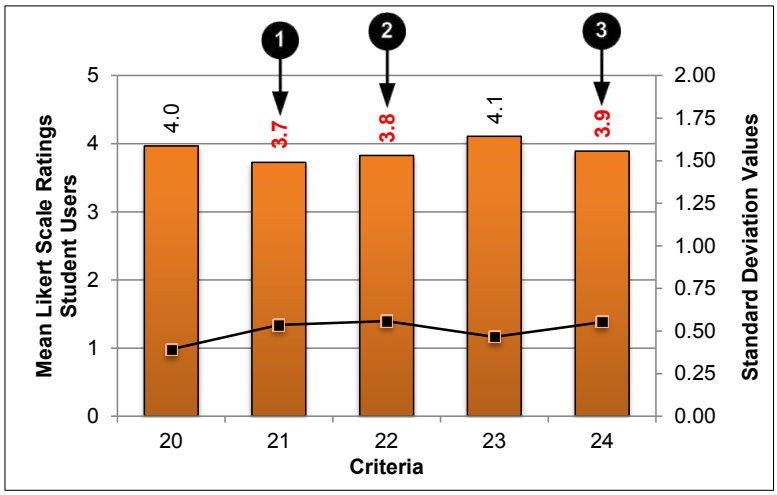

Figure 7-16: Category 4 m-Learning – Learner Users

As for Study 4 among expert evaluators, these findings suggest positive support for the m-learning items listed in Category 4. Comments are provided here on the mean ratings for Criteria 21, 22 and 24 (black arrows in Figure 7-16). Closer inspection indicates that *m-LR* could be improved in three ways:

❶ According to overall mean rating of Criterion 21 (3.7), learners are aware of the negative *influence of contextual factors* that could hinder success in an environment designed to support digital learning.

❷ Criterion 22 evaluates the *practical aspects of m-learning*. The rating (3.8) suggests learners were not completely satisfied with the way the system made provision for practical needs and personal assistance for their Software Engineering program.

❸ Marginally negative responses were allocated to Criterion 24 (3.9) which evaluates *interactivity*. This should contribute to design guidelines regarding the manner in which learners interact digitally via mobile phones

User Experience

Table 7–18 and Figure 7-17 report the mean Likert scale ratings of the seven items in Category 5, User Experience.

Table 7–18: Survey ratings of Category 5 criteria – Learner Users

Category 5 UX		Mean	S.D.
25	Emotional issues	3.9	0.74
26	Contextual factors (hedonic)	4.2	0.97
27	User-centricity (hedonic)	4.0	0.69
28	Social value	4.1	0.65
29	Needs	3.9	0.64
30	Appeal	4.0	0.79
31	Satisfaction	3.9	0.72
	Overall	**4.0**	**0.70**

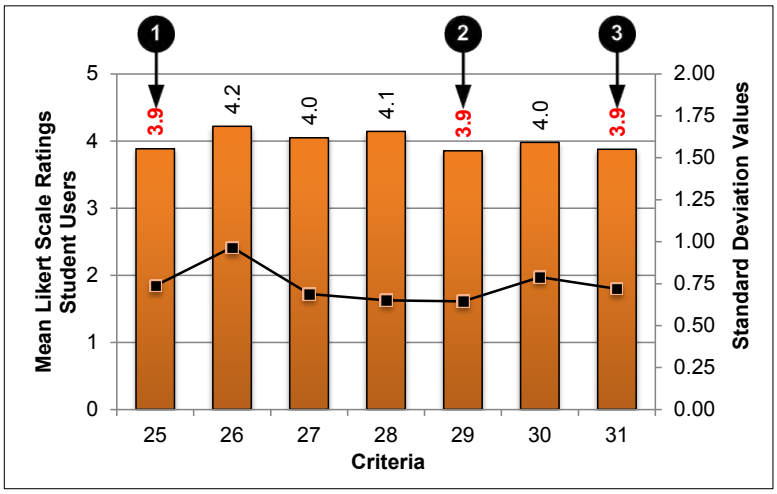

Figure 7-17: Category 5 UX – Learner Users

The pattern of responses in the UX category differentiates the reaction of learner users to the *m-LR* prototype from that of the expert evaluators. Table 7–18 and Figure 7-17 indicate their ratings of UX with three values (in red) being just below the mean of 4.0. The mean Likert rating of 3.7 provided by experts and shown earlier, suggests a more negative perception of UX of $m\text{-}LR_{m1}$. Learners experience the m-learning environment as more fun-filled and familiar than the experts did. However, three items are highlighted for comment:

❶ A rating of 3.9 (S.D.=0.74) for Criterion 25 suggests that the user missed the 'WOW' factor, learners did not find the m-learning experience *entertaining or exciting*.

❷ As such, their *digital need* for instant responses was not adequately addressed (mean =3.9) (Criterion 29).

❸ To sum up the user experience, the *satisfaction* rating appeared to be below par (mean = 3.9) (Criterion 31).

Quantitative findings from qualitative data elicited from the learner surveys

Thematic analysis of the learners' textual data was approached in the same manner as for the textual data provided by the expert evaluators in their responses to open questions. The problems identified by learner users were therefore also categorised according to the eight design and development themes synthesized in Table 4-1, Section 4.3.2.

Thematic analysis was used to classify the problems found by learners. The problems identified by learner users are detailed in Appendix C-2.2 and summarised in Table 7–19, Table 7–20 and Figure 7-18.

Table 7–19: A section from Appendix C-2.2, indicating thematic analysis of the problems reported by learners

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**6**			
	1.1. Mobile phone network issues, long loading time. 1.2. Nothing really, cellphone was just a bit small. 1.3. Some content did not load correctly, not sure if it was my connection. 1.4. It isn't available for my phone and Internet version does have all the options.	4	12.5	Device Constraints	Mobile Specifications
	1.5. There is no quiz for Topic 1. 1.6. I couldn't see the quiz.	2	6.3	Assessment	VLEs
	1.7. To me the navigation is confusing at most times. 1.8. Could not find or read some of the apps. 1.9. I find navigation to be confusing at times. 1.10. Seems like you are going in circles sometimes.	4	9.4	Navigation	Ease of Use
	1.11. Identified that the modules were from 2011.	1	3.1	Design	Design and Development
	1.12. A bit busy at times.	1	3.1	Look and Feel	Design and Development
	1.13. I don't understand some of the feedback 1.14. Sometimes I don't know if I can answer the question as I'm not sure if the application did what it was meant to do, otherwise, works very well.	2	6.3	Feedback	Ease of Use
2	***Match between system and the real world***	**5**			
	2.1. Some borders are broken. 2.2. Quiz takes me to the homepage.	2	6.3	Design	Design and Development

Table 7–19 provides a section of Appendix C-2.2, which is too detailed to be included here in its entirety. An example is used to illustrate the structure and content of Table 7–19:

- Learners indicated that Criterion 1 – Visibility of system status, was associated with seven problems categorised in four themes and four different design guidelines.
- This analysis provides content and environment developers with a structured blueprint for evolutionary adjustments to the m-learning environment.

Table 7–20 provides summary data and indicates that in total, the group of 32 learner users found 62 problems in *m-LR*$_{m1}$, amounting to 21.4% more than those uncovered by experts. The greatest number of issues (27) was identified in Category 1, General Interface Usability, comprising 43.5% of all problems reported by the learner participants.

Table 7–20: Problems reported by Learner Users

	Learner Users	Number of Problems Reported per Category of Criteria					Total
		1	2	3	4	5	
Themes	Design and Development	10	4	1	0	0	15
	Mobile Specifications	5	4	1	5	0	15
	Learner-centricity	0	0	0	0	7	7
	Ease of Use	10	2	1	0	0	13
	Content	1	0	0	0	0	1
	Context	1	0	0	0	0	1
	VLEs	0	2	2	1	0	5
	Web 2.0 Tools	0	0	3	2	0	5
	Total	**27**	**12**	**8**	**8**	**7**	**62**

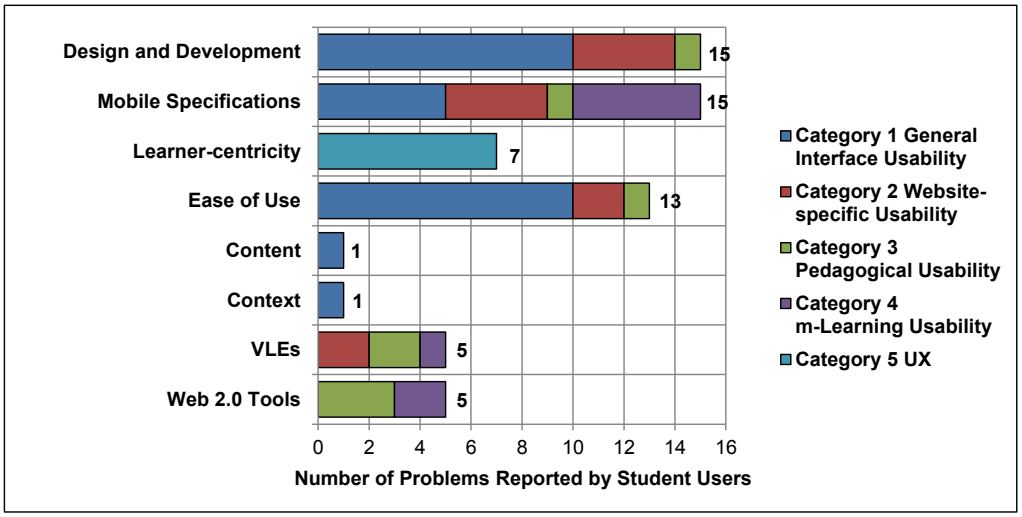

Figure 7-18: Thematic analysis of problems reported across 5 evaluation categories – Learner Users

Figure 7-18 suggests that the same number of problems (15) was reported by learner users for *Design and Development* and for *Mobile Specifications* amounting to 24.2% of problems detected by learners in each case. This observation contrasts with the analysis of problems in Figure 7-12 where issues reported by experts for *Design and Development* (5) and for *Mobile Specifications* (2) represented 17.9% and 7.1% of the experts' identified problems, respectively.

7.3.4 Reflection

Conformance metrics

Basic statistical analysis of the mean ratings provided by the evaluation feedback from experts and from learners, involved the determination of a Learner t-test values. The mean differences in the ratings for experts and learners in Table 7–21 are shown to be significantly different.

Table 7–21: Summary of conformance metrics for Study 6, Main Study 2

Category of Criteria	Expert Evaluators		Learner Evaluators	
	Mean Rating*	Reported Problems	Mean Rating*	Reported Problems
1	3.6	14	3.9	27
2	3.5	6	4.0	12
3	3.6	0	4.0	8
4	3.9	4	3.9	8
5	3.7	4	4.0	7
Overall	**3.7**	**28**	**4.0**	**62**

* t-Value=0.003, $p<0.05$ indicates mean differences for Experts and Learners are statistically significant

Table 7–21 indicates that a dissimilar number of problems were reported by experts (28) and by learners (62). A close inspection of these issues reveals the nature of the identified difficulties (Figure 7-12 and Figure 7-18), illuminating that besides the fact that learners detected a greater number of issues than experts, experts and learners noted difficulties in differing themes. This observation supports the decisions to adopt two evaluation methods, enabling the detection of factors that were pertinent to experts and unique to learners. It is suggested by the researcher that this phenomenon reflects a *digital difference* between the two evaluator profiles, rather than a *digital divide*.

Evaluation approach

As for Study 4 (Section 6.5.4), the evaluation strategy adopted in Study 6 has provided comprehensive usability and UX indices, contained within Table 6–27 above. In addition the multi-level thematic analysis method applied to synthesize problems into categories and themes provides a practical guideline enabling evolutionary adjustments to be made to versions of *m-LR* by content and software designers and developers. The method provides opportunity to capitalise on the Pareto effect where 80% of the improvements are achieved by making adjustments based on the top 20% of issues.

Evolution of m-LR

Both experts and learners indicated that, in general, adjustments according to feedback in Category 1, General Usability, would focus directly on the recommendations for the evolution *m-LR* to the next version, namely $m\text{-}LR_{m2}$. Synthesis of themes corroborates this observation, suggesting that the evolution should focus on issues associated with *design and development*, *mobile specifications*, and *ease of use*.

Digital divide

Study 5 which investigated the nature of the digital divide between cohorts at C1 and C2 produced paradoxical outcomes in that the campus with the greatest need for improved digital technology (C1) indicated the greatest resilience to the very divide that needed to be overcome. These findings suggest that an m-learning environment could provide the means of reducing the digital divide, but if and only if the concept is implemented where a real divide exists. On the campus where learners seemed less inspired by the potential benefit of an m-learning environment (C2), a superior digital knowledge, more advanced mobile devices and a reduced interest in m-learning was noted.

Contribution to the research questions

In Section 7.1, earlier in this chapter, it was indicated that this chapter would contribute to answering research questions ***RQ3*** and ***RQ4*** (contributing to practical outcome of the study) and ***RQ5*** (providing the theoretical outcome).

RQ3 – W*hat are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

Table 6–27 summarises the outcomes of using the MUUX Framework to evaluate $m\text{-}LR_{ps}$, a version of *m-LR*, for usability and UX.

The findings of Study 5, Mobile Learning Digital Divide Survey in Section 7.2.2 concretised the perception that a digital divide existed between C1 and C2. The study provided feedback applicable to answering of ***RQ4***.

Observations were made in Chapter 6, Main Study1, on the manner in which the MUUX framework could contribute to meta-evaluative knowledge in the context of m-learning (***RQ5***). The comments made there are supplemented by extra insight in this chapter, as follows:

- The MUUX Framework of criteria enabled the design of sequential evaluation studies (Study 4 and Study 6), facilitating comparison of findings and providing triangulation of data – essential for the evaluation of m-learning environments;
- In this way, the m-learning environment could be subjected to evaluation using one framework by different cohorts of learners, making provision for the dynamic nature of mobile technology and the differences across time of digital populations;
- MUUX provided the opportunity to compare of the findings of Study 4, Main Study 1 and Study 6, Main Study 2 creating a platform for the validation of the evaluation findings;
- Evolutionary and step-wise changes could be made to *m-LR*, where $m\text{-}LR_1$ and then $m\text{-}LR_{pre}$ lead to $m\text{-}LR_{ps}$ which preceded $m\text{-}LR_{m1}$ resulting ultimately in $m\text{-}LR_{m2}$.
- With each adjustment, the dynamic nature of the m-learning context could be accommodated even where content from different IS disciplines were incorporated into *m-LR*.
- In Study 6, participants completed evaluations using their own devices in a personally chosen space – providing a more naturalistic context, suited to m-learning.

The research questions mentioned here are revisited in Chapter 8, as follows:

- *RQ3* – Section 8.2.2;
- *RQ4* – Section 8.2.4; and
- *RQ5* – Section 8.2.5.

In accordance with a DBR methodology, the study aimed to produce both theoretical and practical contributions (Figure 5-2) which are presented in Sections 8.3.1 and 8.3.2 respectively. Figure 7-1 at the beginning of this chapter indicates that these contributions result from Study 6.

7.4 Conclusion

Chapter 7, Findings and Discussion 2, comprised the second part of findings and discussion of the research study, succeeding the reported outcomes in Chapter 6, Findings and Discussion 1.

The artefact *m-LR*$_{m1}$ resulted from usability and UX evaluation by experts and learners in Study 4. It constituted the m-learning environment evaluated during Study 6. This connection was depicted in Figure 7-1 which provided a summary of the relationship between the two studies in Chapter 7, namely Study 5, Mobile Learning and Digital Divide Survey and Study 6, Main Study 2.

The nature of digital profile of learner participants emerged during Study 5 whilst recommendations for the evolutionary adjustments to *m-LR* leading to the fully functional version, *m-LR*$_{m2}$ resulted from Study 6.

As in Chapter 6, each study included an initial outline followed by an analysis of the quantitative and qualitative findings of the study followed by a concise reflection on the findings of the chapter.

The reflection on the findings of Study 6 discusses conformance metrics, the evaluation approach, the evolution of *m-LR* and aspects of the digital divide. Research questions addressed both practical (***RQ3*** and ***RQ4***) and the theoretical outcomes (***RQ5***) of the study. These questions are revisited in Chapter 8, where the findings and discussion of all studies provide the completed answers.

CHAPTER 8: Conclusions and Recommendations

8.1 Introduction

The main purpose of this research project was the evaluation of the usability and user experience of an m-learning environment, custom-designed for a tertiary educational context. Desk-bound PC-based e-learning provides e-learning opportunities to extend the traditional classroom. However learning via mobile device provides the chance to embrace technology-enhanced learning in general and m-learning in particular.

The study was founded on a real world problem. Learners studying software engineering on two different Western Cape campuses were required to work in groups and produce a comprehensive artefact assessed on the basis of a PBL strategy and team achievements. Several challenges contributed to the real-world problem, namely:

- A diverse and dispersed learner body;
- The context of learning and assessment;
- An inherent digital divide; and
- A lack of meaningful learning experiences.

m-Learning is distinct from e-learning in that, for an m-learning context, learners learn while moving around. They make use of a variety of mobile device brands and models and invariably require Internet connectivity to access course content and educational media. However literature sources have varied opinions about the relationship, if any, between e-learning and m-learning. Of the five different and overlapping perspectives provided (Figure 2-4 to Figure 2-8), the researcher opted for the view that e-learning and m-learning share some attributes whilst having a degree of independence.

The concept of m-learning is characterised by the large variety of mobile device types in use, WBL technology, and the nature of the mobile user. Several challenges result from these attributes:

- The mobile device itself – its characteristics;
- The specific guidelines that are needed for m-learning applications;
- Format of mobile content;
- A complex context of use;
- Technology advancements and limitations;
- Ethical factors; and

- Attitudes and concerns of educational institutions.

The evaluation of an m-learning environment includes provision for usability and UX. Usability is defined by ISO 9241-11 (1998) as "… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". In accordance with ISO 9241-210 (2010) UX represents " … a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service". Evaluation of an m-learning environment aims to accomplish high quality experiences, efficiently and effectively.

This chapter concludes the study. In the next section, the research questions are answered (Section 8.2). A DBR methodology was adopted and culminated in both theoretical and practical contributions, which are presented in Sections 8.3.1 and 8.3.2 respectively. Aspects associated with validity and reliability are summarised in Section 8.4 whilst in Section 8.5, the limitations that were discussed in Chapter 1 are revisited. This leads to Section 8.6 which proposes recommendations and the need for future research. And finally, the study concludes in Section 8.7.

8.2 Answers to the Research Questions

The research questions that underlie this study were presented in Chapter 1, Section 1.5, and revisited in Section 5.2 of Chapter 5. The five research questions, numbered ***RQ1*** to ***RQ5*** are repeated below and answered in the subsections that follow:

RQ1*: To what extent does the m-learning environment, m-LR, custom-designed for a tertiary educational institution, conform to the criteria of the synthesized usability and UX evaluation framework?*

RQ2*: What categories and criteria should be included in a usability and UX evaluation framework for m-learning environments?*

RQ3*: What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

RQ4*: Can mobile technology reduce the digital divide in a tertiary educational context?*

RQ5*: How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

Answers to ***RQ2*** and ***RQ3*** are provided prior to the answer to ***RQ1***, as they contribute to its resolution. Thereafter, ***RQ4*** and ***RQ5*** are answered.

8.2.1 Research Question 2

***RQ2**: What categories and criteria should be included in a usability and UX evaluation framework for m-learning environments?*

The MUUX framework of categories and criteria is presented in Section 5.6 and results from the synthesis of secondary data from literature sources in Sections 2.6, 2.7, 3.5, 3.6, 4.2, and 4.4. It consists of ***five categories*** and a total of ***31 criteria with sub-criteria*** as follows:

- *Category 1* – General interface usability criteria, nine criteria and 27 sub-criteria;
- *Category 2* – Website specific criteria, six criteria and nineteen sub-criteria;
- *Category 3* – Educational criteria, four criteria and eleven sub-criteria;
- *Category 4* – m-Learning criteria, five criteria and 39 sub-criteria; and
- *Category 5* – UX criteria, seven criteria and 21 sub-criteria.

Table 8-1: Final MUUX Framework

MUUX: A Framework of Categories and Criteria for the Evaluation of Usability and UX of m-Learning Environments
Category 1: General Interface Criteria 1 Visibility of system status 2 Match between the system and the real world 3 Learner control and freedom 4 Consistency and adherence to standards 5 Error prevention, in particular, prevention of peripheral usability-related errors 6 Recognition rather than recall 7 Aesthetics and minimalism in design 8 Recognition, diagnosis and recovery from errors 9 Help and documentation
Category 2: Website-specific Criteria 10 Simplicity of site navigation, organisation and structure 11 Relevance of site content to the learner and the learning process 12 Easy to access information 13 Content is both suitable and of a high quality 14 System is simple and easy to use, called easiness 15 Material is of a high quality, i.e. videos and digitisation
Category 3: Educational Criteria 16 Clarity of goals, objectives and outcomes 17 Effectiveness of collaborative learning 18 Cognitive error recognition, diagnosis and recovery 19 Feedback, guidance and assessment
Category 4: m-Learning Criteria 20 Handheld devices and technology 21 Contextual factors (pragmatic) 22 User-centricity (pragmatic) 23 Flexibility 24 Interactivity
Category 5: UX Criteria 25 Emotional issues 26 Contextual factors (hedonic)

27	User-centricity (hedonic)
28	Social value
29	Needs
30	Appeal
31	Satisfaction

8.2.2 Research Question 3

***RQ3**: What are the outcomes of using the MUUX Framework to evaluate m-LR for usability and UX?*

A combination of Table 8-2 and Table 8-3 answers ***RQ3***. Whilst Section 7.2 provides the final outcomes of using the MUUX Framework to evaluate *m-LR* for usability and for UX, the iterative nature of the DBR methodology adopted in this study implies that several ***preceding evaluations contributed to the final outcomes***. In principle, the feedback from experts and from learners culminated in two forms of outcome for each of the main studies, Study 4 and Study 6, namely: a mean Likert rating and a total number of problems reported by each evaluator profile.

The summary of the conformance metrics for Study 4, Main Study 1 was provided in Section 6.5.4 and is repeated here as Table 8-2. Cells containing the conformance metrics are shaded in grey.

Table 8–2: Summary of conformance metrics for Study 4, Main Study 1

Category of Criteria	Expert Evaluators		Learner Evaluators	
	Mean Rating	Reported Problems	Mean Rating	Reported Problems
1	3.5	16	4.0	18
2	3.6	9	4.0	7
3	3.5	7	4.1	6
4	3.6	2	4.0	9
5	3.2	7	4.2	6
Overall	**3.4***	**41**	**4.1***	**46**

* t-Value=0.0007, $p<0.05$ indicates mean differences for Experts and Learners are strongly statistically significant

The summary of the conformance metrics for Study 6, Main Study 2 was provided in Section 7.3.4 and is repeated here as Table 8-3. Cells containing the conformance metrics are shaded in grey.

Table 8–3: Summary of conformance metrics for Study 6, Main Study 2

Category of Criteria	Expert Evaluators		Learner Evaluators	
	Mean Rating*	Reported Problems	Mean Rating*	Reported Problems
1	3.6	14	3.9	27
2	3.5	6	4.0	12
3	3.6	0	4.0	8
4	3.9	4	3.9	8
5	3.7	4	4.0	7
Overall	**3.7**	**28**	**4.0**	**62**

* t-Value=0.003, p<0.05 indicates mean differences for Experts and Learners are statistically significant

Table 8–4 reports the comparison of mean Likert ratings for Study 4 in 2011 and Study 6 in 2012, provided by experts. In the final column, the t-value for Category 5, User Experience is highlighted in red to indicate that differences are statistically significant for this category indicating an important improvement in *m-LR* for UX.

Table 8–4: Comparison of mean Likert ratings for Study 4 and Study 6 - Experts

Category of Criteria	Mean Ratings		t-Values
	Study 4 – Experts (2011)	Study 6 – Experts (2012)	
1	3.5	3.6	0.427
2	3.6	3.5	0.584
3	3.5	3.6	0.726
4	3.6	3.9	0.222
5	3.2	3.7	**0.003***
Overall	**3.4**	**3.7**	

* t-Value=0.003, p<0.05 indicates mean differences for Experts (2011) and Experts (2012) are statistically significant for Category 5, UX

Similarly, Table 8–5 summarises the comparison of mean Likert ratings for evaluations of *m-LR* performed by Learners in Study 4 (2011) and Study 6 (2012). On the basis of the t-values provided in the final column, it can be seen that although the outcomes are consistent and reliable, no statistical significance has been demonstrated.

Table 8–5: Comparison of mean Likert ratings for Study 4 and Study 6 - Learners

Category of Criteria	Mean Ratings		t-Values
	Study 4 – Learners (2011)	Study 6 – Learners (2012)	
1	4.0	3.9	0.440
2	4.0	4.1	0.168
3	4.1	4.1	0.498
4	4.0	4.0	0.495
5	4.2	4.4	**0.185**
Overall	**4.1**	**4.0**	

8.2.3 Research Question 1

RQ1*: To what extent does the m-learning environment, m-LR, custom-designed for a tertiary educational institution, conform to the criteria of the synthesized usability and UX evaluation framework?*

The MUUX Framework of categories and criteria was synthesised and presented in response to ***RQ2*** in Section 8.2.1 above. ***RQ3*** established the outcome of the evaluation of usability and UX, by applying the MUUX framework. ***RQ3*** was answered above in Section 8.2.4. RQ1 is answered by a combination of ***RQ2*** and ***RQ3***.

The outcomes of the evaluation of *m-LR* for usability and UX are reflected in Table 8–2 (Study 4) and Table 8-3 (Study 6).

In Study 4, ***experts' ratings*** resulted in an overall conformance metric of ***3.4***, indicating ***unsatisfactory*** conformance. The extent of the conformance reported by ***experts*** does not comprise a single mean rating, as the five categories of criteria produced five different conformance indicators, namely:

1. General Interface Usability – 3.5;
2. Website-specific Usability – 3.6;
3. Educational Usability – 3.5;
4. m-learning – 3.6; and
5. UX – 3.2.

Conversely in Study 4, ***learners' ratings*** culminated in an overall conformance metric of ***4.1***, suggesting ***satisfactory*** conformance from the learners' perspective. The overall learners' rating resulted from the following five indicators:

1. General Interface Usability – 4.0;
2. Website-specific Usability – 4.0;

3. Educational Usability – 4.1;
4. m-learning – 4.0; and
5. UX – 4.2.

Isolation of ***41*** and ***46*** problems by experts and learners respectively, not only revealed non-conformance issues to be remedied but also led to the refinement and adjustment of $m\text{-}LR_{ps}$ leading to $m\text{-}LR_{m1}$.

Similarly, Table 8-3 indicates the measures of conformance as a result of the subsequent evaluation procedure in Study 6 with overall conformance metrics of ***3.7*** (***unsatisfactory***) and ***4.0*** (***satisfactory***) respectively for ***experts*** and ***learners***. The identification of ***28*** and ***62*** problems by experts and by learners suggests refinement and adjustment to $m\text{-}LR_{m1}$ leading to $m\text{-}LR_{m2}$.

For both Study 4 and Study 6 basic statistical analysis, comparing the outcomes of expert and learner feedback, suggests that the ***differences are statistically significant*** and that a ***more favourable evaluation perspective is expressed by learners than by experts***.

8.2.4 Research Question 4

RQ4*: Can mobile technology reduce the digital divide in a tertiary educational context?*

RQ4 is answered in Section 7.2.3. The study established the existence of a digital divide, leading to the likelihood (or perhaps not) that mobile technology could reduce the divide. A few of the key pointers are reviewed:

- **A *digital divide of a complex nature*** and extent emerged based on learner differences, the shortcomings of the campus infrastructure, aspects associated with the devices such as the device type and data cost, Internet connectivity issues and attitudes to mobile technology.
- The existence emerged of an ***intra-campus divide*** between the two campuses.
- Learners revealed the ownership of ***mobile phone brands with a diversity of capabilities***, reporting that they used their phones in a variety of dissimilar locations, carrying out a range of activities other than telecommunications.
- Learners had already become accustomed to mobile technology through necessity, inadvertently ***reducing their own digital divides***.
- An ***m-learning environment could reduce the digital divide*** in this context.
- The study reveals several ***anomalies***. Learner devices are so diverse that the m-learning environment would have a small chance of success.

- The study highlighted the phenomenon of how ***context*** – both of personal socio-economic situation and the ethos of the academic institution – impacts on learners.
- This, in turns results in differences in the ***types of technologies*** used, in this case mobile phone devices, and the ways in which learners interact with them.

8.2.5 Research question 5

RQ5*: How does the MUUX Framework contribute to meta-evaluative knowledge in the context of m-learning?*

A selection of the ways in which the MUUX Framework contributes to meta-evaluative knowledge in the context of m-learning, is highlighted in the next paragraphs:

- In Section 2.6, the researcher proposed that the nature of the ***transition from e-learning to m-learning*** incorporates facets of social learning, communication and collaboration and multimedia tools.
- Likewise in Section 2.7, it was reported that the context, complexities and challenges of an m-learning environment contributed to an understanding of m-learning.
- The two preceding factors informed the synthesis of the ***structure*** of the MUUX framework, founded on e-learning. In turn, the MUUX framework comprising five categories of evaluation criteria, suggests various categories of information that can be gathered about an m-learning environment.
- Similarly, the literature provided the foundation for the perceived ***relationship between usability and UX evaluation factors***, portrayed in Figure 3-4. The MUUX Framework made provision for a separate category of criteria, Category 5: UX, and incorporated both hedonic and pragmatic dimensions. This structured approach to evaluation is made possible by the view expressed in Section 3.5 that there are three ***mutually exclusive groups of attributes*** to be evaluated, namely: interdependence, intersection and independence. A theoretical outline of the model is provided as Figure 3-5. The final version, comprising 31 criteria specifically worded for m-learning and adapted for the context of m-learning in this study, is given as Table 5-11.
- Section 3.6 highlights the decision to structure MUUX as *a single framework*, built around shared evaluation. An established ***model of categories and criteria*** for evaluating web-based learning environments (Ssemugabi and de Villiers, 2010)

formed its basis. In a similar way, the MUUX Framework establishes a model for evaluating m-learning environments.

- The presentation of data in Sections 6.5 (Main Study 1) and Section 7.6 (Main Study 2) reflects that both categorised and overall evaluation ratings may be interpreted and discussed.
- The MUUX Framework supported the collection of both ***quantitative and qualitative data***, leading to valuable and evolutionary adjustments to versions of *m-LR*, transitioning from version $m\text{-}LR_1$ to $m\text{-}LR_{m2}$. These will be briefly revisited in Table 8-6. The method enabled ***longitudinal studies*** and ***comparison of findings***. The MUUX Framework was used for different types of studies e.g. Pilot and Main Studies. It was customised to generate evaluation instruments for HE by experts and survey questionnaires to be completed by learners. It enabled the collection and analysis of quantitative and qualitative data, leading to metrics that indicate the degree of conformance to each criterion.

8.3 Theoretical and Practical Contributions

In this section, the theoretical and practical contributions of the study are presented.

8.3.1 Theoretical Contributions

The study produced three major theoretical contributions, namely:

- The synthesis of ***a single MUUX Framework of categories and criteria*** for the evaluation of usability and UX of m-learning environments (Section 3.6.8, Figure 3-5);
- The synthesis of a set of ***guidelines for design and development of m-learning environments*** and the use of these guidelines as thematic analysis tools to collate reported problems and hence to establish recommendations for evolutionary adjustments to *m-LR* (Section 4.3.2, Table 4-1); and
- A ***customised design-based research model***, suited to the iterative and evolutionary development of an m-learning environment from a prototype to a fully operational version in situations where a digital divide may exist (Section 5.5, Figure 5-2).

8.3.2 Practical Contribution

A fully operational m-learning environment version of *m-LR*, $m\text{-}LR_{m2}$, was designed and developed as part of the study in an iterative and evolutionary manner defined by DBR principles. This is the practical contribution of this study.

The series of sequential iterative studies was introduced in Table 1-1 in Section 1.7.2, and is repeated here as Table 8-6.

Table 8-6: DBR iterations

Study	DBR Iteration	Date	Versions of *m-LR*	
			Pre-evaluation	Post-evaluation
0	B.Sc Honours Project	May 2010	-	-
1	Pre-Study	Nov 2010	$m\text{-}LR_1$	$m\text{-}LR_{pre}$
2	Mobile Usage Study	Sept 2011	-	-
3	Pilot Study	Oct 2011	$m\text{-}LR_{pre}$	$m\text{-}LR_{ps}$
4	Main Study 1	Nov 2011	$m\text{-}LR_{ps}$	$m\text{-}LR_{m1}$
5	Mobile Learning Digital Divide Study	Mar 2012	-	-
6	Main Study 2	Apr 2012	$m\text{-}LR_{m1}$	$m\text{-}LR_{m2}$

Table 8-6 tracks the path of *m-LR* from $m\text{-}LR_1$ in 2010 to $m\text{-}LR_{m2}$ in 2012.

8.4 Validity and Reliability

Validity and reliability were introduced and addressed in Chapter 5, Section 5.7.

Triangulation was implemented in several ways, including method-, data- and evaluator triangulation.

Method triangulation

- Study 2, the Pilot Study, was conducted as a preliminary usability and UX evaluation as well as ensuring that the appropriate wording was used for the heuristics and questions in the questionnaires.
- Evaluation methods included heuristic evaluation by experts and questionnaire surveys by learner participants.
- A design-based research strategy incorporated iterative cycles of evaluation.

Data triangulation

- The four evaluation studies, Study 1, Study 2, Study 4 and Study 6 included both quantitative (Likert scale) and qualitative (open-ended) items in proximity to each other enabling quantitative and qualitative data analysis.
- In addition, the number of problems detected by evaluators was totalled, eliciting quantitative findings from qualitative data.

Evaluator triangulation

- Both expert and learner evaluators completed the assessments.
- Expert evaluators were selected with varying qualifications and expertise.
- In total, fifteen different experts participated in various evaluation studies, ensuring that each expert participated in just one HE.
- The learner participants in Study 4 comprised C1 learners only.
- Study 5 investigated the nature of a digital divide between cohorts at two campuses, C1 and C2. This study revealed a diverse and ethnographically diverse population of digital consumers. Consequently, the evaluation strategy was adjusted for Study 6 to include learners from both C1 and C2. In this way gathered data was based on a broad spectrum of opinions.

Additional strategies

- User-centred design was informed by feedback from four DBR evaluation study cycles based on MUUX, namely, evaluations of an early prototype, a pilot, and two formative versions of the m-learning environment.

- Data collected for quantitative and qualitative purposes was analysed statistically and thematically (de Villiers, 2005b).

The reliability of findings was measured by comparing the findings of Main Study 1 and Main Study 2 and reported in Section 8.2.2, where the mean values of experts in 2011 are compared with those of experts in 2012. Similarly, the mean ratings of learner evaluations are compared for Study 4 in 2011 and Study 6 in 2012.

8.5 Limitations of the Study

Potential limitations of the study were highlighted at the start of the study and included in Section 1.8.3 in Chapter 1. Section 8.5 addresses the manner in which the limitations of the study were addressed and presents the possible limitations in question format.

8.5.1 Who actually used the mobile device?

- This is still difficult to evaluate, however secure logins limited this problem;
- "In natural context of use" is important so the developer needs to allow this and yet be aware of it; and
- The researcher would need to have some form of logging mechanism for future work.

8.5.2 How was the 'personally unique context' managed?

- By the nature of m-learning, every experience will be unique;
- Iterative cycles of evaluation included data collection across two campuses from all learners in the population;
- Method triangulation was incorporated via the inclusion of HE and survey questionnaires;
- Evaluator triangulation was introduced when expert and learner evaluators were included in the design of the study; and
- An interpretive methodology allowed for analysis of findings.

8.5.3 What factors could constrain the study?

- *Cost of connectivity*: was covered by the researcher;
- *Messiness of the device environment*: This became clear when learners used their own devices;

- *Subjective feedback from evaluators*: the inclusion of open-ended items into Study 2 (2011) and Study 5 (2012) provided explanatory, qualitative findings;
- *Lack of interest in m-learning*: evaluation questionnaires included category items for m-learning and UX, reporting open-ended feedback;
- *Generalizability of findings*: although method, data and evaluator triangulation were included, generalizability to other environments is the subject of future research; and
- *Relationships between usability and UX and academic performance*: this should be the subject of future research.

8.5.4 How applicable is the single evaluation framework, MUUX, to other m-learning environments?

- Category 5, UX, could be reformulated in order to elicit more meaningful user-centric feedback;
- Conformance indices are encouraging and simple to extricate from the data; and
- Additional research across diverse populations is called for.in future research.

8.6 Recommendations and Future Research

The findings of this study suggest further directions in m-learning research. Several avenues are recommended, including:

- Usability and UX evaluation of the fully operational version of *m-LR*, namely $m\text{-}LR_{m2}$;
- The conducting of evaluation studies across further campuses, expanding the number of cohorts in the participant population;
- Application of the MUUX Framework for evaluation in domains other than project management and software engineering;
- Additional research increasing the range of mobile devices, inclusive of tablet devices;
- The investigation of the dynamic nature of the digital environment in tertiary education to determine whether real reduction in the digital divide is possible or whether it is a shifting target;
- The inclusion into the survey and evaluation process of academics and the administrative community;
- The researcher was disappointed in the data collected in response to items in the UX category, Category 5. This observation suggests the structure and content of

the MUUX Framework could be refined, to incorporate more appropriately worded items, better suited to the evaluation of UX; and

- The policy implications associated with mobile technology in tertiary institutions.

8.7 Finally

Traxler (2010b: p. 16) comments that "… learners will come to universities with rapidly changing experiences and expectations of learning and these in turn will shape the learner experience".

This opinion manifests itself in this research study. The learners who participated in the 2011 studies differed from the more digitally savvy 2012 participants who seemed more critical, more technologically savvy, and more aware of their digital needs.

The final study, Study 6, is thus characterised by learner evaluators who responded during evaluations as more 'expert' than the experts, contradicting the view of Nielsen (1994) that a few experts satisfactorily uncover most of the usability problems. The experts were *really* experts and selected for their expertise. However, the learners were erudite software engineering students who were required to be proficient in aspects of HCI as part of their course. Whereas Nielsen suggests that just five experts adequately uncover most errors and issues, the study suggests that in a mobile technology environment, the learners are *more* expert – with respect to digital matters, than the chosen experts. This observation questions, in the researcher's mind the validity of Nielsen's classical comment on evaluation using heuristic experts relative to an m-learning context. In addition, this study highlights a requirement to focus to a greater extent on UX and on UCD in the formulation of an evaluation strategy for m-learning environments.

From a pedagogical perspective, the study reveals a gap in attitude between experts, selected from the academia, and participant learners, to the potential of m-learning to extend the classroom. The success of an m-learning initiative will depend to a greater extent on the ability of the providers of educational content to adjust to the potential benefits of rapidly evolving, technology-enhanced education mechanisms, than on the consumers of content.

The shifting and dynamic "… experiences and expectations …" alluded to by Traxler, support the emergence of a *digital shift*, suggesting a *digital divide* between lecturers and learners, needing to be bridged. Finally, in the context of this study, an observed *digital divide* could more aptly be described as a *digital difference*. This, too, could be the subject of future research.

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APPENDIX A: Instruments and Related Documents

A-1 Ethical Consent Letter from CTI, Tertiary Institution

cti Education Group
You're made for life
www.cti.co.za

Group Head Office
Building 1
Fourways Manor Office Park
Cnr. Roos and Macbeth Streets
Fourways
2191

P.O. Box 1398
Randburg
2125

Tel: 011 467 8422
Fax: 011 467 6528
www.cti.co.za

Ms P.A. Harpur

19 Keerweder Street

Vredelust

Bellville

7530

October 2011

To Who It May Concern

RE: Permission to conduct M.Sc. Information Systems Research Dissertation

I refer to the request for ethical approval for the Masters research project entitled:

"USABILITY AND USER EXPERIENCE EVALUATION OF AN M-LEARNING APPLICATION DELIVERED BY MOBILE HANDHELD DEVICES"

In accordance with the ethical clearance requirements of the Research and Ethics Committee at UNISA's College of Science, Engineering and Technology, please be advised that the application for ethical clearance has been granted.

Involved parties may also consider ethics approval as granted. Prospective student-participants are not hereby compelled to participate in research surveys. Students retain the right to decide whether to participate or not.

It is assumed that sampling will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate.

Yours sincerely

Sharene Menteath

Head: Academics

CTI Head Office

A-2 Ethical Clearance from UNISA

UNISA college of science, engineering and technology

Ms P Harpur (02843501)
School of Computing
UNISA
Pretoria

2011-12-10

Permission to conduct MSc research project

Ref: 019/PH/2011

The request for ethical approval for your MSc (IS) research project entitled "Usability and User Experience Evaluation of an m-Learning Application Delivered by Mobile Handheld Devices" refers.

The College of Science, Engineering and Technology's (CSET) Research and Ethics Committee (CREC) has considered the relevant parts of the studies relating to the abovementioned research project and research methodology and is pleased to inform you that ethical clearance is granted for your study as set out in your proposal and application for ethical clearance.

Therefore, involved parties may also consider ethics approval as granted. However, the permission granted must not be misconstrued as constituting an instruction from the CSET Executive or the CSET CREC that sampled interviewees (if applicable) are compelled to take part in the research project. All interviewees retain their individual right to decide whether to participate or not.

We trust that the research will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate, as stipulated in the UNISA Research Ethics policy. The policy can be found at the following URL:
http://cm.unisa.ac.za/contents/departments/res_policies/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf

Please note that if you subsequently do a follow-up study that requires the use of a different research instrument, you will have to submit an addendum to this application, explaining the purpose of the follow-up study and attach the new instrument along with a comprehensive information document and consent form.

Yours sincerely

HH Lotriet

Prof HH Lotriet
Acting Chair: School of Computing Ethics Sub-Committee

University of South Africa
College of Science, Engineering and Technology
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone + 27 12 429 6122 Facsimile + 27 12 429 6848
www.unisa.ac.za/cset

A-3 Informed Consent Form

(The form applies to Expert and Learner User Evaluations for Studies 3, 4 and 6)

The informed consent form below was completed by either expert or learner user evaluators participating in Main Study 1 in 2011 or Main Study 2 in 2012, where appropriate.

INFORMED CONSENT FORM

I, ……., (first name only) as an Expert Heuristic / Learner User Evaluator give permission for the gathered survey content of attitudes, opinions, comments and/or contributions contained within the Main Study 1 / Main Study 2 survey to be described, shared and discussed.

I am aware that this would be done in a way that preserves anonymity and confidentiality.

I am aware that research findings might be communicated at presentations or be published in academic publications.

Signed:……

(Please Sign Here)

Date:……..

A-4 Evaluation Task List

(This list of tasks applies to Studies 3, 4 and 6 for expert and learner user evaluators)

Device	PC?		Mobile Phone?		Tablet?	

Main Study 1 / Main Study 2 – Expert / Learner User Evaluator

Indicate above whether you have used a mobile phone OR tablet or both devices for the survey activities. Keep notes of any strange things that happen, go wrong, feel uncomfortable or irritate you. Provide an honest evaluation by completing the questionnaire.

To access the **Mobile Learning Research** (**m-LR**) website, choose one of the following three mobile handheld device options:

1. Standard website access (mobile phones and tablets)
   www.m-lr.limewebs.com/research ***OR***
2. Follow the following link via the web browser of your mobile phone
   http://tinyurl.com/6j5cou9 ***OR***
3. DOWNLOAD Moodle MLE for mobile phones
   www.m-LR.limewebs.com/research/blocks/mle/browser.php

Secure Login: Username (your first name, lower case), Password - 12345	☐
Module categories: Software Engineering 2011 / 2012	☐
My modules: Software Engineering Content 2011 / 2012	☐
Topic 1 Introduction to the Lessons: Explore each lesson very briefly: • A Project … • Software Engineering … • The Project Life C cle … • Triple Constraint … • Project Management Fra ework … • 9 Knowledge Areas … • Words of Wisdom from Brooks …	 ☐ ☐ ☐ ☐ ☐ ☐ ☐
Topic Quiz: Complete and submit the quiz	☐
Blog Menu: Edit the new entry “Plagiarism and Ethical Issues”	☐
Forums: dd an entry to the SE Forum, “Project Sniplets” discussion	☐
Glossary: Find “program manager” in the SE Glossary?	☐
SE Chat: Add you own news snippet	☐
SE Wiki: Can you make a contribution to the general SE Wiki?	☐
View: The Triple Constraint - A Short Video	☐

A-5 Expert Heuristic Evaluation Survey Questionnaire

(This questionnaire applies to Studies 3, 4 and 6)

Clearly mark a choice for each statement with a **X**. Please add extra comments, filling in the spaces provided, noting any problems you experience in relation to a particular section.

Category 1: General interface usability criteria: modified for an m-learning environment	
1	*Visibility of system status, provide feedback* 1.1 Feedback is provided by the application. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 1.2 The system is responsive to user actions without odd and unexplained events. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 1.3 Visible feedback icons communicate what is happening. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 1.4 Add any problem(s) you found in the system, in relation to Section 1 below:
2	*Match between system and the real world* 2.1 Clear everyday understandable language has been used in the application. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 2.2 Where metaphors are used they represent real-world objects, ideas and concepts. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 2.3 Symbols and icons follow an intuitive pattern in line with tasks. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 2.4 Information is seen as sequential, logical and as naturally arranged. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 2.5 Add any problem(s) you found in the system, in relation to Section 2 below:
3	*Learner control* 3.1 Users are able to exert control on the system. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 3.2 It is possible to exit at any time even though mistakes might have been made. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 3.3 Undo and Redo options exist.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

3.4 Add any problem(s) you found in the system, in relation to Section 3 below:

4 *Consistency and adherence to standards*

4.1 Patterns of words, symbols, icons repeat logically throughout the application.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

4.2 Platform standards are recognised as similar to PC-oriented standards.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

4.3 Add any problem(s) you found in the system, in relation to Section 4 below:

5 *Error prevention, in particular, prevention of peripheral usability-related errors*

5.1 Errors are preventable – the system is designed to take care of this.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

5.2 An appropriate message is shown if a mistake is made.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

5.3 Add any problem(s) you found in the system, in relation to Section 5 below:

6 *Recognition rather than recall, memory use*

6.1 Objects are visible and familiar; scrolling is needed occasionally.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6.2 The screen is manipulated to view any information without needing to remember.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6.3 Advice on system use is visible and able to be used whenever needed.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6.4 Simple displays are presented with few or no multiple page display options.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6.5 The zoom feature enables easy enlargement of text for improved reading.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6.6 Add any problem(s) you found in the system, in relation to Section 6 below:

7 *Aesthetics and minimalism in design*

7.1 Distracting material of minimal relevance has been excluded.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

7.2 Graphics are used to illustrate a point rather than to decorate the page.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

7.3 Add any problem(s) you found in the system, in relation to Section 7 below:

8 *Recognition, diagnosis and recovery from errors*

8.1 Error messages are easy to follow being presented in straight forward language.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

8.2 Quick and simple solutions are offered if errors are made.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

8.3 Recovery is achieved after constructive help.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

8.4 Add any problem(s) you found in the system, in relation to Section 8 below:

9 *Help and documentation*

9.1 A help facility exists, it is easy to find and support the users' needs.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

9.2 A search facility makes it easy to find information.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

9.3 Support documentation is provided on each page.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

9.5 Add any problem(s) you found in the system, in relation to Section 9 below:

Category 2: Website-specific criteria: the m-learning application is delivered via the mobile handheld device

10 *Simplicity of site navigation, organisation and structure*

10.1 The application is easy to navigate on a mobile handheld device.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

10.2 There are several paths to and from a chosen destination.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

10.3 Related information has been grouped into obvious categories.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

10.4 Information is organised hierarchically.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

10.5 Links and buttons support navigation throughout the site without cluttering it.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

	10.6 Add any problem(s) you found in the system, in relation to Section 10 below:
11	*Relevance of site content to the learner and the learning process, content meaningful to domain and learner* 11.1 The site is interesting and keeps the user's attention focused. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 11.2 Site information is clear and relevant. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 11.3 No racial or gender biases are noted. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 11.4 If material has been copyrighted, this has been made clear. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 11.5 Add any problem(s) you found in the system, in relation to Section 11 below:
12	*Easy to access information* 12.1 Any lesson material or downloadable documents can be reached. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 12.2 The videos open with ease. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 12.3 All links to external sites provide the required connections to additional information. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 12.4 Add any problem(s) you found in the system, in relation to Section 12 below:
13	*Content is both suitable and of a high quality* 13.1 Additional website links provide suitable content. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 13.2 The content is of a high standard. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 13.3 Add any problem(s) you found in the system, in relation to Section 13 below:
14	*System is simple and easy to use, called easiness* 14.1 No difficulties are experienced reaching site material via the mobile interface. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 14.2 It is just as easy to scroll or browse back to the site after visiting another site.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

14.3 It is easy to browse back and forth through the many learning options offered.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

14.4 Add any problem(s) you found in the system, in relation to Section 14 below:

15 *Material is of a high quality i.e. videos and digitisation*

15.1 Text is presented in a legible easy to read format.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

15.2 Digital material is of a high quality, no difficulty is experienced during viewing.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

15.3 Add any problem(s) you found in the system, in relation to Section 15 below:

Category 3: Educational criteria: learner-centred instructional design, grounded in learning theory

16 *Clarity of goals, objectives and outcomes*

16.1 Goals are clearly set out, objectives and expected outcomes for learning are clear too.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

16.2 There is a good reason for the inclusion of each page and this reason is obvious.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

16.3 Add any problem(s) you found in the system, in relation to Section 16 below:

17 *Effectiveness of collaborative learning*

17.1 Activities are experienced encouraging collaborative learning in several different ways.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

17.2 The discussion forum is fun and operational.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

17.3 Chat room facilities are found.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

17.4 Add any problem(s) you found in the system, in relation to Section 17 below:

18 *Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle*

18.1 Problem-based learning strategies have been implemented.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

	18.2 Mistakes can be made affording users the chance to learn from them. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 18.3 Help is provided to recover from cognitive errors. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 18.4 Add any problem(s) you found in the system, in relation to Section 18 below:
19	*Feedback, guidance and assessment* 19.1 Users receive prompt feedback from the application on assessment and progress. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 19.2 Guidance is provided about the tasks and construction of knowledge going on. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 19.3 Activities are graded with grades providing instant feedback and correction. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 19.4 Add any problem(s) you found in the system, in relation to Section 19 below:
Category 4: m-Learning criteria - mobility and the mobile handheld device in the learning context	
20	*Mobile handheld devices and technology* 20.1 Technology has made mobile learning feasible. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.2 The mobile handheld device has adequate capabilities to support mobile learning. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.3 The mobile interface does not hamper working with the application. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.4 Inserting text and numbers is feasible and achievable. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.5 The mobile handheld device system is used to its fullest capability. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.6 Mobile communication channels are provided. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 20.7 Add any problem(s) you found in the system, in relation to Section 20 below:
21	*Contextual factors (pragmatic)* 21.1 A physical environment is noted but it does not hinder the lesson experience.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	

21.2 The lessons in followed where noise and audible interference is experienced.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.3 Prior mobile handheld device knowledge and exposure makes the task easy.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.4 User characteristics have been considered as part of the exercise.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.5 Goals are set and not adjustable.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.6 The application feels and behaves like a normal working environment.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.7 During the lesson, awareness of surroundings is evident.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.8 Users are exposed to rich and complex environments, not limited by the mobile.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

21.9 Add any problem(s) you found in the system, in relation to Section 21 below:

22 *User-centricity (pragmatic)*

22.1 Support for personal approaches to learning is offered.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.2 Experimentation and exploration is possible.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.3 User requirements have been specified.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.4 Self-sufficiency is observed.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.5 Material is presented in a clear, learner-centred format.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.6 Focus is enhanced in that learners spend longer times doing tasks.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.7 Personalised learning format has been provided.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.8 Learners are personally aware of all content with control being given to users.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.9 Learners can customise, applying their own preferences.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.10 Active learning promotes critical thinking: users compare, analyse, classify, deduce.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.11 Users are able to direct their own learning with a sense of ownership.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

22.12 Add any problem(s) you found in the system, in relation to Section 22 below:

23 *Flexibility*

23.1 The lesson may be done at any personal moment in time.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23.2 An adaptable environment has been created.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23.3 Lesson information may be viewed in any order.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23.4 The system can be adjusted to individual needs.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23.5 The systems can be used anytime and anywhere.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

23.6 Add any problem(s) you found in the system, in relation to Section 23 below:

24 *Interactivity*

24.1 Navigational fidelity is experienced.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.2 Multimedia components are appropriate.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.3 Multiple kinds of exercises have been provided.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.4 Synchronous communication is possible.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.5 Asynchronous communication is possible.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.6 Interaction happens in varying ways.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.7 Interaction with the application is smooth.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.8 Support is provided for interactivity with the application.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.9 Interactivity has been encouraged in creative ways.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

24.10 Add any problem(s) you found in the system, in relation to Section 24 below:

Category 5: UX Criteria associated with mobile learning and mobile learning technology

25 *Emotional issues*

25.1 The lessons are motivating and fun.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.2 The application encourages participation with a longer time trying to process the lesson.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.3 The experience is enjoyable.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.4 It is new technology yet it is interesting and an acceptable form of learning.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.5 This way of learning software engineering is exciting.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.6 Add any problem(s) you found in the system, in relation to Section 25 below:

26 *Contextual factors (hedonic)*

26.1 Knowledge of mobile technology makes this way of learning a pleasure.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

26.2 The need for this type of learning suits the current mobile learner environment.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

26.3 Add any problem(s) you found in the system, in relation to Section 26 below:

27 *User-centricity (hedonic)*

27.1 Personalised learning is encouraged.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

27.2 The learner is able to customise the learning environment.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

27.3 Add any problem(s) you found in the system, in relation to Section 27 below:

28 *Social value*

28.1 The application is social, encouraging media sharing.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

28.2 The m-learning approach provides both synchronous and asynchronous interaction.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

28.3 Add any problem(s) you found in the system, in relation to Section 28 below:

29 *Needs*

29.1 The learner is encouraged to express personal opinions.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

29.2 The learning environment is stimulating.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

29.3 A sense of security is achieved.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

29.4 Add any problem(s) you found in the system, in relation to Section 29 below:

30 Appeal

30.1 New impressions of the learning content create an appealing space.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

30.2 The learner is motivated to explore.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

30.3 The experience is visually appealing.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

30.4 Add any problem(s) you found in the system, in relation to Section 30 below:

31	Satisfaction

31.1 The experience adds fun to the learning opportunity.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

31.2 This way of learning is motivating.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

31.3 A satisfying sense of achievement is felt.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

31.4 The learner is encouraged to engage with the course material.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

31.5 Add any problem(s) you found in the system, in relation to Section 31 below:

Conclusion

32 It is easy to use the application via a mobile handheld device.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

33 The application is fast to work with on the mobile handheld device.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

34 The application performs tasks properly.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

35 Once I had learned how to use the application, I found it was easy to use.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

36 I was satisfied with the application.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

37 I see this application working well to supplement the classroom learning environment.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

38 What is your overall rating of this application?

Very good	Good	Adequate	Poor	Very poor

39 What attracted you most to this site?

40 What did you like most about this application?

41 What did you like least about this application?

42 List in the space below at least 5 problems you found most critical in this application

Many thanks for your participation.

A-6 Learner User Survey Questionnaire

(This questionnaire applies to Studies 3, 4 and 6)

Clearly mark a choice for each statement with a **X**. Please add extra comments, filling in the spaces provided, noting any problems you experience in relation to a particular section.

Category 1: General interface usability criteria: modified for an m-learning environment	
1	*Visibility of system status, provide feedback* 1.1 I get feedback from the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 1.2 I understand clearly what the feedback is telling me without extra explanations. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 1.3 Feedback is provided to me within reasonable time. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 1.4 The application does not surprise me with unexpected responses. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 1.5 For every action I take, I see results of that action. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 1.6 Add any problem(s) you found in the system, in relation to Section 1 below:
2	*Match between system and the real world* 2.1 I understand the language used within the application – concepts are explained in a way that is similar to day-to-day. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 2.2 I am not confused by terms used within the system. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 2.3 I am not confused by the way the symbols and icons are used. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 2.4 I am able to follow the Information which is an orderly, logical and naturally arranged. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 2.5 Add any problem(s) you found in the system, in relation to Section 2 below:
3	*Learner control* 3.1 I am able to control the system, rather than it being able to control me.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

3.2 I am able to exit at any time even though I have made mistakes.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

3.3 When I make a mistake I can use Undo and Redo options.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

3.4 Add any problem(s) you found in the system, in relation to Section 3 below:

4 *Consistency and adherence to standards*

4.1 The same standards, style and conventions make it possible for me to work throughout the application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

4.2 It is easy for me to understand the standards as they are similar to those I see in other PC systems.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

4.3 Add any problem(s) you found in the system, in relation to Section 4 below:

5 *Error prevention, in particular, prevention of peripheral usability-related errors*

5.1 The system supports me in such a way that it is not easy to make serious mistakes.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

5.2 Whenever I make a mistake I am given an error message.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

5.3 Add any problem(s) you found in the system, in relation to Section 5 below:

6 *Recognition rather than recall, memory use*

6.1 I am able to view most items onscreen – they are familiar; scrolling is needed occasionally.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

6.2 I am able to enlarge and move around the screen to view any objects without needing to remember their location.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

6.3 I observe visible system advice, using it whenever needed.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

6.4 The screen layout is simple and I can recognise the links one at a time in any sequence, not needing to remember where I came from.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

6.5 I can read screen information more easily using the zoom feature which enables me to make

	text larger for improved reading. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 6.5 Add any problem(s) you found in the system, in relation to Section 6 below:
7	*Aesthetics and minimalism in design* 7.1 I am able to concentrate on relevant information without being distracted by other unimportant information. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 7.2 I am not distracted by graphics which are there to illustrate a concept rather than to decorate the page. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 7.3 Add any problem(s) you found in the system, in relation to Section 7 below:
8	*Recognition, diagnosis and recovery from errors* 8.1 Error messages are expressed in plain language. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 8.2 Error messages tell me quickly what the problem is. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 8.3 I find it easy to recover from mistakes using the error message provided. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 8.4 Add any problem(s) you found in the system, in relation to Section 8 below:
9	*Help and documentation* 9.1 I find the help facility useful. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 9.2 I am easily able to follow the help provided. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 9.3 Links to other resources are helpful. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 9.4 Add any problem(s) you found in the system, in relation to Section 9 below:
Category 2: Website-specific criteria: the m-learning application is delivered via the handheld device	
10	*Simplicity of site navigation, organisation and structure* 10.1 I am able to find my way around the application finding it easy to move around the application on a mobile handheld device.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

10.2 I am able to choose more than one route to the information I require.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

10.3 Related information has been grouped together – I find this helpful.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

10.4 Important information is placed on top of the page.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

10.5 Scrolling is minimised – I do not have to scroll many pages to find required information.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

10.6 Add any problem(s) you found in the system, in relation to Section 10 below:

11 *Relevance of site content to the learner and the learning process, content meaningful to domain and learner*

11.1 The content keeps me engaged.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

11.2 The content is at the appropriate level of my understanding.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

11.3 The material has no gender or racial biases.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

11.4 It is clear which materials are copyrighted and which are not.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

11.5 Add any problem(s) you found in the system, in relation to Section 11 below:

12 *Easy to access information*

12.1 I am able to download material and documents provided within the application for download purposes.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

12.2 The videos open with ease.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

12.3 I follow the provided links with no difficulties reaching additional information.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

12.4 Add any problem(s) you found in the system, in relation to Section 12 below:

13 *Content is both suitable and of a high quality*

	13.1 I visit additional website links which provide suitable content. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 13.2 I see the value in the high quality of the contents presented to me. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 13.3 Add any problem(s) you found in the system, in relation to Section 13 below:
14	*System is simple and easy to use, called easiness* 14.1 I have little difficulty reaching site material via the mobile interface. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 14.2 After visiting a linked site, it is easy to scroll or browse back to the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 14.3 I find it easy to browse back and forth through the many learning options offered. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 14.4 Add any problem(s) you found in the system, in relation to Section 14 below:
15	*Material is of a high quality i.e. videos and digitisation* 15.1 The application text is easy to read. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 15.2 Digital material is of a high quality, I have no difficulty viewing it. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 15.3 Add any problem(s) you found in the system, in relation to Section 15 below:
Category 3: Educational criteria: learner-centred instructional design, grounded in learning theory	
16	*Clarity of goals, objectives and outcomes* 16.1 I understand goals and objectives of the lesson which are clearly set out. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 16.2 I find good reasons for the inclusion of each page – the reasons are obvious to me. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 16.3 Add any problem(s) you found in the system, in relation to Section 16 below:
17	*Effectiveness of collaborative learning* 17.1 Activities are experienced encouraging collaborative learning in several different ways e.g. during a discussion on the forum.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

17.2 I find the discussion forum is fun and encourages me to join in.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

17.3 I find the chat room feature interesting as it offers me chances to share information with other learners.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

17.4 Add any problem(s) you found in the system, in relation to Section 17 below:

18 *Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle*

18.1 The application offers me opportunity to work on problems.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

18.2 I am able to learn from any mistakes I make using this application by for example looking up definitions in the glossary.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

18.3 Help is provided to help me recover when I made errors filling in the quiz.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

Add any problem(s) you found in the system, in relation to Section 18 below:

19 *Feedback, guidance and assessment*

19.1 I enjoy the concept of immediate feedback and assessment on progress.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

19.2 I am guided when doing tasks and when improving knowledge.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

19.3 Instant feedback given after the quiz helps me correct my mistakes with immediate learning.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

19.4 Add any problem(s) you found in the system, in relation to Section 19 below:

Category 4: m-Learning criteria - mobility and the mobile handheld device in the learning context

20 *Mobile handheld devices and technology*

20.1 I am aware that without advances in technology new ways of learning would not be possible.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

20.2 I enjoy learning with the handheld device which has the all the capabilities I need to support mobile learning.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

	20.3 The mobile interface does not hamper me when I work with the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 20.4 I have little difficulty inserting text and numbers. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 20.5 I am using all aspects of the handheld device while learning from the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 20.6 I am able to communicate socially with the mobile device and the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 20.7 Add any problem(s) you found in the system, in relation to Section 20 below:
21	*Contextual factors(pragmatic)* 21.1 I am aware of my physical surroundings but this does not interfere with the lesson experience. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.2 While I explore the application, there is noise and audible interference is experienced. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.3 I have worked with a smartphone already; this experience makes the exploration of the application easier. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.4 My personal study needs have been considered as part of the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.5 Learning goals have been built into the application – they are set. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.6 When I use the application, I feel as if I am in a learning environment; the application feels and behaves like a normal learning environment. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.7 I am aware of my surroundings during the lesson. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.8 I find the learning experience to be rich and complex; I am not limited by the mobile device. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 21.9 Add any problem(s) you found in the system, in relation to Section 21 below:
22	*User-centricity (pragmatic)* 22.1 I feel my personal study approaches to learning have been considered.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.2 With this type of study method, I am free to experiment and explore.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.3 I see clearly what I am required to do.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.4 I enjoy the feeling of independence the application offers – can look after myself.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.5 This material represents my way of thinking in a clear manner.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.6 I would be able to focus better; work longer stretches of time on problems in this way.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.7 I could easily personalise this learning environment to suit my own needs.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.8 I am aware of all content offered by the application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.9 I am able to customise this application environment to suit my own style.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.10 I am actively involved in thinking and creating.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.11 I can decide when and where I want to learn with this application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

22.12 Add any problem(s) you found in the system, in relation to Section 22 below:

23 *Flexibility*

23.1 This is a great way to gather information any time.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

23.2 I am free to adjust my learning environment- I can see the merit in this.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

23.3 The way I see things – I can study the lesson in any order I choose.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

23.4 The application can be personalised and Customised the way I want it to be.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

23.5 I can use the system anytime and anywhere.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

23.6 Add any problem(s) you found in the system, in relation to Section 23 below:

24 *Interactivity*

24.1 I am able to move exactly where I want in this application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.2 I enjoyed the multimedia components which are appropriate for the subject content.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.3 It is great that so many different kinds of exercise options have been provided.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.4 Synchronous communication is possible via the chat room.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.5 The discussion forum makes synchronous communication possible.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.6 Interaction happens in varying ways.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.7 I am able to smoothly connect to and participate with the application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.8 I am supported when I try to interact with the application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.9 I experience multiple creative ways of interacting with the application.

Strongly agree	Agree	Undecided	Disagree	Strongly Disagree

24.10 Add any problem(s) you found in the system, in relation to Section 24 below:

Category 5: UX Criteria

25 *Emotional issues*

25.1 The lesson format is fun – it motivates me.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.2 I feel encouraged to stay focused for longer.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.3 I enjoy sharing lesson information with other learners.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

25.4 I appreciate the opportunity to use technology and my mobile handheld device to learn.

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

	25.5 I feel enthusiastic, studying software engineering in this way. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 25.6 Add any problem(s) you found in the system, in relation to Section 25 below:
26	*Contextual factors (hedonic)* 26.1 It's a pleasure for me to use my phone to do things I know already about mobile technology. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 26.2 It is convenient for me to look up information on my mobile handheld device whenever I like. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree Add any problem(s) you found in the system, in relation to Section 26 below:
27	*User-centricity (hedonic)* 27.1 I appreciate that the application allows me to have a personal learning experience. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 27.2 I am able to change my learning environment to suit my needs. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 27.3 Add any problem(s) you found in the system, in relation to Section 27 below:
28	*Social value* 28.1 I feel totally at home using social networking tools to share course information. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 28.2 I like the opportunity to interact with other learners immediately or when I choose. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 28.3 Add any problem(s) you found in the system, in relation to Section 28 below:
29	*Needs* 29.1 The application encourages me to express myself whilst learning. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 29.2 I find that the stimulating mobile environment suits me. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 29.3 I am safe and secure while I interact with the application. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 29.4 Add any problem(s) you found in the system, in relation to Section 29 below:

30	*Appeal* 30.1 I find the mobile handheld device way of communicating course material appealing. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 30.2 I enjoy the opportunity to explore, learning on my own when I need to. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 30.3 I love the visual aspects of a mobile learning environment. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 30.4 Add any problem(s) you found in the system, in relation to Section 30 below:
31	*Satisfaction* 31.1 I am satisfied by the opportunity to learn in this way. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 31.2 I am motivated by mobile learning via my mobile handheld device. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 31.3 I am satisfied with the results I achieve. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 31.4 I am encouraged to explore the course material. Strongly Agree | Agree | Undecided | Disagree | Strongly Disagree 31.5 Add any problem(s) you found in the system, in relation to Section 31 below:
Conclusion	
	32 I found it easy to use the application via the mobile handheld device. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 33 The application is fast to work with on the handheld device. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 34 The application performs tasks properly. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 35 Once I had learned how to use the application, it was easy to use it. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 36 I was satisfied with the application. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree 37 I see this application working well to supplement the classroom learning environment. Strongly agree | Agree | Undecided | Disagree | Strongly Disagree

38 What is your overall rating of this application?

Very good	Good	Adequate	Poor	Very poor

39 What attracted you most on this site?

40 What did you like most about this application?

41 What did you like least about this application?

42 List in the space below at least 5 problems you found most critical in this application.

Many thanks for your participation.

A-7 Mobile Usage Survey Questionnaire

(This questionnaire applies to Study 2)

Section A: General Information

1. Your name (enter only your first name in the space below)?

2. What is your age (select one category)?

From 18 to 20 ☐	From 21 to 22 ☐	Older than 22 ☐

3. At which HWU CTI Campus do you attend classes (select CTN or DBV)?

CTN ☐	DBV ☐

4. In which year have you first registered for Software Engineering (select one category)?

2010 ☐	2011 ☐

5. For which semester have you registered for Software Engineering (select First or Second)?

First ☐	Second ☐

6. Are you a fulltime or part-time learner (select FT or PT)?

FT ☐	PT ☐

7. How much time do you spend travelling to and from CTI per week (select one option)?

< 1 hour ☐	1- 2 hours ☐	2-3 hours ☐	3-4 hours ☐	> 4 hours ☐

8. What is your most often used mode of transport (select one option)?

Car ☐	Bus ☐	Taxi ☐	Train ☐	Bike ☐	Walking ☐	Other ☐

9. How often do you have your mobile phone with you (select one option)?

Never!☐	Seldom ☐	Sometimes ☐	Often ☐	Always! ☐

10. Is there any specific time that you do not carry your mobile phone (select one option)?

Mornings☐	Afternoons ☐	Evenings ☐	Weekends ☐	Other ☐

11. Where do you most often use your mobile phone (select one option)?

At home☐	On campus ☐	Travelling ☐	TV time ☐	Other ☐

12. Do you always carry a mobile phone on campus (select Yes or No)?

Yes ☐	No ☐

13. What is your mobile phone brand (select one option)?

Nokia ☐	BlackBerry ☐	Samsung☐	HTC ☐	LG ☐	iPhone ☐	Other ☐

14. What is your mobile phone brand (enter model information in the space below)?

15. Prepaid (PRE) or Contract (CON) mobile phone (select PRE or CON)?

PRE ☐	CON ☐

16. Is your mobile phone – in your opinion – a Smartphone (select Yes or No)?

Yes ☐	No ☐

Section B: Mobile Phone Usage

17. Do you have Internet access through a WiFi connection on your mobile phone?

Yes ☐	No ☐

18. Do you have Internet access through a cellular network on your mobile phone?

Yes ☐	No ☐

19. What activities do you do via your mobile phone (select each applicable activity)?

Calls	☐	SMS	☐	Email	☐	Internet browsing	☐
Banking	☐	Photo sharing	☐	Music listening	☐	Music downloads	☐
Music sharing	☐	Video downloads	☐	Video watching	☐	Podcast downloads	☐
Podcast watching	☐	Facebook	☐	Twitter	☐	MXit	☐
Mobile education	☐	Study notes	☐	Research	☐	Games	☐
Other	☐						

20. If you selected "Other" above, list the "Other" mobile phone activities below:

Section C: Personal Feelings and Attitudes Concerning Your Mobile Phone

In questions 21 - 28 below, select the most appropriate option:

21. Do you feel self-conscious using your mobile phone in public?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do ☐	Absolutely! ☐

22. Do you feel comfortable installing and operating third party software on a mobile phone?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I would ☐	Absolutely! ☐

23. Do you believe that your mobile phone could support learning in groups?

Not at all!☐	Not really ☐	Unsure ☐	Yes, it would ☐	Absolutely! ☐

24. Would learning by mobile phone motivate you to achieve better study outcomes?

Not at all!☐	Not really ☐	Unsure ☐	Yes, it would ☐	Absolutely! ☐

25. To what extent do you think using your mobile phone for learning would be frustrating?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I agree ☐	Absolutely! ☐

26. Do you find the idea of submitting quiz answers by mobile phone, trustworthy?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do ☐	Absolutely! ☐

27. Do you regard your cell phone as a fashion item (select Yes or No)?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do ☐	Absolutely! ☐

28. If you would like to add personal mobile phone feelings and attitudes, list them below:

Section D: Mobile Technology and Your Studies

In questions 29 - 35 below, select the most appropriate option:

29. Would you feel comfortable allowing your lecturers to contact you through your mobile phone?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would ☐	Absolutely! ☐

30. Would you feel safe receiving exam and coursework results via SMS?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would ☐	Absolutely! ☐

31. Would you agree that having course materials such as slides, lecture notes and practice quizzes available on your mobile phone would be beneficial to your study process?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I agree ☐	Absolutely! ☐

32. Would you invest personal time learning to use and install software that could make these resources available on a mobile phone?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would ☐	Absolutely! ☐

33. Would you be willing to purchase a new mobile device if you thought it would improve your performance at HWU?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would ☐	Absolutely! ☐

34. Do you feel that the use of some kind of mobile learning software would improve overall success in your courses?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I do ☐	Absolutely! ☐

35. If you have any additional mobile learning comments, list them below:

Section E User Experience

36. How would you best describe your own mobile phone? Select the most appropriate point between the two extreme words:

Outstanding								Second-rate
Exclusive								Standard
Impressive								Nondescript
Unique								Ordinary
Innovative								Conservative
Exciting								Dull
Interesting								Dull

A-8 Mobile Learning Digital Divide Survey Questionnaire

(This questionnaire applies to Study 5)

Section 1: General Mobile User Information

1. Your name? Insert only your first name in the space below.

2. What is your age? Select one category.

From 18 to 20☐	From 21 to 23 ☐	From 24 to 26 ☐	Older than 27 ☐

3. What is your nationality?

South African ☐	Namibian ☐	Angolan ☐	Ghanaian ☐	Other ☐ Name it:

4. What is your home language?

English☐	Afrikaans☐	Portuguese☐	Other ☐ Name it:

5. At which campus do you attend classes? Select CTN or DBV.

CTN ☐	DBV ☐

6. In which year did you first register for Software Engineering? Select one category.

2011☐	2012☐

7. For which semester did you register for Software Engineering? Select First or Second.

First ☐	Second ☐

8. Prior to registration, were you an LSBM or MLM learner?

LSBM☐	MLM ☐

9. What is the total weekly travel time of all your daily journeys? Select one option.

< 1 hour ☐	1- 2 hours ☐	2-3 hours ☐	3-4 hours ☐	> 4 hours ☐

10. What is your main mode of transport? Select one most often used option.

Own car☐	Lift ☐ someone else's car	Bus☐	Taxi☐	Train ☐	Bike ☐	Walk ☐	Other☐ Describe:

11. Do you have a driver's licence?

Yes ☐	No ☐

12. Is there a family car you can borrow regularly to attend classes on campus?

Yes ☐	No ☐

Section 2: Mobile Phone Usage

13. How often do you use your mobile phone to make or receive calls or text messages, or to acquire information off the Internet? Select one option.

< 3 times a week☐	3-6 times a week☐	1-3 times a day ☐	3-6 times a day ☐	> 6 times a day ☐

14. Is there any specific time that you do not use your mobile phone? Select one option.

No specific time ☐	Mornings ☐	Afternoons ☐	Evenings ☐	Weekends ☐	Other ☐ Describe:

15. Where do you most often use your mobile phone? Select one option.

At home☐	On campus ☐	Travelling ☐	TV time ☐	Other ☐ Describe:

16. How often do you have your mobile phone on campus? Select one option.

Always ☐	Most of the time ☐	Occasionally ☐	Hardly ever ☐	Never ☐

17. What BRAND of mobile phone do you use? Select one option.

Nokia ☐	Blackberry ☐	Samsung☐	HTC ☐	LG ☐	iPhone ☐	Other ☐ Describe:

18. What is the MODEL of your mobile phone? Enter model information in the space below.

19. Is your mobile phone – in your opinion – a Smartphone? Select Yes or No.

Yes ☐	No ☐

20. Do you have Pre-paid (PRE) or Contract (CON) mobile connectivity? Approximately how much do you spend each month?

PRE ☐	Monthly Pre-paid Spend?	

CON ☐	Monthly Contract Spend?	

21. What percentage of your monthly Pre-paid or Contract spend is used for Internet connectivity?

< 25% ☐	Between 25% and 50% ☐	Between 50% and 75% ☐	> 75% ☐

22. Do you buy additional data bundles to connect to the Internet via your mobile phone?

Yes ☐	No ☐

23. If yes, approximately how much do you spend each month on additional data bundles?

24. Do you access the Internet via a 3G connection on your mobile phone?

Yes ☐	No ☐

25. Do you access the Internet via a GSM (cellular) network on your mobile phone?

Yes ☐	No ☐

26. Which of the following activities are performed via your mobile phone? Select each applicable activity.

Calls	☐	SMS	☐	Email	☐	Internet browsing	☐
Banking	☐	Photo sharing	☐	Music listening	☐	Music downloads	☐
Music sharing	☐	Video downloads	☐	Video watching	☐	Podcast downloads	☐
Podcast watching	☐	Facebook	☐	Twitter	☐	MXit	☐

Mobile education	☐	Study notes	☐	Research	☐	Games	☐
Other	☐	Describe:					

Section 3: Personal Mobile Handheld Device Feelings and Attitudes

27. Do you feel self-conscious about using your mobile phone in public?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do☐	Absolutely!☐

28. Do you feel comfortable installing and operating third party apps on your mobile phone?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I would☐	Absolutely! ☐

29. Do you believe that your mobile phone could support your studies?

No, not at all!☐	No, not really ☐	Unsure ☐	Yes, it would☐	Yes, definitely! ☐

30. If you answered 'Yes, it would' or 'Yes, definitely!' to the question 29 above, mention some of the ways in which your studies could be supported:

31. Do you believe that your mobile phone could support learning in groups?

Not at all!☐	Not really ☐	Unsure ☐	Yes, it would☐	Absolutely! ☐

32. Would learning by mobile phone motivate you to achieve better study outcomes?

Not at all!☐	Not really ☐	Unsure ☐	Yes, it would☐	Absolutely! ☐

33. Do you think your mobile phone forms part of your image of yourself?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do☐	Absolutely! ☐

34. List your personal mobile phone feelings, attitudes, frustrations, disappointments, wish lists in the block below:

Section 4: Mobile Technology and the Software Engineering Module

35. Do you think that the submitting of revision test answers to your lecturer by mobile phone is possible?

Not at all!☐	Not really ☐	Unsure ☐	Yes, I do ☐	Absolutely! ☐

36. Would you feel comfortable allowing your lecturers to contact you via your mobile phone?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would☐	Absolutely! ☐

37. Would you feel secure receiving Software Engineering coursework and exam results by mobile phone?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would☐	Absolutely! ☐

38. Do you think that having course materials such as slides, lecture notes and revision quizzes available on your mobile phone would be beneficial to your studies in Software Engineering?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I agree ☐	Absolutely! ☐

39. Would you invest personal time installing and learning to use software applications that could make these resources available on a mobile phone?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would☐	Absolutely! ☐

40. Would you be willing to purchase a new mobile device if you thought it would improve your performance in your studies?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I would☐	Absolutely! ☐

41. Do you feel that the use of some kind of mobile learning software would improve overall success in your Software Engineering module?

Not at all!☐	No, not really ☐	Unsure ☐	Yes, I do☐	Absolutely! ☐

42. List any problems that could limit or restrict the use of your mobile phone for learning purposes:

Section 5: Internet Access

43. Based on all forms of Internet access, how often do you access the Internet?

Less than once a week ☐	At least once a week ☐	About once a day ☐	Several times a day ☐	Very often, during the day and night ☐

44. Approximately how many hours per week do you spend on the Internet?

45. Approximately how much do you spend each month to connect to the Internet?

46. Do you have access to the Internet at home?

Yes ☐	No ☐

47. If yes, what type of connection do you have?

ADSL (capped)☐	ADSL (uncapped) ☐	Dial-up☐	Wireless 3G☐	Wireless GSM (Cellphone) ☐

48. If yes, what is the speed of your home connection?

Very slow!☐	Slow ☐	OK ☐	Fast ☐	Very fast! ☐

49. If you were able to connect via ADSL, how much would you be prepared to pay monthly for this service?

50. What alternative Internet connectivity options do you have? Select all additional options.

Mobile phone ☐	Library ☐	Family ☐	Friends ☐	Internet café ☐	Campus☐	Church☐

51. If you connect via an Internet café, do you find the connection costs to be … ?

Very cheap!☐	Cheap ☐	OK ☐	Expensive ☐	Very expensive! ☐

52. If you connect on campus, is the connection … ?

Very slow!☐	Slow ☐	OK ☐	Fast ☐	Very fast! ☐

53. Do you use more than one device to connect to the Internet?

Yes ☐	No ☐

54. If yes, which devices do you use? Select all device options.

Mobile phone ☐	Tablet ☐	Laptop ☐	Desktop PC ☐	DSTV ☐

55. Are you able to connect to the Internet via a mobile device e.g. smartphone, tablet or laptop to a campus wireless network?

Yes ☐	No ☐

56. Does your campus library have online digital facilities?

Yes ☐	No ☐

57. Which on-campus Internet-related restrictions/issues do you experience? Select each applicable option.

Connectivity speed	☐	Connection problems	☐	Buffering e.g. YouTube videos	☐	Social networking e.g. Facebook browsing	☐
Search engine features	☐	Website look-up options	☐	Academic database use	☐	Journal download permissions	☐
Electronic article downloads	☐	Video downloads	☐	Audio downloads	☐	Podcast downloads	☐
PC/Lab availability	☐	Referencing software access	☐	Turnitin usage/speed	☐	Online software downloads	☐
On-campus wireless network	☐	Other	☐	Describe:			

58. How well do you understand what the following terms mean?

Refresh	Not well ☐	General idea ☐	Very well ☐
Operating System	Not well ☐	General idea ☐	Very well ☐
Internet Browser Cookie	Not well ☐	General idea ☐	Very well ☐
JPEG file	Not well ☐	General idea ☐	Very well ☐
Spyware or Malware	Not well ☐	General idea ☐	Very well ☐
Widget	Not well ☐	General idea ☐	Very well ☐

59. How would you categorise your digital technology personality (Horrigan, 2010)? Choose the best option:

Digitally distant	Not interested in Internet access at all	☐
Digitally hopeful	Would like to be connected but do not have the resources	☐
Digitally uncomfortable	Have the resources but do not have the right mix of skills	☐
Near convert	Have the skills but struggle with monthly costs	☐
Fully digitally equipped	Have the skills, resources and monthly income for digital connectivity	☐

Section 6 User Experience

60. How would you best describe the experience of using your own mobile phone? Select the most appropriate number (1-7) between the two extreme words. Example place a ✓ under 1 if you feel the experience is outstanding or place a ✓ under 7 if you feel it is second-rate. Otherwise try to select a value matching your opinion between 1 and 7.

	1	2	3	4	5	6	7	
Outstanding								Second-rate
Exclusive								Standard
Impressive								Nondescript
Unique								Ordinary
Innovative								Conservative
Exciting								Boring
Interesting								Dull

APPENDIX B: Main Study 1 Ratings and Reported Problems

B-1 Study 4: Main Study 1 HE Ratings and Problems Reported by Experts

B-1.1 HE Ratings by Experts

#	Category 1: General Interface Usability HE Statements	5	4	3	2	1	Ave.	S.D.
1	***Visibility of system status, provide feedback***							
1.1	Feedback is provided by the application.	0	60	20	20	0	3.4	0.80
1.2	The system is responsive to user actions without odd and unexplained events.	0	80	20	0	0	3.8	0.40
1.3	Visible feedback icons communicate what is happening.	0	80	0	20	0	3.6	0.80
2	***Match between system and the real world***							
2.1	Clear everyday understandable language has been used in the application.	40	40	20	0	0	4.2	0.75
2.2	Where metaphors are used they represent real-world objects, ideas and concepts.	20	40	40	0	0	3.8	0.75
2.3	Symbols and icons follow an intuitive pattern in line with tasks.	20	40	40	0	0	3.8	0.75
2.4	Information is seen as sequential, logical and as naturally arranged.	20	40	0	20	20	3.2	1.47
3	***Learner control***							
3.1	Users are able to exert control on the system.	20	20	40	20	0	3.4	1.02
3.2	It is possible to exit at any time even though mistakes might have been made.	20	40	20	20	0	3.6	1.02
3.3	Undo and Redo options exist.	0	60	20	0	20	3.2	1.17
4	***Consistency and adherence to standards***							
4.1	Patterns of words, symbols, icons repeat logically throughout the application.	20	80	0	0	0	4.2	0.40
4.2	Platform standards are recognised as similar to PC-oriented standards.	20	60	0	20	0	3.8	0.98
5	***Error prevention, in particular, prevention of peripheral usability-related errors***							
5.1	Errors are preventable – the system is designed to take care of this.	0	80	20	0	0	3.8	0.40
5.2	An appropriate message is shown if a mistake is made.	0	20	40	40	0	2.8	0.75
6	***Recognition rather than recall, memory use***							
6.1	Objects are visible and familiar; scrolling is needed occasionally.	20	20	40	0	20	3.2	1.33
6.2	The screen is manipulated to view any information without needing to remember.	20	40	20	20	0	3.6	1.02
6.3	Advice on system use is visible and able to be used whenever needed.	0	20	0	60	20	2.2	0.98
6.4	Simple displays are presented with few or no multiple page display options.	0	40	40	20	0	3.2	0.75
6.5	The zoom feature enables easy	20	60	20	0	0	4.0	0.63

	enlargement of text for improved reading.							
7	***Aesthetics and minimalism in design***							
7.1	Distracting material of minimal relevance has been excluded.	20	80	0	0	0	4.2	0.40
7.2	Graphics are used to illustrate a point rather than to decorate the page.	40	40	20	0	0	4.2	0.75
8	***Recognition, diagnosis and recovery from error***							
8.1	Error messages are easy to follow being presented in straight forward language.	0	20	80	0	0	3.2	0.40
8.2	Quick and simple solutions are offered if errors are made.	0	20	60	20	0	3.0	0.63
8.3	Recovery is achieved after constructive help.	0	20	60	20	0	3.0	0.63
9	***Help and documentation***							
9.1	A help facility exists, it is easy to find and support the users' needs.	0	40	20	40	0	3.0	0.89
9.2	A search facility makes it easy to find information.	0	40	40	0	20	3.0	1.10
9.3	Support documentation is provided on each page.	0	60	0	20	20	3.0	1.26
	Mean Ratings (%)	**11.1**	**45.9**	**25.2**	**13.3**	**4.4**	**3.5**	

#	**Category 2: Website-specific Usability HE Statements**	**5**	**4**	**3**	**2**	**1**	**Ave.**	**S.D.**
10	***Simplicity of site navigation, organisation and structure***							
10.1	The application is easy to navigate on a mobile handheld device	20	40	0	0	40	3.0	1.67
10.2	There are several paths to and from a chosen destination.	0	40	40	20	0	3.2	0.75
10.3	Related information has been grouped into obvious categories.	20	40	40	0	0	3.8	0.75
10.4	Information is organised hierarchically.	40	40	20	0	0	4.2	0.75
10.5	Links and buttons support navigation throughout the site without cluttering it.	20	40	0	40	0	3.4	1.20
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***							
11.1	The site is interesting and keeps the user's attention focused.	0	40	40	20	0	3.2	0.75
11.2	Site information is clear and relevant.	40	0	40	20	0	3.6	1.20
11.3	No racial or gender biases are noted.	60	40	0	0	0	4.6	0.49
11.4	If material has been copyrighted, this has been made clear.	40	20	40	0	0	4.0	0.89
12	***Easy to access information***							
12.1	Any lesson material or downloadable documents can be reached.	20	60	20	0	0	4.0	0.63
12.2	The videos open with ease.	20	0	40	20	20	2.8	1.33
12.3	All links to external sites provide the required connections to additional information.	20	40	20	20	0	3.6	1.02
13	***Content is both suitable and of a high quality***							
13.1	Additional website links provide suitable content.	20	20	60	0	0	3.6	0.80
13.2	The content is of a high standard.	20	0	80	0	0	3.4	0.80
14	***System is simple and easy to use, called easiness***							

14.1	No difficulties are experienced reaching site material via the mobile interface.	20	20	20	40	0	3.2	1.17
14.2	It is just as easy to scroll or browse back to the site after visiting another site.	20	40	40	0	0	3.8	0.75
14.3	It is easy to browse back and forth through the many learning options offered.	20	60	0	20	0	3.8	0.98
15	***Material is of a high quality i.e. videos and digitisation***							
15.1	Text is presented in a legible easy to read format.	40	60	0	0	0	4.4	0.49
15.2	Digital material is of a high quality, no difficulty is experienced during viewing.	20	40	0	20	20	3.2	1.47
	Mean Ratings (%)	**24.4**	**33.3**	**27.8**	**12.2**	**2.2**	**3.7**	

#	Category 3: Educational Usability HE Statements	5	4	3	2	1	Ave.	S.D.
16	***Clarity of goals, objectives and outcomes***							
16.1	Goals are clearly set out, objectives and expected outcomes for learning are clear too.	0	40	0	60	0	2.8	0.98
16.2	There is a good reason for the inclusion of each page and this reason is obvious.	0	40	40	20	0	3.2	0.75
17	***Effectiveness of collaborative learning***							
17.1	Activities are experienced encouraging collaborative learning in several different ways.	0	40	40	20	0	3.2	0.75
17.2	The discussion forum is fun and operational.	0	80	20	0	0	3.8	0.40
17.3	Chat room facilities are found.	40	20	20	0	20	3.6	1.50
18	***Cognitive error recognition, diagnosis and recovery***							
18.1	Problem-based learning strategies have been implemented.	20	60	20	0	0	4.0	0.63
18.2	Mistakes can be made affording users the chance to learn from them.	0	80	20	0	0	3.8	0.40
18.3	Help is provided to recover from cognitive errors.	0	40	60	0	0	3.4	0.49
19	***Feedback, guidance and assessment***							
19.1	Users receive prompt feedback from the application on assessment and progress.	20	80	0	0	0	4.2	0.40
19.2	Guidance is provided about the tasks and construction of knowledge going on.	0	40	40	20	0	3.2	0.75
19.3	Activities are graded with grades providing instant feedback and correction.	20	60	20	0	0	4.0	0.63
	Mean Ratings (%)	**8.0**	**52.0**	**26.0**	**12.0**	**2.0**	**3.5**	

#	Category 4: m-Learning HE Statements	5	4	3	2	1	Ave.	S.D.
20	***Mobile handheld devices and technology***							
20.1	Technology has made mobile learning feasible.	60	40	0	0	0	4.6	0.49
20.2	The mobile handheld device has adequate capabilities to support mobile learning.	40	20	0	20	20	3.4	1.62

20.3	The mobile interface does not hamper working with the application.	20	60	20	0	0	4.0	0.63
20.4	Inserting text and numbers is feasible and achievable.	0	80	20	0	0	3.8	0.40
20.5	The mobile handheld device system is used to its fullest capability.	0	60	20	20	0	3.4	0.80
20.6	Mobile communication channels are provided.	0	40	40	20	0	3.2	0.75
21	***Contextual factors(pragmatic)***							
21.1	A physical environment is noted but it does not hinder the lesson experience.	0	80	20	0	0	3.8	0.40
21.2	The lessons in followed where noise and audible interference is experienced.	0	80	20	0	0	3.8	0.40
21.3	Prior mobile handheld device knowledge and exposure makes the task easy.	20	80	0	0	0	4.2	0.40
21.4	User characteristics have been considered as part of the exercise.	0	60	20	20	0	3.4	0.80
21.5	Goals are set and not adjustable.	0	40	60	0	0	3.4	0.49
21.6	The application feels and behaves like a normal working environment.	20	40	0	20	20	3.2	1.47
21.7	During the lesson, awareness of surroundings is evident.	0	40	0	60	0	2.8	0.98
21.8	Users are exposed to rich and complex environments, not limited by the mobile.	0	40	60	0	0	3.4	0.49
22	***User-centricity (pragmatic)***							
22.1	Support for personal approaches to learning is offered.	0	40	20	40	0	3.0	0.89
22.2	Experimentation and exploration is possible.	0	80	0	20	0	3.6	0.80
22.3	User requirements have been specified.	0	40	40	20	0	3.2	0.75
22.4	Self-sufficiency is observed.	0	60	40	0	0	3.6	0.49
22.5	Material is presented in a clear, learner-centred format.	0	40	40	20	0	3.2	0.75
22.6	Focus is enhanced in that learners spend longer times doing tasks.	0	40	40	20	0	3.2	0.75
22.7	Personalised learning format has been provided.	0	40	0	60	0	2.8	0.98
22.8	Learners are personally aware of all content with control being given to users.	0	60	0	40	0	3.2	0.98
22.9	Learners can customise, applying their own preferences.	0	20	20	40	20	2.4	1.02
22.10	Active learning promotes critical thinking: users compare, analyse, classify, deduce.	0	60	40	0	0	3.6	0.49
22.11	Users are able to direct their own learning with a sense of ownership.	0	80	0	0	20	3.4	1.20
23	***Flexibility***							
23.1	The lesson may be done at any personal moment in time.	80	20	0	0	0	4.8	0.40
23.2	An adaptable environment has been created.	0	40	40	20	0	3.2	0.75
23.4	Lesson information may be viewed in any order.	80	20	0	0	0	4.8	0.40
23.5	The system can be adjusted to individual needs.	0	20	60	20	0	3.0	0.63
23.5	The systems can be used anytime and anywhere.	80	20	0	0	0	4.8	0.40
24	***Interactivity***							

24.1	Navigational fidelity is experienced.	0	40	40	0	20	3.0	1.10
24.2	Multimedia components are appropriate.	20	40	40	0	0	3.8	0.75
24.3	Multiple kinds of exercises have been provided.	20	60	20	0	0	4.0	0.63
24.4	Synchronous communication is possible.	20	60	20	0	0	4.0	0.63
24.5	Asynchronous communication is possible.	20	60	20	0	0	4.0	0.63
24.6	Interaction happens in varying ways.	20	60	20	0	0	4.0	0.63
24.7	Interaction with the application is smooth.	0	60	0	40	0	3.2	0.98
24.8	Support is provided for interactivity with the application.	0	60	40	0	0	3.6	0.49
24.9	Interactivity has been encouraged in creative ways.	20	20	20	40	0	3.2	1.17
	Mean Ratings (%)	**13.3**	**48.7**	**21.5**	**13.8**	**2.6**	**3.6**	

#	Category 5: UX HE Statements	5	4	3	2	1	Ave.	S.D.
25	***Emotional issues***							
25.1	The lessons are motivating and fun.	0	20	20	60	0	2.6	0.80
25.2	The application encourages participation with a longer time trying to process the lesson.	0	60	40	0	0	3.6	0.49
25.3	The experience is enjoyable.	0	40	20	40	0	3.0	0.89
25.4	It is new technology yet it is interesting and an acceptable form of learning.	20	20	40	20	0	3.4	1.02
25.5	This way of learning software engineering is exciting.	20	0	20	60	0	2.8	1.17
26	***Contextual factors (hedonic)***							
26.1	Knowledge of mobile technology makes this way of learning a pleasure.	0	60	20	20	0	3.4	0.80
26.2	The need for this type of learning suits the current mobile learner environment.	0	40	40	0	20	3.0	1.10
27	***User-centricity (hedonic)***							
27.1	Personalised learning is encouraged.	20	40	0	40	0	3.4	1.20
27.2	The learner is able to customise the learning environment.	0	20	40	40	0	2.8	0.75
28	***Social value***							
28.1	The application is social, encouraging media sharing.	0	60	20	20	0	3.4	0.80
28.2	The m-learning approach provides both synchronous and asynchronous interaction.	0	100	0	0	0	4.0	0.00
29	***Needs***							
29.1	The learner is encouraged to express personal opinions.	0	60	40	0	0	3.6	0.49
29.2	The learning environment is stimulating.	0	40	0	60	0	2.8	0.98
29.3	A sense of security is achieved.	0	60	20	20	0	3.4	0.80
30	***Appeal***							
30.1	New impressions of the learning content create an appealing space.	0	40	20	40	0	3.0	0.89

30.2	The learner is motivated to explore.	0	60	0	40	0	3.2	0.98
30.3	The experience is visually appealing.	0	40	0	60	0	2.8	0.98
31	***Satisfaction***							
31.1	The experience adds fun to the learning opportunity.	0	40	20	40	0	3.0	0.89
31.2	This way of learning is motivating.	0	20	60	20	0	3.0	0.63
31.3	A satisfying sense of achievement is felt.	0	20	80	0	0	3.2	0.40
31.4	The learner is encouraged to engage with the course material.	0	40	40	20	0	3.2	0.75
	Mean Ratings (%)	**2.9**	**41.9**	**25.7**	**28.6**	**1.0**	**3.2**	

B-1.2 Problems Reported by Experts

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**3**			
	1.4. When I downloaded the PDF it put it into my downloads folder but did not tell me so it appeared it has not worked.	1	20	Feedback	Ease of use
	1.5. The last Q in the test had no place to enter data. Don't use a free form field in a test marked by machine.	1	20	Assessment	Content
	1.6. I think you could add breadcrumbs on the top and a site map or search site box.	1	20	Navigation	Ease of use
2	***Match between system and the real world***	**2**			
	2.3. Tablet version would be easy to use for a PC based user not familiar with mobile phones.	1	20	Device Constraints	Context
	2.4. Couldn't find chat so I assumed a message on the forum. If this is correct then Chat and Forum message was used interchangeably.	1	20	Social Networking: Chat	Web 2.0
3	***Learner control***	**3**			
	3.4. After getting to the last review of my answers to the quiz, the only way back was to use the start button and go right back to the beginning page, rather than returning to the previous level that I was on.	1	20	Navigation	Ease of use
	3.5. I didn't see any undo options other than those inherent on my phone.	1	20	Errors	Ease of Use
	3.6. When I did go to see the SE Glossary to find an answer for the quiz, it did not remember my previous answers.	1	20	Feedback	Ease of use
4	***Consistency and adherence to standards***	**2**			
	4.1. Navigation was unclear at first. Got back to main page and had to find SE page again.	1	20	Navigation	Ease of use
	4.2. Could put in drop down menus on the top for ease of navigation.	1	20	Navigation	Ease of use
5	***Error prevention, in particular, prevention of peripheral usability-related errors***	**1**			
	5.1. Login does not show messages, default text can be used.	1	20	Feedback	Ease of use
6	***Recognition rather than recall, memory use***	**2**			
	6.1. Plenty scrolling, not occasionally.	1	20	Navigation	Ease of use
	6.2. The zoom feature is built into my phone. Didn't see one for the app.	1	20	Navigation	Ease of use
7	***Aesthetics and minimalism in design***	**1**			
	7.1. Although, the resolution of the images used is poor and unreadable, but I assume it is for example purposes.	1	20	Look and Feel	Design and Development
8	***Recognition, diagnosis and recovery from errors***	**1**			
	8.1. No error messages 8.2. No errors, except login. Login recovery said that e-mail sent, but it did not send anything 8.3. I can't comment on this section as I saw no error help whatsoever, and I am not sure if I should have as I don't know if I triggered anything.	3	60	Errors	Ease of use
9	***Help and documentation***	**1**			
	9.1. I could not find the help facility although help is provided through chats, forums, wikis etc. 9.2. No help. 9.3. Could not find help page. Search only on glossary page. Support only on main page. 9.4. I might have missed it, but I was looking for the site search and couldn't find it. Also, I don't recall any obvious page helps anywhere.	4	80	Help	Ease of use
	Total Number of Problems Reported by Experts	**16**			

#	Category 2: Website-specific Usability Problems	*f*	%	Theme	Design Guidelines
10	***Simplicity of site navigation, organisation and structure***	**2**			
	10.1. SE101 button on every page could be like "Main Menu".	1	20	Navigation	Ease of use
	10.2. Difficulty to understand the logic of the flow.	1	20	Navigation	Design and Development
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***	**1**			
	11.1. SE wiki is only accessible under topic outline and not on activities section on the left.	1	20	Social Networking: Wiki	Web 2.0
12	***Easy to access information***	**1**			
	12.1. Put PDFs in the library for easy access later. There were no videos to open. 12.2. Could not find video. 12.3. I was able to navigate to the video page but there was no link for the video itself.	3	60	Media	VLEs
13	***Content is both suitable and of a high quality***	**2**			
	13.1. Could not find some links.	1	20	Navigation	Ease of use
	13.2. It doesn't replace a text book and is too point form. It is a good reminder site but I don't think it is, in its current form, extensive enough on the parts it covered.	1	20	Pedagogy	Content
14	***System is simple and easy to use, called easiness***	**2**			
	14.1. Quiz answers not stored when visiting other links.	1	20	Assessment	Content
	14.2. I couldn't get my head around the hierarchy.	1	20	Navigation	Ease of use
15	***Material is of a high quality i.e. videos and digitisation***	**1**			
	15.1. No videos. 15.2. Couldn't find video.	2	40	Media	VLEs
	Total Number of Problems Reported by Experts	**9**			

#	Category 3: Pedagogical Usability Problems	*f*	%	Theme	Design Guidelines
16	***Clarity of goals, objectives and outcomes***	**1**			
	16.1. I could not see goals or expected outcomes. 16.2. The goals section, if I am not mistaken, is part of the first "chapter". I would like it to be more apparent as a separate step. There seems to be a sort of repetition of the first couple of buttons in my home page and my content page. Knowing where to go to get to the blog, or chatting is not that clear.	2	40	Navigation	Ease of use
17	***Effectiveness of collaborative learning***	**3**			
	17.1. Could not edit blog or glossary items.	1	20	Social Networking: Chat	Web 2.0
	17.2. Couldn't find chat room.	1	20	Social Networking: Chat	Web 2.0
	17.3. Group assignment had no data. I saw no collaborative learning.	1	20	Pedagogy	VLEs
18	***Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle***	**2**			
	18.1. Problem with help system.	1	20	Help	Ease of use
	18.2. I didn't find evidence of this type of learning.	1	20	Pedagogy	VLEs
19	***Feedback, guidance and assessment***	**1**			
	19.1. Problem with type of written assessment answers. 19.2. Having a free form field in a quiz can mark correct answers incorrectly. 19.3. I couldn't answer the last question. There was no	3	60	Assessment	Content

	question box to type into/select.				
	Total Number of Problems Reported by Experts	**7**			

#	Category 4: m-Learning Usability Problems	*f*	%	Theme	Design Guidelines
20	***Mobile phones and technology***	**1**			
	20.1. Limit use of numbers as that takes extra time on keyboard time due to toggling.	1	20	Device Constraints	Mobile Specifications
21	***Contextual factors (pragmatic)***	**0**			
	Nil	-	-	-	-
22	***User-centricity (pragmatic)***	**0**			
	Nil	-	-	-	-
23	***Flexibility***	**0**			
	Nil	-	-	-	-
24	***Interactivity***	**1**			
	24.1. Problem with help system.	1	20	Help	Ease of use
	Total Number of Problems Reported by Experts	**2**			

#	Category 5: UX Problems	*f*	%	Theme	Design Guidelines
25	***Emotional issues***	**1**			
	25.1. The hierarchy of pages is confusing. 25.2. I struggled … .	2	40	UX	Learner-centricity
26	***Contextual factors (hedonic)***	**1**			
	26.1. … I find their addition distracting.	1	20	UX	Learner-centricity
27	***User-centricity (hedonic)***	**1**			
	27.1. I will concede that I am not a youngster … . 27.2. I know I really should embrace these things in order to not become extinct. 27.3. There is not enough on the forum to be fun, but it could be. 27.4. I believe the experience could be better.	4	80	UX	Learner-centricity
28	***Social value***	**1**			
	28.1. I don't use blogs/social media type things … 28.2. Value of the forum depends on the calibre of the users	2	40	UX	Learner-centricity
29	***Needs***	**1**			
	29.1. Not everyone can afford phones or Internet bandwidth capable of delivering the platform.	1	20	UX	Learner-centricity
30	***Appeal***	**1**			
	25.1. Visually unappealing.	1	20	UX	Learner-centricity
31	***Satisfaction***	**1**			
	31.1. Could be more intuitive … . 31.2. This might be my perception but not happy with the experience.	2	40	UX	Learner-centricity
	Total Number of Problems Reported by Experts	**7**			

B-2 Study 4: Main Study 1 Evaluation Ratings and Problems Reported by Learners

B-2.1 Evaluation Ratings by Learner Users

#	Category 1: General Interface Usability Learner User Statements	5	4	3	2	1	Ave.	S.D.
1	***Visibility of system status, provide feedback***							
1.1	I get feedback from the application.	29	65	6	0	0	4.2	0.55
1.2	I understand clearly what the feedback is telling me without extra explanations.	35	53	12	0	0	4.2	0.64
1.3	Feedback is provided to me within reasonable time.	53	41	6	0	0	4.5	0.61
1.4	The application does not surprise me with unexpected responses.	35	47	12	6	0	4.1	0.83
1.5	For every action I take, I see results of that action.	41	47	12	0	0	4.3	0.67
2	***Match between system and the real world***							
2.1	I understand the language used within the application – concepts are explained in a way that is similar to day-to-day.	35	59	6	0	0	4.3	0.57
2.2	I am not confused by terms used within the system.	18	76	6	0	0	4.1	0.47
2.3	I am not confused by the way the symbols and icons are used.	12	65	18	6	0	3.8	0.71
2.4	I am able to follow the Information which is an orderly, logical and naturally arranged.	18	65	18	0	0	4.0	0.59
3	***Learner control***							
3.1	I am able to control the system, rather than it being able to control me.	29	53	18	0	0	4.1	0.68
3.2	I am able to exit at any time even though I have made mistakes.	29	47	24	0	0	4.1	0.73
3.3	When I make a mistake I can use Undo and Redo options.	12	47	35	6	0	3.6	0.76
4	***Consistency and adherence to standards***							
4.1	The same standards, style and conventions make it possible for me to work throughout the application.	41	47	6	6	0	4.2	0.81
4.2	It is easy for me to understand the standards as they are similar to those I see in other PC systems.	24	71	6	0	0	4.2	0.51
5	***Error prevention, in particular, prevention of peripheral usability-related errors***							
5.1	The system supports me in such a way that it is not easy to make serious mistakes.	12	65	24	0	0	3.9	0.58
5.2	Whenever I make a mistake I am given an error message.	24	59	18	0	0	4.1	0.64
6	***Recognition rather than recall, memory use***							
6.1	I am able to view most items onscreen – they are familiar; scrolling is needed occasionally.	18	76	0	6	0	4.1	0.64
6.2	I am able to enlarge and move around the screen to view any objects without needing to remember their location.	18	53	24	6	0	3.8	0.78
6.3	I observe visible system advice, using it whenever needed.	6	59	35	0	0	3.7	0.57
6.4	The screen layout is simple and I can recognise the links one at a time in any sequence, not needing to remember	24	65	12	0	0	4.1	0.58

	where I came from.							
6.5	I can read screen information more easily using the zoom feature which enables me to make text larger for improved reading.	29	53	18	0	0	4.1	0.68
7	***Aesthetics and minimalism in design***							
7.1	I am able to concentrate on relevant information without being distracted by other unimportant information.	35	47	6	12	0	4.1	0.94
7.2	I am not distracted by graphics which are there to illustrate a concept rather than to decorate the page.	35	53	6	6	0	4.2	0.78
8	***Recognition, diagnosis and recovery from error***							
8.1	Error messages are expressed in plain language.	47	47	0	6	0	4.4	0.76
8.2	Error messages tell me quickly what the problem is.	29	41	12	12	6	3.8	1.16
8.3	I find it easy to recover from mistakes using the error message provided.	18	53	24	6	0	3.8	0.78
9	***Help and documentation***							
9.1	I find the help facility useful.	6	53	29	12	0	3.5	0.78
9.2	I am easily able to follow the help provided.	6	47	47	0	0	3.6	0.60
9.3	Links to other resources are helpful.	18	71	12	0	0	4.1	0.54
	Mean Ratings (%)	**25.4**	**56.0**	**15.4**	**3.0**	**0.2**	**4.0**	

#	**Category 2: Website-specific Usability Learner User Statements**	**5**	**4**	**3**	**2**	**1**	**Ave.**	**S.D.**
10	***Simplicity of site navigation, organisation and structure***							
10.1	I am able to find my way around the application finding it easy to move around the application on a mobile handheld device.	24	41	29	6	0	3.8	0.86
10.2	I am able to choose more than one route to the information I require.	24	53	18	6	0	3.9	0.80
10.3	Related information has been grouped together – I find this helpful.	53	47	0	0	0	4.5	0.50
10.4	Important information is placed on top of the page.	12	59	24	6	0	3.8	0.73
10.5	Scrolling is minimised – I do not have to scroll many pages to find required information.	12	59	18	6	6	3.6	0.97
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***							
11.1	The content keeps me engaged.	6	76	18	0	0	3.9	0.47
11.2	The content is at the appropriate level of my understanding.	41	59	0	0	0	4.4	0.49
11.3	The material has no gender or racial biases.	71	29	0	0	0	4.7	0.46
11.4	It is clear which materials are copyrighted and which are not.	12	24	47	18	0	3.3	0.89
12	***Easy to access information***							
12.1	I am able to download material and documents provided within the application for download purposes.	35	47	18	0	0	4.2	0.71
12.2	The videos open with ease.	29	18	29	12	12	3.4	1.33
12.3	I follow the provided links with no difficulties reaching additional information.	41	53	6	0	0	4.4	0.59

13	***Content is both suitable and of a high quality***							
13.1	I visit additional website links which provide suitable content.	6	94	0	0	0	4.1	0.24
13.2	I see the value in the high quality of the contents presented to me.	12	76	12	0	0	4.0	0.49
14	***System is simple and easy to use, called easiness***							
14.1	The system supports me in such a way that it is not easy to make serious mistakes.	6	35	41	18	0	3.3	0.82
14.2	After visiting a linked site, it is easy to scroll or browse back to the application.	41	47	6	6	0	4.2	0.81
14.3	I find it easy to browse back and forth through the many learning options offered.	41	53	6	0	0	4.4	0.59
15	***Material is of a high quality i.e. videos and digitisation***							
15.1	The application text is easy to read.	29	59	6	6	0	4.1	0.76
15.2	Digital material is of a high quality, I have no difficulty viewing it.	18	59	18	6	0	3.9	0.76
	Mean Ratings (%)	**27.1**	**52.6**	**14.7**	**4.6**	**1.0**	**4.0**	

#	Category 3: Educational Usability Learner User Statements	5	4	3	2	1	Ave.	S.D.
16	***Clarity of goals, objectives and outcomes***							
16.1	I understand goals and objectives of the lesson which are clearly set out.	12	76	12	0	0	4.0	0.49
16.2	I find good reasons for the inclusion of each page – the reasons are obvious to me.	6	82	12	0	0	3.9	0.42
17	***Effectiveness of collaborative learning***							
17.1	Activities are experienced encouraging collaborative learning in several different ways e.g. during a discussion on the forum.	35	65	0	0	0	4.4	0.48
17.2	I find the discussion forum is fun and encourages me to join in	35	53	6	6	0	4.2	0.78
17.3	I find the chat room feature interesting as it offers me chances to share information with other learners	59	29	12	0	0	4.5	0.70
18	***Cognitive error recognition, diagnosis and recovery***							
18.1	The application offers me opportunity to work on problems	6	65	29	0	0	3.8	0.55
18.2	I am able to learn from any mistakes I make using this application by for example looking up definitions in the glossary	41	53	0	6	0	4.3	0.75
18.3	Help is provided to help me recover when I made errors filling in the quiz	29	41	24	6	0	3.9	0.87
19	***Feedback, guidance and assessment***							
19.1	I enjoy the concept of immediate feedback and assessment on progress	47	41	12	0	0	4.4	0.68
19.2	I am guided when doing tasks and when improving knowledge	12	71	18	0	0	3.9	0.54
19.3	Instant feedback given after the quiz helps me correct my mistakes with immediate learning	41	53	0	6	0	4.3	0.75
	Mean Ratings (%)	**29.4**	**57.2**	**11.2**	**2.1**	**0.0**	**4.1**	

#	Category 4: m-Learning Learner User Statements	5	4	3	2	1	Ave.	S.D.
20	***Mobile handheld devices and technology***							
20.1	I am aware that without advances in technology new ways of learning would not be possible.	76	24	0	0	0	4.8	0.4
20.2	I enjoy learning with the handheld device which has the all the capabilities I need to support mobile learning.	41	35	12	12	0	4.1	1.0
20.3	The mobile interface does not hamper me when I work with the application.	12	47	29	12	0	3.6	0.8
20.4	I have little difficulty inserting text and numbers.	18	47	12	18	6	3.5	1.1
20.5	I am using all aspects of the handheld device while learning from the application.	12	65	24	0	0	3.9	0.6
20.6	I am able to communicate socially with the mobile device and the application.	18	53	24	6	0	3.8	0.8
21	***Contextual factors(pragmatic)***							
21.1	I am aware of my physical surroundings but this does not interfere with the lesson experience.	18	53	18	12	0	3.8	0.9
21.2	While I explore the application, there is noise and audible interference is experienced.	12	53	18	12	6	3.5	1.0
21.3	I have worked with a smartphone already; this experience makes the exploration of the application easier.	29	24	47	0	0	3.8	0.9
21.4	My personal study needs have been considered as part of the application.	12	59	29	0	0	3.8	0.6
21.5	Learning goals have been built into the application – they are set.	0	82	18	0	0	3.8	0.4
21.6	When I use the application, I feel as if I am in a learning environment; the application feels and behaves like a normal learning environment.	18	71	12	0	0	4.1	0.5
21.7	I am aware of my surroundings during the lesson.	12	71	12	6	0	3.9	0.7
21.8	I find the learning experience to be rich and complex; I am not limited by the mobile device.	18	59	18	6	0	3.9	0.8
22	***User-centricity (pragmatic)***							
22.1	I feel my personal study approaches to learning have been considered.	0	82	18	0	0	3.8	0.4
22.2	With this type of study method, I am free to experiment and explore.	18	76	6	0	0	4.1	0.5
22.3	I see clearly what I am required to do.	24	71	0	6	0	4.1	0.7
22.4	I enjoy the feeling of independence the application offers – can look after myself.	35	65	0	0	0	4.4	0.5
22.5	This material represents my way of thinking in a clear manner.	18	29	47	6	0	3.6	0.8
22.6	I would be able to focus better; work longer stretches of time on problems in this way.	18	59	12	12	0	3.8	0.9
22.7	I could easily personalise this learning environment to suit my own needs.	6	59	24	12	0	3.6	0.8
22.8	I am aware of all content offered by the application.	18	53	18	12	0	3.8	0.9
22.9	I am able to customise this application environment to suit my own style.	0	35	41	24	0	3.1	0.8
22.10	I am actively involved in thinking and creating.	6	53	35	6	0	3.6	0.7

22.11	I can decide when and where I want to learn with this application.	47	47	6	0	0	4.4	0.6
23	***Flexibility***							
23.1	This is a great way to gather information any time.	65	35	0	0	0	4.6	0.5
23.2	I am free to adjust my learning environment- I can see the merit in this.	41	35	24	0	0	4.2	0.8
23.3	The way I see things – I can study the lesson in any order I choose.	41	35	18	6	0	4.1	0.9
23.4	The application can be personalised and Customised the way I want it to be.	0	29	59	12	0	3.2	0.6
23.5	I can use the system anytime and anywhere.	65	35	0	0	0	4.6	0.5
24	***Interactivity***							
24.1	I am able to move exactly where I want in this application.	35	59	6	0	0	4.3	0.6
24.2	I enjoyed the multimedia components which are appropriate for the subject content.	12	65	24	0	0	3.9	0.6
24.3	It is great that so many different kinds of exercise options have been provided.	41	53	6	0	0	4.4	0.6
24.4	Synchronous communication is possible via the chat room.	24	59	12	6	0	4.0	0.8
24.5	The discussion forum makes synchronous communication possible.	18	65	18	0	0	4.0	0.6
24.6	Interaction happens in varying ways.	29	59	6	6	0	4.1	0.8
24.7	I am able to smoothly connect to and participate with the application.	47	41	12	0	0	4.4	0.7
24.8	I am supported when I try to interact with the application.	6	88	6	0	0	4.0	0.3
24.9	I experience multiple creative ways of interacting with the application.	41	47	12	0	0	4.3	0.7
	Mean Ratings (%)	**24.3**	**53.2**	**17.3**	**4.8**	**0.3**	**4.0**	

#	Category 5: UX Learner User Statements	5	4	3	2	1	Ave.	S.D.
25	***Emotional issues***							
25.1	The lesson format is fun – it motivates me.	29	59	6	6	0	4.1	0.76
25.2	I feel encouraged to stay focused for longer.	29	41	24	6	0	3.9	0.87
25.3	I enjoy sharing lesson information with other learners.	35	59	0	6	0	4.2	0.73
25.4	I appreciate the opportunity to use technology and my mobile handheld device to learn.	65	35	0	0	0	4.6	0.48
25.5	I feel enthusiastic, studying software engineering in this way.	53	47	0	0	0	4.5	0.50
26	***Contextual factors (hedonic)***							
26.1	It's a pleasure for me to use my phone to do things I know already about mobile technology.	59	35	6	0	0	4.5	0.61
26.2	It is convenient for me to look up information on my mobile handheld device whenever I like.	65	35	0	0	0	4.6	0.48
27	***User-centricity (hedonic)***							
27.1	I appreciate that the application allows me to have a personal learning	41	59	0	0	0	4.4	0.49

	experience.							
27.2	I am able to change my learning environment to suit my needs.	12	53	35	0	0	3.8	0.64
28	***Social value***							
28.1	I feel totally at home using social networking tools to share course information.	35	53	12	0	0	4.2	0.64
28.2	I like the opportunity to interact with other learners immediately or when I choose.	59	35	6	0	0	4.5	0.61
29	***Needs***							
29.1	The application encourages me to express myself whilst learning.	12	71	18	0	0	3.9	0.54
29.2	I find that the stimulating mobile environment suits me.	12	76	6	6	0	3.9	0.64
29.3	I am safe and secure while I interact with the application.	24	71	6	0	0	4.2	0.51
30	***Appeal***							
30.1	I find the mobile handheld device way of communicating course material appealing.	47	41	6	6	0	4.3	0.82
30.2	I enjoy the opportunity to explore, learning on my own when I need to.	47	47	6	0	0	4.4	0.60
30.3	I love the visual aspects of a mobile learning environment.	6	65	18	12	0	3.6	0.76
31	***Satisfaction***							
31.1	I am satisfied by the opportunity to learn in this way.	41	53	6	0	0	4.4	0.59
31.2	I am motivated by mobile learning via my mobile handheld device.	29	53	12	6	0	4.1	0.80
31.3	I am satisfied with the results I achieve.	24	41	29	0	6	3.8	1.00
31.4	I am encouraged to explore the course material.	35	65	0	0	0	4.4	0.48
	Mean Ratings (%)	**2.9**	**41.9**	**25.7**	**28.6**	**1.0**	**3.2**	

B-2.2 Problems Reported by Learner Users

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**4**			
	1.8. Internet is slow, but the app is good.	1	5.9	Device Constraints	Mobile Specifications
	1.9. I couldn't change the glossary wording. 1.10. Problem changing glossary wording.	2	11.8	Design	Content
	1.11. I couldn't see the triple constraint video. 1.12. The video didn't play.	2	11.8	Media	VLEs
	1.13. The blog entry was confusing. 1.14. On Blog page, I clicked on "Turn edit button on" but still was unable to edit the plagiarism and ethics topic.	2	11.8	Social Networking: Blog	Web 2.0
2	***Match between system and the real world***	**2**			
	2.3. There are links that are not displayed nicely.	1	5.9	Navigation	Ease of Use
	2.4. Topic outline - the green letters are too big, the colour does not help when reading and they are too big.	1	5.9	Look and Feel	Design and Development
3	***Learner control***	**1**			
	3.2. There are no short navigation descriptions that tells you where to click - like a short HELP popup message.	1	5.9	Navigation	Ease of Use
4	***Consistency and adherence to standards***	**2**			
	4.1. Seeing that this is a learner app maybe you could	1	5.9	Look and	Design and

	make provision for skins.			Feel	Development
	4.2. Home page font colour is green but on the different web pages like "A project" the font colour is black.	1	5.9	Look and Feel	Design and Development
5	***Error prevention, in particular, prevention of peripheral usability-related errors***	**0**			
	Nil	-	-	-	-
6	***Recognition rather than recall, memory use***	**4**			
	6.1. Buttons like edit for the Glossary is easily missed sometimes.	1	5.9	Navigation	Ease of Use
	6.2. Did not see a ZOOM feature.	1	5.9	Navigation	Ease of Use
	6.3. The font becomes too small and constant adjusting and scrolling is needed.	1	5.9	Navigation	Ease of Use
	6.4. The things written on the pages are all over the page. They are organised but I have to move my eyes all over the screen to find what I want.	1	5.9	Navigation	Ease of Use
7	***Aesthetics and minimalism in design***	**2**			
	7.1. Ian Sommerville's picture doesn't look good, it is fading out.	1	5.9	Look and Feel	Design and Development
	7.2. The Software Engineering 2011 webpage has quite large font size and this is quite disturbing.	1	5.9	Look and Feel	Design and Development
8	***Recognition, diagnosis and recovery from errors***	**1**			
	8.1. I've encountered changing glossary wording.	1	5.9	Design	Design and Development
9	***Help and documentation***	**2**			
	9.1. I could not find the help link (feature) links painted out. 9.2. Unable to find help facility unless pointed out. 9.3. Help question mark link was difficult to find. Perhaps text with icon. Found it by chance. Not all links work on help. Misinterpreted: http:" as a link. How to Wiki? 9.4. On the message box (forum page) the HELP button has nothing in the links. 9.5. Can't find the HELP facility. 9.6. HELP on the Chat webpage do not provide relevant information such as "How to add a chat message".	6	35.3	Help	Ease of Use
	9.7. Maybe a dictionary would be equally helpful.	1	5.9	Design	Content
	Total Number of Problems Reported by Learners	**18**			

#	Category 2: Website-specific Usability Problems	*f*	%	Theme	Design Guidelines
10	***Simplicity of site navigation, organisation and structure***	**2**			
	10.1. It would be nice if there were some extra shortcuts.	1	5.9	Navigation	Ease of Use
	10.2. There is constant need to scroll as small screen cannot display all the information at once.	1	5.9	Navigation	Ease of Use
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***	**0**			
	Nil	-	-	-	-
12	***Easy to access information***	**1**			
	12.1. Network does not allow certain actions. 12.2. With the videos, access was denied because of administrative rights. 12.3. The video required additional apps in order for me to run it. 12.4. Video opens with ease provided that it has not been blocked the website. 12.5. The video has been blocked. 12.6. Not able to view all materials because of network problems.	6	35.3	Device Constraints	Mobile Specifications
13	***Content is both suitable and of a high quality***	**1**			
	13.1. "Word of mouth" webpage does not include the article that is referred to in the webpage.	1	5.9	Design	Content
14	***System is simple and easy to use, called easiness***	**1**			
	14.1. I had to click the back button numerous times to go	1	5.9	Navigation	Content

	back to certain materials.				
15	***Material is of a high quality i.e. videos and digitisation***	**2**			
	15.1. Certain words are not always familiar to me so a bit more definition is needed.	1	5.9	Design	Design and Development
	15.2. The type is a bit messy for me, the letters are too close to each other.	1	5.9	Look and Feel	Learner-centricity
	Total Number of Problems Reported by Learners	**7**			

#	Category 3: Pedagogical Usability Problems	*f*	%	Theme	Design Guidelines
16	***Clarity of goals, objectives and outcomes***	**0**			
	Nil	-	-	-	-
17	***Effectiveness of collaborative learning***	**1**			
	17.1. The comment section requires you to wait for each person to comment before you get a chance to do so yourself. 17.2. A message should POP UP when an incoming message occurs.	2	11.8	Social Networking: Chat	Web 2.0
18	***Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle***	**3**			
	18.1. The open ended questions must not be case sensitive as the learner may be a novice.	1	5.9	Assessment	VLEs
	18.2. Unable to view glossary while in the quiz section.	1	5.9	Assessment	VLEs
	18.3. Answer section of quiz should not be case-sensitive. No space to answer last question. 18.4. Matching of similar text in the written questions should be considered in the marking e.g. quiz. 18.5. My answer to the last question was part of the text but I still got it wrong.	3	17.6	Assessment	VLEs
19	***Feedback, guidance and assessment***	**2**			
	19.1. Multiple choice sections work correctly but answer section of quiz should not be case-sensitive. I provide the correct answer but it is marked as incorrect because of case sensitivity. 19.2. Written questions, answers with similar text must be considered.	2	11.8	Assessment	VLEs
	19.3. Would have been perfect if "no save" is required from the user because it clears out all filled in answers while navigating unless user selects "save without submitting" every time.	1	5.9	Navigation	Ease of Use
	Total Number of Problems Reported by Learners	**6**			

#	Category 4: m-Learning Usability Problems	*f*	%	Theme	Design Guidelines
20	***Mobile phones and technology***	**3**			
	20.1. Only problem doing the quiz is that it's sort of slow.	1	5.9	Device Constraints	Mobile Specifications
	20.2. I do not have to be in a static focused location.	1	5.9	Location	Context
	20.3. The chats don't work well on my phone.	1	5.9	Social Networking: Chat	Web 2.0
21	***Contextual factors (pragmatic)***	**1**			
	21.1. The device is limiting because it requires extra effort and adapting to.	1	5.9	Device Constraints	Mobile Specifications
22	***User-centricity (pragmatic)***	**1**			
	22. I cannot find the button for customising the application.	1	5.9	Design	Design and Development
23	***Flexibility***	**3**			
	23.1. I haven't seen a clear way showing the user that they are able to customise their environment.	1	5.9	Look and Feel	Design and Development
	23.2. If Internet access is based on airtime this may be a problem if one is low on airtime.	1	5.9	Device Constraints	Mobile Specifications

	23.3. Data is difficult to find.	1	5.9	Navigation	Ease of Use
24	***Interactivity***	**1**			
	24.1. Multimedia will also come up as a problem within my environment as such sites are blocked.	1	5.9	Media	VLEs
	Total Number of Problems Reported by Learners	**9**			

#	Category 5: UX Problems	*f*	%	Theme	Design Guidelines
25	***Emotional issues***	**1**			
	25.1. Maybe a small bit of frustration … . 25.2. This could frustrate the user … . 25.3. Just a bit confused … . 25.4. Irritated by constant scrolling. 25.5. Access being denied for video viewing, is not good.	5	29.4	UX	Learner-centricity
26	***Contextual factors (hedonic)***	**1**			
	26.1. The problem with a mobile device is that I was easily distracted … .	1	5.9	UX	Learner-centricity
27	***User-centricity (hedonic)***	**1**			
	27.1. Time taken to find targets is too long for me. 27.2. Slowness of the network connection.	2	11.8	UX	Learner-centricity
28	***Social value***	0			
	Nil	-		-	-
29	***Needs***	**1**			
	29.1. … I would like happy colourful skins … .	1	5.9	UX	Learner-centricity
30	***Appeal***	**1**			
	30.1. … making the web app a bit ugly. 30.2. Layout not very appealing. 30.3. The way it looks makes me tired, it is not very interesting.	3	17.6	UX	Learner-centricity
31	***Satisfaction***	**1**			
	31.1. I tend to be interested to explore other interesting sections about the website … . 31.2. Unacceptable that certain functions are hidden.	2	11.8	UX	Learner-centricity
	Total Number of Problems Reported by Learners	**6**			

APPENDIX C: Main Study 2 Ratings and Reported Problems

C-1 Study 6: Main Study 2 HE Ratings and Problems Reported by Experts

C-1.1 HE Ratings by Experts

#	Category 1: General Interface Usability HE Statements	5	4	3	2	1	Ave.	S.D.
1	***Visibility of system status, provide feedback***							
1.1	Feedback is provided by the application.	0	80	0	20	0	3.6	0.8
1.2	The system is responsive to user actions without odd and unexplained events.	0	60	20	20	0	3.4	0.8
1.3	Visible feedback icons communicate what is happening.	0	60	20	20	0	3.4	0.8
2	***Match between system and the real world***							
2.1	Clear everyday understandable language has been used in the application.	20	80	0	0	0	4.2	0.4
2.2	Where metaphors are used they represent real-world objects, ideas and concepts.	20	80	0	0	0	4.2	0.4
2.3	Symbols and icons follow an intuitive pattern in line with tasks.	0	60	40	0	0	3.6	0.5
2.4	Information is seen as sequential, logical and as naturally arranged.	0	20	60	20	0	3.0	0.6
3	***Learner control***							
3.1	Users are able to exert control on the system.	0	100	0	0	0	4.0	0.0
3.2	It is possible to exit at any time even though mistakes might have been made.	20	80	0	0	0	4.2	0.4
3.3	Undo and Redo options exist.	0	60	20	20	0	3.4	0.8
4	***Consistency and adherence to standards***							
4.1	Patterns of words, symbols, icons repeat logically throughout the application.	20	60	20	0	0	4.0	0.6
4.2	Platform standards are recognised as similar to PC-oriented standards.	0	80	0	20	0	3.6	0.8
5	***Error prevention, in particular, prevention of peripheral usability-related errors***							
5.1	Errors are preventable – the system is designed to take care of this.	0	60	20	20	0	3.4	0.8
5.2	An appropriate message is shown if a mistake is made.	20	40	20	20	0	3.6	1.0
6	***Recognition rather than recall, memory use***							
6.1	Objects are visible and familiar; scrolling is needed occasionally.	0	80	20	0	0	3.8	0.4
6.2	The screen is manipulated to view any information without needing to remember.	0	40	40	20	0	3.2	0.7
6.3	Advice on system use is visible and able to be used whenever needed.	20	40	20	20	0	3.6	1.0
6.4	Simple displays are presented with few or no multiple page display options.	40	20	20	20	0	3.8	1.2
6.5	The zoom feature enables easy	20	20	40	20	0	3.4	1.0

	enlargement of text for improved reading.							
7	***Aesthetics and minimalism in design***							
7.1	Distracting material of minimal relevance has been excluded.	0	80	20	0	0	3.8	0.4
7.2	Graphics are used to illustrate a point rather than to decorate the page.	0	80	20	0	0	3.8	0.4
8	***Recognition, diagnosis and recovery from error***							
8.1	Error messages are easy to follow being presented in straight forward language.	20	40	20	20	0	3.6	1.0
8.2	Quick and simple solutions are offered if errors are made.	20	40	20	20	0	3.6	1.0
8.3	Recovery is achieved after constructive help.	40	20	20	20	0	3.8	1.2
9	***Help and documentation***							
9.1	A help facility exists, it is easy to find and support the users' needs.	20	20	40	20	0	3.4	1.0
9.2	A search facility makes it easy to find information.	20	20	40	20	0	3.4	1.0
9.3	Support documentation is provided on each page.	0	20	60	20	0	3.0	0.6
	Mean Ratings (%)	**11.1**	**53.3**	**22.2**	**13.3**	**0.0**	**3.6**	

#	**Category 2: Website-specific Usability HE Statements**	**5**	**4**	**3**	**2**	**1**	**Ave.**	**S.D.**
10	***Simplicity of site navigation, organisation and structure***							
10.1	The application is easy to navigate on a mobile handheld device	0	60	20	20	0	3.4	0.8
10.2	There are several paths to and from a chosen destination.	0	40	0	60	0	2.8	1.0
10.3	Related information has been grouped into obvious categories.	0	60	20	20	0	3.4	0.8
10.4	Information is organised hierarchically.	0	60	0	40	0	3.2	1.0
10.5	Links and buttons support navigation throughout the site without cluttering it.	20	60	20	0	0	4.0	0.6
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***							
11.1	The site is interesting and keeps the user's attention focused.	0	40	60	0	0	3.4	0.5
11.2	Site information is clear and relevant.	0	40	60	0	0	3.4	0.5
11.3	No racial or gender biases are noted.	20	80	0	0	0	4.2	0.4
11.4	If material has been copyrighted, this has been made clear.	20	40	40	0	0	3.8	0.7
12	***Easy to access information***							
12.1	Any lesson material or downloadable documents can be reached.	0	40	20	40	0	3.0	0.9
12.2	The videos open with ease.	0	0	20	60	20	2.0	0.6
12.3	All links to external sites provide the required connections to additional information.	0	60	20	20	0	3.4	0.8
13	***Content is both suitable and of a high quality***							
13.1	Additional website links provide suitable content.	20	60	20	0	0	4.0	0.6
13.2	The content is of a high standard.	20	60	20	0	0	4.0	0.6
14	***System is simple and easy to use, called easiness***							

14.1	No difficulties are experienced reaching site material via the mobile interface.	20	40	20	20	0	3.6	1.0
14.2	It is just as easy to scroll or browse back to the site after visiting another site.	0	80	0	20	0	3.6	0.8
14.3	It is easy to browse back and forth through the many learning options offered.	20	60	0	20	0	3.8	1.0
15	***Material is of a high quality i.e. videos and digitisation***							
15.1	Text is presented in a legible easy to read format.	40	40	20	0	0	4.2	0.7
15.2	Digital material is of a high quality, no difficulty is experienced during viewing.	20	20	0	60	0	3.0	1.3
	Mean Ratings (%)	**11.1**	**48.9**	**18.9**	**20.0**	**1.1**	**3.5**	

#	Category 3: Educational Usability HE Statements	5	4	3	2	1	Ave.	S.D.
16	***Clarity of goals, objectives and outcomes***							
16.1	Goals are clearly set out, objectives and expected outcomes for learning are clear too.	0	60	40	0	0	3.6	0.5
16.1	There is a good reason for the inclusion of each page and this reason is obvious.	0	60	0	40	0	3.2	1.0
17	***Effectiveness of collaborative learning***							
17.1	Activities are experienced encouraging collaborative learning in several different ways.	20	60	20	0	0	4.0	0.6
17.2	The discussion forum is fun and operational.	20	60	20	0	0	4.0	0.6
17.3	Chat room facilities are found.	20	60	20	0	0	4.0	0.6
18	***Cognitive error recognition, diagnosis and recovery***							
18.1	Problem-based learning strategies have been implemented.	20	40	20	20	0	3.6	1.0
18.2	Mistakes can be made affording users the chance to learn from them.	20	60	20	0	0	4.0	0.6
18.3	Help is provided to recover from cognitive errors.	0	0	80	20	0	2.8	0.4
19	***Feedback, guidance and assessment***							
19.1	Users receive prompt feedback from the application on assessment and progress.	20	40	20	20	0	3.6	1.0
19.2	Guidance is provided about the tasks and construction of knowledge going on.	0	40	40	20	0	3.2	0.7
19.3	Activities are graded with grades providing instant feedback and correction.	20	60	0	20	0	3.8	1.0
	Mean Ratings (%)	**12.0**	**48.0**	**28.0**	**12.0**	**0.0**	**3.6**	

#	Category 4: m-Learning HE Statements	5	4	3	2	1	Ave.	S.D.
20	***Mobile handheld devices and technology***							
20.1	Technology has made mobile learning feasible.	0	100	0	0	0	4.0	0.0
20.2	The mobile handheld device has adequate capabilities to support mobile learning.	20	60	20	0	0	4.0	0.6

20.3	The mobile interface does not hamper working with the application.	40	40	20	0	0	4.2	0.7
20.4	Inserting text and numbers is feasible and achievable.	60	20	20	0	0	4.4	0.8
20.5	The mobile handheld device system is used to its fullest capability.	20	40	40	0	0	3.8	0.7
20.6	Mobile communication channels are provided.	40	40	20	0	0	4.2	0.7
21	***Contextual factors(pragmatic)***							
21.1	A physical environment is noted but it does not hinder the lesson experience.	20	60	0	20	0	3.8	1.0
21.2	The lessons in followed where noise and audible interference is experienced.	0	60	20	20	0	3.4	0.8
21.3	Prior mobile handheld device knowledge and exposure makes the task easy.	40	60	0	0	0	4.4	0.5
21.4	User characteristics have been considered as part of the exercise.	0	100	0	0	0	4.0	0.0
21.5	Goals are set and not adjustable.	20	40	40	0	0	3.8	0.7
21.6	The application feels and behaves like a normal working environment.	0	80	20	0	0	3.8	0.4
21.7	During the lesson, awareness of surroundings is evident.	0	60	20	20	0	3.4	0.8
21.8	Users are exposed to rich and complex environments, not limited by the mobile.	0	60	0	40	0	3.2	1.0
22	***User-centricity (pragmatic)***							
22.1	Support for personal approaches to learning is offered.	0	60	40	0	0	3.6	0.5
22.2	Experimentation and exploration is possible.	0	100	0	0	0	4.0	0.0
22.3	User requirements have been specified.	0	60	40	0	0	3.6	0.5
22.4	Self-sufficiency is observed.	0	60	20	20	0	3.4	0.8
22.5	Material is presented in a clear, learner-centred format.	20	60	20	0	0	4.0	0.6
22.6	Focus is enhanced in that learners spend longer times doing tasks.	0	40	20	40	0	3.0	0.9
22.7	Personalised learning format has been provided.	20	40	20	20	0	3.6	1.0
22.8	Learners are personally aware of all content with control being given to users.	20	60	20	0	0	4.0	0.6
22.9	Learners can customise, applying their own preferences.	0	40	20	40	0	3.0	0.9
22.10	Active learning promotes critical thinking: users compare, analyse, classify, deduce.	40	40	20	0	0	4.2	0.7
22.11	Users are able to direct their own learning with a sense of ownership.	20	80	0	0	0	4.2	0.4
23	***Flexibility***							
23.1	The lesson may be done at any personal moment in time.	40	60	0	0	0	4.4	0.5
23.2	An adaptable environment has been created.	0	100	0	0	0	4.0	0.0
23.3	Lesson information may be viewed in any order.	20	80	0	0	0	4.2	0.4
23.4	The system can be adjusted to individual needs.	0	80	20	0	0	3.8	0.4
23.5	The systems can be used anytime and anywhere.	60	40	0	0	0	4.6	0.5
24	***Interactivity***							

24.1	Navigational fidelity is experienced.	0	40	40	20	0	3.2	0.7
24.2	Multimedia components are appropriate.	0	40	60	0	0	3.4	0.5
24.3	Multiple kinds of exercises have been provided.	0	80	20	0	0	3.8	0.4
24.4	Synchronous communication is possible.	40	40	20	0	0	4.2	0.7
24.5	Asynchronous communication is possible.	40	40	20	0	0	4.2	0.7
24.6	Interaction happens in varying ways.	20	80	0	0	0	4.2	0.4
24.7	Interaction with the application is smooth.	0	80	20	0	0	3.8	0.4
24.8	Support is provided for interactivity with the application.	0	40	40	20	0	3.2	0.7
24.9	Interactivity has been encouraged in creative ways.	0	60	20	20	0	3.4	0.8
	Mean Ratings (%)	**15.4**	**59.5**	**17.9**	**7.2**	**0.0**	**3.8**	

#	Category 5: UX HE Statements	5	4	3	2	1	Ave.	S.D.
25	***Emotional issues***							
25.1	The lessons are motivating and fun.	0	60	20	20	0	3.4	0.8
25.2	The application encourages participation with a longer time trying to process the lesson.	20	20	20	40	0	3.2	1.2
25.3	The experience is enjoyable.	20	20	40	20	0	3.4	1.0
25.4	It is new technology yet it is interesting and an acceptable form of learning.	20	80	0	0	0	4.2	0.4
25.5	This way of learning software engineering is exciting.	0	40	40	20	0	3.2	0.7
26	***Contextual factors (hedonic)***							
26.1	Knowledge of mobile technology makes this way of learning a pleasure.	40	40	20	0	0	4.2	0.7
26.2	The need for this type of learning suits the current mobile learner environment.	60	20	20	0	0	4.4	0.8
27	***User-centricity (hedonic)***							
27.1	Personalised learning is encouraged.	20	60	0	20	0	3.8	1.0
27.2	The learner is able to customise the learning environment.	20	20	20	40	0	3.2	1.2
28	***Social value***							
28.1	The application is social, encouraging media sharing.	20	60	20	0	0	4.0	0.6
28.2	The m-learning approach provides both synchronous and asynchronous interaction.	20	60	20	0	0	4.0	0.6
29	***Needs***							
29.1	The learner is encouraged to express personal opinions.	40	40	20	0	0	4.2	0.7
29.2	The learning environment is stimulating.	20	40	20	20	0	3.6	1.0
29.3	A sense of security is achieved.	40	0	40	20	0	3.6	1.2
30	***Appeal***							
30.1	New impressions of the learning content create an appealing space.	0	40	40	20	0	3.2	0.7
30.2	The learner is motivated to explore.	40	40	20	0	0	4.2	0.7

30.3	The experience is visually appealing.	0	60	20	20	0	3.4	0.8
31	***Satisfaction***							
31.1	The experience adds fun to the learning opportunity.	0	60	20	20	0	3.4	0.8
31.2	This way of learning is motivating.	0	80	0	20	0	3.6	0.8
31.3	A satisfying sense of achievement is felt.	0	60	20	20	0	3.4	0.8
31.4	The learner is encouraged to engage with the course material.	20	60	0	20	0	3.8	1.0
	Mean Ratings (%)	**19.0**	**45.7**	**20.0**	**15.2**	**0.0**	**3.7**	

C-2.2 Problems Reported by Experts

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**4**			
	1.5. There is little form of interaction between the user and the system.	1	20	Feedback	Ease of Use
	1.6. Server unavailable.	1	20	Device Constraints	Mobile Specifications
	1.7. Cannot find blog or video.	1	20	Media	VLEs
	1.8. The only indicator of the system or its pages loading is in the URL indicator.	1	20	Design	Design and Development
2	***Match between system and the real world***	**2**			
	2.3. Some pages have little or not enough information which shows the importance of the pages.	1	20	Feedback	Ease of Use
	2.4. Got lost in menus.	1	20	Navigation	Ease of Use
3	***Learner control***	**1**			
	3.2. Able to use the 'back' button without having to 'save'.	1	20	Navigation	Ease of Use
4	***Consistency and adherence to standards***	**2**			
	4.3. Inconsistent with PC standards that allow for user friendly message that assists the user to use the application.	1	20	Feedback	Ease of Use
	4.4. Unable to select 'search' without text being added.	1	20	Design	Design and Development
5	***Error prevention, in particular, prevention of peripheral usability-related errors***	**1**			
	5.1. No incorrect login message.	1	20	Error	Ease of Use
6	***Recognition rather than recall, memory use***	**1**			
	6.1. There is no zoom feature.	1	20	Navigation	Ease of Use
7	***Aesthetics and minimalism in design***	**1**			
	7.1. Graphic primarily contained in PDF.	1	20	Look and feel	Design and Development
8	***Recognition, diagnosis and recovery from errors***	**1**			
	8.1. There are no error messages.	1	20	Errors	Ease of Use
9	***Help and documentation***	**1**			
	9.1. There is no help and documentation. 9.2. I didn't find the system search facility and the support documentation, therefore if this information is available, then it is not strategically placed.	2	40	Help	Ease of Use
	Total Number of Problems Reported by Experts	**14**			

#	Category 2: Website-specific Usability Problems	*f*	%	Theme	Design Guidelines
10	***Simplicity of site navigation, organisation and structure***	**2**			
	10.1. On looking for contiguous information and links some appeared out of order. 10.2. I found it very hard to follow the logical hierarchy of the system, especially understanding its starting objective and being precise in providing the information.	2	40	Navigation	Ease of Use
	10.3. Could not find blog or video.	1	20	Media	VLEs
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***	**0**			
	Nil	-	-	-	-
12	***Easy to access information***	**2**			
	12.1. Bandwidth restricted certain actions.	1	20	Device Constraints	Mobile Specifications
	12.2. Unable to access any video/s.	1	20	Media	VLEs
13	***Content is both suitable and of a high quality***	**0**			
	Nil	-	-	-	-

14	***System is simple and easy to use, called easiness***	**0**			
	Nil	-	-	-	-
15	***Material is of a high quality i.e. videos and digitisation***	**2**			
	15.1. Unable to access any digital material.	1	20	Media	VLEs
	15.2. Some text typo's.	1	20	Look and Feel	Design and Development
	Total Number of Problems Reported by Experts	**6**			

#	Category 3: Pedagogical Usability Problems	*f*	%	Theme	Design Guidelines
16	***Clarity of goals, objectives and outcomes***	**0**			
	Nil	-	-	-	-
17	***Effectiveness of collaborative learning***	**0**			
	Nil	-	-	-	-
18	***Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle***	**0**			
	Nil	-	-	-	-
19	***Feedback, guidance and assessment***	**0**			
	Nil	-	-	-	-
	Total Number of Problems Reported by Experts	**0**			

#	Category 4: m-Learning Usability Problems	*f*	%	Theme	Design Guidelines
20	***Mobile phones and technology***	**0**			
	Nil	-	-	-	-
21	***Contextual factors (pragmatic)***	**1**			
	21.1. User physical environment influences the learning experience.	1	20	Location	Context
22	***User-centricity (pragmatic)***	**0**			
	Nil		-	-	-
23	***Flexibility***	**2**			
	23.1. System may be used anytime, and anywhere, but it does not necessarily promote learning.	1	20	Pedagogy	VLEs
	23.2. Its focus is therefore on specific studious learners.	1	20	Design	Design and Development
24	***Interactivity***	**1**			
	24.1. Unable to access multimedia components.	1	20	Media	Content
	Total Number of Problems Reported by Experts	**4**			

#	Category 5: UX Problems	*f*	%	Theme	Design Guidelines
25	***Emotional issues***	**1**			
	25.1. Frustration - "for the life of me" … . 25.2. Unpleasant to scroll so much. 25.3. Extremely frustrating waiting for sections to load due to bandwidth limitations.	3	60	UX	Learner Centricity
26	***Contextual factors (hedonic)***	**1**			
	26.1. Lost focus at times – environment might suit certain learner types only e.g. advanced learners.	1	20	UX	Learner Centricity
27	***User-centricity (hedonic)***	**1**			
	27.1. Too much freedom – I would prefer being guided by constraints.	1	20	UX	Learner Centricity
28	***Social value***	**0**			

	Nil	-	-	-	-
29	***Needs***	**0**			
	Nil	-	-	-	-
30	***Appeal***	**1**			
	30.1. Did not enjoy getting lost in the menus. 30.2. Too much information on a page for my screen.	2	40	UX	Learner Centricity
31	***Satisfaction***	**0**			
	Nil	-	-	-	
	Total Number of Problems Reported by Experts	**4**			

C-2 Study 6: Main Study 2 Evaluation Ratings and Problems Reported by Learners

C-2.1 Evaluation Ratings by Learner Users

#	Category 1: General Interface Usability	5	4	3	2	1	Ave.	S.D.
1	***Visibility of system status, provide feedback***							
1.1	I get feedback from the application.	38	56	6	0	0	4.3	0.6
1.2	I understand clearly what the feedback is telling me without extra explanations.	28	56	16	0	0	4.1	0.6
1.3	Feedback is provided to me within reasonable time.	25	34	25	16	0	3.7	1.0
1.4	The application does not surprise me with unexpected responses.	25	47	28	0	0	4.0	0.7
1.5	For every action I take, I see results of that action.	50	38	6	6	0	4.3	0.8
2	***Match between system and the real world***							
2.1	I understand the language used within the application – concepts are explained in a way that is similar to day-to-day.	44	50	6	0	0	4.4	0.6
2.2	I am not confused by terms used within the system.	28	50	19	0	3	4.0	0.9
2.3	I am not confused by the way the symbols and icons are used.	25	66	9	0	0	4.2	0.6
2.4	I am able to follow the Information which is an orderly, logical and naturally arranged.	34	56	6	3	0	4.2	0.7
3	***Learner control***							
3.1	I am able to control the system, rather than it being able to control me.	22	59	16	3	0	4.0	0.7
3.2	I am able to exit at any time even though I have made mistakes.	41	50	9	0	0	4.3	0.6
3.3	When I make a mistake I can use Undo and Redo options.	13	38	41	6	3	3.5	0.9
4	***Consistency and adherence to standards***							
4.1	The same standards, style and conventions make it possible for me to work throughout the application.	41	50	6	3	0	4.3	0.7
4.2	It is easy for me to understand the standards as they are similar to those I see in other PC systems.	34	41	16	9	0	4.0	0.9
5	***Error prevention, in particular, prevention of peripheral usability-related errors***							
19	The system supports me in such a way that it is not easy to make serious mistakes.	19	63	19	0	0	4.0	0.6
20	Whenever I make a mistake I am given an error message.	19	34	34	13	0	3.6	0.9
6	***Recognition rather than recall, memory use***							
6.1	I am able to view most items onscreen – they are familiar; scrolling is needed occasionally.	31	44	6	16	3	3.8	1.1
6.2	I am able to enlarge and move around the screen to view any objects without needing to remember their location.	25	41	16	13	6	3.7	1.2
6.3	I observe visible system advice, using it whenever needed.	13	56	19	9	3	3.7	0.9
6.4	The screen layout is simple and I can recognise the links one at a time in any sequence, not needing to remember	25	28	22	25	0	3.5	1.1

	where I came from.							
6.5	I can read screen information more easily using the zoom feature which enables me to make text larger for improved reading.	22	53	16	9	0	3.9	0.9
7	***Aesthetics and minimalism in design***							
7.1	I am able to concentrate on relevant information without being distracted by other unimportant information.	31	50	13	6	0	4.1	0.8
7.2	I am not distracted by graphics which are there to illustrate a concept rather than to decorate the page.	41	38	16	6	0	4.1	0.9
8	***Recognition, diagnosis and recovery from error***							
8.1	Error messages are expressed in plain language.	22	50	28	0	0	3.9	0.7
8.2	Error messages tell me quickly what the problem is.	25	38	38	0	0	3.9	0.8
8.3	I find it easy to recover from mistakes using the error message provided.	19	53	25	3	0	3.9	0.7
9	***Help and documentation***							
9.1	I find the help facility useful.	25	34	19	16	6	3.6	1.2
9.2	I am easily able to follow the help provided.	13	47	28	9	3	3.6	0.9
9.3	Links to other resources are helpful.	19	50	22	9	0	3.8	0.9
	Mean Ratings (%)	**27.4**	**47.2**	**18.2**	**6.3**	**1.0**	**3.9**	

#	Category 2: Website-specific Usability	5	4	3	2	1	Ave.	S.D.
10	***Simplicity of site navigation, organisation and structure***							
10.1	I am able to find my way around the application finding it easy to move around the application on a mobile handheld device.	25	44	16	13	3	3.8	1.1
10.2	I am able to choose more than one route to the information I require.	25	44	28	3	0	3.9	0.8
10.3	Related information has been grouped together – I find this helpful.	41	56	3	0	0	4.4	0.5
10.4	Important information is placed on top of the page.	31	63	3	3	0	4.2	0.6
10.5	Scrolling is minimised – I do not have to scroll many pages to find required information.	28	47	13	0	13	3.8	1.2
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***							
11.1	The content keeps me engaged.	19	63	19	0	0	4.0	0.6
11.2	The content is at the appropriate level of my understanding.	50	47	3	0	0	4.5	0.6
11.3	The material has no gender or racial biases.	69	31	0	0	0	4.7	0.5
11.4	It is clear which materials are copyrighted and which are not.	16	44	22	13	6	3.5	1.1
12	***Easy to access information***							
12.1	I am able to download material and documents provided within the application for download purposes.	19	44	19	19	0	3.6	1.0
12.2	The videos open with ease.	16	28	22	22	13	3.1	1.3
12.3	I follow the provided links with no difficulties reaching additional information.	28	44	22	6	0	3.9	0.9

13	***Content is both suitable and of a high quality***							
13.1	I visit additional website links which provide suitable content.	25	38	31	6	0	3.8	0.9
13.2	I see the value in the high quality of the contents presented to me.	44	34	16	6	0	4.2	0.9
14	***System is simple and easy to use, called easiness***							
14.1	The system supports me in such a way that it is not easy to make serious mistakes.	34	38	13	16	0	3.9	1.0
14.2	After visiting a linked site, it is easy to scroll or browse back to the application.	28	59	6	6	0	4.1	0.8
14.3	I find it easy to browse back and forth through the many learning options offered.	28	53	6	13	0	4.0	0.9
15	***Material is of a high quality i.e. videos and digitisation***							
15.1	The application text is easy to read.	56	44	0	0	0	4.6	0.5
15.2	Digital material is of a high quality, I have no difficulty viewing it.	31	34	22	13	0	3.8	1.0
	Mean Ratings (%)	**32.6**	**45.0**	**13.7**	**6.9**	**1.7**	**4.0**	

#	Category 3: Educational Usability	5	4	3	2	1	Ave.	S.D.
16	***Clarity of goals, objectives and outcomes***							
16.1	I understand goals and objectives of the lesson which are clearly set out.	28	66	6	0	0	4.2	0.54
16.2	I find good reasons for the inclusion of each page – the reasons are obvious to me.	25	44	28	3	0	3.9	0.80
17	***Effectiveness of collaborative learning***							
17.1	Activities are experienced encouraging collaborative learning in several different ways e.g. during a discussion on the forum.	16	63	19	3	0	3.9	0.68
17.2	I find the discussion forum is fun and encourages me to join in	28	28	38	6	0	3.8	0.93
17.3	I find the chat room feature interesting as it offers me chances to share information with other learners	38	34	22	6	0	4.0	0.92
18	***Cognitive error recognition, diagnosis and recovery***							
18.1	The application offers me opportunity to work on problems	25	53	16	6	0	4.0	0.81
18.2	I am able to learn from any mistakes I make using this application by for example looking up definitions in the glossary	28	56	16	0	0	4.1	0.65
18.3	Help is provided to help me recover when I made errors filling in the quiz	25	38	19	9	9	3.6	1.22
19	***Feedback, guidance and assessment***							
19.1	I enjoy the concept of immediate feedback and assessment on progress	63	22	16	0	0	4.5	0.75
19.2	I am guided when doing tasks and when improving knowledge	22	47	31	0	0	3.9	0.72
19.3	Instant feedback given after the quiz helps me correct my mistakes with immediate learning	31	25	34	3	6	3.7	1.12
	Mean Ratings (%)	**29.7**	**45.0**	**20.9**	**3.4**	**0.9**	**4.0**	

#	Category 4: m-Learning	5	4	3	2	1	Ave.	S.D.
20	***Mobile handheld devices and technology***							
20.1	I am aware that without advances in technology new ways of learning would not be possible.	69	22	3	6	0	4.5	0.8
20.2	I enjoy learning with the handheld device which has the all the capabilities I need to support mobile learning.	41	31	9	13	6	3.9	1.2
20.3	The mobile interface does not hamper me when I work with the application.	25	41	28	6	0	3.8	0.9
20.4	I have little difficulty inserting text and numbers.	41	25	13	19	3	3.8	1.2
20.5	I am using all aspects of the handheld device while learning from the application.	13	66	16	6	0	3.8	0.7
20.6	I am able to communicate socially with the mobile device and the application.	16	66	19	0	0	4.0	0.6
21	***Contextual factors(pragmatic)***							
21.1	I am aware of my physical surroundings but this does not interfere with the lesson experience.	16	72	6	6	0	4.0	0.7
21.2	While I explore the application, there is noise and audible interference is experienced.	9	31	9	41	9	2.9	1.2
21.3	I have worked with a smartphone already; this experience makes the exploration of the application easier.	41	34	16	9	0	4.1	1.0
21.4	My personal study needs have been considered as part of the application.	16	56	22	6	0	3.8	0.8
21.5	Learning goals have been built into the application – they are set.	16	69	13	3	0	4.0	0.6
21.6	When I use the application, I feel as if I am in a learning environment; the application feels and behaves like a normal learning environment.	13	44	22	19	3	3.4	1.0
21.7	I am aware of my surroundings during the lesson.	34	63	3	0	0	4.3	0.5
21.8	I find the learning experience to be rich and complex; I am not limited by the mobile device.	22	31	19	16	13	3.3	1.3
22	***User-centricity (pragmatic)***							
22.1	I feel my personal study approaches to learning have been considered.	25	59	9	6	0	4.0	0.8
22.2	With this type of study method, I am free to experiment and explore.	34	44	13	9	0	4.0	0.9
22.3	I see clearly what I am required to do.	16	59	22	3	0	3.9	0.7
22.4	I enjoy the feeling of independence the application offers – can look after myself.	31	50	6	13	0	4.0	0.9
22.5	This material represents my way of thinking in a clear manner.	25	50	22	3	0	4.0	0.8
22.6	I would be able to focus better; work longer stretches of time on problems in this way.	19	31	28	19	3	3.4	1.1
22.7	I could easily personalise this learning environment to suit my own needs.	19	34	25	19	3	3.5	1.1
22.8	I am aware of all content offered by the application.	22	53	19	6	0	3.9	0.8
22.9	I am able to customise this application environment to suit my own style.	9	28	41	22	0	3.3	0.9
22.10	I am actively involved in thinking and creating.	13	63	16	9	0	3.8	0.8

22.11	I can decide when and where I want to learn with this application.	44	47	9	0	0	4.3	0.6
23	***Flexibility***							
23.1	This is a great way to gather information any time.	56	34	6	3	0	4.4	0.7
23.2	I am free to adjust my learning environment- I can see the merit in this.	28	53	16	0	3	4.0	0.8
23.3	The way I see things – I can study the lesson in any order I choose.	31	63	6	0	0	4.3	0.6
23.4	The application can be personalised and Customised the way I want it to be.	6	34	50	9	0	3.4	0.7
23.5	I can use the system anytime and anywhere.	50	47	0	3	0	4.4	0.7
24	***Interactivity***							
24.1	I am able to move exactly where I want in this application.	44	38	16	3	0	4.2	0.8
24.2	I enjoyed the multimedia components which are appropriate for the subject content.	13	53	25	9	0	3.7	0.8
24.3	It is great that so many different kinds of exercise options have been provided.	22	56	13	9	0	3.9	0.8
24.4	Synchronous communication is possible via the chat room.	16	53	25	3	3	3.8	0.9
24.5	The discussion forum makes synchronous communication possible.	22	59	16	3	0	4.0	0.7
24.6	Interaction happens in varying ways.	28	50	19	3	0	4.0	0.8
24.7	I am able to smoothly connect to and participate with the application.	22	56	13	9	0	3.9	0.8
24.8	I am supported when I try to interact with the application.	16	50	25	9	0	3.7	0.8
24.9	I experience multiple creative ways of interacting with the application.	19	50	22	9	0	3.8	0.9
	Mean Ratings (%)	**25.6**	**47.8**	**16.8**	**8.6**	**1.2**	**3.9**	

#	Category 5: UX	5	4	3	2	1	Ave.	S.D.
25	***Emotional issues***							
25.1	The lesson format is fun – it motivates me.	13	66	19	3	0	3.9	0.6
25.2	I feel encouraged to stay focused for longer.	19	34	25	22	0	3.5	1.0
25.3	I enjoy sharing lesson information with other learners.	19	47	25	9	0	3.8	0.9
25.4	I appreciate the opportunity to use technology and my mobile handheld device to learn.	53	34	6	6	0	4.3	0.9
25.5	I feel enthusiastic, studying software engineering in this way.	34	47	3	13	3	4.0	1.1
26	***Contextual factors (hedonic)***							
26.1	It's a pleasure for me to use my phone to do things I know already about mobile technology.	41	50	0	3	6	4.2	1.0
26.2	It is convenient for me to look up information on my mobile handheld device whenever I like.	47	47	0	0	6	4.3	1.0
27	***User-centricity (hedonic)***							
27.1	I appreciate that the application allows me to have a personal learning experience.	38	56	3	3	0	4.3	0.7

27.2	I am able to change my learning environment to suit my needs.	22	50	16	13	0	3.8	0.9
28	***Social value***							
28.1	I feel totally at home using social networking tools to share course information.	31	47	16	3	3	4.0	0.9
28.2	I like the opportunity to interact with other learners immediately or when I choose.	34	59	6	0	0	4.3	0.6
29	***Needs***							
29.1	The application encourages me to express myself whilst learning.	22	47	25	6	0	3.8	0.8
29.2	I find that the stimulating mobile environment suits me.	16	38	31	13	3	3.5	1.0
29.3	I am safe and secure while I interact with the application.	38	50	9	3	0	4.2	0.7
30	***Appeal***							
30.1	I find the mobile handheld device way of communicating course material appealing.	31	50	6	6	6	3.9	1.1
30.2	I enjoy the opportunity to explore, learning on my own when I need to.	31	50	9	9	0	4.0	0.9
30.3	I love the visual aspects of a mobile learning environment.	34	41	13	13	0	4.0	1.0
31	***Satisfaction***							
31.1	I am satisfied by the opportunity to learn in this way.	38	34	22	3	3	4.0	1.0
31.2	I am motivated by mobile learning via my mobile handheld device.	22	41	22	13	3	3.7	1.0
31.3	I am satisfied with the results I achieve.	22	53	16	6	3	3.8	0.9
31.4	I am encouraged to explore the course material.	19	66	13	3	0	4.0	0.7
	Mean Ratings (%)	**29.6**	**47.9**	**13.5**	**7.1**	**1.8**	**4.0**	

C-2.2 Problems Reported by Learners

#	Category 1: General Interface Usability	*f*	%	Theme	Design Guidelines
1	***Visibility of system status, provide feedback***	**6**			
	1.15. Mobile phone network issues, long loading time. 1.16. Nothing really, cellphone was just a bit small. 1.17. Some content did not load correctly, not sure if it was my connection. 1.18. It isn't available for my phone and Internet version does have all the options.	4	12.5	Device Constraints	Mobile Specifications
	1.19. There is no quiz for Topic 1. 1.20. I couldn't see the quiz.	2	6.3	Assessment	VLEs
	1.21. To me the navigation is confusing at most times. 1.22. Could not find or read some of the apps. 1.23. I find navigation to be confusing at times. 1.24. Seems like you are going in circles sometimes.	4	9.4	Navigation	Ease of Use
	1.25. Identified that the modules were from 2011.	1	3.1	Design	Design and Development
	1.26. A bit busy at times.	1	3.1	Look and Feel	Design and Development
	1.27. I don't understand some of the feedbac.k 1.28. Sometimes I don't know if I can answer the question as I'm not sure if the application did what it was meant to do, otherwise, works very well.	2	6.3	Feedback	Ease of Use
2	***Match between system and the real world***	**5**			
	2.3. Some borders are broken. 2.4. Quiz takes me to the homepage.	2	6.3	Design	Design and Development
	2.5. I can access the same thing from more than one	3	9.4	Navigation	Ease of Use

	place on the Web, makes you have to decide which one to select. 2.6. Overall navigating site isn't natural. 2.7. One can easily choose the wrong module.				
	2.8. Slow loading.	1	3.1	Device Constraints	Mobile Specifications
	2.9. Icons can be confusing.	1	3.1	Look and Feel	Design and Development
	2.10. Viewing blog is too complicated.	1	3.1	Social Networking	Web 2.0 Tools
3	***Learner control***	**2**			
	3.1. Found I couldn't undo my mistakes. 3.2. No problems come up because I just press the red reset button. 3.3. Never saw undo or redo. 3.4. For some sections like the forum the functions of Redo/Undo are hidden. 3.5. Could not exit.	5	15.6	Errors	Ease of Use
	3.6. Tried to go to the home page several times, but not able to.	1	3.1	Navigation	Ease of Use
4	***Consistency and adherence to standards***	**3**			
	4.3. Finding items in the application was harder. Grouping items could be better. 4.4. It could be more close to PC system standards. 4.5. Items on the application were hard to find, they can be grouped together so that it can work.	3	9.4	Design	Design and Development
	4.6. They could have done better with the GUI.	1	3.1	Look and Feel	Design and Development
	4.7. It's a mobile phone which at times limited my navigation unlike a normal PC.	1	3.1	Device Constraints	Mobile Specifications
5	***Error prevention, in particular, prevention of peripheral usability-related errors***	**2**			
	5.1. I did make a mistake by clicking on the wrong stuff but I did not get an error message. 5.2. Login - when wrong username is put in, system must give a notification.	2	6.3	Errors	Ease of Use
	5.3. Was not able to access some content.	1	3.1	Device Constraints	Mobile Specifications
6	***Recognition rather than recall, memory use***	**4**			
	5.1. It is hard to view some of the icons without zooming in at times. 5.2. Text was not easy to view. I had to zoom a lot. 5.3. Problem: to enter text or click a button, had to zoom in a few times before doing the action I wanted.	3	9.4	Navigation	Ease of Use
	5.4. Page loads a lot of data. Can cost a lot of money in the end.	1	3.1	Device Constraints	Mobile Specifications
	5.5. Could not find the blog or enter it 5.6. Pages use quite a bit of data	2	6.3	Design	Content
	5.7. The screen layout is a little bit complicated	1	3.1	Look and Feel	Design and Development
7	***Aesthetics and minimalism in design***	**2**			
	7.1. It needs to be a bit more colourful, is bland.	1	3.1	Look and Feel	Design and Development
	7.2. They should strongly concentrate more on the content. 7.3. Info on Homepage is too long. 7.4. There were links everywhere on the other pages. 7.5. Too much information at times. 7.6. There were too many icons.	5	15.6	Design	Design and Development
8	***Recognition, diagnosis and recovery from errors***	**1**			
	9.1. I played through the program but did not find an error message. 9.2. Did not get an error message. 9.3. Hardly any error messages. 9.4. I didn't get error messages. 9.5. When I tried to log in I entered a password and it did not work. 9.6. When I tried to view a video it didn't throw an error message to say the video is not available. 9.7. I never experienced an error message within the blog.	8	25	Error	Ease of Use

	9.8. The error messages in particular weren't reliable.				
9	***Help and documentation***	**2**			
	9.1. I did not see the help function. 9.2. I could find any help facilities. 9.3. The "Help" is not that easy to understand. 9.4. I couldn't find help in relation to the problems I was having in the application. 9.5. Never found or saw a help function, sorry.	5	15.6	Help	Ease of Use
	9.6. Not all links work 100%.	1	3.1	Design	Design and Development
	Total Number of Problems Reported by Learners	**27**			

#	Category 2: Website-specific Usability Problems	*f*	%	Theme	Design Guidelines
10	***Simplicity of site navigation, organisation and structure***	**3**			
	10.1. I followed the links to my desired route, but on my cellphone I have to scroll a lot. Might be because it is old. 10.2. It is not easy using the mobile on this.	1	3.1	Device Constraints	Mobile Specifications
	10.3. Lots of scrolling to do	1	3.1	Navigation	Ease of Use
	10.4. There are too many pages, making it difficult finding something specific. 10.5. Instead of using "Start" use "Home". 10.6. Once I entered the menu I was not able to exit it. 10.7. The links on top are redundant and takes you to the same page. I'd recommend activities stay the same and outline has the latest posts/updated posts. 10.8. Get to forum quickly. 10.9. The problem may not be scrolling but maybe too much information in one place.	6	18.8	Design	Design and Development
11	***Relevance of site content to the learner and the learning process, content meaningful to domain and learner***	**1**			
	11.1. They don't show at all what's copyrighted. 11.2. It does not show which material are copyrighted on the mobile.	2	6.3	Design	Design and Development
12	***Easy to access information***	**3**			
	12.1. Site does not provide full capability to all phones. 12.2. I only was able to download the video, but couldn't access the quiz. 12.3. My cellphone had problems with download. 12.4. My phone had compatibility issues regarding the quiz. 12.5. My phone had compatibility issues - to the quiz. 12.6. My phone won't open a PDF. 12.7. I can download additional content, but my device doesn't support PDF. Can't view it. 12.8. Video does not play on LG KP 500, phone cannot display content. 12.9. There are delays getting through the links.	9	28.1	Device Constraints	Mobile Specifications
	12.10. The video doesn't want to open. 12.11. I could view the video, but not play it. 12.12. Couldn't download. 12.13. The video had difficulty opening. 12.14. Did not load. 12.15. Video does not open. 12.16. I couldn't find the videos. 12.17. Video didn't work. 12.18. Video didn't open at all.	9	28.1	Media	VLEs
	12.19. The link for PMI is currently unavailable, should be removed till site is up.	1	3.1	Design	Design and Development
13	***Content is both suitable and of a high quality***	**0**			
	Nil				
14	***System is simple and easy to use, called easiness***	**3**			
	14.1. My phone crashed a lot going back and forward. I	1	3.1	Device	Mobile

	think it is my phone, not the program.			Constraints	Specifications
	14.2. WWW.pmi.org takes too long to open.	1	3.1	Design	Design and Development
	14.3. I found it easier to just go back to the start than pressing the back button. 14.4. Once you have opened another link, it is difficult to go back.	2	6.3	Navigation	Ease of Use
15	***Material is of a high quality i.e. videos and digitisation***	**2**			
	15.1. Video not in a format to view from my phone. 15.2. Visibility is a problem, phone has a small screen. 15.3. Takes too long to load. 15.4. I had difficulty viewing some digital material.	3	9.4	Device Constraints	Mobile Specifications
	15.5. The higher the video quality, the less the people will watch it due to data usage.	1	3.1	Media	VLEs
	Total Number of Problems Reported by Learners	**12**			

#	Category 3: Pedagogical Usability Problems	*f*	%	Theme	Design Guidelines
16	***Clarity of goals, objectives and outcomes***	**2**			
	16.1. Still needs to be clearer. 16.2. Some unnecessary steps e.g. clicking glossaries takes me to a random page where I have to click again - why not take me right there?	2	6.3	Design	Design and Development
	16.3. Not all goals were clear enough to understand on the mobile.	1	3.1	Device Constraints	Mobile Specifications
17	***Effectiveness of collaborative learning***	**3**			
	17.1. I couldn't find the way to take part in the chat room or the Wiki page.	1	3.1	Social Networking: Wiki	Web 2.0 Tools
	17.2. Chat room seems flat. 17.3. Chat room needs improvement. 17.4. Chat didn't work. 17.5. Make it an IM type chat.	4	12.5	Social Networking: Chat	Web 2.0 Tools
	17.6. Usually you want immediate responses, instead of making a thread and waiting. 17.7. There is a lack of users in the forum. 17.8. Could not enter the discussion forum.	3	9.4	Social Networking: Forum	Web 2.0 Tools
18	***Cognitive error recognition, diagnosis and recovery strategies for the cognitive error recognition, diagnosis and recovery cycle***	**1**			
	18.1. Couldn't view quiz. 18.2. No quiz for Topic 1. 18.3. No questions in the quiz, it's easy using the glossary. 18.4. Could not access the quiz. 18.5. Never got to do quiz. 18.6. Cannot do the quiz at all. 18.7. Could not do quiz. 18.8. I could not get to the quiz. 18.9. Did the quiz have questions, mine was blank.	9	28.1	Assessment	VLEs
19	***Feedback, guidance and assessment***	**2**			
	19.1. I received no guidance whilst improving knowledge.	1	3.1	Feedback	Ease of Use
	19.2. Couldn't view quiz. 19.3. The quiz did not work on my phone. 19.4. The quiz was not working on my phone. 19.5. Could not do the quiz - kept taking me back to start page.	4	12.5	Assessment	VLEs
	Total Number of Problems Reported by Learners	**8**			

#	Category 4: m-Learning Usability Problems	*f*	%	Theme	Design Guidelines
20	***Mobile phones and technology***	**1**			
	20.1. It is sometimes difficult to insert numbers. 20.2. I'm not sure if I could learn from the device long-term.	8	25	Device Constraints	Mobile Specifications

	20.3. Not a big fan of mobile technology as I don't usually need it. 20.4. Application needs to be made for Nokia E7 and Symbian Belle. 20.5. Screen size is too small, compared to the freedom of a PC screen. The label to insert text is too small. 20.6. The phone screen is too small, this will work much better on a tablet. 20.7. I find that on the tablet the site isn't adapted to the device. Textboxes and buttons are small and I can't use the device's unique navigation options (pinch, multi-touch). 20.8. I need to get a new phone, I found m-learning quite miserable.				
21	***Contextual factors (pragmatic)***	**2**			
	21.1. Useful only when you do not have access to computer. 21.2. Personally it's easier to work on a computer screen. 21.3. I don't think I would study using my phone in an ordinary environment when studying.	3	9.4	Device Constraints	Mobile Specifications
	21.4. I think I am more suited to traditional way of studying but nevertheless I need to get with the times.	1	3.1	Pedagogy	VLEs
22	***User-centricity (pragmatic)***	**1**			
	22.1. I won't be using the device long-term, because I find it difficult to work on such a small screen. 22.2. It would be much easier to work on a PC.	2	6.3	Device Constraints	Mobile Specifications
23	***Flexibility***	**1**			
	23.1. Cellphone is not always fast enough to use the application everywhere. 23.2. Only where there is a signal.	2	6.3	Device Constraints	Mobile Specifications
24	***Interactivity***	**3**			
	24.1. Connecting to real-time chat will always be issues for some people. 24.2. To make it more interactive make use of live Chat, this will be more interactive and better communication. 24.3. The chat experience isn't that great.	3	9.4	Social Networking: Chat	Web 2.0 Tools
	24.4. Not all content loaded. 24.5. I'm starting to get an error with mobile app.	2	6.3	Device Constraints	Mobile Specifications
	24.6. Took a while to find my way - blog entry	1	3.1	Social Networking: Blog	Web 2.0 Tools
	Total Number of Problems Reported by Learners	**8**			

#	Category 5: UX Problems	*f*	%	Theme	Design Guidelines
25	***Emotional issues***	**1**			
	25.1. The phone is slow to use this application properly. 25.2. I would prefer studying software engineering from a PC. 25.3. The mass of information can be overwhelming. 25.4. Don't understand some things. 25.5. I had trouble. 25.6. The orders are difficult to follow. 25.7. Slow speed of loading was frustrating.	7	21.9	UX	Learner-centricity
26	***Contextual factors (hedonic)***	**1**			
	26.1. Not all content displays e.g. videos. 26.2. Phone is too old. 26.3. I am not at all that familiar with this "program"; which makes it difficult. 26.4. Distracting. 26.5. I easily get distracted. 26.6. I am open to the possibility - seeing how much I am around these devices.	6	18.8	UX	Learner-centricity
27	***User-centricity (hedonic)***	**1**			
	27.1. Did not see any form of customization options. 27.2. I did not see the customization part in the application. 27.3. I am not sure about my learning environment that	7	21.9	UX	Learner-centricity

	suits me yet. 27.4. Didn't feel completely or averagely in control. Wasn't intuitive enough to feel in command of the system. 27.5. Maybe if I became more proficient/used to the system it would seem more natural. 27.6. You could've given a much better experience. 27.7. Wouldn't be too bothered about customizing.				
28	***Social value***	**1**			
	28.1. I tried liking the page or broadcasting it via Twitter but I couldn't.	1	3.1	UX	Learner-centricity
29	***Needs***	**1**			
	29.1. Cannot use phone in certain "Ghetto areas". 29.2. It will suit me netter on a big screen. 29.3. I could get distracted depending on the environment and the notifications received on the device. 29.4. Unable to request additional information.	4	12.5	UX	Learner-centricity
30	***Appeal***	**1**			
	30.1. Not possible with a mobile device, with a PC - Yes. 30.2. It is easier and more accessible but prefer the PC. 30.3. Screen size limits the visual aspects. 30.4. Could have provided a richer learning experience. 30.5. In all honestly, m-learning without the right resources (equipment) is not nice! 30.6. Site too cluttered for me.	6	18.8	UX	Learner-centricity
31	***Satisfaction***	**1**			
	31.1. Phone freezes as exploring is not really for when your phone freezes. 31.2. It gets frustrating working from such a small screen, takes a lot of concentration. 31.3. It gets frustrating working from such a small screen, takes a lot of concentration. 31.4. Still got to stay focused on the task at hand and not get distracted.	4	12.5	UX	Learner-centricity
	Total Number of Problems Reported by Learners	**7**			

APPENDIX D: Conference Paper IDIA Turkey 2012

Title

Can mobile technology reduce the Digital Divide? A study in a South African tertiary education context

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Abstract

Undergraduate software engineering learners are often required to participate in problem-based learning (PBL) and team-based project work. Assessment of information communication and technology (ICT) project deliverables contributes a major portion of the course mark. Collaboration and communication are supported to some extent by mobile hand-held devices, yet are limited by the digital divide created from not all learners having access to smartphone devices and mobile Internet connectivity.

This study describes the findings of a mobile learning and digital divide (MLDD) survey undertaken by the primary researcher as part of an ICT4D 2.0 project. The survey investigated the nature and extent of the digital divide between software engineering learners on two Western Cape campuses of the same tertiary education institution. A survey questionnaire synthesised for this purpose was administered to 35 fulltime software engineering learners in March 2012. Survey findings indicate the nature and extent of the digital divide between learners enrolled for the same course on the same campus and between learners at the two different campuses.

Although survey findings indicate positive learner attitudes to and perception of an m-learning solution to the digital divide, challenges associated with extending a face-to-face classroom experience to a blended mobile technology environment materialised. Study results indicate that whilst mobile technology does offer digital divide reduction

opportunities, mobile technology implementation in itself could result in a paradoxical mobile technology digital divide.

Keywords
Digital divide, ICT4D 2.0, m-Learning, Mobile hand-held devices, Mobile technology, Problem-based learning (PBL), Software engineering

Introduction

For undergraduate learners studying software engineering, teamwork in the form of collaborative projects and problem-based learning (PBL) in a social constructivist style are important components of the coursework. Projects are conducted jointly on laptop computers and individually from home-based personal computers (PCs), being supported partially by mobile hand-held devices. The primary researcher, who is an academic at a private, international university with campuses in South Africa, teaches courses in software engineering (SE) and knowledge management on two of these campuses, termed C1 and C2, which are situated in different parts of the city of Cape Town.

As teams of software engineering learners worked on their collaborative projects, she encountered an anomaly in the differences between the approaches of learners on the two different campuses. Certain learners who had limited or no Internet access at home, and who could be viewed as being restricted by the digital divide, more readily conducted Internet research using mobile hand-held devices, some of which were highly sophisticated technologies.

To investigate the situation further, she undertook a mobile learning and digital divide (MLDD) survey as part of an ICT4D 2.0 project. The aim was to determine the nature and extent of the digital divide between information technology (IT) learners on these two notably different campuses of the institution and to establish whether an m-learning application delivered by mobile hand-held devices could reduce this digital divide.

SE Tertiary Education and PBL

Although some face-to-face academic content was provided during twelve classroom-based SE lectures, examination of the theoretical part of the course contributed minimally to the final assessment. The major assessment portion comprised four project deliverables associated with one real-world software development project per team, in keeping with a PBL strategy. This approach aims to prepare the learner for the real world of the business workplace and thus required a demonstration and evaluation of

individual, technical programming as well as team work, leadership skills and time management strategies.

Internet Connectivity

The demographically-diverse classes on the two different campuses (C1 and C2) provided an opportunity to explore the digital divide between Internet-deprived learners (C1) and Internet-wealthy learners (C2). Whilst C1 classes comprised both South African and international learners, the learner body at C2 consisted only of South African learners from backgrounds that were apparently more affluent. C1 learners had limited on-campus Internet access and PC laboratory facilities, whilst C2 learners had an Internet-enabled PC laboratory dedicated to their studies. A wireless network was also installed at C2.

The university has recognised the major influence of the digital era on education, acknowledging the positive impact of Web 2.0 social networking tools such as Facebook. In a pilot study, the potential is currently being investigated of electronic delivery of digital textbooks to all learners via tablets.

In order to implement this project, several issues have been considered including the provision of mobile hand-held devices to learners and the need for affordable, effective and safe Internet connectivity via an on-campus wireless network. Success of such a project would be dependent on positive attitudes on the part of learners.

The next section considers the work of other researchers in relation to SE tertiary education and PBL, the digital divide and ICT4D 2.0, Internet connectivity and mobile technology contexts and, finally, mobile technology as a digital divide reduction factor. Various current trends contribute to overcoming the digital divide.

Related Literature

SE and PBL

Sommerville (2011) defines SE as a two-fold domain involving both the engineering discipline and software production activities with tools, techniques and methods aimed at the development of high quality products. SE learners need to demonstrate both technical and communication skills, whilst collaborating on complex, real-world projects. The ideal SE learner project requires software development abilities, and focuses on teamwork while motivating learner creativity (Shata, 2011). It also requires the development of metacognitive skills and the acquisition of planning and negotiation skills as if real problems are being solved (Sheppard, 2011).

Real-world situations are simulated through a PBL strategy. PBL originated within the Faculty of Medicine, McMaster University, Canada circa 1960 when Howard Barrows and associates, a group of young physicians, championed the PBL learning model (Barrows, 1996). PBL is characterised by the challenge of open-ended problems to be solved in collaborative groups, supported by a teacher who is more a facilitator and guide than an instructor (Hmelo-Silver and Barrows, 2006). Findings of Qiu and Chen (2010) indicate that learner collaboration on PBL projects produced a positive attitude to the relevance and interactivity for PBL project work.

Once in a real-world environment many of the SE graduates are likely to gain from first-hand undergraduate PBL experience and be simultaneously reminded of the challenges of the digital divide.

Digital Divide

The digital divide is a complex phenomenon. It is experienced by individuals, in teams, within and between diverse nations and across continents. It is a major global ICT issue. Mobile technology provides an opportunity to reduce the digital divide between developed and developing nations. ICT4D projects seek ways to reduce this divide.

The digital divide can be described as the gap that emerges between those who are able to efficiently and effectively access digital information via the Internet and those who remain disadvantaged, either with poor access or no access to the global information society.

Hilbert (2011) highlights the complexity of a digital divide definition which should incorporate *people* (in this case, learners, teams, academic staff, campuses), their *characteristics* (age, culture, home languages), and *devices* (smartphones, laptops, netbooks, tablets), as well as *connectivity methods* (dial-up, ADSL, wireless, GSM, 3G) used.

National factors affect the prevalence of the digital divide. Typically, people from developed nations experience the impact of the digital divide to a lesser extent than citizens of developing nations. Digital technology constraints may include lagging infrastructure and power supply problems (Urien, 2011) as experienced by Nigerian citizens. In addition, urban and rural communities do not experience similar connectivity quality. For example, a particular form of digital divide is evident in Botswana where major regional disparities are reported (Oladokun and Aina, 2011).

According to Brown, Campbell and Ling (2011), the exponential proliferation of mobile phones has facilitated Internet connectivity “on-the-move” among US teenagers,

suggesting the emergence of a bridge across the digital divide. They indicate that young people in poorer communities seem more likely to spend their money on mobile technology. This introduces a paradox: poorer teenagers are prepared to, and do actually, pay more for connectivity than wealthier citizens.

A comparison of active mobile-broadband subscription trends for developed and developing countries throughout the world clearly illustrates a mobile phone digital divide (ITU World Telecommunications, 2012). Africa, with 3.79 subscriptions per 100 inhabitants, trails behind Europe and the Americas with 54.10 and 30.49 subscriptions per 100 inhabitants respectively. Although there is an increase in the uptake of mobile-broadband subscriptions in Africa, ITU statistics suggest that the gap is widening between developed and developing countries.

Researchers emphasize the role of education and the value, in an African context, of competence in digital skills and positive attitudes of both learners and teachers, as well as the importance of improving university education as a means of bridging the digital divide (Otuonye, 2011; Yusuf and Balogen, 2011). In a bid to uplift ICT education, educational initiatives in Africa aim to narrow the divide both for impoverished learner communities and for privileged learner groups adversely affected by digital divide (Oneya and Gitau, 2011). One such initiative named BADILIKO, which means “change” in Swahili, is being sponsored by Microsoft and the British Council (Yussif, 2012). The project will finance digital infrastructure and technology training across the African continent.

Similar ICT4D 2.0 projects aim to find digital ways to reduce the divide in developing countries, by incorporating aspects of Web 2.0.

ICT4D 2.0

According to Heeks (2006), ICT4D is a four-part research strategy comprising:

- **I** Information - library and information sciences;
- **C** Communication - communication studies;
- **T** Technologies - information systems;
- **D** Development - a link to development studies.

By incorporating Web 2.0 principles of co-operation and co-creation into ICT4D, a transformed ICT4D 2.0 model materialises (Heeks, 2009). Telecommunications and wireless technology application development can provide connectivity solutions for developing countries where participation in social networking sites (e.g. Facebook) and interactive communication exploit digital technologies. A shift has occurred towards user-centric ICT4D projects.

Foster (2011) refers to a “para-poor” participatory development strategy, where ICT4D work occurs side-by-side with poor communities to develop content and products that reduce the digital divide. The user is no longer viewed as passive, but rather as an active, empowered participant (Banerji and Basu, 2006; Maail, 2011).

The exponential growth of the mobile phone industry, mobile connectivity and user involvement in a mobile technology context, seem central to producing a solution to the digital divide.

Internet Connectivity and Mobile Technology Contexts

South Africa is regarded as a developing nation with inadequate mobile technology penetration levels and a lack of quality cost-effective mobile connectivity for a diverse user profiles and contexts. Development projects for Africa such as the netsurfer Touch - a cost-effective tablet device in South Africa, M-Pesa (mobile finance) in Kenya and the West African Cable System (WACS) are attempting to make a difference. Digital learning management systems could alleviate the digital divide in an African educational context; however, researchers provide cautionary advice concerning limitations.

The benefits arising from the rapid spread of mobile technologies in developing countries where the digital divide is prevalent, by far transcend telephonic communication, since many mobile devices also provide Internet connectivity and contribute to reducing disparities in access to the electronic society (Duncombe, 2012).

Penetration levels for certain African countries are as follows: Nigeria (2.70%), Kenya (3.27%), Botswana (10.56%), Egypt (13.23%) and South Africa (9.42%), while the figure

for Africa as a whole is 4.28%. A comparison of these levels with Europe (28.55%) and North America (44.04%) shows that Africa is far behind. The 9.42% for South Africa, where the present study is situated is one of the highest in Africa and, by implication, indicates awareness and use of Facebook among South African youth (*Facebook Statistics by Continent*, 2012).

South Africa is classified as one of the developing nations of Africa. South Africans experience Internet connectivity restrictions that include:

- Expensive and limited bandwidth;
- Poor quality connectivity and slow download speeds.

These factors differentiate users who are able to connect (albeit with difficulty) from users who are truly digitally disadvantaged. Various initiatives to alleviate the divide are now briefly addressed.

Ho, Smyth, Kam and Dearden (2009) discuss a mobile barrier comprising the prohibitive cost of affordable computing, together with the challenge of cross-cultural design to accommodate various environments and users.

Figure 1: netsurfer TOUCH

Figure 1 shows a cost-effective tablet solution for varied contexts and user characteristics. The device, called the netsurfer TOUCH (Future Mobile Technology, 2012) is assembled locally in South Africa. It offers mobile Android Internet connectivity and reaches out to the digital 'have-nots' within communities who might not be able to afford tablet (e.g. the Apple iPad) or laptop technology. This attempt to bridge the digital divide supports the view of Peña-López (2012) who suggests that ICT4D now represents a convergence of social sciences (affordable Internet connectivity for impoverished citizens) and digital technology (implementation of ICT4D methods and techniques).

Over a five year period Kenya's M-Pesa mobile money has reached more than 15 million "unbanked" citizens out of a total population of 40 Million Kenyans. Money transactions via mobile devices have become a highly effective mobile banking concept. M-Pesa is the product of a Vodafone-Safaricom ICT4D partnership. The project initially focused on urban workers who wanted to send money home to families in rural communities. The success of M-Pesa has been accredited to low transaction costs, people-contact rather than faceless bank interactions, and the support of an extensive distribution of networked

agents. M-Pesa, which targets mobile subscribers without banking facilities, has grown exponentially (Mutuku, 2012) in parallel to mobile technology.

The West African Cable System (WACS) rollout was launched in May 2012. WACS will comprise submarine fibre optic cable, providing enhanced bandwidth for various West African countries including South Africa, Namibia, Togo, Nigeria and DRC linking Western Africa and European digital technology. WACS aims to improve data transfer speeds and capacity and to introduce competitive tariffs for Internet connectivity in Africa (Tredger, 2012). An opportunity to deliver an improved service to Africa will likely improve connectivity costs.

Whilst digital learning management systems may be regarded as a solution within Africa, researchers highlight limitations such as infrastructural issues and a lack of trained educators, equipped to promote, utilise and manage these systems (Unwin, Kleessen, Hollow, Williams, Oloo, Alwala, Mutimucuio, Eduardo and Muianga, 2010).

Research Design and Methodology

Research Questions

The purpose of the mobile learning and digital divide (MLDD) survey was to determine the nature and extent of the digital divide among third-year undergraduate learners enrolled for software engineering on two different Western Cape campuses. In addition, the study aimed to investigate whether an m-learning environment, as part of the course context, could contribute to reducing the digital divide. The research questions are:

1. What is the nature and extent of the digital divide between IT learners on two campuses in the same city and of the same university?
2. Can an m-learning application delivered by mobile hand-held devices reduce the digital divide?

Research Design

This study forms part of a longitudinal design-based research project. A design-based research strategy is iterative and focuses on solving real problems, whilst looking towards future solutions. An important part of this research process is understanding the inherent digital divide between learners.

The interpretive research design of the project involved the development of a custom-built m-learning environment, which evolved via an iterative design-development-evaluation approach. Following an initial design-and-research iteration, the need emerged for a specifically designed MLDD survey to explore mobile technology aspects associated with learner profiles. The findings of this survey will inform and influence the

next iteration. The survey involved mixed-method data collection and analysis, using a questionnaire comprising formal quantitative and qualitative questions, as well as informal qualitative post-questionnaire interviews.

Participants

Using a non-probabilistic sample of convenience (Oates, 2008), the researcher surveyed 35 learners out of a total of 37 enrolled for the same final-year SE course at two different campuses, as part of a BSc in Computer Studies. Two learners, who were absent on the day of the survey, could not participate. All the learners were members of campus-specific teams of four to seven members randomly assigned to collaborative groups, which undertake team-based SE projects over a ten-month period. There were two cohorts of participants from the two campuses respectively:

- Cohort 1: Thirteen (13) participants from Campus 1
- Cohort 2: Twenty two (22) participants from Campus 2.

For ease of reference, Cohort 1 is termed C1, in line with the Campus 1 institution and Cohort 2 is termed C2.

Table 1 provides a breakdown of the sample.

Table 1: Software engineering learners at two campuses, C1 and C2, in the Western Cape

	C1		C2	
Students	#	%	#	%
Males	7	53.8%	22	91.7%
Females	6	46.2%	0	0%
Absentees	0	0%	2	8.3%
Total	13	100%	24	100%
Nationalities	South African, Namibian, Angolan, Ghanaian		South African	
Home Languages	English, Afrikaans, Xhosa, Tswana, Portuguese		English, Afrikaans, Xhosa	
Mode of Transport (%)	Bus (30.8), Own car (15.4), Taxi (7.7), Walking (23.1), Bicycle (7.7), Lift (7.7), Train (7.7)		Bus(0), Own car (72.7), Taxi (4.5), Walking (0), Bicycle(0), Lift(13.6), Train(9.2)	

This sample comprised 10.5% of the institution's national total of 324 learners taking the same SE course in the same semester across twelve campuses of the institution. The findings in Table 1 provided the first proof that a digital divide exists between the two cohorts.

Although course content and structure is identical, learners at the two campuses are demographically, culturally and financially heterogeneous. For example, in C1 only 15.4% of learners used their own car for transport to campus, whereas in C2 there was a

high percentage of 72.7% using their own car. Conversely, 23.1% of C1 learners walked to campus and 7.7% rode a bike, while no C2 learners walked or rode by bike. Similarly, almost 50% of C1 learners used public transport, while less than 15% of C2 learners did. Furthermore, C1 included a greater range of ethnic and regional groupings than C2.

Approach

The questionnaire survey was designed with the digital technology learner in mind (Horrigan, 2010). In line with Olivier (2009), ethical consent was acquired, and confidentiality and anonymity were ensured. The questionnaire was administered in printed form, with qualitative and quantitative data in a single instrument. Respondents on both campuses completed it in approximately ten minutes, as part of a mandatory lesson on evaluating software applications.

Data Collection and Analysis

In order to evaluate the nature and extent of the digital divide on the two campuses, the MLDD questionnaire gathered data in six categories, together with attitudes to, and perception of, the potential of mobile technology to reduce the digital divide:

- General personal information;
- Mobile phone usage data;
- Personal mobile hand-held device feelings and attitudes;
- Mobile technology and the SE module;
- Internet access;
- User experience.

Findings and Discussion

The survey elicited quantitative and qualitative data, which is shown in both tabular and graphical formats. Firstly, quantitative data is presented, relating to brands, usage and location of use, Internet connectivity factors and learner attitudes to a mobile technology strategy. Secondly, the qualitative data is presented.

Quantitative Findings

Mobile Phone Brands, Usage Location and Mobile Phone Activities

Learners reported owning a variety of mobile phone brands, which they used in various locations. They also indicated the activities most often performed via these phones.

Figures 2 and 3 respectively provide information that compares the mobile phone brands used by C1 and C2 learners and that shows where they use their m-phones. Figure 4 illustrates the activities performed by learners on their mobile phones (m-phones).

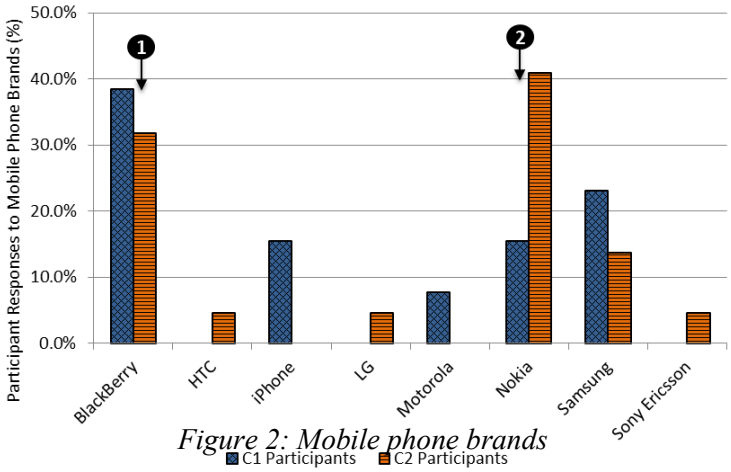


Figure 2: Mobile phone brands

Figure 2 illustrates the m-phone brand choices of C1 and C2 learners. Key differences are noted for BlackBerry and Nokia.

❶ C1 learners (38.5%) have a stronger BlackBerry culture than C2 learners (31.8%), reflecting the greater appeal to C1 of the almost-free Internet connectivity offered by BlackBerry. Three C1 learners used iPad tablets regularly, in addition to their smartphones. However, no use of tablets was reported by C2 learners.

❷ On the contrary, more C2 learners (40.9%) used Nokia devices than C1 learners (15.4%). C2 learners indicated they did not need free Internet, and preferred to use a phone brand that is popular among their peers.

Learners used their mobile phones in various places. Figure 3 reflects these locations.

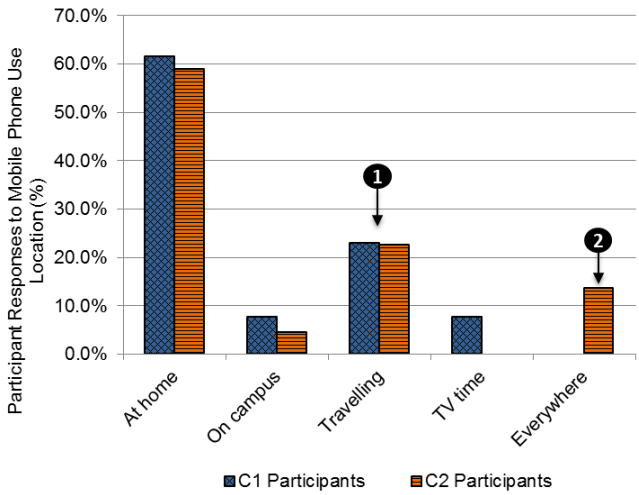


Figure 3: Location of mobile phone usage

❶ C1 learners (23.1%) and C2 learners (22.7%) used their phones to similar extents whilst travelling to and from campus, although C1 learners travelled greater distances and for longer periods. The similarity between the two sets of results reflects the characteristic nature of university learners, who tend to use their phones on an ongoing basis.

❷ However, 13.6% of C2 learners claim they use their phones everywhere, compared with no C1 learners. This is likely due to the issue of security. In a follow-up discussion after questionnaire completion, C1 learners verbally mentioned the risks of using technology on public transport. The mobile device is a precious commodity and, if stolen, is not easily replaceable.

Figure 4 shows a range of activities performed by learners on their mobile devices. Activities include calls, SMS's (text messages), Internet browsing, banking, photo sharing, listening to music, music downloads, music sharing, video downloads, watching videos, podcast downloads, podcast watching, Facebook, Twitter, MXit, mobile education, study notes, research and games. Four activities from Figure 4 have been selected for further discussion, namely: Banking, Facebook, MXit and a combination of Mobile Education, Study Notes and Research.

❶ *Banking*: Mobile handheld devices are used more regularly and readily by C1 learners (69.2%) for banking than C2 learners (22.7%). This pattern strongly differentiates the more cosmopolitan culture of C1 learners from the culture of the purely South African C2 learners, who are more likely to have uncapped ADSL at home or who use their own transport to get banking done.

❷ *Facebook*: C1 learners (92.3%) show a greater propensity for Facebook use via m-phone and are more receptive to social networking sites via mobile devices than C2 learners (63.6%). This difference suggests the likelihood that C1 learners would more easily adapt to a Web 2.0 context, regarding mobile technology as an important way of staying in touch.

❸ *MXit*: Greater use is made of the free messenger application MXit by C2 learners (59.1%) than by C1 (30.8%). This is in line with the findings that fewer C2 learners use BlackBerry smartphones. As stated previously, BlackBerries have certain associated free communication facilities. In order to communicate at no cost, C1 learners therefore need to make use of MXit.

❹ *Mobile Education, Study Notes and Research*: Mobile education, study notes on mobile devices, and research via mobile Internet are more common among C1 learners (38.5%, 69.2%, 76.9 % respectively) than C2 (13.6%, 31.8% and 18.2% respectively).

This supports the notion that m-learning would be more relevant for, and acceptable to, C1 learners.

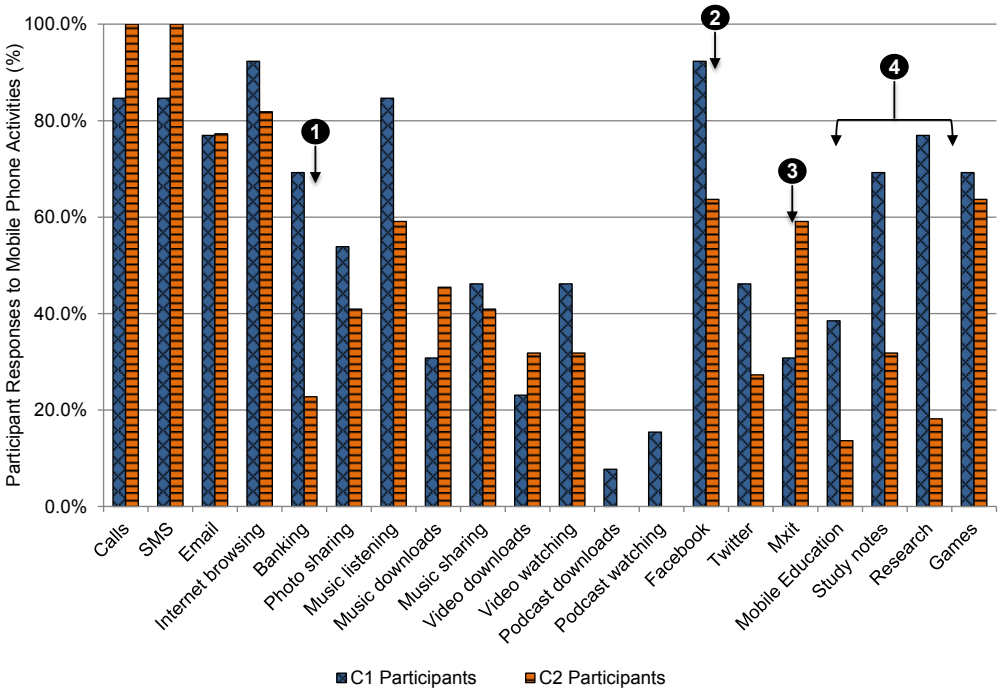


Figure 4: Mobile phone activities

In summary, C1 learners are Web 2.0 savvy and, due to the digital divide they experience on a daily basis, have developed mobile coping mechanisms based on the use of their phones. On the other hand, C2 learners prefer to send SMS's and make calls with their phones because, for Internet connectivity, they have other options.

C1 learners would probably find it fairly easy to adapt to an official m-learning strategy, while C2 learners would likely need to be persuaded to take ownership of the concept. C1 learners, with their limited financial resources, have learned to do Internet research on their mobile phones. In contrast, the phone brands and activities chosen by C2 learners show that they regard m-phones primarily as a means of communication.

Internet Connectivity Factors

In the cases where learners use PC's in the university laboratories, several factors contribute to an inability to perform optimally. When performing SE research activities on campus, they encounter issues such as connection problems; buffering whilst watching videos; blocked video, audio, podcast and software downloads; problematic availability of PC's in the lab; and limited access to a campus wireless network. Figure 5 illustrates

participants' perceptions of digital divide restrictions that resulted, not from the divide as such, but from policies regarding on-campus usage of Internet and limitations on the research activities undertaken by SE learners. The percentages show the percentage of learners in each cohort who perceived that issue as a problem.

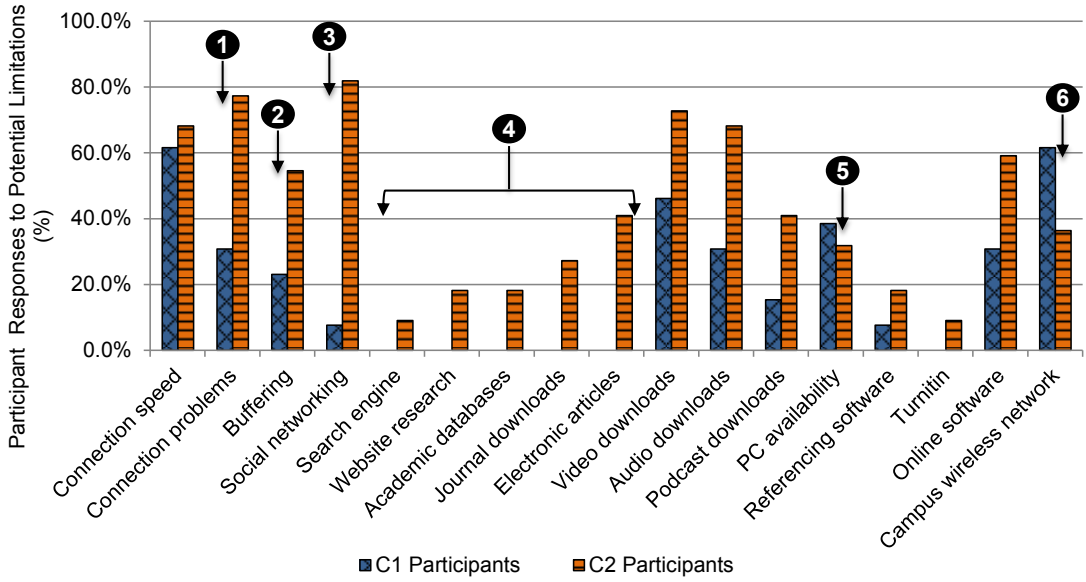


Figure 5: Learner perception of on-campus digital limitations that could hamper SE research

Six limitation categories have been selected for further discussion.

❶ *Connection problems*: The campus network is intermittently disrupted. C2 learners complain about this to a greater extent (77.3%) than C1 learners (30.8%). This is easily explained. C1 learners seldom use the on-campus facilities, whilst C2 learners have a dedicated PC lab for third year learners.

❷ *Buffering*: This problem has a similar explanation. The lecturer downloads all lecture material onto a USB and transfers it to a PC in the lab from which learners copy it to their own USB drives, so that they are not disadvantaged by buffering problems. Although C2 had the better network, those learners complained more (54.5%) than C1 (23.1%).

❸ *Social networking*: Some C1 learners innovatively organised their own internal social networking system, by setting up a group. C2 learners (82.8%) complained that the campus does not provide this option, versus only (7.7%) of C1 learners who experienced this as an on-campus limitation.

❹ *Search engine, Website research, Academic databases, Journal downloads and Electronic articles*: These issues relate to using the Internet for research to acquire deeper insight into course content, due to the lack of university libraries. C1 participants

did not report limitations, whereas a number of C2 participants did: search engines (9.1%); website research (18.2%); academic databases (8.2%); journal downloads (27.3%) and electronic articles(40.9%). This is certainly the opposite of what might have been expected, as C1 facilities do not match those at C2. However, the researcher knows that C1 learners spontaneously use their mobile devices to Google for information, because they are accustomed to poor Internet access on campus and had no expectations in this regard. From the researcher's observation, C2 learners seldom use Google for academic information.

❺ *PC availability*: C1 learners (38.5%) found PC availability more of a limitation than C2 learners (31.8%). This is understandable due to the availability on C2 of a dedicated, fully-equipped PC laboratory with both wired and wireless Internet connectivity. Contrarily, C1 learners have limited access to PCs, relying instead on personal mobile devices for their software engineering studies.

❻ *Campus wireless network*: C1 learners (61.5%) complained about not having a wireless network option. However, some C2 learners have been able to access the campus wireless network, resulting in fewer complaints (36.4%).

Mobile Internet Access

Table 2 compares the connectivity packages used by C1 and C2 and learners' estimates of monthly expenditure on mobile telephony. Table 3 summarises Internet access for C1 and C2 participants who have 3G and GSM access via their mobile phones. Similar levels were reported from C1 and C2 by those learners who had 3G and GSM connectivity.

Table 2: Type of mobile phone connectivity and associated monthly expenditure

	C1			C2			Overall		
Connectivity Package	#	%	Average Monthly Spend (ZAR)	#	%	Average Monthly Spend (ZAR)	#	%	Average Monthly Spend (ZAR)
Prep-paid	10	76.9	246.50	12	54.5	106.17	22	62.9	169.95
Contract	3	23.1	200.00	10	45.5	299.00	13	37.1	276.15
Totals	13	100.0	235.77	22	100.0	210.13	35	100.0	209.40

Table 3: Mobile phone Internet access via 3G and GSM

	C1		C2		Overall	
Internet Access	#	%	#	%	#	%
3G	9	69.2	12	54.5	21	60.0
GSM	10	76.9	12	54.5	22	62.9

Table 2 shows that more C1 learners invest in pre-paid connectivity (76.9%) than in contract connectivity (23.1%). By contrast, C2 learners report greater levels of contract connectivity (45.4%). The average monthly expenditures for C1 and C2 for pre-paid connectivity (ZAR 246.50 and ZAR 106.17, respectively) reflect the greater use made by C1 learners of their mobile phones for Internet access.

In summary, in order to beat the digital divide, C1 learners take the digital lead by investing time, money and energy on mobile Internet access, readily engaging in social networking, spending more of their money to stay connected. Contrarily, C2 learners suggest that connectivity via mobile phone is associated with telecommunication, rather than with access to Internet-based information. They expect the campus to provide the access that they require. The connectivity limitations reported by learners support these observations.

Learner Attitudes to a Mobile Technology Strategy

The survey included two sections in which learners' attitudes to mobile phones (Table 4 and Figure 6) and m-learning (Table 5 and Figure 7) were investigated. These sections were included to explore the perspective of learner users, whilst supporting a central tenet of the design-based research strategy, whereby real problems are solved and solutions are developed for the future (de Villiers, 2005).

Ten questions, each based on a five-point Likert scale where 1= Strongly Disagree, 2= Disagree, 3 = Unsure, 4 = Agree and 5 = Strongly Agree, were presented to participants. Six questions targeted learners' attitudes to the use of mobile phones, whilst four questions related to attitudes on the use of an m-learning environment.

Table 4 and Figure 6 present findings on attitudes to using mobile phones. Table 5 and Figure 7 depict attitudes to the use of an m-learning environment. In order to establish whether or not differences between observed Likert scale averages were significant, two-tail two-sample t-test analysis assuming unequal variances, was conducted for each question and for both sections.

Table 4: Likert scale averages of learner attitudes to the use of mobile phones

	Use of Mobile Phones	C1	C2	t-Values
Q1	Do you believe that the use of your mobile phone could support your studies?	3.9	3.2	**0.034***
Q2	Could mobile phone technologies provide support for course group activities?	4.2	2.8	**0.001***
Q3	Would you feel safe submitting quizzes and coursework by mobile phone?	3.6	3.3	0.381
Q4	Are you comfortable with lecturers contacting you by mobile phone?	4.2	3.3	**0.004***
Q5	Would you feel secure receiving SE exam results by mobile phone?	3.8	3.5	0.612
Q6	Would it be beneficial having study resources on your mobile phone?	4.1	3.8	0.548
	Averages: Use of Mobile Phones	4.0	3.3	**0.013***

* p < 0.05 – Mean differences between C1 and C2 are significant; these values are discussed further.

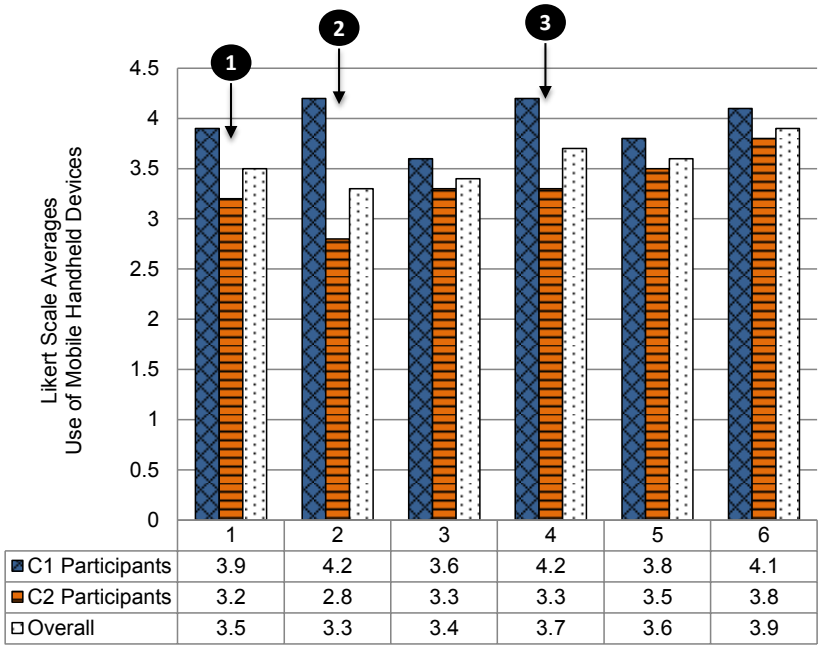


Figure 6: Learner attitudes to the use of mobile phones in the context of studying SE

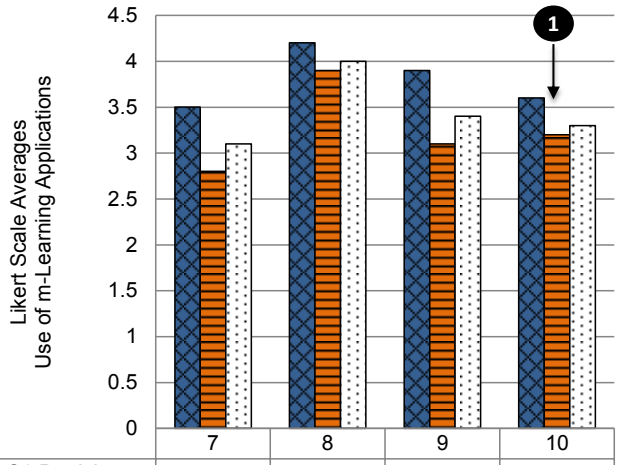
Average responses to Questions 1, 2 and 4 by C1 and C2 have been highlighted in Table 4 (red t-values) and Figure 6 (black arrow placement). The average Likert ratings are higher for C1 participants than for C2. In comparison with C2 learners, C1 learners strongly agree that: ❶ the use of the mobile phone could contribute to support for studies (3.9) and ❷ group activities (4.2) indicating ❸ comfort about lecturers making mobile phone contact (4.2).

The t-values of 0.034, 0.001 and 0.004 for these three questions respectively, indicate significant differences in attitude between C1 and C2, contributing to a significant overall t-value of 0.013 for the section.

Table 5: Likert scale averages for learner attitudes to the use of an m-learning environment

	Use of an m-Learning Environment	C1	C2	t-Values
Q7	Would m-learning motivate you to achieve improved results?	3.5	2.8	0.079
Q8	Are you willing to install a 3rd party m-learning application on your mobile phone?	4.2	3.9	0.348
Q9	Are you prepared to purchase a new mobile device for m-learning?	3.9	3.1	0.081
Q10	Could you improve overall course outcomes with an m-learning application?	3.6	3.2	**0.031***
	Averages: Use of an m-Learning Environment	3.8	3.2	**0.033***

* $p < 0.05$ – Mean differences between C1 and C2 are significant; these values are discussed further.



	7	8	9	10
C1 Participants	3.5	4.2	3.9	3.6
C2 Participants	2.8	3.9	3.1	3.2
Overall	3.1	4	3.4	3.3

Figure 7: Learner attitudes to mobile phones and m-learning in the context of studying SE

Average responses to Question 10 by C1 and C2 have been highlighted in Table 5 (red t-values) and Figure 7 (black arrow placement). The average Likert ratings are higher for C1 participants than for C2. Both C1 and C2 agree to some extent that: ❶ an m-learning application could improve course outcomes. A t-value of 0.031 indicates that a significant difference between C1 and C2 learner feedback exists for question ten.

In summary, C1 learners indicate overall positive attitudes to educational benefits that could be achieved via a mobile technology strategy, namely: support for studies (Q1); collaborative group activities (Q2); lecturer communication via mobile phone (Q4); and improved outcomes (Q10). Although C2 learners demonstrate a measure of positive attitude, t-values indicate that the difference in responses is likely to be significant and not due to chance.

Qualitative Findings

The survey elicited qualitative data as well. Qualitative textual information was gathered from participants in responses to three open-ended questions in the survey. Participants were explicitly asked about positive ways in which mobile technology can support learning and about negative aspects or limitations associated with using mobile phones for learning. Their unprompted responses were thematically analysed to determine themes and patterns that emerged.

Table 6 presents feedback from C1 and C2 participants regarding *positive* ways in which mobile phones might scaffold their studies. Table 7 summarises various *negative factors*, as learners expressed opinions regarding limitations entailed in studying via a mobile phone.

Comments and quotations in Tables 6 and 7 are attributed to the participants as follows: [P1.X] refers to a comment by Participant X in Cohort 1, while [P2.Y] refers to a comment by Participant Y in Cohort 2.

Positive ways in which mobile phones could support studies

Table 6 summarises positive feedback from C1 and C2 regarding how phones could be used to support studies. Comments were grouped into a six themes: course announcements, academic tasks, support functions, research-related aspects, working on-the-go, and communication.

[P1.1] is a truly digitally disadvantaged learner, who had no Internet access, neither on a computer nor via a smartphone. Unlike campus peers who had overcome the divide by using their mobile phones to support their studies, he had no connectivity and was embarrassed as indicated by his comments in Table 7.

[P2.15], on the other hand, was totally and solely connected via m-phone, using it to type assignments; upload documents; and download PDF's, images and research articles. He displayed many of the attributes of a stereotypical member of the C1 cohort but, due to living closer to C2 than to C1, he was enrolled there and could be viewed as being on the 'wrong' campus. Similar to [P1.1], though conversely, he has different characteristics and abilities from his/her peers and has difficulties settling into the designated C2 team.

Limitations when using mobile phones to learn

Table 7 summarises C1 and C2 feedback regarding the limitations of using m-phones in learning. Comments are grouped into three categories: mobile handheld devices; connectivity issues; and attitudes. A learner from C1, [P1.1], expressed strong feelings about not having the same quality of connectivity as others in his/her cohort. This emphasised the divide between his/her technical potential and the requirements of being part of a PBL team project. The attitude of [P1.10] whose phone represented the latest technology was one of joy about his/her phone. In contrast, attitudes of [P2.4], [P2.5] and [P2.16] towards their mobile phones, indicated negativity.

Table 6: Learner feedback - ways in which mobile phones can support studies

C1	C2
• ***Course announcements*** Learners can be sent reminder SMS's for deliverables [P1.1]*; Could be notified about readings [P1.1]*; announcements/updates [P1.7]; Specific module info [P1.7]; Forum to answer or ask questions about course subject matter [P1.7].	• ***Course announcements*** Receive notifications, important information [P2.6]; Get tips on course and study work [P2.8].
• ***Academic tasks*** Write study notes [P1.2]; Uploading from YouTube [P1.2]; Load study notes onto phone [P1.2].	• ***Academic tasks*** Download study information [P2.1]; I use my phone as a laptop; phone is my personal device; I use it to do research and upload work [P2.15]**.
• ***Support functions*** Record lectures [P1.3]; Search for info [P1.3]; Make notes [P1.6]; Can open documents e.g. spread sheets; can make PowerPoint shows and PDFs [P1.3]; Typing is less tiring than writing [P1.3]; My phone supports me in my studies because I use the dictionary; open emails, download documents [P1.11].	• ***Support functions*** Record chapters to listen to while doing chores [P2.1]; Can get (previous) exam papers on my phone which will help me to study [P2.17]; Access documents: PDFs, Office docs [P2.21].
• ***Research-related*** When I don't understand something or a word in my studies, I can research it on my mobile, as it is faster than researching it on a computer [P1.10]; Researching online [P1.2]; File sharing with other learners (my team) [P1.8]; Research done easier [P1.8].	• ***Research-related*** Access Internet at any time via Blackberry [P2.10]; Do a lot of mobile research on the Internet access Internet at any time via Blackberry [P2.10]; Do a lot of mobile research on the Internet [P2.14].
• ***Working on-the-go*** Ideal for reading on the go [P1.4]; Use on train, buses [P1.3]; Browse Web for info while travelling [P1.6].	• ***Working on-the-go*** Read on the go [P2.1]; BBM other learners [P2.10].
• ***Communication*** Communicating with teachers [P1.5]; receiving class notes from teachers [P1.5].	• ***Communication*** An excellent teaching medium between teacher and learner [P2.13]; Exchange SMS's with friends using my phone to ask them about study questions [P2.19].

[P1.X] and [P2.Y] refer to feedback from learner X from C1, and learner Y from C2, respectively.

* [P1.1]: this C1 learner is disadvantaged in several ways. He has an old phone which is only capable of sending and receiving SMSs. He travels long distances to campus and has no computer facilities at home. When group work was being done, his team complained bitterly about his lack of delivery on electronic promises and ostracised him. His computer literacy skills are rudimentary compared with other members of his team.

** [P2.15]: this C2 learner is a genuine mobile learner, suffering from digital divide pressures. His words explain: *"I have to share a computer with my family, so I use my phone as a laptop to do assignments and to do research and my work on it. I type and upload my assignments with my phone."* His mobile-technology literacy skills are advanced, due to his determination to overcome the challenges.

Table 7: Learner feedback - limitations when using mobile phones to learn

C1	C2
• ***Mobile handheld devices*** Spam, compatibility of software for mobile devices [P1.1]*; RIM (BlackBerry) has a limit on its browser cache and downloads, phone is a bit slow [P1.3]; Phones too small for proper research, phones must also be faster [P1.4]; What about learners who do not have smartphones? [P1.5]; What about those who cannot pay for the Internet? [P1.5]; The small size of the screen [P1.8], [P1.13]; Reading documents from the phone is quite hard, limited screen resolution [P1.9]; Space is limited, meaning I might need to get a device that could store more [P1.12].	• ***Mobile handheld devices*** Some phones are too old to use then cannot connect to Internet, can just make calls and SMS [P2.4]***, [P2.5]****; Most phones do not support all applications - incompatibility e.g. PDFs [P2.10], [P2.16]*****, [P2.21], [P2.22]; Slow response rate [P2.10], [P.21]; Limited battery power; security risks [P2.8], [P2.11], [P2.15]; Screen resolution; small keyboard can be tiring. [P2.10], [P2.13]; Small screen size [P2.14], [P2.18], [P2.20].
• ***Connectivity issues*** Cost of data. Would have to use wireless at home (WiFi) [P1.7]; Absence of an Internet connection; not all files can be opened [P1.11].	• ***Connectivity issues*** Mobile connectivity issues [P2.6]; Connectivity costs and lack of airtime could restrict use for learning purposes [P2.8]; Data is expensive; doing work via a computer is cheaper than mobile phones; no airtime [P2.9], [P2.15], [P2.17]; expensive to download large files [P2.18]; Coverage not always trustworthy, available; difficulty viewing large documents on small screen [P2.2].
• ***Attitudes*** Distractions on your phone such as MXIT, Facebook, BBM, Games, Music which could pull learners away from studies [P1.6], [P1.10]**.	• ***Attitudes*** Distraction from social networking, SMS's, random phone calls [P2.1], [P2.12].

[P1.X] and [P2.Y] refer to feedback from learner X from C1, and learner Y from C2, respectively.

* [P1.1]: "You are almost inexistent if you're not on BBM or WhatsApp, if you don't have a smartphone, you appear broke and uncool."

** [P1.10]: *"I love my phone; I can't stay more than half-an-hour without it."*

*** [P2.4]: expresses a general C2 attitude, *"I don't have feelings for my phone!"*

**** [P2.5.]: in disgust, "*You can kill somebody with it, it is a brick!"*

***** [P2.16]: emotive and negative about his phone, *"I find my BlackBerry claustrophobic and terribly incompatible, which is why I am looking for an upgrade to an android-based mobile device"*.

Conclusion

An MLDD survey was conducted among SE learners in a tertiary educational context, with the aim of answering the following research questions:

1. What is the nature and extent of the digital divide between IT learners on two campuses in the same city and of the same university?
2. Can an m-learning application delivered by mobile hand-held devices reduce the digital divide?

To answer the first question, various digital divide factors which emerged from the findings of this study are summarised. A digital divide of a complex nature and extent was identified. This divide was based on the differences between learners; shortcomings of campus infrastructure; device-specific aspects such as the device type and data cost; Internet connectivity issues; and attitudes to mobile technology.

On each campus, an intra-campus divide occurred. On C1, a learner who was ostracised for not being able to use a phone for mobile research, expressed disgruntlement with the 'smartphone brigade'. On C2, a mobile-savvy learner who had no option other than to type assessment reports on a mobile phone, equally experienced conflict with team mates when deadlines for deliverable were missed.

It was expected that a digital divide would materialise on C1 due to the cosmopolitan nature of the C1 learners, as well as the sub-standard Internet connectivity and PC facilities offered on the campus. However, feedback from C1 learners indicated that they had independently developed mobile Internet research methods which compensated for shortcomings of the campus infrastructure and the connectivity gaps they encountered due to lack of Internet access at home. This interesting paradox is emphasised by feedback from C2 learners, who, whilst benefitting from having their own transport, higher household incomes, and powerful on-campus and at-home connectivity, complained about Internet connectivity issues. Several of the C2 learners did not regard their mobile phones as potential learning tools, but rather as tools for communicating by calls and SMS's.

Learners owned a variety of mobile phone brands with diverse capabilities and used their phones in various locations, carrying out a range of activities other than telecommunications. C1 learners revealed a generally positive attitude to their mobile phones, whilst several C2 learners seemed negative about the functionality of their

phones. Statistical analysis of C1 and C2 attitudes to using mobile phones and an m-learning environment, revealed significant differences between the C1 and C2 participants, thus providing quantitative measures of the divide.

To answer the second question, feedback from C1 indicated that learners had become accustomed to mobile technology through necessity, unintentionally reducing their own digital divides. An m-learning environment, as part of the educational context, could further reduce the digital divide.

However, the study reveals several anomalies. Learner devices are so diverse that there would be major complexities in implementing an official m-learning environment. Learners across the board would need to be equipped with similar mobile hand-held devices. Further issues are that there is no wireless network to support connectivity at C1 and the network at C2 is inadequate. These infrastructural issues need to be addressed. Finally, attitudes of all the learners on both campuses would need to be aligned positively to a mobile technology strategy.

This research was limited in two respects. The survey targeted only two out of twelve national campuses in the institution. Each of the other ten is likely to reveal its own digital divide and idiosyncrasies. Although the small sample provides interesting feedback, the results cannot be generalised. Future research incorporating the entire population of twelve national campuses would be valuable. Moreover, the study excluded the input of academics and administrative leaders, as well as the content designers, policymakers and motivators who would be required to energise the implementation of a mobile technology learning strategy.

Despite the small size of the sample, insight has been provided about the nature and extent of the digital divide in a tertiary educational context in South Africa. The findings indicate that an m-learning application has the potential to reduce this divide. Further ICT4D 2.0 research is suggested, involving aspects suggested in the previously-mentioned definition of ICT4D by Heeks (2006).

Finally, this research highlights the phenomenon of how context – both the context of personal socio-economic situation and the ethos of the academic institution – impacts on learners. This, in turn, results in differences in the types of technologies used, in this case mobile phone devices, and the ways in which learners interact with them.

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