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A Framework for Measuring the Usability Issues and Criteria of Mobile Learning Applications

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Engineering Science
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A FRAMEWORK FOR MEASURING THE USABILITY ISSUES AND CRITERIA OF MOBILE LEARNING APPLICATIONS

by

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Abstract

With the continuing growth of mobile devices outpacing that of desktops and laptops, mobile devices have become the new personal computer. These devices have become increasingly sophisticated and extremely powerful in the last few years. Substantial work has been done to measure mobile applications' level of quality; many researchers have attempted to figure out why certain applications fail and others succeed.

In this thesis, a conceptual framework for measuring the quality aspects and criteria of m-learning is produced. Furthermore, a software prototype application for smartphones to assess usability issues of m-learning applications has been designed and implemented. This prototype application is developed using Java language and the Android Software development Kit, such that the recommended guidelines of the proposed framework are maintained. A questionnaire survey was conducted at Western University with approximately 96 undergraduate software engineering students. Five identical smartphones are used to evaluate the developed prototype in terms of ease of use, user satisfaction, attractiveness and learnability.

Keywords: Electronic Learning, Mobile Learning, Mobile Applications, Quality Issues, Usability Issue, User Interface, User-Centered Design, Android Software Development Kit, Empirical Study.

"Say: Though the sea became ink for the Words of my Lord, verily the sea would be used up before the words of my Lord were exhausted, even though we brought the like thereof to help" (Quran: Chapter 18, Verse No:109)

"There is no substitute for hard work"
Thomas Edison

"The only place success comes before work is in the dictionary"
Vincent Lombardi

"Arriving at one goal is the starting point to another"
John Dewey

"Anyone who has never made a mistake has never tried anything new"
Albert Einstein

Acknowledgments

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List of Abbreviations

Bb	Blackboard
CPU	Central Processing Unit
CSS	Cascading Style Sheets
d-learning	Distance Learning
Eclipse IDE	Eclipse Integrated Development Environment
e-Learning	Electronic Learning
GPS	Global Positioning System
HTC	Hit the Cell
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
IBM	International Business Machines
ICT	Information and Communication Technology
ISO/IEC	International Organization for Standardization and the International Electrotechnical Commission
m-learning	Mobile Learning
MOSAD	Mobile System Analysis and Design
PCs	Personal Computers
PDA	Personal Digital Assistance
PIM	Personal Information Management
RIM Blackberry	Research In Motion. Ltd, Blackberry
SAD	System Analysis and Design
SDK	Software Development Kit
SMS	Shot Message Service
UI	User interface

URL   Uniform Resource Locator

XML   Extensible Markup Language

List of Terms

Android   "It is a Linux-based operating system designed primarily for touch-screen mobile devices such as smartphones and tablet computers. Initially developed by Android, Inc., which Google backed financially and later purchased in 2005" [70].

Distance Learning (d-learning)   Defined as "a process to create and provide access to learning when the source of information and the learners are separated by time, distance, or both" [9].

Educational Resources   Can be defined as all types of resources that are useful for learning, teaching, education, and research purposes [34].

Electronic Learning (e-learning)   All forms of teaching and learning that utilize educational technologies, communication technologies and information—whether networked learning or not—serving as a specific media outlet to implement the learning process [7] [8] [9] [10] [11].

Formal Learning   "Formal learning takes place in education and training institutions, leading to recognized diplomas and qualifications" [34].

Informal Learning   Informal Learning is a natural accompaniment to everyday life. Unlike intentional learning, it is often not recognized as contributing to individuals' knowledge and skills—even by people themselves [34].

Learning Content   A type of information that has to be delivered to learners for them to obtain knowledge [7] [44] [46].

Learning Style   "Refers to an individual's characteristics and consistent approach to perceiving, organizing, and processing information" [41].

Mobile Devices   Also known as handheld devices, handheld computers or simply handheld, mobile devices are small, hand-held computing devices, typically with a display screen, with touch input and/or a miniature keyboard [1] [9] [12] [13] [27].

Mobile Learning (m-learning)   Has many different meanings for different communities. Although it is related to e-learning and distance education, it is distinct in its focus on learning across contexts and with mobile devices. It is defined as any sort of learning that occurs when

the user is not at a predetermined location, and they are taking advantage of the learning opportunities offered by mobile technologies [9] [12] [14] [15] [35] [36] [37] [38].

One-Handed Devices	Users interact with these devices with one hand, because they have small screen sizes and always have standard keypads for inputting data [34].
Pearson Correlation Coefficient	"It is a measure of the correlation (linear dependence) between two variables X and Y, giving a value between +1 and −1 inclusive. It is widely used in the sciences as a measure of the strength of linear dependence between two variables".
Personal Computers (PC)	General-purpose computers that have an expansive size and capabilities which makes them powerful and useful tool for users. They're intended to be used directly by an end-user
Short Message Service.	A means of sending short messages to and from mobile phones [20].
Spearman Correlation Coefficient	"It is a non-parametric measure of statistical dependence between two variables. It assesses how well the relationship between two variables can be described using a monotonic function. If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other".
Stylus Devices	Have screen sizes that are much larger than the previous models; users interact with them through a touch screen [34].
Two-Handed Devices	Two-handed devices have small keyboards and large screen sizes compared with one-handed devices. Generally, they require the user to hold the device with one hand and operate it with the other. It is possible to be operated with one hand as well [34].
Ubiquity	Means that the learner, with the support of wireless connectivity, can access and use content for learning at any place, regardless of location [7].

Usability	The ease of use, learnability, understandability, attractiveness, and user satisfaction of a human-made object. These objects include software applications, tools, websites, processes, or anything that a user interacts with.
User Interface	The space where interaction between users and devices occurs. It is the system by which users interact with a machine. The user interface includes software (e.g., logical) components and hardware (e.g., physical) [23] [24] [25] [26] [27] [31] [32].

Chapter 1

Introduction

Since the arrival of mobile phones in the 1980s, they have become widely used among all ages. In fact, they are becoming the new personal computers (PCs) as users are increasingly utilizing mobile phones instead of desktops to access material and services [1] [2] [3]. Mobile phones are not just communication devices simply used for communicating and interacting between people; they are also personal and portable [4]. Due to the significant diffusion of mobile technologies, most students today already have their own mobile devices. These devices have a possible advantage for applying technology in the educational field, as they are cheaper than desktops and laptops [5]. Wang et al. [6] reported that mobile phones can be used to deliver on-line courses to university students. Whereas Prensky in [4] asked, why not take advantage of these devices for educational purposes? He emphasized that students will be able to learn "anything, if developers designed it right."

With the advancement of technology, new possibilities have been introduced in education systems; for example, the way to access and control a knowledge base, which consists of on-line courses, learning resources, has greatly changed since the advent of the Internet. A dynamic approach for learning has been introduced—called electronic learning (or e-learning for short). This approach can be either collaborative or individual [7] [8] [9] [10]. The collaborative approach enables people to share and exchange learning materials with each other; for example, e-learning enables learners to connect with colleagues, professionals, and expert peers within the scope of e-learning systems [11]. Additionally, e-learning enables individuals to select material and activities based on their background [11].

On the other hand, the demand for learning anytime and anywhere has specified the need for a new type of electronic learning called mobile learning (or m-learning for short), acknowledging the use of mobile devices (mobile laptop, personal device assistant, mobile phones, etc.) which are becoming more and more popular [9] [12]. Figure 1

depicts the structure of m-learning systems [12]. Users can utilize the mobile communication terminals to help them to learn, and with the support of the Internet and wireless connectivity, they can obtain educational resources [9] [12] [13]. Furthermore, Figure 1 shows that users can obtain the information he/she needs, using mobile devices, only with the availability of the communication network and the Internet.

Communication networks

Mobile terminal instrument

Internet

Education resource Web servers
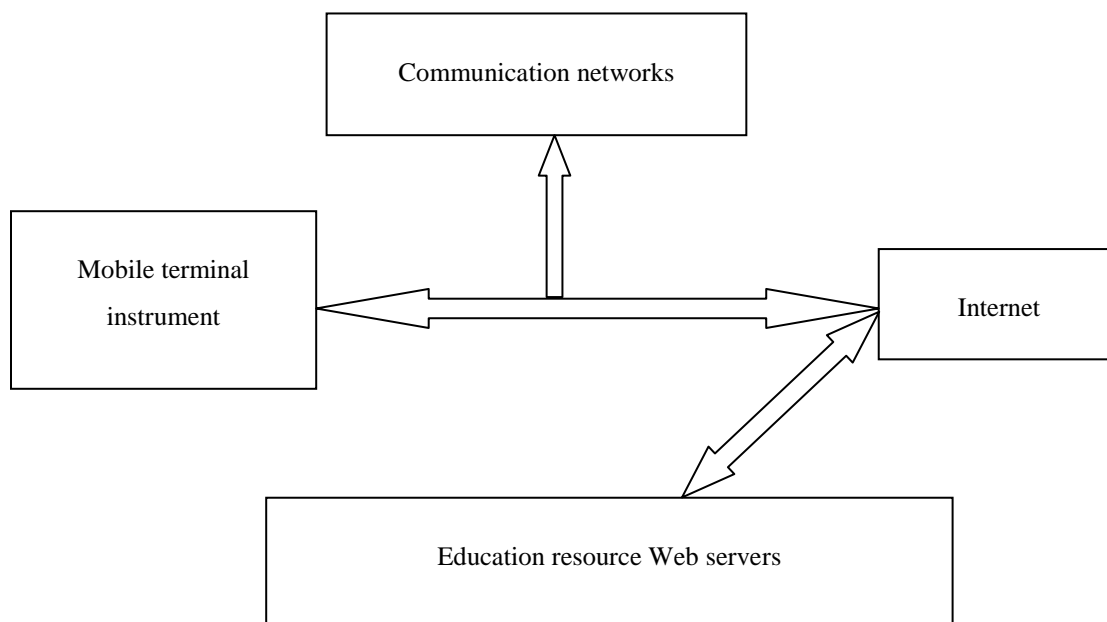
Figure 1.1 The structure of mobile learning systems

Brevern [14] explained the organization of the learning content. He emphasized that it should enable a human-like interactive learning experience, which relies on many factors, such as how knowledge is represented, structured and introduced, and also user behaviour. The use of educational mobile phone applications has increased significantly in recent years largely due to the accessibility and availability of wireless networks, and the specific capabilities they have (e.g. touch-screen, camera, and GPS receiver). These applications must be robust and of high quality so that they're accepted by a wide audience (i.e. students, instructors, etc.). Furthermore, research has emphasized that there are some design issues that must be taken into consideration when developing mobile applications. In addition, there are only a few studies targeting quality issues in m-

learning applications, and there is a lack of research about the usability of mobile devices for learning.

1.1 Motivation

In designing desktop applications, many usability guidelines are used. However, these guidelines cannot be utilized to design and develop m-learning applications, simply because they do not address the issues related to mobile phones and their current limitations. There are a lack of good-quality usability guidelines for designing and developing mobile applications with user-friendly interfaces.

Furthermore, literature has shown that usability and its related issues have been a key area of research for electronic learning in general, and m-learning in particular [1] [15] [16]. Usability has previously been less extensively covered than the technological aspects of the m-learning. Studies have also revealed that usability issues have a great impact on the success of mobile phone applications; however, there is a lack of research about learnability, understandability, ease of use, effectiveness, and efficiency of mobile applications—all aspects of usability [1] [3] [7] [15] [16].

Additionally, research has emphasized that there are some design issues that must be taken into consideration when developing mobile applications. However, as previously mentioned, there are only a few studies targeting quality issues in m-learning applications, and there is a lack of work regarding the usability of m-learning in general [15] [16].

1.2 Research Questions

With the continuing growth of mobile phones outpacing that of machine desktops, mobile phones are considered the new personal computer. These mobile phones have started to become increasingly sophisticated and extremely powerful. In addition to making phone calls, they have capabilities to perform a variety functions—including for use as a classroom tool.

The experience of end users has a profound impact on the success of m-learning; thus, usability and its related issues has been a key area of research in the context of m-learning [16]. Therefore, a mobile phone application must be designed and developed with respect to different technological skills, learning capacities, and language proficiencies. These considerations will increase the usability and acceptance level of mobile applications by a wide range of individuals (e.g. students, instructors).

In order to precisely identify where improvement is required, assessment needs to be conducted. Therefore, the main purpose of this research study is to find answers to a series of formulated research questions—in order to fill the research gap in the area of m-learning usability assessment.

1- How can we design smartphone applications with a high level of usability?
2- How can we improve the quality of the mobile applications' user interface?
3- Can the proposed framework be used as a guideline when designing and developing mobile applications?

To answer these questions we have developed a framework for measuring the quality aspects of m-learning, and then designed, implemented, and tested a prototype m-learning application for smartphones. This prototype consists of two user interfaces named Model A and Model B. The first user interface (Model A) was designed and developed based on a user interface adopted from the Blackboard[1] (Bb) website; while the other user interface was developed following the Android SDK recommendation and our framework as a guideline.

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[1] **Blackboard Inc.** is an enterprise software company, and it is primarily known as a developer of education software, in particular learning management systems. The company provides education, mobile, communication, and commerce software and related services to clients, including education providers, corporations, and government organizations.

1.3 Methodology

This thesis describes a novel framework for measuring major quality aspects of m-learning and proposes a user interface prototype to support the proposal measuring factors recommended by this framework. This support is provided in a form of technical survey that has been conducted by 2nd and 3rd year software engineering students at Western University.

The m-learning user interface (UI) prototype has used heuristic evaluation as a technique to measure usability factors. Heuristic evaluation is an engineering method for easy, quick, and cheap evaluation of a user interface design [15]. It is known as one of the most popular usability inspection methods, and it is done as a systematic inspection of user interface design for usability [15]. As mentioned, a usability questionnaire was conducted to evaluate the usability issues of the prototype application among *96* students.

However, using this technique and by giving the participants real mobile devices, participants could use this application to share opinions regarding their experiences while interacting with the real prototype application. Participants rated each question from 1 to 5 on a Likert scale (1=very easy, 5=very difficult), see Appendix A.

Upon collecting the data, we investigated the level of usability by evaluating the application's user interfaces, which include ease of use, user satisfaction, and attractiveness and learnability. A comparison has been done to determine the most user-friendly interface that our prototype consists of (see chapter 6).

In addition to the developed prototype, we have created a framework for measuring the quality aspects of m-learning, which we have used as a guideline while designing and developing our Prototype application (presented and discussed in chapter 4).

Figure 1.2 shows our research plan we have used to design, develop, implement, test and evaluate our prototype application for smartphones. We will answer the questions provided in section 1.3.

Identify Research Area/Literature review

Developing m-learning Quality of Service Framework

Designing a prototype appilcation

Designing UI using Android recommendation and our framework as a guideline

Adopting and designing UI exactly the same, from Blackboard website

Developing and implementing the prototype application

Model A/User Interface

Model B/User Interface

Questionnaire Survey with 96 software engineering undergraduate students at Western University

Statistical Analysis

Comparing the two Models to determine which one has the best user interface

Results and Recommendations

Figure 1.2: Research methodology

1.4 Contribution

The assessment of usability factors in regards to m-learning devices is an important area of research. In fact, much work needs to be done to create a guideline for designing and developing mobile applications—to increase the acceptance level of those applications by different users. Accordingly, this research contributes to this field in the following ways:

1. Creating a framework for measuring the quality aspects of m-learning.

2. Designing, developing, implementing a prototype application for smartphones, this will be tested and evaluated by users with smartphones.

3. Empirical evaluation, validation, and comparison of usability issues of the developed prototype application.

1.5 Thesis Organization

The organization of this thesis is based on two articles that have been published and one article still in preparation in software engineering conferences.

In chapter 2, we provide a literature review regarding the quality issues of m-learning application; we also provide a related research that deals with the usability issues of m-learning applications.

Chapter 3 introduces a widespread literature review that presents the concepts of m-learning. Also, it discusses three factors related to m-learning including, learning style, mobile application, and learning content. Furthermore, the features of m-learning are introduced as the classification of mobile technologies. Finally, a brief literature review on mobile devices is presented, and the evolution of smartphones is introduced.

 In chapter 4, the technical and non-technical quality issues of m-learning are explained, and a conceptual framework for measuring the quality aspects of m-leaning is introduced. A detailed analysis and discussion on the Busuu project; which is an online social network application in which learners can assist each other to improve their language

skills, are presented based on the proposed framework. Also, the design, development, implementation, and testing stages of the developed prototype application for smartphones are presented.

Chapter 5 presents an empirical investigation for studying the usability issues of m-learning, based on the developed prototype and our framework. The study conducted and reported in this chapter can enhance the understanding of m-learning concepts, especially while designing and developing smartphone applications.

Chapter 6 concludes the thesis by highlighting and summarizing this research and the research contributions of this dissertation. It also suggests and discusses future research that should be done in this specific area.

Chapter 2

Literature Review and Related Work

This chapter presents a literature review about quality issues related to m-learning in general, and usability issues in particular. It also presents a related work that deals with usability issues, and user interface concerns of mobile applications.

2.1   Literature Review

Mobile and wireless technologies are the future of m-learning. M-learning has been widely accepted by younger generations who have grown up with mobile devices in their hands. Therefore, software developers have been trying to design m-learning applications that will be embraced and accepted by these generations. M-learning, nowadays, provides a variety of methods that people use to learn, stay connected with their colleagues, and access instructional resources [15].

Mobile technologies have become widespread. As such, professors and learners will become increasingly mobile as time goes on, and will utilize more mobile devices as illustrated in [16]. The proliferation of several m-learning systems depicts the importance of developing mobile and wireless learning applications [17] [18] [19]. However, mobile applications can be developed for many different purposes. One such purpose is as a tool for helping learners to review their lectures. In this section we analyze and summarize a selection of the most relevant literature that addresses different ways of supporting the learning process in the context of m-learning.

In 2003, Seppala and Alamaki [20] introduced an m-learning application which was designed to aid in teacher training. The application utilized simple technologies, digital pictures, and short messages in the form of (SMS), to enable learners to build a digital portfolio in a central database. Text messaging was utilized to enable the participants to collaborate, communicate and share their learning experiences with each other. Feedback received from the participants showed that messages and pictures could be shared with other learners. Teachers benefited from being able to use the learning content generated

by the participants in the shred database. In this application text messaging was used for communicating information, while images were utilized to give insights into the classroom.

In 2004, a project called Ambient Wood project [21] was initialized to design an application to enable students to share their learning experiences from a field trip within the context of a classroom—with the support of mobile devices. The main research goals of this project were to determine which kind of digital material was needed, how much to offer, when to offer/deliver it, and how much control and interaction students should have with the material.

The results indicate that students were able to share and display information from a field trip onto their mobile devices. Learners also obtained desired information when they were detected in a particular location. Most importantly, the project was effectively designed—in a manner that avoided overloading students with too much digital information at once—which might distract them from their interactions with each other, and explorations of the physical world. Finally, the project showed that mobile applications can enable novel interactions and collaboration between students, in terms of their ability to pass/obtain information in real time and over a distance.

In 2007, the Personal Learning Organizer project was introduced [22]. It was established as a guide for gathering some requirements in a system to provide location aware as a support for universities students. They have started gathering information based on an interview with ten university students in order to specify what types of learning context, material, tasks and design features that would be suitable to be delivered in this context. The result of this work identified that students had different needs in their m-learning content based on their university level. This enabled a system to be developed in a way that could provide different needs for different student interests.

In 2008, Evans [23] conducted a study investigating the effectiveness of m-learning using Podcast revision lectures. Podcasting is the process of providing a series of video or audio files that can be reviewed over and over again. After completing a course at the Department of Information and Communication Technology (ICT) at a university in

London, UK, as preparation for the final examination, 200 undergraduate students were provided with a revision Podcast of the course. The results of the study indicate that students believed that Podcasts are a great way to help students in their educational process by giving them an opportunity to review and revise their lecture materials.

In 2011, Bitesize [24] [25] launched a Java m-learning application tool for review and revision of course material. The application was designed in a way to enable the learner to use it either on-line or of-line: on-line users could access learning material through a certain URL, and off-line users accessed content via an application that had been installed in their mobile devices. This application mainly covers three subject areas: science, english, and mathematics. Learners can use this application to review their lectures before taking their final examinations.

2.2   Related Work

In this section we discuss literature that deals with the usability of mobile applications, and we summarize a selection of the most relevant findings. To start, in the ISO 9241-11 (1997) standard, usability is defined 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". However, ISO/IEC 9126-1 (2001), states that usability is "the capability of the software product to be understood, learned, used and attractive to the user, when used underspecified conditions." Zhang and Adipat [26], on the other hand, emphasize that there is much literature available addressing usability, user interface design, and related topics for mobile devices, in particular for smartphones. They show that mobile devices have limited features that pose a number of challenges for assessing usability; for instance, small screen size, and connectivity. That is, a mobile application must be developed and designed with respect to all users' technological ability, skills, and language proficiency. This forces developers to be very careful with design issues in order to maximize the level of usability with all its sub-characteristics.

Ziefle and Bay [27] demonstrate that awareness of the user interface structure is one of the most important issues in regards to cell phones. On the other hand, a vast number of empirical research, such as in [31], has been done on exciting applications which have

unclear naming and location of some functions, as well as unclear design of the keys—reducing the level of the usability.

In 2007, Jarvela et. al. [28] studied how to help users to participate in collaborative learning using smartphones. The researchers utilized a mobile lecture interaction tool to encourage higher education students to participate in a class discussion. This tool enabled participants to ask and answer questions, as well as to rate classmates' questions. The main purpose of this survey was to get students' feedback on the usability of the tool. The feedback showed that participants were satisfied with, and more active in answering questions when using this tool. Also, the participants proved that mobile tools with a high level of usability will definitely increase their engagement in valuable discussions. The mobile technology allows the users to communicate instantly; this characteristic plays a vital role for a successful m-learning environment. However, usability issues are found to be important factors learners' high satisfaction level with cooperative learning available with use of the system. For instance, if the user did not receive the message and/or comment within a specific timeframe, he/she would likely not feel satisfied with the system; thus, resulting in less engagement in system. However, this kind of problems has already been solved by using Short Message Service (SMS). This type of service increase interactions between users, and allows them to build their positive and desirable social network.

In 2008, Shen et. al. [29] developed a system for a blended classroom where a traditional class and real-time class, in a different location, communicate and interact with each other using mobile phones. Basically, this system helps instructors to track and monitor their online students, so the instructors are aware of their activities. This system offers many educational functions such as exchanges of information through text messages, and real-time interactions between instructors and their students. This new type of learning is very helpful for both students and instructors. For instance, this two-way communication and interaction will definitely motivate the instructors in the learning process as well.

In 2009, Huang et al [30] developed a mobile blogging system. Their study included approximately 40 undergraduate students from the Department of Engineering Science, National Cheng Kung University in Taiwan. The students were placed in five different groups, and each group was required to participate in a discussion based on a specific topic. Therefore, there were five different topics on the developed system. The topics were introduced in a classroom, so students could study the topic in two different formats: as a lecture or they can use the system to take the same topic. However, when two-month have passed since they have started to use the developed system, an online survey was conducted in order to measure the effectiveness of the system. Finally, the result depicted that the students ranked this mobile system as a helpful tool to increase their knowledge.

In 2010, an m-learning application for sciences was introduced [32]. It was designed to provide learners with notes and exercises to review during their spare time. The developers used familiar terminologies, which can be found in most mobile applications, including, "Main Menu", "Delete", "Back", "More", "Select", "Option", "OK", "Cancel". After students tested the application, they reported that they were satisfied with the interface and the content of the application overall. However, they gave some suggestions that could improve the performance and capabilities of the application. Most of these suggestions were mainly pointing to some weakness in the design. Many of the participants stated that some of the words and phrases were not clear enough; for instance, "Read Notes" was confusing and they suggested that it would be clearer and more simple if "Notes" was used instead. They also suggested that it would be helpful if the "Back Button" were displayed on every single page in order to improve the navigation process. Also, using numbers instead of letters was reported as another key component that would improve the application. Fill-in-the-blank exercises are an additional problem that needs to be resolved, since students have been asked to enter their answers in different pages, which make it difficult to remember what the initial question was. Furthermore, participants stated that the "Get Help" function was easy to use, but they suggested that adding graphics on each individual page, which would enhance the usability of the application.

In 2011, the mobile System Analysis and Design (MOSAD) application was introduced [24]. It is a mobile application used as a revision tool for the System Analysis and Design (SAD) course at University Technology PETRONAS. The researchers' main goal was to design an m-learning application that allows students to review, and read notes during their spare time—but more importantly, to evaluate this application by considering some design issues that could be modified to improve its usability. After the application was designed, a heuristic evaluation was completed to measure its level of usability. Many tests were conducted, and the purpose of those tests was to receive feedback from participants to determine the level of the usability of this application. The results indicate that adding some features to the design will be useful, and improve the overall usability of the application. For instance, adding shortcut keys on every page increases participants' understanding of the application; therefore, speeding up the learning process. Also, participants indicated that improving the font size and type, and the text colour would help them differentiate the text from the background colour. Additionally, they suggested to include links such as references pointing them to further reading material. Another helpful suggestion the students made was to differentiate the levels or importance of the content via different text sizes and colours. Furthermore, adding some buttons, such as "next" and "back" buttons would be helpful, improving the usability of the application, in addition to the number key-pressed navigation mechanism. Additionally, appropriate pictures or images should also be included in the design, and some colours of text should be changed since they are difficult to read.

2.3   Summary

In this chapter, we have reviewed 18 research articles. Most of these articles deal with existing and established projects, from which we have gained an excellent foundation to build up our own knowledge. As presented, a detailed literature review has been introduced regarding m-learning. Additionally, related work, beginning from 2007 to 2011, has been covered, dealing mainly with mobile applications.

Although much work has been done to assess the quality of mobile applications, many researchers are still attempting to figure out the most important reasons why some

applications fail. However, m-learning is still in the initial stages of development, and there are many issues that need to be resolved to reach a high level of usability—in terms of ease of use, learnability, understandability, and attractiveness. With a significant increase in the use of m-learning by individuals, the level of usability and its related issues must be addressed thoroughly. Nevertheless, the usability aspects of m-learning cannot be improved unless there are ways to test and measure those aspects.

Typically, people usually carry their mobile devices (e.g. laptop, PDA, Cell-Phones, smartphones, etc.) with them and frequently check their text messages and emails. Therefore, the fact that individuals are so connected to their mobile devices can also be a factor that increases the interaction between students and teachers— which can in turn increase the quality of the learning experience for both instructors and students. This forces us to pay a lot more attention to the usability issues of m-learning.

Chapter 3

Mobile Learning and Technologies

This chapter starts with a literature review on the concepts of m-learning in section 3.2. Three factors regarding m-learning are discussed in detail in section 3.3: learning style, mobile application, and learning content. Furthermore, the features of m-learning are presented and discussed in section 3.4. Additionally, a possible classification of mobile technologies is illustrated in section 3.5. Finally, a brief literature review on mobile devices is introduced in section 3.6, and the evolution of smartphones is presented in section 3.6.1.

3.1   The Concept of Mobile Learning

The use of electronic learning has increased significantly in recent years, largely due to the accessibility and availability of the Internet. Also, the demand for learning anywhere and anytime has specified the need for a new type of electronic learning called m-learning (m-learning)—to take advantages of the mobile devices (i.e. mobile Laptops, personal device assistants, mobile phones, etc.) which are becoming more and more popular [9] [12]. M-learning is one of the education modes in which students can use mobile communication terminals to assist them in learning [9] [12] [13]. M-learning is a subset of Electronic learning (e-learning), which in turn, is a subset of Distance learning (d-learning) as illustrated in figure 3.1.

D-learning has been defined as "a process to create and provide access to learning when the source of information and the learners are separated by time or distance, or both" [9]. In the past, the disadvantages of d-learning were many, including time and location restrictions, climate factors, and the fact that learners were unable to take lessons again, since lessons were mainly delivered via satellite—so if they missed the lesson, they missed it. Additionally, learners were unable to interact and communicate with their teachers [13]. Nowadays, Distance Learning relies heavily on the advancement of communication technologies, and makes the process of delivering educational content much easier than before, and in a way that cannot be affected by time, location, or even

climate [13]. E-learning is a product of the advancement of communication technologies, and has been defined as "the delivery of education content using some electronic media; for instance, Internet, audio/video tapes, TV and CD-ROM" [27]. Conceptually, e-learning environments can be divided into either on-line learning (wired), or m-learning (wireless).
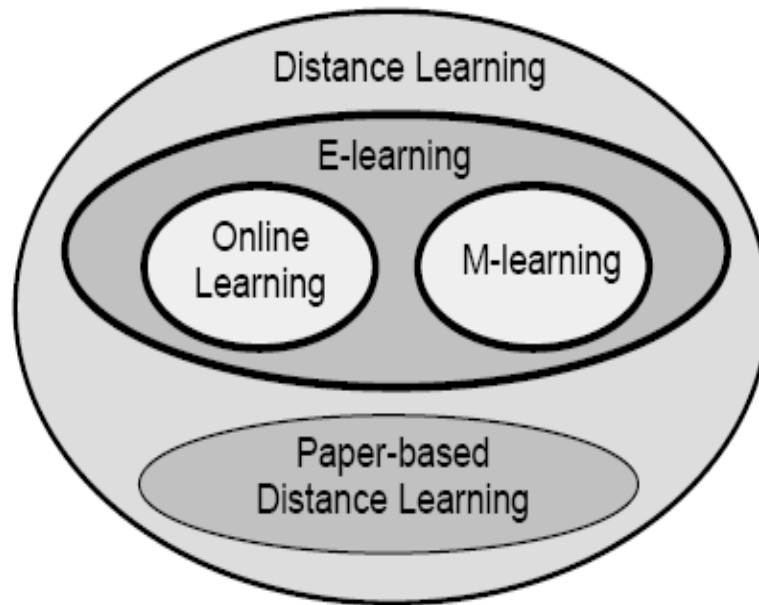
Figure 3.1: Distance learning and its subsets [9]

Mobile learning, through the use of wireless mobile technologies, allows anyone to obtain learning content from anywhere and at anytime [34]. Therefore, learners have control over when they learn, and from which location they use their mobile devices to learn. There is no time or location restriction anymore; learners have the ability to learn whenever and wherever they want [15]. Also, pupils do not have to only learn what is initially introduced to them [35], but they have the ability to use wireless mobile technology for formal and informal learning—where they can access additional and personalized learning content from the Internet—and choose whatever they want to learn about [15] [36]. On the other hand, workers on the job can use mobile technology to access training materials and information when they need it for just-in-time training, which encourages high level of learning since they access the learning content right

away. In fact, educators and trainers are further empowered since they can use the mobile technology to communicate with people from anywhere and at anytime. Meanwhile, educators and trainers can also access learning resources from anytime and anywhere to plan and deliver their lessons [34].

In the literature, m-learning has been defined in different ways. For instance, Parsons and Ryu [35] define it as an approach to electronic learning, or just another channel to deliver the same content. Jin [12] defines it as the "rudiments of ubiquitous learning" which means that the learners can obtain the information that he/she needs based on their interests—wherever and anytime by using wireless connectivity. Yuan et al [37] define and classify m-learning as the "fourth wave of learning" using the Internet, while desktop computers and mainframe computers represent the third, second, and first waves, respectively. Meanwhile, Ting [15] defines m-learning as a new method of education, utilizing mobile devices as tools, enhancing digital channels, obtaining educational information, resources and services anywhere and at anytime. Cavus and Ibrahim [38], on the other hand, define it as a special kind of electronic learning, bound by a different number of special characteristics and the capabilities, including bandwidth and other properties of the network technology being utilized. Another possible definition could be introduced from a more geographical viewpoint. In fact, learning from a predetermined location and by combining all the previous definitions together can be seen as a starting point for another definition: "Learning that happens when the learner is not at a fixed, predetermined location or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies" [36].

3.2   Three Pillars for Mobile Learning

There are three important factors which need to be put into consideration when dealing with m-learning systems; thus, ensuring that these systems have the desirable level of quality [39] [40].

These three pillars are:

- The learner's style

- The mobile device/applications.

- The learning content

Learner Style

Mobile Phone

Learning Content
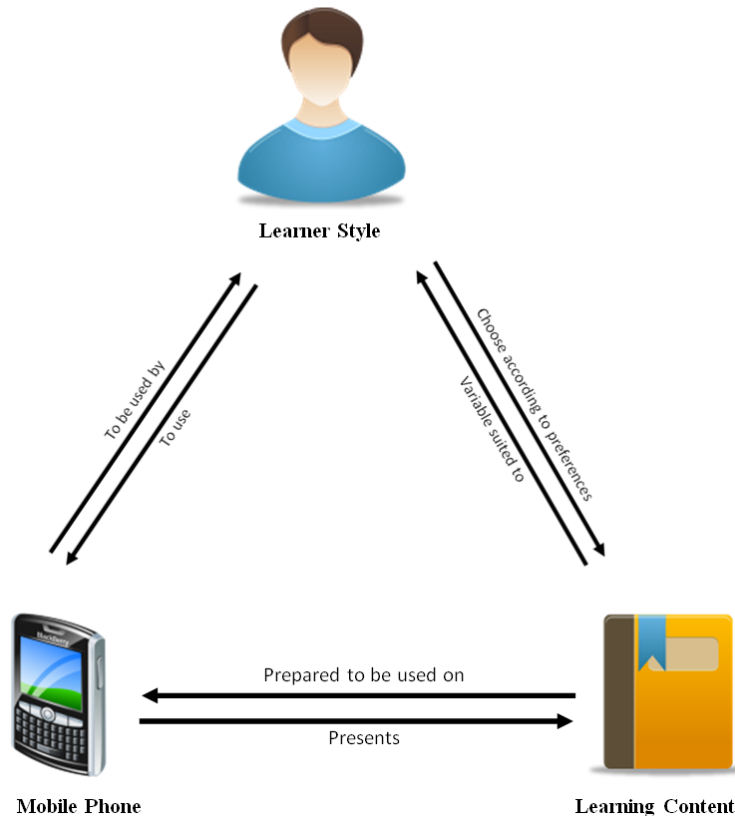
Figure 3.2: Three Pillars for m-learning

As depicted in Figure 3.2, each pillars of the m-learning system environment depends on, or is influences by the other pillars listed above [39] [40].

3.2.1 Learning Style

Capretz [41] describes learning style as "a term that refers to an individual's characteristics and consistent approach to perceiving, organizing and processing information." Every individual has his or her own learning style, and in order to understand these styles the learning process itself must be understood. Learning in its natural, structured manner involves a two-step process: reception and processing of information [41] [42]. In the first step, external information, which is observable through the senses, and internal information will become available to the learners. The second

step, processing of information, is based on the availability of learning material. Learners will choose and utilize learning material that they are able to process and skip the rest of it.

According to the definitions listed above, learning styles group students based on the way they handle, receive, and process information. These learning styles must be analyzed in order to determine which preferences should be catered to and supported by m-learning, and which preferences should be overlooked. We have chosen the Felder and Silverman Model, which was introduced in [42], to classify these learning preferences. Basically, this Model was developed for engineering classes only; however, results obtained indicate that this model can be applied to many different classes—not only for engineering classes as originally intended. This model defines four different dimensions of learning. Each one of these dimensions has two characteristics that differentiate it from the other dimensions, determining the users own particular learning style. Table 3.1 illustrates and defines the four dimensions of learning [42].

Learners have the following preferences:

1- Understanding Dimension. The understanding dimension includes two characteristics: global and sequential. Globally, pupils learn using one of the more popular techniques utilized by students: skimming and scanning the information. In doing so, they often "get" the material quickly, grasping its meaning suddenly and with little strain. However, they may not be able to explain how they comprehended the material, or solved the problem at hand [42]. Whereas, on the other hand, Sequential learners follow a logical step-by-step process to learn the desired material, and they can work with the learning material if they understood it superficially [42].

Table 3.1: The four dimensions of learning & their characteristics (based on Felder & Silverman Model) [42]

Preferred Learning Style	
Understanding	Global
	Sequential
Input	Visual
	Verbal
Perception	Sensing
	Intuitive
Processing	Active
	Reflective

2- Input Dimension. The input dimension includes two characteristics: visual and verbal. With the visual characteristic learners prefer to use presentations, flowchart, pictures, and diagrams to learn from [42]. They may struggle to remember what has been said to them, and if they would like to remember something they will probably visualize a diagram, picture, etc. Whereas, verbal learners prefer to learn from formal dialogue and conversation, using both the written and spoken word [42]. They also prefer to talk a lot and they learn most effectively by explaining concepts to others.

3- Perception Dimension. The perception dimension includes two characteristics: intuitive and sensing. The intuitive learners like innovation and prefer to discover novel relationships and possibilities independently [42]. These learners do not enjoy detailed material; however, they prefer to work with complicated problems and they are good at grasping and understanding new concepts. Intuitive learners, even though they tend to complete their work very quickly, are careless and do not like repetitions [42]. Sensing learners, on the other hand, prefer to work with hard data, facts, experimentation, and they like problem solving [42]. These learners prefer to work with detailed material, and are good at memorizing facts. They complete their work in a very careful, methodical manner, and work very

slowly. They also tend to dislike surprises, and do not welcome complicated problems.

4- Processing Dimension. Finally, this dimension has two characteristics: active and reflective. The active type likes to discuss topics and to understand them well enough to explain concepts to other learners [42]. Active learners do not learn well by being alone, and they like to work and discuss topics in groups and in teams [42]. Active learners have also been classified as experimentalists [42]. Alternatively, reflective types like to reflect on topics in a quiet manner, and they prefer to work individually [42]. These learners do not learn very well in situations where there was no chance to think about the material provided beforehand.

An online questionnaire was developed by Felder and Silverman to determine learners' preferences [43], Figure 3.3 shows some results that were obtained. These results indicate that learners may have the following learning style modes, as shown by the X character in the four rows.

Result for: Student

					X									
Active	11	9	7	3	1	0	1	3	5	7	9	11	Reflective

			X											
Sensing	11	9	7	3	1	0	1	3	5	7	9	11	Intuitive

									X					
Visual	11	9	7	3	1	0	1	3	5	7	9	11	Verbal

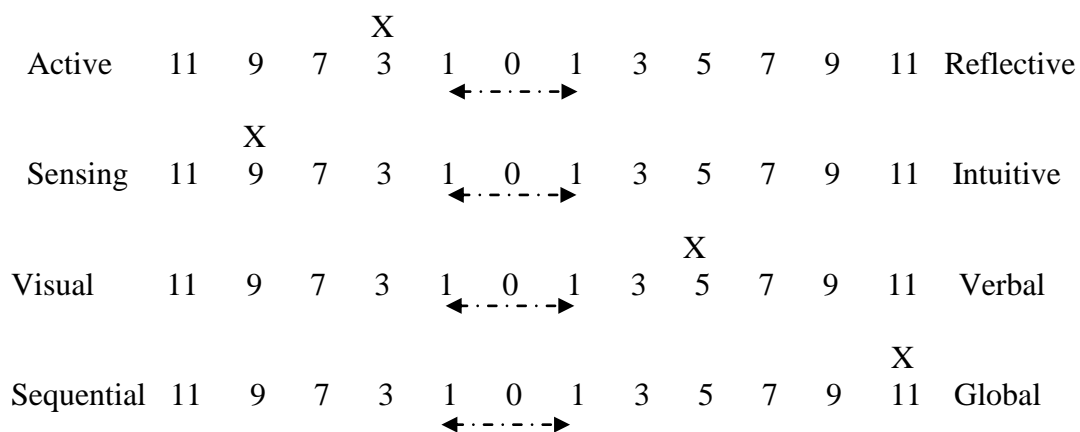|											X			
Sequential	11	9	7	3	1	0	1	3	5	7	9	11	Global

Figure 3.3: Learning styles according to Felder and Silverman model

By analyzing all the previous learning dimensions we figured out that m-learning has no influence on the understanding these dimensions, since the differences between the

characteristics rely on the way the learners use the information provided to understand the material provided. For example, global learners learn in a big step using one of the most popular techniques for instance skimming and scanning and they can get it suddenly while sequential learners like to go through the material, so the material presented by m-learning will absolutely satisfy both types of learning styles. Secondly, for the Input dimensions, m-learning supports visual learning by enabling them to see a visualization of the topic, for instance tower, bridge while they are learning the topic. Today, most of the m-learning applications consist of pictures and diagrams. Since visual learners prefer this type of information, it will be easy for them to use the application, which will in turn improve the usability of the m-learning device. On the other hand, m-learning supports verbal learners too, since they can read text on the mobile devices. Also, there some applications that have the ability to read text to the learner, which will also ease the process of learning for these individuals.

In regards to the perception dimension, m-learning supports sensing learning by enabling learners to review the learning material anywhere and anytime. Additionally, m-learning could be an advantage for the intuitive learners. Finally, the active and reflective learners will get benefits from m-learning as well. Active learners have the ability to utilize m-learning to communicate with other learners, for example, using the discussion board on WebCT to exchange information. In addition, reflective learners can utilize mobile devices to receive specific information about any topic while studying alone, for instance, or when reading about topics uploaded by the instructor or reading some blogs.

3.2.2   Mobile Application

Mobile applications are just as important as learning style. They're the cornerstone of m-learning environments. M-learning environments need a robust application to deliver learning content in an efficient way to meet learners' needs. These applications are either pre-installed on phones during the manufacturing process, downloaded by users from different mobile software distribution platforms, or through web applications obtained over HTTP; for instance, JavaScript. However, these applications could include office documents, a tutoring application, or even WebCT contents [42]. The possible

classifications of these applications are numerous: Figure 3.4 illustrates one possible classification.

In general, m-learning applications are classified into three groups. First of all, the "documents" application group, which contains (DOC, PPT, PDF, etc) files. Secondly, website applications are classified into two groups: interactive websites, which may consist of JavaScript functionality, or static sites that consist of CSS and HTML formats. The final group: stand-alone applications. For instance, applications developed using one of the programming languages, such as Java, C #, C++, etc.
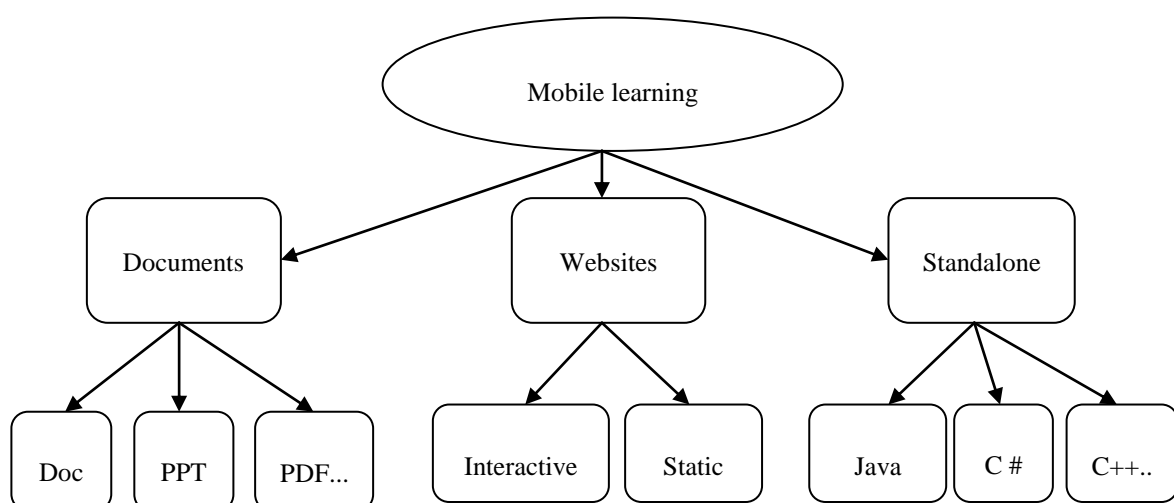
Figure 3.4: Classification of m-learning applications

3.2.3 Learning Content

Learning content is the type of information that has to be delivered to the learners for them to obtain knowledge [44]. This knowledge could be gained by reading or surveying the content. In order for the learners to obtain knowledge the learning content should be new, and not be introduced before.

Typically, there is a strong relationship between learning style, learning content, and mobile applications—any mismatch between these three important factors will lead to lack of motivation to utilize m-learning—which will, in turn, cause some usability

issues.; for instance, lack of learnability or understandability [46]. As a result, learning content in itself should be prepared in different versions or formats; that way the learner is free to choose which version of the learning content they prefer. On the other hand, mobile devices have more varied capabilities than desktop machines. This forces software developers to structure learning content in a way that will be compatible and work in different kinds of devices, because not all the learners prefer to use the same types of devices. In fact, some learners prefer to use laptops or smartphones, and others prefer PDA. Software developers can use the Extensible Markup Language (XML) to provide learners with the same content that will work across a range of platforms. The learning content, in this case, can be dynamically transferred to different mobile devices [7].

To briefly conclude, it is important that software developers understand different learning styles, and design robust applications, providing learning content in varied formats that will be compatible with these learning styles and work in different devices at the same time. By doing so, the quality aspects of m-learning devices will be at the desirable level, which will in turn help learners reach even higher levels of knowledge.

3.3   Features of Mobile Learning

With the help of m-learning students can learn anywhere and anytime [12]. m-learning, which has been defined as a subset of e-learning, is a new kind of e-learning that heavily relies on wireless technology to utilize mobile devices. And, in turn, these devices obtain learning material and educational resources for students [15] [36] [38]. With these wireless technologies, mobile learners can personalize the learning platforms to suit their needs. Here, learners are not just students but also include instructors, workers, and others. Under the concept of lifelong education, older generations can enjoy learning—not only new generations. Therefore, m-learning has wireless mobility features, extensive, interactive, high portability and sharing [47].

However, m-learning has many features compares with the traditional methods. The features of m-learning are unaccountable and some of it can be listed as being ubiquity, location awareness, virtualization and personalization [7]. Ubiquity means that the

learner, with the support of wireless connectivity, can access and use the learning content at any place, regardless of location [7]. Location awareness in m-learning can be supported by many technologies, for instance with Global Positioning System (GPS). So, localization is another key component of mobile devices since services can now be offered to the learner anywhere they may be. Convenience is accomplished by the non-stop availability of mobile devices for use [7]. In addition, instructors and learners have the ability to create virtual classrooms, which will establish a dynamic and virtual relationship between the instructor and learners [15]. Additionally, personalization is a specific strength of mobile devices. The small screen size and the challenges of navigation that users face, it means that it is really important for developers to be careful with the content of mobile applications and that they should target the learning material as much as possible.

In particular, the main pedagogical difference between e-learning and m-learning is that the former occurs in a classroom, in front of a computer, or in Internet labs—during a prefixed time and location—while the latter occurs at anytime and in any location using mobile devices [12] [48]. M-learning can be utilized to enrich, add, or enliven different lessons and courses, and m-learning facilitates both individual and collaborative learning experiences [38]. Also, it helps disconnected or unfocused learners to stay more focused for longer periods of time [15] [48].

Furthermore, one of the most important features of m-learning is always having access to the latest information [48]. This information might range from breaking news delivered on-line, to stock and share prices, other business information, or the latest weather forecasts in your area. As such, having up-to-date information helps you to make the right decisions with all the correct information at hand. Another practical use of mobile technologies is to find information regarding the area around you. For example, you might want to find the nearest hotel, restaurant, or bar and your mobile phone could tell you this information quickly. You could also get certain recommendations and find a map. Most of the smartphones today come set up with a GPS system, which utilizes satellites to determine the user's location and to offer specific information based on that

location. This means the information you obtain using mobile phones is personalized for you; thus, it's often more useful.

3.4   Classification of Mobile Technology

A variety of technologies can be classified as "mobile." The word mobile in itself means movable and portable, and is associated with the meaning of personal as opposed to shared use [49]. Mobile devices are often described as both "mobile" and "personal;" however, a device could be one without being the other. In general, mobile technologies can be classified using the two dimensions suggested: [49], personal vs. shared, and portable vs. static, as illustrated in Figure 3.5.
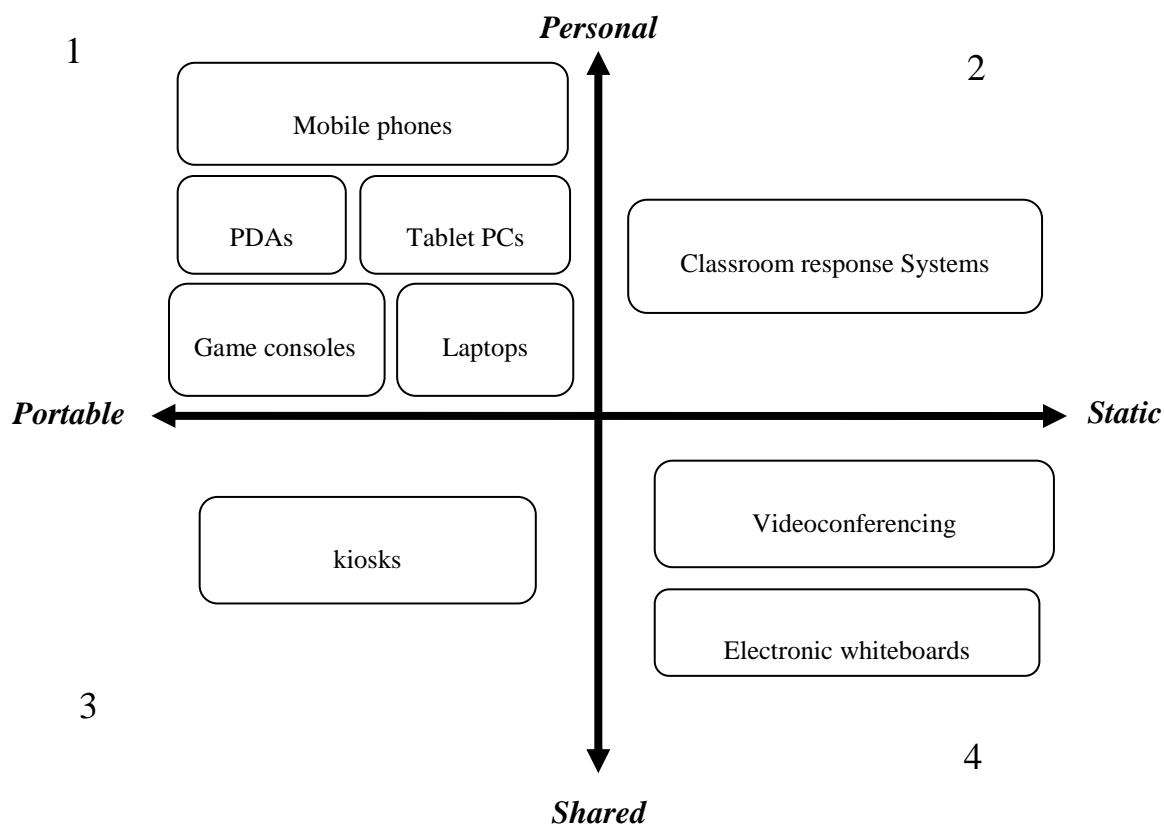
Figure 3.5: Classification of mobile learning technologies

The first quarter of the diagram encompasses devices that are considered both personal and portable at the same time. Many devices can be listed under this category; for example, mobile phones, PDAs, tablet PCs and laptops. Handheld video game consoles are also included under this category. Since a single user utilizes these devices, they are classified to be personal. Although these devices themselves are portable and personal, the information and the learning material on them can be shared, in an easy manner, with other learners. Also, these devices are portable because they can be carried from place to place; hence, they can be used in many locations. Even though, under this category, there are some technologies that are less portable than mobile phones and tablet PCs, they all have the ability to provide the learner with personal interaction with. For instance, a classroom response system, depicted in the second quarter of the diagram, an individual learning device that can be used to respond to answers to questions administrated by another learner on the central database. As in the third-quarter, there are some examples of these technologies that have the ability to provide learning experiences; however, the devices themselves are physically unmovable; for instance, street kiosks. The large size of this type of devices means that are more suitable for multiple-learner interaction and they can be classified as being shared portable technologies.

The devices themselves, to be shareable, the interactions must be larger and less portable. For instance, videoconferencing and whiteboards, as illustrated in fourth quarter, are not considered to be mobile technologies, but we have included it to illustrate the complete space of possibilities within this classification.

In the literature, there are many classifications of mobile devices. For example, Riggs and Vandenbrink [34] classified mobile phones into three separate categories based on the type of device, and how users interact with them. The three categories are one-handed, two-handed, and stylus. One-handed devices are usually utilized with one hand, because these devices have small screen sizes and always have standard keypads as the input method. Two-handed devices have small keyboards and a larger screen size compared with the first type. Generally, this type of devices requires the user to hold the device with one hand, and operate it with the other one; yet, it is possible to operate the device

with one hand as well. Finally, with stylus devices the screen sizes are much larger than the previous devices, and users interact with the stylus device through a touch screen.

3.5   Mobile Devices

Mobile devices are becoming more important and smartphones are a common sight in industrialized countries. "What started out as a product by IBM in 1992 was a niche product for a long time" [35]. This changed rapidly with the release of the Apple iPhone in 2007. One year later, Google and the Open Handset Alliance released their Android platform, which gained a lot of popularity in the following years.

Mobile devices, nowadays, are one of the factors that influence m-learning. In general, mobile devices can be defined as any type of computer device that has the capability to connect to the Internet without a permanent cable connection [34]. However, there are many types of mobile devices in the market today; for instance, cell phones, smartphones, laptops, PDAs, notebooks and net-books [34] [50] [50] [51]. The most widely used among these are cell phones and smartphones. These mobile devices are becoming increasingly sophisticated. In fact, even the most basic mobile phones offer simple personal information management (PIM); for instance, a calendar and address book.

 Today, most mobile phones have cameras and Bluetooth connectivity for exchanging information between users, and most have modems, which enable them to be linked with other devices such as laptops, or to be connected to the Internet [51]. In addition, they have the capability to send both short messaging services and multimedia messaging service [34]. Also, users of these devices are conducting online banking transactions, browsing through informative web portals, and taking advantage of gaming, etc. [34] [50].

Smartphones are considered to be mobile phones that provide more advanced computation abilities and connectivity than basic phones [51]. Smartphones have significantly increased capabilities and performance in terms of CPU power, memory

usage, and connectivity [50]. With the significant improvement in the technology over the years, the mobile markets have already shifted from cell phones to smartphones.

Furthermore, the availability of open source software platforms such as Androids, and the free development frameworks such as Java has brought the business world together with researchers from different fields—for instance, networking, imaging, gaming and many others —and the result of these changes is the creation of more sophisticated applications [50].

In particular, smartphone applications are designed, developed, and executed on these devices in order to perform some tasks for users [51]. These applications can be installed on smartphones either by manufactures or can be downloaded by users from the global smartphones application markets [50] [51].

In the last decade, markets for mobile applications have significantly grown. The Apple App store, which can be classified as the first smartphone application market, created incredible improvement in the smartphone industry; however, the most popular mobile phone markets today are the Apple App store, Google Android Market, Nokia OVI, RIM Blackberry App World, and Microsoft Windows Market [54].

As stated previously, the dream of being able to be connected with other people anywhere and at any time has eventually become true with the advent of smartphones in late 2006 [3] [53].

3.6.1 Evolution of Smartphones

We live in a revolutionary epoch for communication. The number of mobile phones, especially smartphones, has exceeded landlines in many countries [50]. The current trend of powerful mobile devices has changed the computing markets from personal computers to smartphones [51]. Companies such Apple, Microsoft, and HTC lead with smartphone technologies and every-year there are new smartphones introduced with higher

performance capabilities compared previous years [53] [52]. Nowadays, smartphones are supported with high processors, big memory storage, fancy human interfaces, touch-screens, and varied connection capabilities [50] [51] [52].

In fact, today's smartphones are the result of the advancement and development of mobile phones over the past few years by many institutions; the development began in 1992 when IBM introduced the first smartphone, available to the public by BellSouth [55]. This device, in addition to its mobile phone features, has an address book, calendar, calculator, world clock, notepad, e-mail, games, and an ability to send and receive faxes [1]. Nokia introduced its first smartphone in 1996 called Nokia 9000; the Nokia 9210, which consists of the first colour screen. The first camera-phone and Wi-Fi phone was introduced by Nokia, called the 9500 Communicator [1].

In the year of 2000, Ericsson introduced the touch-screen smartphone R380; this device was the first one to use the new Symbian operating system, and it was an advanced piece of equipment for its time [1]. The following year, Microsoft made an announcement to introduce a smartphone that would utilize Windows operating System, named "Microsoft Windows Powered smartphone 2002" [54].

In 2002, Sony Ericsson introduced one of its camera-phones: the P800. This phone has a touch-screen, and removable flip [55].

In 2004, Blackberry introduced a phone called 6120 Model. This phone featured a touch-screen, email support, QWERTY keyboard, and was thumb-operated. However, this phone has a disadvantage: it does not support a speaker phone [55].

In 2007, Apple introduced the first iPhone; it was the first phone to be fully controlled using a touch-screen [55]. This phone featured a 480x320 pixel touch-screen display with multi-touch support, and proximity sensors to turn off the screen once it is become closer to the face, 4 or 8 GB of storage at that time, camera, and automatic Wi-Fi.

In 2009, Motorola introduced another smartphone that was a powerful device at the time. This device combined the most technological features, running on Android 2.0. Its many

features include a 550MHz Texas Instruments OMAP3430 processor, 256MB of RAM, GPS, Wi-Fi, a proximity sensor, accelerometer, a slide-out QWERTY keyboard, and a 5 mega-pixel camera [55].

In 2010, Apple introduced the iPhone 4. The features of this device are as follows. The measurement of the screen is 4.5 x 2.31 inches; it is 0.37 thick and weighs 1.37 grams. It also has a 3.5-inch touch-screen with a resolution of 960 x 640 pixels [55]. In the same year, Samsung released the Android-based Galaxy S1. Some of this phone's features are as follows. The screen size is 4 inches, the processor is 1 GHz, the Bluetooth is 3.0, and the camera is 5 mega-pixels [55].

In 2011, the Galaxy S2 and the iPhone 4S were both released. And in 2012, the Galaxy S3 was released with a tag on it saying it is made "for the human," offering interaction features that are natural and easy-to-use [55].

In 2012, the iPhone 5 was introduced. It is a touch-screen-based smartphone developed by Apple. It is the 6th generation of the iPhones, and has many features. For instance, it is a slimmer, lighter model with high resolution, and a 4-inch screen [56].

In sum, smartphones are categorized according to the OS that is installed on the device, and the most eminent OSs includes Google's Android OS, iPhone OS, Microsoft Windows's mobile OS, and Blackberry's RIM OS. Android is currently the leader in the market with 56.1% smartphone sales during the year 2012 [57].

3.6   Summary

In this chapter we have introduced the concepts of m-learning. We also studied the relationships between the three factors of m-learning, and we showed their influence on the success of m-learning systems. This section mentioned three factors that need to be considered when developing mobile applications to ensure a high level of quality. Furthermore, the features of m-learning and the classification of mobile technology are discussed in detail. Finally, a brief summary on mobile devices is presented, and the evolution of smartphones is introduced.

Chapter 4

A conceptual Framework for Assessment of

Quality of Mobile Learning

In this chapter, we extend and discuss our research knowledge by investigating the technical and non-technical aspects of m-learning in section 4.2. We will also introduce a conceptual framework for measuring the quality aspects of m-learning applications. Analysis and discussion on the usability issues, based on the proposed framework, are presented and analyzed in detail.

The impact of mobile devices is becoming increasingly distinguished in our daily lives. Many researchers are experimenting with the use of these devices for different learning and teaching purposes; however, unlike personal computers (PC), mobile phones have some restrictions for displaying content, e.g. screen size and resolution. Yet, in the last two decades mobile phones and wireless communications technologies have been widely utilized in higher education to deliver different materials, because of the availability and accessibility of wireless connectivity. Learning using mobile phones, and specifically smartphones, nowadays is highly integrated within education systems—in order to support real-time communication and to deliver learning materials.

Smartphones are used in many universities as a classroom tool to engage and support students in communicative, collaborative, supportive, and constructive activities. Also, mobile technologies enable learners to build knowledge, construct understandings, and change the pattern of their work activity/learning [1]. Furthermore, the use of mobile technologies offers more opportunities for new types of learning, because they change the nature of the physical relations between instructors, students, and the objects of learning. They are a great way to ensure mobility and ubiquity in learning without technical limitations, time, and place restrictions. However, mobile applications used for educational purposes have a very complex user interface with many hidden options. The need to design and develop attractive, user-friendly mobile applications has already become hot topic—so that they're accepted by the younger generations who have grown

up with mobile devices in their hands [3]. These applications, in order to be accepted by widespread audiences, must be robust and of high quality. Nowadays, most of the applications on the market are difficult to use and learn, difficult to attract or keep users, and also difficult to remember. The key component of a successful and acceptable educational application is its ease of use. Thus, when designing a user interface for mobile phones, especially for education purposes, we should consider the special user requirements, and capabilities of these devices.

M-Learning applications for university students, instructors, and administrative staff must be designed and developed with consideration to different learning capabilities, language proficiencies, and technological skills. As discussed in the previous chapters, mobile phones, and specifically smartphones, have small screen sizes when compared to desktop computers and laptops; therefore, to develop m-learning applications that will be embraced by many different users, we have to study the technical and non-technical quality issues of m-learning.

4.1 Technical Quality Aspects of Mobile Learning

Mobility, which means "the ability to move or be moved freely and easily" , and its platform have many benefits that support m-learning. These benefits can be listed as ubiquity, location awareness, virtualization, and personalization [7] [15]. Ubiquity means that the learner, with the support of wireless connectivity, can access and use learning content at any place, regardless of their location [7] [15]. Location awareness in m-learning can be supported by many technologies: for instance, Global Positioning Systems (GPS), accelerometers, cameras, and touch-screens. Since mobile devices can offer services to the learner anywhere, localization is another key component of these devices. Convenience is offered by the availability of mobile devices anytime [7] [15]. In addition, instructors and learners have the capability to create virtual classrooms, which will establish a dynamic and virtual relationship between the instructor and learners [15]. Personalization is a specific strength of mobile devices. The small screen size and the subsequent navigation challenges mean that it is really important for developers to be

careful with the content of mobile applications—by targeting the learning material as much as possible.

All the aforementioned benefits can be considered based on technical quality, software, hardware, or the carrier network. However, there are some m-learning aspects, in relation to quality, that can be measured from a technical point of view. One of these aspects is quality of service, in terms of wireless connectivity and reliability [7]. The limitations of storage and the limited battery life mean that network connectivity is one of the challenging components, in terms of speed, of m-learning environments. Thus, not all types of the learning content can be downloaded to mobile devices. The speed and the reliability of such wireless connections determine which kinds of learning content can be used in an m-learning environment; for instance, video streaming can only be used with high-speed wireless connectivity. Another technical aspect for consideration is the screen size and resolution of most mobile devices. Furthermore, to be successful, mobile applications must be designed and developed in ways that enable them to work on many different devices and operating systems.

4.2   Non-Technical Quality Aspects of Mobile Learning

According to The International Standards Organization/International Electrotechnical Commission (ISO/IEC) 9126 [54], usability includes the attractiveness, operability, understandability, learnability, and usability compliance sub-characteristics. Usability is known as a qualitative attribute that determines how easy the user interface can be utilized [59]. It assesses the quality of users' interaction with the system's environment. Usability is considered to be one of the most important characteristics when targeting systems that will be used by widespread audiences, such as university students, without direct training and support [59]. In general, mobile applications must not be complicated, the input should be easy to insert, and simplified using location aware functions [8] [32] [60]. In addition, mobile applications must have well-designed interfaces with appropriate colour and font sizes, because mobile users must be able to concentrate on the system for easy use [59]. The operability sub-characteristics are affected by the mobile phone's attributes; for instance, screen size, keyboard, and numeric pad, which

restrict input and output interaction possibilities. The input capabilities are determined by the screen size of mobile phones, and this must be taken into consideration by developers. They must limit data input to minimal required data, and use automatic filled-in blanks and prefixed options.

On the other hand, the output restrictions of mobile phones are decided by their screen size, which restricts the learning material that will be displayed. Developers must overcome this limitation too, for instance, by displaying the learning material across multiple pages [8]. Another critical issue when operating the system in a public environment is that users may not be able to enter the correct information [60]; this will cause input errors, slowness, and inaccuracy. The ability to reach the mobile feature "anywhere and anytime" will increase the application's attractiveness [58]. On the other hand, understandability and learnability determine how easy users perform their basic tasks the first time they use the application [59].

Mobile usability issues are considered one of the main reasons why mobile applications fail [60]. However, current research suggests that with m-learning, a user-centre design approach can be effective, resulting in better m-learning usability [8] [60]. A user-centered design approach does not simply mean planning learning goals and actions; it means determining the varied contexts of use, and the requirements needed to be accepted by varied users, including "instructors, students and administrative staff" [60]. With several factors influencing the usability of mobile phones in education, the MOBIlearn project [36] emphasizes that it is important to observe the usability requirements for users who will be utilizing the systems. This will ensure the acceptability, and high level of usability of those systems [60].

Another approach to improving usability issues is to make the user interface adaptable to/by the user [8] [60], by making the learning content personally valuable and acceptable in a given context. Nonetheless, due to the many reasons for the utilization of m-learning in education, it is difficult to make any generalizations about usability requirements by different users (students, instructors and content creators) [8]. More importantly, there are some attempts to classify these requirements—including user interface and usability [60].

Nielsen [61] has realized that even general usability standards can be applied to m-learning. There are some additional considerations. For instance, there is always a need to keep the learning content fresh and up-to-date in the user's mind, so as not to forget what he/she has learnt while performing other tasks. User-centered design has been driven by the concept of tasks, and it is possible to list the types of tasks that users will perform. Fagerberg et al., [62] suggest that mobile users need to be able to conduct varied tasks including studying the course materials, reading announcements, doing assignments, and discussing some topics by communicating, interacting and collaborating with other users. Research indicates that a learning environment will be either accepted or refused by users according to its acceptability factors, which includes its usability [61] [62].

4.3 A Conceptual Framework for Assessment of Quality of Mobile Learning

Based on the quality issues of m-learning discussed in the previous sections, we have developed a framework for measuring the quality aspects in m-learning [63] [64]. Basically, this framework is a combination of structural factors [65]: rules, goals, outcomes, competition, interaction, and representation. It also integrates dimensions of the learning context [66]: identity, time-location, facility (mobile phones), activity, learner on the move, and community. A similar framework has been introduced [7]; however, we have identified three design issues which are:

1- Usability
2- Communication
3- Interactivity
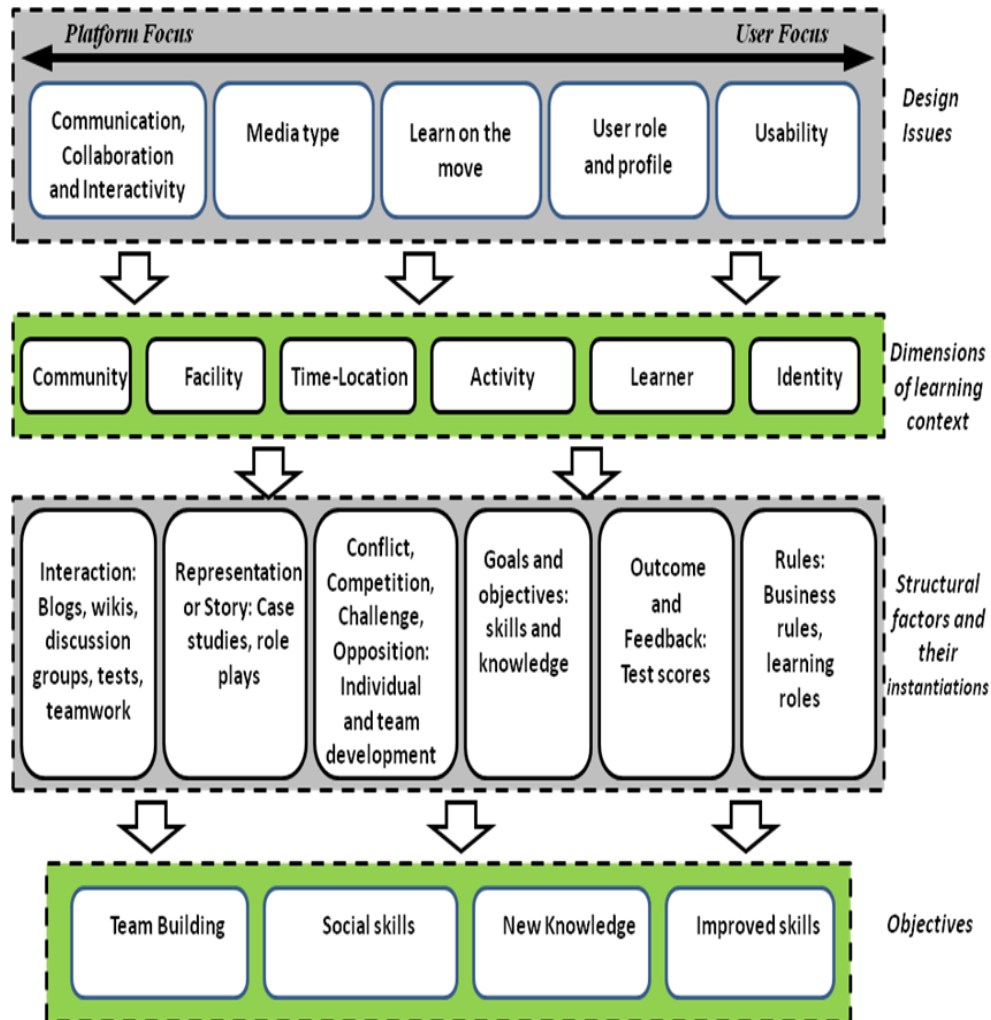
Figure 4.1: A conceptual framework for measuring the quality aspects for mobile learning

In addition to the previous design issues that were identified [7], which are learn on the move, media type, collaboration, user role, and profile. Firstly, these design issues have been linked to the dimensions of learning context, and then to the structural factors. From these two steps we are targeting social skills and team building, new knowledge, and improved skills. Key features of the framework are that it identifies the importance of design issues, dimensions of the learning context, and structural factors—in order to address learning objectives that have a user focus and also that have a platform focus.

To illustrate the usability design issue, which includes ease of use and understanding, can be achieved if the users were able to use the applications (usability design issue).

This also can be achieved by using identifiers of each user that must be unique in the name-space, and that are accessed by the application via a log-on system (with a user name, password and/or special devices such as smart cards or fingerprint reader). All these identifiers are classified under the "identity dimension" within the learning context. Furthermore, the ease of use and the ability to utilize specific identifiers for each user will enable them to perform tasks such as reviewing the lessons, doing assignments, and participating in group sessions with other users—with the support of mobile devices (structural factors: business rules and learning roles).

Finally, the learning objectives will be addressed which may include improving of skills, acquiring new knowledge, social skills, or team building; however, and as we have mentioned in this paper, each design issue may be linked with more than one of the dimensions within learning content. In sum, most of the components of this framework will relate to each other in one way or another. For example, usability factors can be affected by more than one of the learning contexts including identity, learner, activity, time-location, facility (mobile phone), and the community. On the other hand, each dimension of the learning context may be linked with more than one of the structural factors, which in turn, are linked with different learning objectives.

4.3.1 Analysis and Discussion of the Proposed Framework

Based on the metrics that ISO/IEC provides for measuring software quality in process and in use, the analysis of our framework from the quality point of view requires us to put into consideration the boundary between quality metrics that are user focused, from ISO/IEC, and those that are product related. The relationship between the quality of use, internal quality, and external quality metrics are shown in Figure 4.2.

Based on the analysis of our framework, if we can apply some extensions to the ISO/IEC metrics, we will be able to map these metrics with our framework in order to measure the design issues related to learning on the move, user roles and profiles, media type, and

usability issues. However, additional metrics are needed to complement the contexts of use dimensions of the quality in use metrics. To analyze our framework, we are considering a case study.
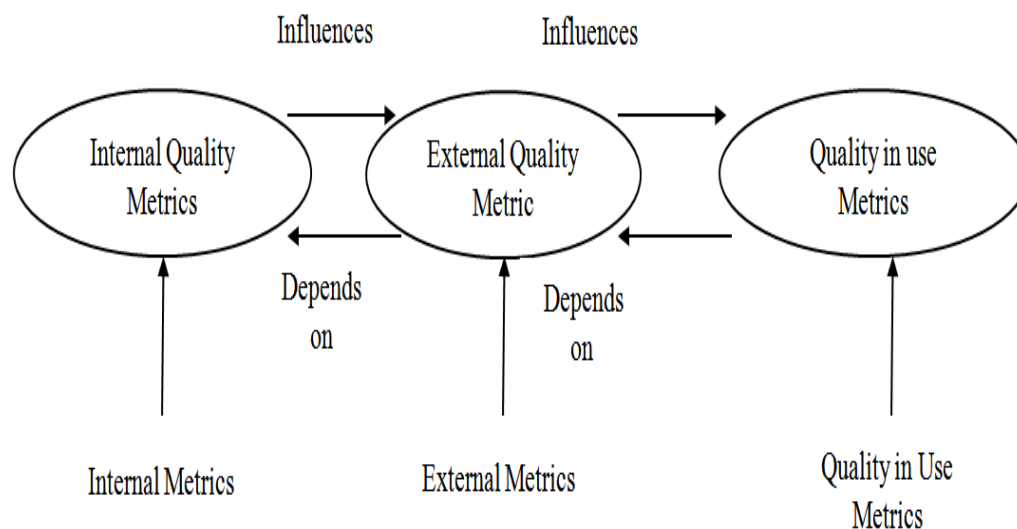
Figure 4.2: The relationships between the quality metrics based on ISO/IE

To analyze our framework, we are considering a case study and the metrics that (ISO/IEC) provides. The most suitable example is Busuu project [67]. The Busuu project is an online social network application in which learners can assist each other to improve their language skills. The application provides learning units for twelve different languages, and it can be downloaded to mobile phones to use. This application was designed to enable users to set up a profile and practice (quality metrics of user roles and profiles). Software developers were careful with the learning content that displayed on screens; they targeted as much learning content as possible (quality metric of media type). On the other hand, since the application can be downloaded to mobile phones, users are free to use it wherever network connectivity is available (quality metrics of learning on the move). In addition, each individual user of this application is not only a student of a foreign language, but also a tutor of his or her own mother tongue. One user can communicate and interact with other users (quality metrics of communication,

collaboration and interactivity). However, by using some of the appropriate metrics from ISO/IEC (e.g., functionality, scalability, service quality, etc.), we will be able to measure the quality of m-learning applications.

Table 4.1: Analysis of the Busuu project based on our framework

Objectives	Learning experience	Learning contexts	Design issues
Initial interaction: **1.** Exploring, discovering and getting familiar with the software. **2.** Communicating, interacting and collaborating with peers by asking and answering questions.	**Rules: business rules, learning roles** different users meet in the context of a simulation. **Outcome and feedback:** asking questions and getting answers. Goals and objectives: to get familiar with the application. **Conflict, competition, challenge, opposition:** discussing and challenging opinions (team work and new skills) **Interaction: blogs, wikis, discussion groups, test, teamwork:** One to one, one to many and many to one.	**Identity:** user name and password for each individual user. **Learner:** different users. **Activity:** To engage in participatory simulation of a dynamic system. **Time - Location:** Co-located same time and different time. **Facility:** different mobile devices. **Community:** different user with different background using the mobile devices with the support the wireless connectivity can discuss many different topics in order to improve their language skills.	**User roles and profiles:** New users - few ideas of how to use the application. **Learn on the move:** Mobile devices with the support of wireless connectivity. **Media type:** text, images, comprehensive audiovisual learning material with photos and recordings by native speakers, avoid information overload. **Communication, collaboration and interactivity:** users can communicate, collaborate using text, verbal and video-chat communication support.
Learning new language: by sharing and exchanging information between users can obtain new knowledge that will help them to improve language skills and help them to conduct the following objectives: **1. Team building** **2. Social skills** **3. New knowledge** **4. Improved skills**	**Rules: business rules, learning roles:** lessons, tutorials, assignments, assessments, group sessions with the support of mobile devices. **Goals and objectives:** To get, give answers and to engage in participatory simulation to learn a new language and/or improve language skills. **Conflict, competition, challenge, opposition:** discussing and challenging opinions. **Interaction: blogs, wikis, discussion groups, test, teamwork:** One to one, one to many and many to one.	**Identity:** different users. **Learner:** different users. **Activity:** Explaining and discussing participative experience. **Time - Location:** Co-located place, same or different time. **Facility:** different mobile devices. **Community:** different user with different background using the mobile devices with the support the wireless connectivity can discuss many different topics in order to improve their language skills.	**User role:** Participant in group discussion (users). **Learn on the move:** Mobile devices with the support of wireless connectivity **Media:** text, images, comprehensive audio-visual learning material with photos and recordings by native speakers, vocabulary and key phrases, dialogues, audio, podcasts and PDFs and avoid information overload. **Communication, collaboration and interactivity:** users can communicate, collaborate using text, verbal and video-chat communication support.

Table 4.1 shows the analysis of the Busuu project based on our framework. In this case, the analysis—as outlined with the table—walks us through from the objectives to the design issues. The purpose of this reverse engineering is to see how successful the Busuu project is and also to determine which design issues our framework can assess and address.

The results indicate that the Busuu project is a successful project since it has met all the requirements of our framework. Also, the success of this project can be determined by the number of downloads. In less than two years, the Bussu project's applications for Android, iPhone, and iPad have already been downloaded over 10 million times, and every day there are 20,000 new downloads [67]. On the other hand, the results also show that our framework can be used to assess all the design issues; for instance, by using the existing metric (ISO/IEC). However, one of the goals of our framework is that it should be used to support forward engineering, and be used as a design guideline for developing educational m-learning applications.

Usability has been stated as one of the most important fundamentals of m-learning applications [63] [64] [68]. For example, if the applications have the following weaknesses: i) difficult to use, ii) user interface that is hard to learn how to use, iii) user interface that is difficult to remember how to reuse; iv) learning content structure that is unclear; v) the process's work-flow that is difficult to perform: users will not be efficient, effective, and productive [64]. Thus, users in this case will not be efficient, effective, or productive, and will get lost. The user interface must be effective and easy to use, which will help users to focus of their learning goals, learning content, and activities—instead of how the system works [63] [64]. Furthermore, utilizing design guidelines are vital in developing reusable learning systems, and are the most effective and valuable methods in evaluating and testing users [63].

4.4   Design of the Prototype Application

We have designed a prototype application similar to WebCT. This application, like any other application developed for Android, is placed on the application layer. To illustrate:

the applications installed on the application layer appear on the home screen of the Android emulator—with the native applications as shown in Figure 4.3.

The interface of the Main Menu of the developed application is shown in Figure 4.4.

Figure 4.3: Android emulator

Basically, this prototype application consists of two user interfaces named Model A and Model B. Model A was designed and developed based on a user interface adopted from the Blackboard (Bb) website, as mentioned before, while the Model B was developed following Android SDK recommendations, and by using our framework as a guideline. We have used familiar terminologies in this prototype application that could be seen on most of WebCT such as "Course Map", "Course Information", "Assignments", "Announcements", "Discussion Board", "Media", "Grades", and "Blogs"—as shown in Figure 4.5 and Figure 4.6, respectively.

The main purpose for developing these different user interfaces is to find out the best way to design and develop a user-friendly user interface for mobile applications—in order to increase the usability level of these applications.
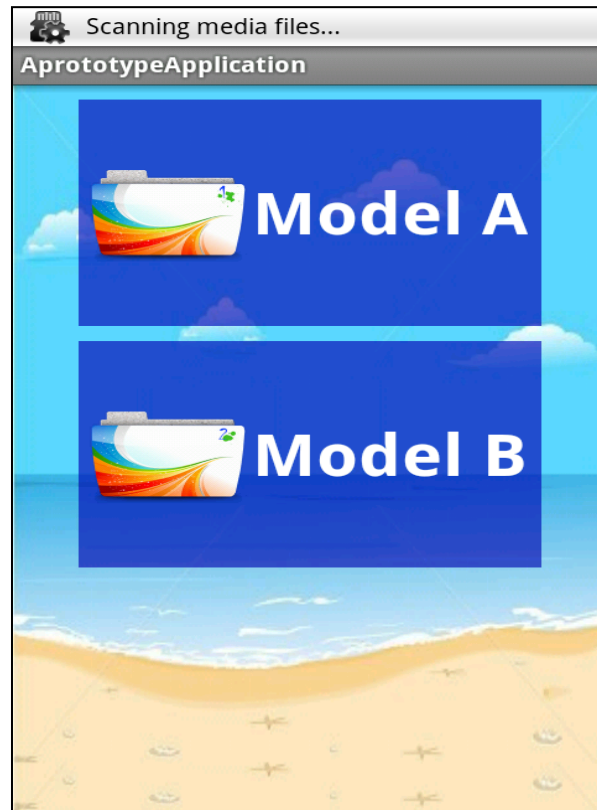
Figure 4.4: Main menu of the prototype application
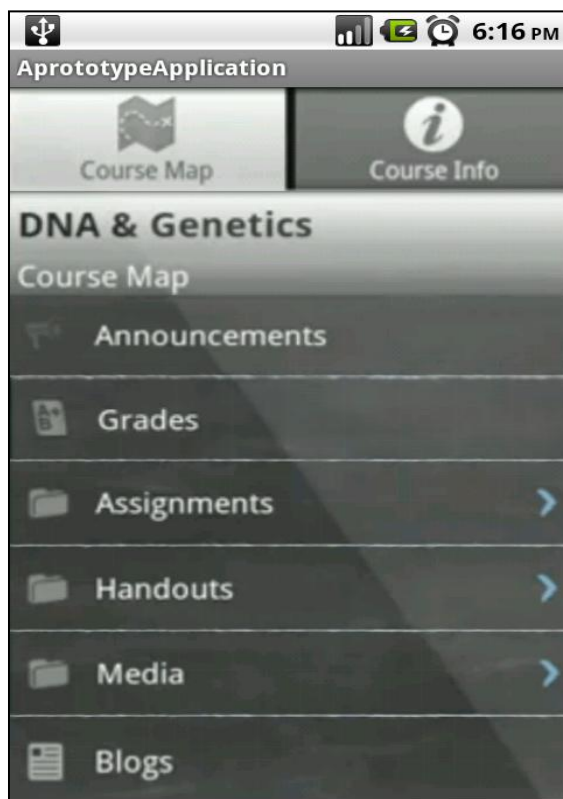
Figure 4.5: Model A based on Blackboard website
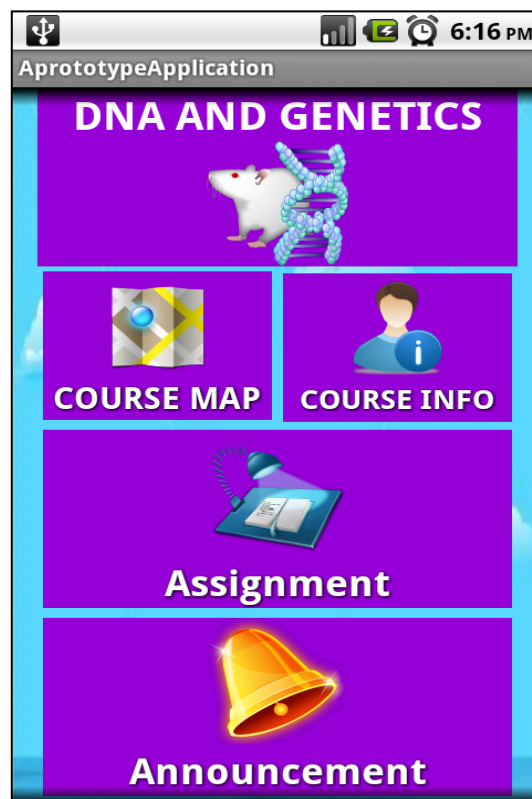
Figure 4.6: Model B based on Android recommendations and our framework as a guideline

4.5 Developing and Implementation of the Prototype Application

We have used Java Languages, and the Android Software Development Kit (SDK) to develop and implement a prototype application for smartphones. The SDK comes with a user-friendly development environment, including a device emulator (as depicted in Figure 4.3), tools for debugging, memory, and a plug-in for the Eclipse IDE. The Eclipse is used as the development tool with a Google supplied Android plug-in. The new user-friendly, desktop-like application development approach makes it interesting to explore the possibilities of this platform; see Appendix B for more information.

```xml
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:gravity="center"
    android:orientation="vertical"
    android:padding="15dp" >

    <Button
        android:id="@+id/b1"
        android:layout_width="fill_parent
        android:layout_height="wrap_conte
        android:layout_alignParentBottom=
        android:layout_alignParentLeft="t
        android:gravity="center"
        android:text="OK"
        android:textSize="25dp"
        android:textStyle="bold" />

    <ImageButton
        android:id="@+id/imageButton1"
        android:layout_width="match_paren
        android:layout_height="wrap_conte
        android:layout_above="@+id/b1"
        android:layout_alignParentLeft="t
        android:layout_alignParentTop="tr
        android:layout_marginTop="28dp"
        android:layout_weight="1.04"
        android:src="@drawable/western" /

</RelativeLayout>
```

Figure 4.7: XML-based notation for rendering Android based format

Furthermore, we have used one of the building blocks of the Android application development named "Activity." Activity base class is used to display a single user interface, and to handle user interactions within that user interface in the application. Each user interface corresponds to other user interfaces—namely the Course map, Course Information, Assignments, Announcements, Media, Grades, and Blogs. An Android Activity class has to implement the onCreate() method which initializes the activity by

calling setContentView(int) with a layout resource defining UI of the activity. The User interface is displayed and the method findViewById(int) is utilized to call the widgets in that UI, so that the user interaction can be controlled within the prototype application. After implementing the Activity class, to utilize it in the prototype application, the Activity class must have a corresponding "<activity>" declaration in the application's manifest file. The Android manifest file is a mandatory file for every single application in Android, and it is named AndroidManifest.xml. It prescribes global values for the packages, including all the application components (like activities, etc.) that the package exposes, and the implementation classes for each component, including where they can be launched.

Using Android SDK we can create two different types of User interfaces, either by utilizing XML or by utilizing the program code. However, when Android SDK compiles the application it compiles each file into a user-interface resource that can be displayed on the screen by the application's controller classes. In our application, all the layout and components are developed using XML. Each user interface is defined using a tree of Views, which are the basic units of UI design in Android. A View displays a rectangular shape on the screen, and it is drawing and event handling; see Appendix B for more information about Android SDK. However, in XML the View layout appears as shown in figure 4.7.

4.6   Testing of the Developed Prototype Application

As mentioned in section 1.3, Heuristic evaluation has been utilized as a technique to measure the usability issues of the application; it is a method for easy, quick, and cheap evaluation of user interface designs [15]. Also, a usability questionnaire was conducted to evaluate the usability issues of the prototype application among 96 software engineering undergraduate students at Western University. For collecting and identifying the usability level of the prototype, participants must fill out the provided questionnaire survey forms and answer the questions. After they have been given the questionnaire survey form they will be provided with real smartphone device. The main goal here is to compare the two user interfaces in the four sections and determine which one of these interfaces is the best, in terms of the usability sub-characteristics. For instance, to compare the Blogs

icons and also to compare the announcement icons in both interfaces (Models), as illustrated in Figure 4.8, 4.9, 4.10 and 4.11 in term of ease of use, user satisfaction, Understandability, and learnability.

Figure 4.8: User interface for blog's icon in Model A
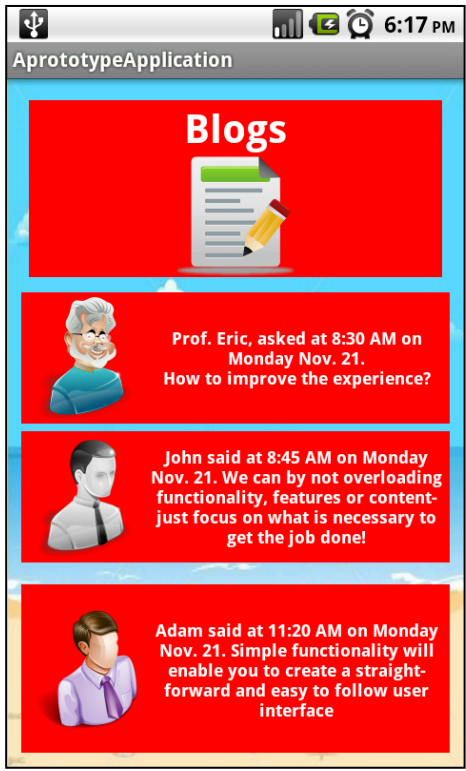
Figure 4.9: User interface for blog's icon in Model B
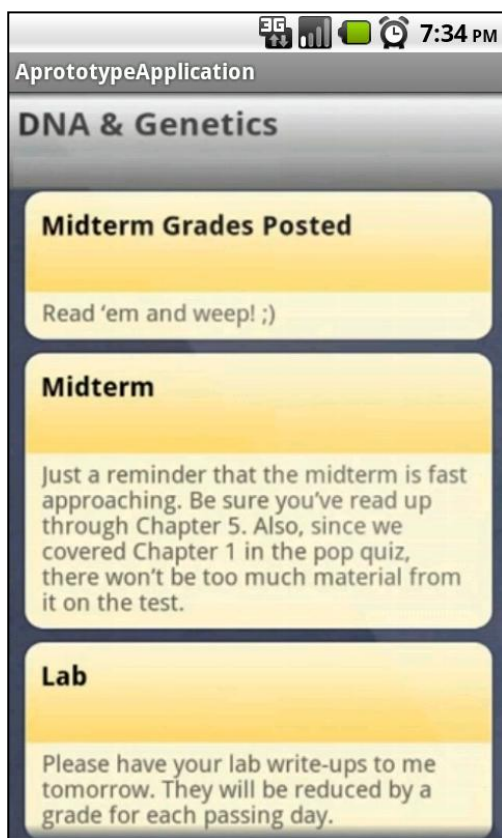
Figure 4.10: User interface for announcement's Icon in Model A
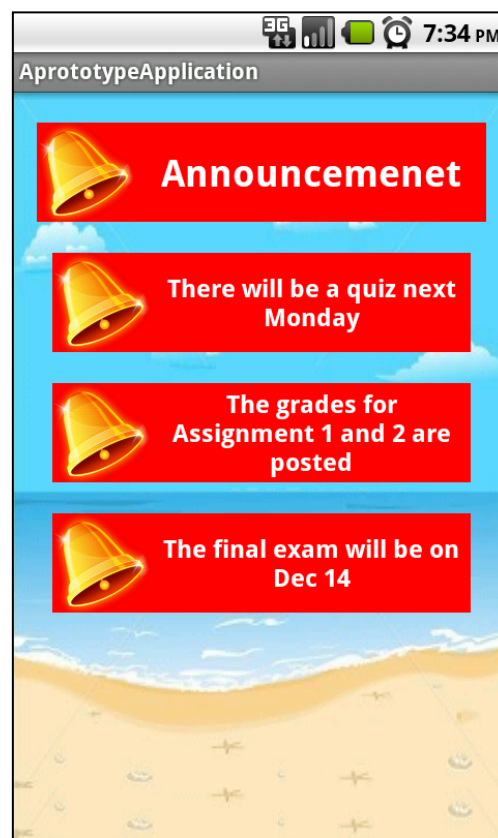
Figure 4.11: User interface for announcement's Icon in Model B

4.7 Summary

Without a doubt, smartphones are the way of the future. Designers and developers of mobile applications need to consider the quality aspects of these applications, and more specifically the usability issues, to be accepted by the new generation. This chapter discusses the technical and non-technical aspects and contexts for m-learning. It illustrates how quality characteristics can be measured in the context of a conceptual framework for m-learning applications. A case study has been considered based on our framework; it showed which design issues can be measured using the established quality metrics from (ISO/IEC). Also, we suggested that additional metrics are needed to complement the contexts of use dimensions of the quality-in-use metrics.

Additionally, in this chapter, we have introduced the tools and languages that we have used to build our prototype application—which are Eclipse platform, Java, XML, and Android SDK. Also, we have discussed the design and developmental stages of our prototype application in detail. Furthermore, screenshots of the user interfaces of our application were presented here as well.

Chapter 5

An Empirical Comparison of the Models

In this chapter, we conduct an empirical study of the data we have collected to determine which of the application's user interfaces has the best and most user-friendly interface. In Section 5.2 the purpose of the analysis is introduced. The preliminary data analysis is discussed in Section 5.3, and in Section 5.4 reliability and validity of the data is explained in detail. Finally, the association relationship is introduced in Section 5.5.

5.1   Purpose of the Analysis

This data analysis aims at comparing two user interfaces for smartphone applications. This specific comparison will focus on the following aspects ease of use, user satisfaction, attractiveness, and learnability. The sample contains 96 students who use the UI for the application and finish the survey correspondingly. The analysis process will contain the following steps: preliminary data cleaning; reliability test and association relationship test.

5.2   Preliminary Data Analysis

Since we have gathered the data for user interfaces (Model A and Model B), based on the four sections: ease of use, user satisfaction, attractiveness, and learnability as illustrated in Table 5.1.

Initially, we could preliminary explore the histogram distribution and compare the data for Model A and Model B. Since we used multiple questions for the users to evaluate the Models in each section (from different angles), we could assume the same weight to every question for the overall evaluation of this section.

Table 5.1: Statistical analysis of the data

Sections	Statistical analysis for Model A		Statistical analysis for Model B	
	Mean	Standard Deviance	Mean	Standard Deviance
Ease of Use	2.47	0.37	1.74	0.14
User Satisfaction	2.23	0.27	1.76	0.19
Attractiveness	3.16	0.27	2.05	0.13
Learnability	2.17	0.1	1.71	0.09

5.3.1 Ease of Use

Table 5.1 shows the Statistical analysis for Model A and Model B, and we can see that Model B, with the mean of 1.74, has a lower score than Model A, with the mean of 2.47—in the ease of use section—which means that users evaluate Model B as the more easier-to-use User interface compared with Model A. In addition, the standard deviance for Model B is (0.14), which is also lower than that of Model A (0.37). This illustrates that the evaluation towards Model B is more consistent and less variable, than Model A as well. Therefore, we could plot the comparison plot as illustrated in Figure 5.1, since our survey is conducted based on the paired experiment.

As illustrated in Figure 5.1, we can see that for all the six questions:

1. I found navigating around the prototype screen to be (To determine how easy for the user to find and move from one task to another):

   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

2. How easy was it to distinguish the appropriate icon for information you wanted (To determine how quick is it for the users to differentiate the icon that they want from the other icons)?

   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

3. How easy was it to scan the prototype in text to find the information you wanted (To determine how easy and quick for the users to find the appropriate icon by reading the text only)?

___Very Easy ___ Easy ___Average ___Difficult ___Very Difficult

4. How easy was it to scan the prototype in graphic to find the information you wanted (To determine how easy and quick for the users to find the appropriate icon by searching for graphic only)?

___Very Easy ___ Easy ___Average ___Difficult ___Very Difficult

5. How do icons fit its purpose (To determine whether the icons represent their purposes)?

___Very Easy ___ Easy ___Average ___Difficult ___Very Difficult

6. How user friendly is the prototype (To determine whether the application has all the features that make the user satisfied to use it)?

___Very Easy ___ Easy ___Average ___Difficult ___Very Difficult

The users who participated in our survey will give Model B a lower score than Model A.
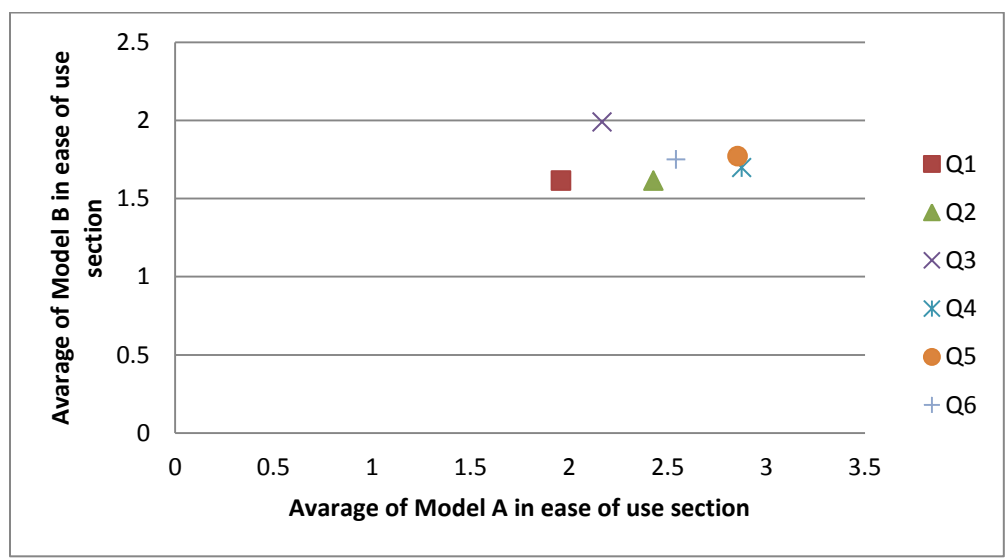
Figure 5.1: Score average of Model A and Model B in ease of use sub-characteristic

5.3.2 User Satisfaction

It is one of the usability sub-characteristics that we have included in our research. As illustrated in Table 5.1, and for the descriptive statistics for Model A and Model B, we can see that Model B with the mean of (1.76) has lower score than Model A with the Mean of (2.23) (in the user satisfaction section)—which means that users evaluate Model B with more satisfaction than Model A. In addition, the standard deviance for Model B is (0.19) which is also lower than Model A (0.27); which illustrates that the evaluation toward Model B has more consistency, and is less variable than Model A. Therefore, we could plot the comparison plot as illustrated in Figure 5.2, since our survey is conducted based on the paired experiment.

Figure 5.2: Score average of Model A and Model B in user satisfaction sub-characteristic

It is obviously clear from Figure 5.2—that according to the five questions this section consists of in our survey which are:

7. Do you agree that the font size is easy to read (The purpose of this question is to know whether the text size is clear and readable for all users or no)?

     ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

8. Do you agree that the prototype has all the features (download, submit…) required by a user (To determine if the application has all the required features by the users)?

   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

9. Do you agree the prototype provides you enough suggestions and prompt you towards the right usage ()?

   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

10. Are the terminologies (for example, assignments, grades, media…) that have been used in this prototype familiar to you (To determine whether if all the terminologies that have been used in this application are familiar and understandable by all users)?

   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

11. How would you rate the organization of the prototype (To determine the level of the organization of the application)?

   ___ Excellent   ___ Very good   ___ Good   ___ Bad

Users evaluate Model B as more satisfactory than Model A.

5.3.3 Attractiveness

Attractiveness is one of the usability sub-characteristics that we have included in our research; it is illustrated in Table 5.1. For the descriptive statistics (in attractiveness section) of Model A and Model B we can see that the Model B, with the mean of (2.05), has a lower score than Model (3.16), which means that users evaluate Model B as more attractive than Model A. In addition, the standard deviance for Model B is (0.13), which is also lower than that of Model A (0.27); this illustrates that the evaluation of Model B has more consistency, and is less variable than Model A as well. Therefore, we can draw out the comparison plot as illustrated in Figure 5.3—since our survey is conducted based on the paired experiment.
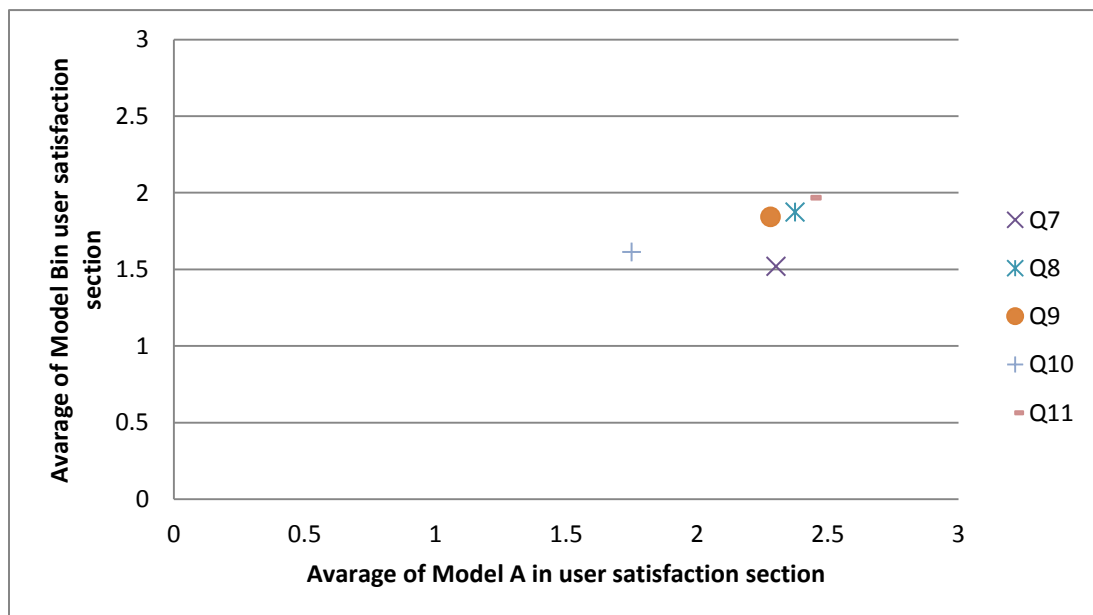
Figure 5.3: Score average of Model A and Model B in attractiveness sub-characteristic

It is obvious from Figure 5.3, and according to the five questions which are:

12. Did you find the prototype attractive (To determine the attractive level of the application in general for the users in terms of the text size, color and graphics that have been used)?

   ___Strongly agree   ___Agree   ___Somewhat agree   __Disagree.

13. How would you rate the flexibility of the prototype (How flexible the application is)?

   ___ Excellent   ___ Very good   ___ Good   ___ Bad

14. Are the colors and graphics of the icons clear and attractive (To determine whether the colors and graphics of icons that have been used in the application are attractive or no)?

   ___ Excellent   ___ Very good   ___ Good   ___ Bad

15. Are the colors and graphics of the background clear and attractive (To determine whether the colors and graphics of background that have been used in the application are attractive or no)??

   ___ Excellent   ___ Very good   ___ Good   ___ Bad

16. My overall impression of the prototype is (To determine the impression in general of the application for each user):

   ___ Excellent   ___ Very good   ___ Good   ___ Bad

 Users evaluate Model B as more attractive than Model A.

5.3.4 Learnability

Learnability is one the usability sub-characteristics included in our research. In learnability section (as illustrated in Table 5.1) with the descriptive statistics for Model A and Model B, we can see that Model B with the mean of (1.71) has lower score than Model A (2.17)—which means that users evaluate Model B as easier to learn than Model A. In addition, the standard deviance for Model B is (0.09) which is also lower than Model A (0.1)—which indicates that the evaluation towards Model B has more consistency and is less variable than Model A. Therefore, we can draw out the comparison plot as illustrated in Figure 5.4, since our survey is conducted based on the paired experiment.
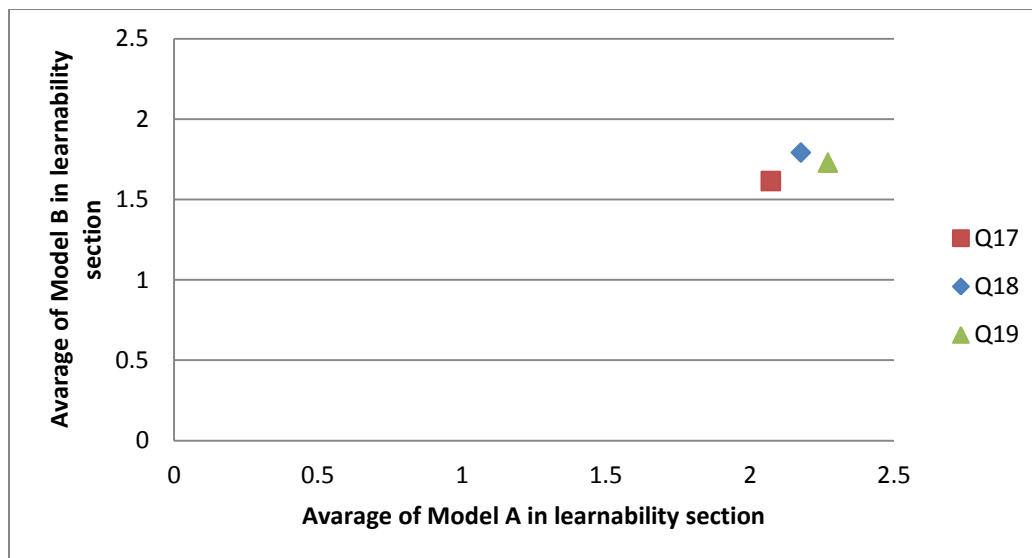
Figure 5.4: Score average of Model A and Model B in learnability sub-characteristic

It is clear from Figure 5.4, and according to the three questions which are:

17. Learning to operate the system is (To determine the level of the learnability to operate the application):

   ___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult

18. Remembering and reaching function's name is (To determine whether if it easy to remember how to use the application again and finding)

   ___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult

19. Understanding the hierarchical of the program is(To determine how easy to understand to move from function to another and how easy to the structure of the program as well)

   ___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult

Users evaluate Model B as more learnable than Model A.

5.3.5 General Case
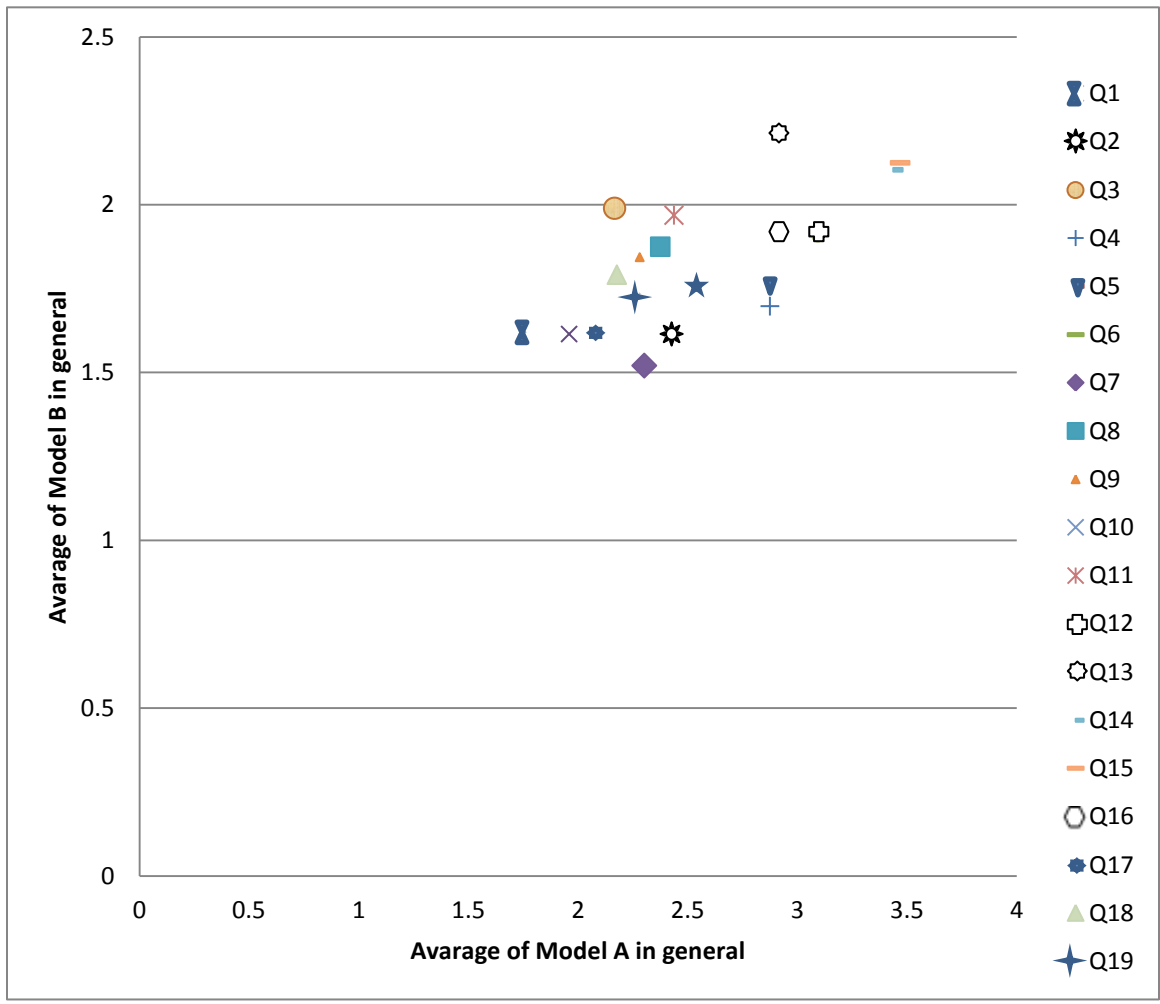
Figure 5.5: Score average of Model A and Model B in general case

We can know that the general score for Model B will be less than Model A as depicted in Figure 5.5, which indicates that Model B will outperform Model A in the four section comparisons.

5.4 Reliability and Validity

To validate our intuitive understanding regarding the comparison between Model A and Model B, we employ the paired T-test and F-test to test the different scores between Model A and Model B, and the variance differences between them as well.

Our hypothesis for the four sections is that Model B will perform the same as Model A (as depicted in Table 5.2).

Table 5.2: Hypothesis for the usability sections

Hypothesis	Statement
Ease of Use	
User Satisfaction	*Model B performs the same as Model A.*
Attractiveness	
Learnability	

The outcomes are presented as followed:

Table 5.3: Analysis of the data using T-Test and F-Test

| Hypothesis | Paired T- Test | | Paired F -Test | |
	Test Statistics	Confidence Interval (α=0.05)	Test Statistics	Confidence Interval (α=0.05)
H1: Ease of Use	15.0*	(0.64, 0.82)	1.32*	(1.12, 1.57)
H2: User Satisfaction	10.5*	(0.38, 0.55)	1.30*	(1.09, 1.55)
H3: Attractiveness	20.7*	(1.0, 1.21)	0.70*	(0.58, 0.83)
H4: Learnability	7.9*	(0.35, 0.58)	1.37*	(1.09, 1.73)
General Case	*27.3*	*(0.67, 0.77)*	*1.32*	*(1.19,1.44)*

(*) Significant at P-Value < 0.05, and (**) insignificant at P-Value > 0.05.

5.4.1 Ease of Use

As depicted in Table 5.3, we can see that our hypothesis that Model A and Model B will perform the same in the ease of use section is rejected. This is due to the significantly small number of P-Value, which is statistically significant at P-Value < 0.05, and indicates that Model A and Model B perform significantly different in the ease of use category. Furthermore, we can see from the confidence interval, for the mean difference between Model A and Model B, is (0.64, 0.82). Both of the lower bound and upper bound scores are larger than 0 (T-test confidence interval), which indicates that the score for

Model A is higher than that of Model B. This data validates our intuitive understanding that Model B is better than Model A—in regards to the data based on the preliminary data analysis.

As for the variance and consistency analysis, we can assume our hypothesis is that the variance of Model A is the same as that of Model B in the ease of use section. And we can see from the outcomes that the P-value < 0.05, which means we reject our hypothesis. From this outcome, we can say that the consistency situation for Model A and Model B is different. Furthermore, if we take a detailed look at the confidence interval, which is (1.12, 1.57) with the lower bound larger than 1; thus, we can say that the estimation for Model B is more consistency than that of Model A.

5.4.2 User Satisfaction

As illustrated in Table 5.3, our hypothesis that Model A and Model B perform the same in the user satisfaction section is rejected due to the significantly small number P-Value of which is statistically significant at P-Value < 0.05—and indicates that Model A and Model B perform significantly different in the user satisfaction section as well. Furthermore, we can see from the confidence interval for the difference between Model A and Model B is (0.38, 0.55). Both the lower bound and upper bound numbers are larger than 0. This indicates that the score for Model A is higher than that of Model B—which, in turn, validates our intuitive understanding that Model B is better than Model A—based on the data from our preliminary data analysis.

As for the variance and consistency analysis, we can assume our hypothesis is that the variance of Model A is the same as Model B in the user satisfaction section. And we can see from the outcomes that the P-value < 0.05, which means we reject our hypothesis. From this outcome, we see that the consistency situation for Model A and Model B is different. Furthermore, the confidence interval is (1.09, 1.55) with the lower bound number larger than 1; thus, it is clear that Model B has more consistency than that of Model A.

5.4.3 Attractiveness

As depicted in Table 5.3, we can see that our hypothesis that Model A and Model B will perform the same in the attractiveness section is rejected due to the significantly small number P-Value (of which is statistically significant at P-Value < 0.05), indicating that Model A and Model B perform significantly different in attractiveness section. Furthermore, we can see from the confidence interval for the difference of Model A and Model B is (1.0, 1.21). Both of the lower bound and upper bound are larger than 0; this indicates that the score for Model A is higher than that of Model B, which validates our intuitive understanding that Model B is better than Model A (based on the preliminary data analysis).

However, as for the consistency analysis for Model A and Model B in the attractiveness section, we can see that the P-value < 0.05, which forces us to reject our hypothesis that Model A and Model B are the in terms of consistency. However, must notice that the confidence interval in this section is (0.58, 0.83), which has an upper bound number of less than 1. Therefore, in this section, Model A will be more, in terms of consistency, than Model B. Nevertheless, if we further explore the reasons for this phenomenon we realize that since attractiveness is more of a subjective judgment for users to evaluate the Models. One possible cause for this outcome is because the samples we took have a more concentrated and focused evaluation of Model A. We asked half of the questions in this section about colours that have been used in the prototype application—and one of the most used color of Model B is "*Red*"—and we have got a lot of suggestion and feedback not to use this color.

5.4.4 Learnability

As illustrated in Table 5.3, we see that our hypothesis that Model A and Model B perform the same in the learnability section is rejected due to the significantly small number P-Value (of which is statistically significant at P-Value < 0.05). These results indicate that Model A and Model B perform significantly different in the learnability section as well. Furthermore, we see that the confidence interval for the difference between Model A and Model B is (0.38, 0.58). Both of the lower bound and upper bound numbers are larger

than 0—this indicates that the score for Model A is higher than that of Model B—which validates our intuitive understanding that Model B is better than Model A (based on the preliminary data analysis).

As for the variance and consistency analysis, our hypothesis is that the variance of Model A is the same as that of Model B in the learnability section. And we see from the outcomes that the P-value < 0.05, which means we reject our hypothesis. From this outcome, we can say that the consistency situation for Model A and Model B is different. Furthermore, taking a detailed look at the confidence interval, which is (1.09, 1.73) with the lower bound larger than 1, it is clear that Model B has more consistency than Model A.

5.4.5 General Validation

For the General Validation section, and the Table 5.3 as well, we can see that our hypothesis that Model A and Model B perform the same in general is rejected, due to the significantly small number P-Value (of which is statistically significant at P-Value < 0.05). These results indicate that Model A and Model B perform significantly different in general. Furthermore, we see that the confidence interval regarding the difference between Model A and Model B is (0.67, 0.77), and that both the lower bound and upper bound numbers are larger than 0. This indicates that the score for Model A in general is higher than that of Model B, validating our intuitive understanding that Model B is better than Model A (based on the preliminary data analysis).

Regarding the variance and consistency analysis, our hypothesis is that the variance of Model A is the same as that of Model B. And we see from the outcome that the P-value < 0.05, which means we reject our hypothesis. From this outcome, we see that the consistency situation for Model A and Model B is different. Furthermore, if we take a detailed look at the confidence interval, which is (1.19, 1.44) with the lower bound larger than 1, it is clear that Model B has more consistency than Model A.

5.5 Association Analysis

Since the evaluation of Model A and Model B is conducted simultaneously, it is essential and necessary for us to test the association levels between the evaluation of Model A, and Model B to see whether the user evaluates these two Models independently or not.

To test the hypotheses H1-H4 of the research model, as shown in Table 5.2, the Pearson correlation coefficient between Model A and Model B is one of the methods to define the association level in parametric statistics: "In statistical hypothesis testing, the P-Value is the probability of obtaining a test statistic. The lower the p-value, the less likely the result is if the null hypothesis is true, and consequently the more "significant" the result is, in the sense of statistical significance" [69]

Table 5.4: Analysis of the data using Pearson and Spearman Correlation Coefficient Methods

Hypothesis	Section	Pearson Correlation Coefficient	Spearman Correlation Coefficient
H1	Ease of Use	0.06 **	0.09*
H2	User Satisfaction	0.20 *	0.21*
H3	Attractiveness	-0.010 **	-0.008 **
H4	Learnability	0.22 *	0.24*
H5	General	0.16 *	0.17*

(*) Significant at P-Value <0.05, and (**) insignificant at P-Value > 0.05.

The Spearman Correlation Coefficient is the counterpart of the Pearson Correlation Coefficient in non-parametric analysis, which defines the correlation between the two Models. The non-parametric statistics will be more data-driven and sensitive. The results of the statistical calculations for the Pearson correlation coefficient, and the Spearman Correlation Coefficient are displayed in Table 5.4.The outcomes are presented as follows:

Firstly, in ease of use section we got some relatively contradictive outcomes regarding the association between Model A and Model B. The Pearson Correlation Coefficient test is positive (0.06) at P-Value > 0.05, hence, our hypothesis fails to be rejected. The Spearman Correlation Coefficient test, on the other hand, is (0.09) at P-Value < 0.05; therefore, our hypothesis is rejected. However, if we take a closer look at the P-value, we can see that the P-Value for the Spearman coefficient is (0.027), which is close to the boundary of 0.05. This situation indicates the inaccuracy of this test. Another possible cause for this situation is that the spearman coefficient is non-parametric association estimation. Therefore, the sample size plays a very important role in the accuracy of this coefficient estimation. Yet, our sample is limited to 96 students who took our survey. The limited sample size will make the coefficient less accurate, and we should take the outcome of the Pearson coefficient which indicate these two models evaluation is independent in this section as illustrated in Table 5.4.

Secondly, in the user satisfaction section, The Pearson Correlation Coefficient between Model A and Model B is positive (0.20) (P-Value < 0.05), and the Spearman Correlation Coefficient test is also positive (0.21) (P-Value < 0.05). Since the P-Values for the two Coefficients indicate the significance of the test, we see that both the Pearson Coefficient and the Spearman Coefficient indicate that we should reject the hypothesis. Therefore, the evaluation of Model A has a positive relationship with that of Model B—which indicates that the users who evaluate Model A with a higher score will also tend to evaluate Model B with a higher score (as illustrated in Table 5.4).

Thirdly, from the outcomes of the attractiveness section, we find that the P-value for the Pearson Coefficient and the Spearman Coefficients are negative (-0.010, -0.008) with P-Value > 0.05. Since the P-Values for the two Coefficients indicate the insignificance of the test, both the Pearson Coefficient and Spearman Coefficient indicate that we will fail to reject our null hypothesis about the independence situation between these two Models. However, since attractiveness is purely a subjective judgment towards the models, the evaluation will be independent between Model A and Model B. Also, based on the

feedback we received from the participants suggesting some changes—some of these suggestions indicate that we should not use the red color—and should add some functions such as "Help", "Back" and "Forward" options to the design. Additionally, participants remarked that it is better not to use the Scrollable feature for all the user interfaces of the developed prototype.

Fourthly, in the learnability section of the design, the Pearson correlation coefficient between Model A and Model B is positive (0.22) (P-Value < 0.05). Furthermore, the Spearman Correlation Coefficient test is also positive (0.24) (P-Value < 0.05); the P-Values for the two coefficients indicate the significance of the test. Therefore, the Pearson Coefficient and Spearman Coefficient suggest that we should reject the hypothesis. Moreover, the evaluation of Model A has a positive relationship with that of Model B, which suggests that users who evaluated Model A with a higher score also tend to evaluate Model B with a higher score (as illustrated in Table 5.4).

Finally, in the general case section, the Pearson Correlation Coefficient between Model A and Model B is positive (0.16) (P-Value < 0.05), and the Spearman Correlation Coefficient test is also positive (0.17) (P-Value < 0.05). Since the P-Values for the two coefficients indicate the significance of the test, the Pearson Coefficient and Spearman Coefficient indicate that we should reject our hypothesis. Also, the evaluation for Model A has a positive relationship with that of Model B, suggesting that the users who evaluate Model A with a higher score also tend to evaluate Model B with a higher score (as illustrated in Table 5.4).

5.6   Analysis and Discussion

From the preliminary data analysis, we see that the distribution of Model B will be smaller than that of Model A. According to our pre-settled options for the questions, practitioners tend to rank Model B better than model A.

In order to support our intuitive idea of the data, we performed a validation test of the Models. Since the Models' evaluation is paired together, we have chosen the Paired T-

test to evaluate the difference between the mean of Model A and Model B for each question and the general case. We used the F-test to test whether the variance of Model A will be the same as that of Model B in different sections. Then according to the outcomes we received we could see that—since the P-value for the T-test and F-test tend to be smaller than 0.05— this gives us the information that we should reject the null hypothesis (the difference between the mean of the two Models is 0). Furthermore, we could see that the Confidence Interval is larger than 0, which indicates that the mean of Model A minus that of Model B will be smaller than 0. These outcomes tell us that the students think that Model B is better than Model A.

We further analyzed the samples, employing the association test to examine whether there is relationship between when students evaluate Model A and Model B. Here, the major statistics we used are the Pearson Correlation Coefficient and the Spearman Correlation Coefficient. After testing the hypothesis we discovered that, for some questions, students evaluate Model A and Model B independently. But speaking overall, we discovered that there is a positive correlation between the evaluation of Model A and Model B, indicating that students who evaluate Model A higher tend to evaluate Model B higher.

In conclusion, through our analysis we discovered that Model B will be superior to Model A in the four sections we evaluated: ease of use, user satisfaction, attractiveness, and learnability; therefore, Model B has the best, most User-Friendly interface.

Chapter 6

Limitations, Future Work and Conclusion

The prime objective of this work is to propose a conceptual framework for measuring the quality aspects and criteria of m-learning is produced. Furthermore, a software prototype application for smartphones to assess usability issues of m-learning application has been designed and implemented.

6.1 Limitations and Future Work

In this study only undergraduate software engineering students participated in the questionnaire survey. It is expected that a more diverse group of participants, in terms of demographics, would provide excellent feedback regarding the usability issues of this prototype application. Time is another limitation of this study. Since there were 96 participants in this survey they have been divided into two sessions. In each session, there were approximately 45 participants, yet we only provided them with 5 smartphones. The participants finished this survey within 45 minutes, which means that each participant spent less than 5 minutes in total answering all the questions, because they were required to read the provided forms carefully to get an accurate rating of the user interfaces.

This study has focused mainly on usability issues in the context of m-learning; specifically, pertaining to how we can design and develop mobile applications with user interfaces of the highest quality.

Although, we have studied the design issues in the context of m-learning— using our proposed framework and by considering a case study—there is some work that needs be done and information studied in further detail.

- We suggest that learning content should be measured from a quality perspective. This metric measures what type of learning contents should be effectively used by m-learning systems including media type.

- Assessing the design issues of Learn on the move, collaboration and communication and interactivity.

6.2 Conclusion

Applying user interface design guidelines while designing and developing mobile applications is very important. In the design and development processes, it is vital to consider user interface design principles and to implement them, since this can be useful for users to increase their performance. A user-friendly user interface and usable interaction of mobile applications will definitely enhance the learning process. Furthermore, mobile applications, specifically smartphones, must be designed and developed in a professional manner. It is important to meet usability needs of those applications in terms of satisfying the needs of end-users since user interface plays the most important role for each individual's interaction between the user and his/her smartphone application. Thus, mobile applications must be easy to use, learnable, understandable, and attractive as well as providing an enjoyable experience for users.

Usability assessment of m-learning systems is one of the hottest areas of research today, and it plays a critical role in the success rate of mobile applications; however, little attention has been paid to this area of research, and little work has been done by researchers to cope with problems that exist with these applications (as mentioned in this context). Accordingly, one of the main contributions of this work is the conceptual framework we developed for measuring the quality aspects of m-learning. This framework can be utilized to support ongoing engineering research and the field in general. Additionally, we have approved this framework as a guideline to support forward and reverse engineering, and for future use while developing mobile applications [63] [64].

We have also developed a prototype application for smartphones using the Java Language and an Android Software Development Kit by following the proposed framework as a guideline. Furthermore, we conducted a questionnaire survey at Western University. In addition, the data collected was analyzed, and we have used the Paired T-

test and F-test for the validation and reliability factors in our data analysis. We employed the Association Test to examine whether there is relationship between when students evaluate Model A and Model B. After testing the hypothesis we discovered that for some questions students evaluate Model A and Model B independently. But speaking overall discovered that there is some positive correlation between the evaluation of Model A and Model B, indicating that students who evaluate Model A higher will also tend to evaluate Model B higher. The major statistics we used in our study are the Pearson Correlation Coefficient and the Spearman Correlation Coefficient.

In conclusion, through our analysis, the proposed framework can be used as a guideline to support reverse engineering (as shown in section 4.3.2). Additionally, we have approved that our framework can be used as a guideline to support forward engineering. We discovered that Model B, which was developed using our framework as a guideline, is better than Model A in the four sections we evaluated (ease of use, user satisfaction, attractiveness and learnability), supporting our initial ideas; therefore, the proposed framework can be used as a guideline to support forward and reverse engineering while developing mobile applications.

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Appendix A: Questionnaire Survey

There were **96** undergraduate students from 2nd and 3rd year at Western University participated in this Questionnaire Survey.

Section 1 ease of use:
1. **I found navigating around the prototype screen to be:**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

2. **How easy was it to distinguish the appropriate icon for information you wanted?**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

3. **How easy was it to scan the prototype in text to find the information you wanted?**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

4. **How easy was it to scan the prototype in graphic to find the information you wanted?**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

5. **How do icons fit its purpose?**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult
6. **How user friendly is the prototype?**
   ___Very Easy   ___ Easy   ___Average   ___Difficult   ___Very Difficult

Section 2 user satisfaction:
7. **Do you agree that the font size is easy to read?**
   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

8. **Do you agree that the prototype has all the features (download, submit…) required by a user?**
   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

9. **Do you agree the prototype provides you enough suggestions and prompt you towards the right usage?**
   ___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

10. **Are the terminologies (for example, assignments, grades,media…) that have been used in this prototype familiar to you?**

___Strongly agree   ___Agree   __Somewhat agree   ___Disagree.

11. How would you rate the organization of the prototype?
___ Excellent   ___ Very good   ___ Good   ___ Bad

Section 3attractiveness:

12. Did you find the prototype attractive?
___Strongly agree   ___Agree   ___Somewhat agree   __Disagree.

13. How would you rate the flexibility of the prototype?
___ Excellent   ___ Very good   ___ Good   ___ Bad

14. Are the colors and graphics of the icons clear and attractive?
___ Excellent   ___ Very good   ___ Good   ___ Bad
15. Are the colors and graphics of the background clear and attractive?
___ Excellent   ___ Very good   ___ Good   ___ Bad

16. My overall impression of the prototype is:
___ Excellent   ___ Very good   ___ Good   ___ Bad

Section 4learnability:

20. **Learning to operate the system is**:
___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult
21. **Remembering and reaching function's name is**
___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult
22. **Understanding the hierarchical of the program is**
___ Very Easy   ___Easy   ___ Average   ___Difficult   ___Very Difficult

Appendix B: Android Software Development Kit (SDK)

1. About Android

"Google Android, as the new contestant on the market, gained great popularity after being first announced in November 2007. With its announcement, it also was accompanied by the founding of the Open Handset Alliance. We will take a closer look at Google Android and describe its parts, functionalities, eventual problems and more. But first, we will start with a basic understanding of Google Android" [70].
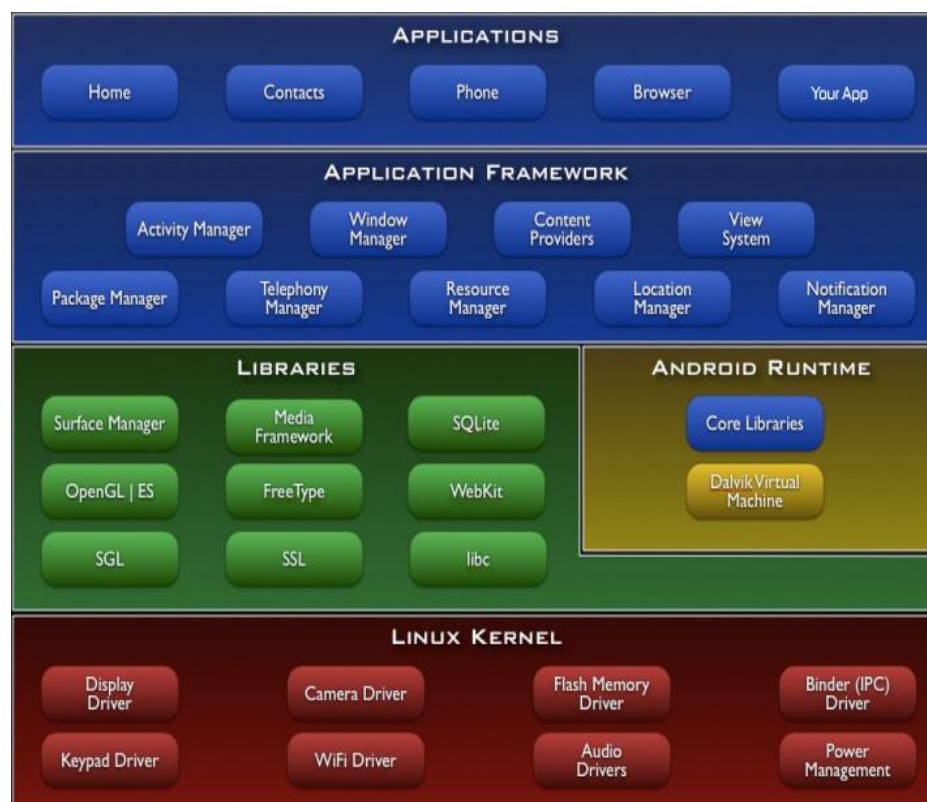
B2.1: Android architecture [70]

The Android SDK released by Google has a 4 level architecture and it includes an Operating System (OS), a middle ware with core libraries and a run-time environment, an application development framework, and some applications and it is created on a Linux kernel as shown in the following figure. The software stack consists of Java applications running on a virtual machine, and components are written in Java, C, C++, and XML.

Android comes with a set of libraries that offers most of the functionality available in the core libraries of the Java programming language. These libraries support the Android Runtime Engine called Dalvik Virtual Machine (DVM).The DVM relies on the Linux kernel for underlying functionality such as threading and low-level memory management. Every application on Android runs as an independent process on its own instance of the DVM. The DVM executes files in the Dalvik Executable (.dex) format. A tool called "dx" is utilized to convert classes created by a Java compiler into the .dex format. The Application Framework layer is completely written in Java which is used by the application developed by user and the core applications alike. Another interesting feature of this architecture is that functions or resources published by one application can used by another application depending on the security constraints forced by the framework. The main components of this layer are as follows:

- Package Manager: it tracks of the installed applications on the device.
- Window Manager: it offers access to the core library named surface manager that controls application windows.
- Telephony Manager: offers the basic application programming interfaces (APIs) for the telephone applications.
- Notification Manager – it allows all applications to display custom alerts in the status bar.
- Content providers: it is one of the features of this platform that enables application to share its own data and/or to access data from other applications.
- Location Manager: it allows applications to get frequent updates of the device's location or an alert when the user changes his location.
- Resource Manager: it enables to access to different type of resources; for instance, graphics, layout files, and localized strings.
- View System: consists of a set of Views which can be utilized to develop an application's User interface like grids, text boxes, lists, buttons, and more.

- Activity Manager: controls the lifecycle of the developed applications and offers a common navigation for the applications running as a separate process to have a smooth navigation.

However, an activity has essentially 4-states:

First, If it is at the top of the stack (*active* or *running)*, and it becomes also in the foreground of the screen.

Second, it is *paused* if it has lost focus but is still visible. A paused activity is completely alive; however, can be killed by the system when there is a low memory is left.

Third, it is totally *cancelled whenever the* activity is completely hidden by another activity. Usually in this case, when memory is needed the activity will be killed by the system, and it will not be visible to the user.

Forth, if the activity is stopped or paused, the system drops the activity from memory by killing it or commands it to finish its process. However, when the activity displays again to the user, it has to be restarted.

The following diagram illustrates the important steps of an Activity. The Activity can be in one of the major conditions as shown by the colored ovals. The rectangles depict callback methods.
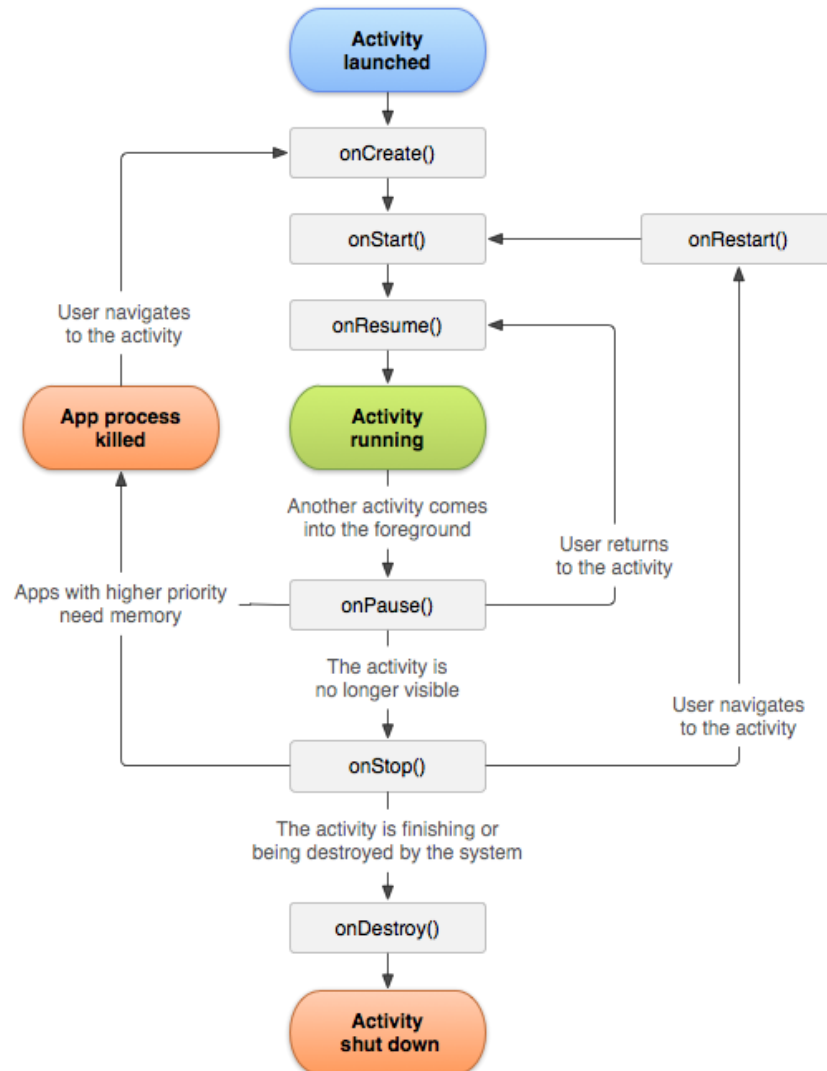
B2.2: Activity lifecycle [71]

The applications are running on top of the Application Framework layer that consist of both user developed applications and platform supplied. The SDK includes a user friendly development environment which consists of a device emulator, memory, tools for debugging and performance profiling, and a plug-in for the Eclipse IDE.

Curriculum Vitae

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Honours and Awards:

1. A full scholarship from the Scholarship Department at Higher Ministry of Education in Libya as one of the best project managers starting from January, 2007 until April, 2009.
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Publications:

[1] A. Ali, A. Ouda and L. Capretz "A conceptual framework for measuring the quality aspects of m-learning", *Bulletin of the IEEE Technical Committee on Learning Technology*, vol. 14, no. 4, pp. 31-34, Oct. 2012

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