Design of a Context-Aware User Interface in Mobile Learning

By
Uhoud Abdullah Zamzami

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Science in computer science

Supervised by
Dr. Hana Al-Nuaim

Faculty of Computing and Information Technology
King Abdul Aziz University
Jeddah-Saudi Arabia
Safar 1431 H- January 2010 G
Chapter 1

Introduction

The great advancement and rapid progression in the mobile and wireless technologies have transformed mobile devices, such as mobile phones and Personal Digital Assistants (PDAs), from simple communication and personal information organization tools to handheld computers. Today, mobile devices are equipped with powerful operating systems and are capable of performing an increasing number of features and operations: phone, SMS, MMS, camera, games, media players, running applications, connectivity, and enabling wireless access to the Internet. In addition, they include additional communication functions, such as GPS (Global Positioning System) which allows the use of location-based services. These devices are very small and weigh much less than laptop computers, but they encompass the computing power of mid 1990s personal computers, and they are expected to replace desktop and laptop computers in the near future.

Moore, one of the founders of Intel Corporation, observed that the number of transistors per area doubles every 18 months (Zwick, Schmitz, & Kühl, 2005). This observation had been known as Moor’s law and it is still valid until today and it explains the reason of the constant reduction of technical devices’ prices. The constant reduction of the size and price of technical components creates mobility, and thus, the opportunity to get higher levels of personalized computing (Zwick et al., 2005).

Every year, new smaller and more powerful mobile devices are being launched into the market. As a result of this great advancement, handheld computers are
getting more attention and popularity around the world (Y. S. Lee, 2003) and their use, in everyday life, has been an essential need. The penetration of these devices world-wide has reached 50% (Christine, 2007). It is worth saying that the Saudi market is one of the fastest growing markets in the Middle East. According to the official reports released by Saudi Communications and Information Technology Commission (CITC), the mobile penetration rate has reached 116%, by the end of 2007, with an increase of 34% from the penetration rate of year 2006 (82%) (CITC, 2008). By the end of 2008, the mobile penetration rate has reached 143.6%, with an increase of 27% from 2007. Figure 1.1 shows the mobile penetration rate from 2002 to 2008. The average penetration rate during these years is 63.7%, which indicates the rapid growth in the mobile Saudi market.

![Figure 1.1: Mobile Penetration Rate 2002-2008 (CITC, 2008)](image)

1.1. Background

Mobile devices provide powerful, portable, and wireless means to access information at ‘anytime’ and ‘anywhere’ (Y. S. Lee, 2003). Many innovative mobile applications are emerging, aiming to provide users with ubiquitous access to information (Zhang & Adipat, 2005). These mobile applications have become relevant to all aspects of computing, including healthcare, business, and learning.

A few years ago, the question was ‘whether students have mobile devices or not?’. Today, almost every student owns a mobile device and the question has changed to ‘which model?’, ‘which functions, features, and applications are used?’ (Holdener, 2008). Many students come to their universities and schools carrying advanced mobile devices, due to their reasonable prices and useful functionalities.
This led to the assumption that mobile devices are practical and helpful to be used in learning. But in practice, many teachers and educators still regard the mobile technology as a disruptive technology (Holdener, 2008; M. Sharples, 2002) and they still consider mobile devices as distractions to the learning process (Prensky, 2005). In fact, these devices are like all other communication and computing devices, they can be used to support various learning activities, such as reading, listening, writing, and even questioning (Prensky, 2005). Instead of rejecting these devices, teachers and educators should look for exploiting their potential and find good ways to use them for the benefit of learning.

During the last years, handheld devices, or ‘Handheld Computers’ as they might be called, have received a considerable attention in learning, because of their portability, mobility, and multi-functionality, which can be used to support different learning activities in various manners (Y. S. Lee, 2003). Integrating mobile devices into learning practices, so called ‘mobile learning’ or often referred to as ‘m-learning’, is a new field that has emerged from e-learning and distance education. Mobile learning is becoming an important form of learning in formal and informal education.

Recognizing the potential of using handheld devices in learning, the design and development of mobile learning projects has become an area of significant research in the past few years in many educational institutions. Many universities and schools have experimented different ways to use handheld computers in learning activities (Y. S. Lee, 2003). ‘Mobilearn’ and ‘m-learning’ are two examples of European initiatives that adopted mobile learning research. Despite the relatively large number of m-learning projects and researches, a basic question might still be asked ‘can handheld devices provide students with the knowledge and skills that will help them succeed in their schools, their jobs, and their lives?’ (Prensky, 2005). A possible answer to that question might be ‘yes, if they were designed right’.

1.2. Statement of the Problem

Mobile learning addresses the needs of a new generation of learners, who are extremely mobile and considered as ‘digital natives’ (Holdener, 2008; Prensky, 2005). Those learners grow up with the new technology, and consider it as so familiar to them (Holdener, 2008). Although m-learning is a young field of research,
a very large number of experiments and investigations, in all kinds of pedagogical and scientific directions, have been carried out to find out whether m-learning could be beneficial for learning (Holdener, 2008).

As every rise of a new technology is accompanied by great expectations, it is also faced with rejection. Mobile learning is one of the fields where opposing opinions become apparent in many experiences (Holdener, 2008). In theory, students can use mobile devices to interact with the course materials and with their peers at anytime and anywhere, with greater ease. Practically, results of m-learning studies are very diverse. Positive results are reported as new ways to interact and increased cooperation and collaboration among students are practiced (Holdener, 2008), while negative results were found when users interact with mobile devices to access course materials.

There is a gap between visions and expectations of using the mobile technology to support the current learning theories on one hand, and the current learning practices on the other hand (Holdener, 2008). Despite the many uses of handheld devices for information access, developers, designers, and educators are still looking for an adequate use of this technology for learning and information presentation. Positive and negative attitudes towards mobile learning lead to a lot of questions to investigate the effective use of this technology in education.

Using mobile devices for learning requires rethinking about their interactions and evaluating their designs (Naismith, Lonsodale, Vavoula, & Sharples, 2004). Unfortunately, only few studies have investigated the development of effective interaction techniques for mobile devices. The reason is that Mobile Human Computer Interaction (Mobile HCI) is relatively a new immature field, and as any other immature field, Mobile HCI tend to be technology driven and focuses primarily on producing solutions, rather than ensuring that these solutions are useful and usable (Gorlenko & Merrick, 2003; Kjeldskov & Graham, 2003).

M-learning activities are performed on devices that were not designed with educational applications in mind, and thus, usability problems were always detected. Remarkably, the lack of ease of use, due to the small screen size, is the main cause of dissatisfaction when using mobile devices in a learning context (Holdener, 2008;
Waycott & Kukulska-Hulme, 2003). The more limitations imposed by the form factor, such as the small screen, the more acute the design problems become (S. S. Chan et al., 2002). Negative comments from learners’ show common frustration with the design and usability of information for small devices (Uther, 2002).

The greatest challenge for mobile applications’ developers is their usability (Davies, 2007). Handheld devices have limitations, compared to desktop and laptop computers. The literature has identified a number of limitations affecting the use of handheld devices for learning. One of the most serious limitations of handheld devices is the user interface. In fact, “user interface design has been identified as second only to security as a barrier to user acceptance of m-commerce” (Buranatrived & Vickers, 2002). If this is true for Mobile Commerce (m-commerce), then user interface design might be the first barrier to user acceptance of m-learning. Despite the reasonable amount of m-learning projects and case studies, only few of them have paid attention to the user-interface design issues of handheld devices. Therefore, usability problems were detected in almost all of these projects and practices.

Usability of mobile applications is vulnerable to the limited input/output capabilities and the varied context of use. With the advancement of the mobile technology, mobile devices’ sizes have been reduced a lot (Chong, So, Shum, Li, & Goyal, 2004) and due to the requirements of mobility, these devices will remain small in size if they do not get smaller. The input and output capabilities of handheld devices are limited by the small size of the device, and so the presentation of information and the efficient use of the input capabilities are increasingly important issues to consider. In addition to the small displays and the input limitations of handheld devices, they are operated in varying and dynamically changing context of use. Y. E. Lee & Benbasat (2004) have identified the mobile devices’ constrains and the mobile settings as the two elements that affect the design of the mobile user interface.

Designing an application with an easy to use interface is necessary for the successful adoption of that application. According to that, user interface design is one of the major concerns in the design of mobile applications. In many applications, handheld devices have inherited the interface design of personal desktop computers,
although it is clearly not the best design for these devices (Morris & Tomlinson, 2008). Compared to desktop and laptop computers, the most obvious barrier to the usability of mobile applications is the lack of any standardization for user interface design. The hardware and software standards for mobile devices cannot be situated because of the rapidly growing nature of the technology.

Evaluating the usability and considering the importance of the user interface design of m-learning applications are two important issues. The utility of these applications and the learning outcomes might be reduced by the problems of accessing information resources through small displays, manipulating extremely small keyboards, and performing numerous delicate operations by selecting very small icons, while most handheld devices lack any type of a pointing device (Winters & Price, 2004). These problems become more critical, as these devices are operated in varying contexts, far from the ideal settings of desktop computers used in conventional e-learning or computer-based learning applications.

To integrate mobile devices into learning effectively, we have to deal with the mobile devices’ limitations and the mobile context of use. Mobile applications’ designers are required to build mobile applications that are not only useful, but are easy to use, regardless of the devices’ limited capabilities, and their varying context of use. The field of Mobile HCI recognizes the importance of considering the complex and variable context surrounding the use of mobile applications. Despite the significant amount of research that has been done in the area of m-learning, there have been little research that focused on the nature of the relationship between m-learning, user interface design, and the context of use.

Design principles or design guidelines are tools, or recommendations, used for ensuring or improving the usability of a particular application. User frustrations would be alleviated by following user interface guidelines (Uther, 2002). The growing use of mobile devices has incorporated research into developing guidelines for designing effective user-interfaces on these devices. However, until now there is no complete, or an approach to a complete, set of evaluated user interface design guidelines for using this technology in learning.
1.3. Motivations

This research has been motivated by several factors:

1. **Lack of similar experiences in our local community:** m-learning has been developed mainly in Europe, United States and in parts of East Asia, primarily in an English medium, and in environments of rapid technology advancement. Experiences with mobile learning in local communities are very limited. Mobile learning can enhance education in our societies, if they were thoroughly analyzed and modified to suit our settings and needs.

2. **The importance of usability for mobile learning:** the fact that usable interfaces increase retention of information and accessibility should provide a clear justification for the value of designing usable interfaces for mobile learning applications (Uther, 2002). In addition, considering the growing volume of information and the richness of the mobile learning content, improving the usability of mobile learning applications is very important for improving learners’ satisfaction, and productivity.

3. **The current state of m-learning studies:** to develop interface guidelines, usability issues should be tracked over a long period, from the initial use of the technology to a state of relative experience with it. M-learning research has reached a stage where considerable indications from projects, trials, and practices are available for reviewing usability of mobile devices in learning in a more global way.

4. **The increased popularity of touch-screen devices:** although most of the widespread mobile devices feature classic numeric pad and non-touch screen display, larger touch-screen devices are gaining more popularity, as indicated by the introduction of the currently available devices, such as the Apple iPhone, LG prada (Karlson, 2007), and Samsung Omnia series. By reviewing the literature, the lack of design guidelines for learning services implemented on touch-screen devices was obvious. However there are many resources to look for design guidelines from a variety of domains, but these guidelines must be modified and tailored in order to be applicable to mobile devices in general and touch-screen devices in particular. This should be done after analyzing the learning requirements and the main characteristics of these devices to understand their influence on the available guidelines (Kärkkäinen & Laarni, 2002).
5. **The currently available m-learning guidelines are abstract and de-contextualized:** the existing m-learning guidelines lack an awareness of the unique influences of the mobile context of use and needs to be enhanced by adding and considering contextual information. Little research has been done to integrate the mobile use context into the guidelines development process and to accumulate knowledge about the interface design, in a form that can capture relationships between specific contexts and application guidelines. In addition, most of the existing guidelines were not evaluated in real contexts.

6. **Building the m-learning user interface on the closest relative domain:** it is recommended that the style and logic of the interface may be based on the closest relative domains and their guidelines (Kärkkäinen & Laarni, 2002). Borrowing from well-designed applications, when user interface standards and guidelines are not available or are not developed enough to support the service, is common for designing mobile applications (Weiss, 2002). For example, developers of mobile commerce applications, tend to utilize Web design principles and guidelines. User interface guidelines from traditional desktop computers do not suit well the mobile settings (Chae & Kim, 2004). It is nearly impossible to directly apply all of the traditional usability approaches and guidelines of related fields, such as those of desktop applications, and e-learning to m-learning applications, due to the hardware limitations of mobile devices. This difficulty becomes extremely harder, especially with the dynamically changing contexts of m-learning interactions. However, a new set of guidelines, which considers the unique demands of the mobile use context, are required (Khaled Hassanein & Melena Head, 2003). Most of the currently available m-learning guidelines are bases on traditional user interface guidelines of desktop computing, including: Web, and e-learning user interface guidelines. In addition, newer guidelines are available from different fields related to m-learning, such as m-commerce and mobile Web, which might be applicable to m-learning. Determining whether the usability principles and guidelines of these fields form an appropriate basis for instructional design guidelines and strategies, for mobile learning, could be a motivating point of research.
1.4. **Significance of the Study**

Mobile learning is especially suitable for emerging nations, as larger numbers of the population have mobile devices, compared to personal computers.

“Mobile applications must be easy to use, in order to be successful” (Davies, 2007). The presentation of information by means of the small screen interface is a determinant factor in the efficiency of learning through mobile devices, which imposes other problems such as the unsuitability of the content to the context and the device (Grasso & Roselli, 2005). A poorly designed interface, confusing menus, unclear buttons, or illogical links becomes a barrier to effective learning and information preservation (Ardito et al., 2004). Students will become confused, frustrated, and they will not learn from such an interface. In fact, if m-learning applications were not easy to use and enjoyable, students will not use them.

Only, few guidelines are available for the development of usable user interfaces for mobile applications in general and mobile learning in particular. Significantly, this thesis recognizes the importance of considering the context of use in the design and evaluation of user interfaces for mobile learning applications. By improving the available guidelines and tailoring them for the mobile setting, results from this study are supposed to contribute to the development of a larger set of user interface guidelines for m-learning, and to the evaluation of such guidelines.

Mobile users often use mobile devices to access a specific piece of information related to their contexts. Walking is the most common use context of mobile devices. Aside from in-class mobile communication applications, mobile applications are most probably to be used while the user is walking, such as, accessing course material and playing learning games. In addition, mobile devices are used in many indoor and outdoor applications, where users are required to move or walk from one location to another during interaction, such as, museums guides and outdoor activities.

Learners’ feedback is the most important issue in the interface design of learning systems. This study combined the rational sound of user interface guidelines and the practical sound of evaluation to provide further insights. Many usability problems can be avoided by following guidelines, but testing with real users is
necessary in order to be sure. By following user interface guidelines, the designer can ensure that the user interface is easy to use and learn by the users, but relying on guidelines alone to ensure usability of the user interface is not enough, as some of these guidelines may be general, too specific, or conflicting with one another (MSDN, 2009). Usability testing with real users is necessary to make sure about the design decisions made for designing the user interface and to test whether they satisfy the user’s needs. In this study, usability testing was done to investigate the learner’s attitudes toward m-learning.

Finally, it is important to note that all of these guidelines are intended for mobile learning user interface, although they can be applied to some extent to other mobile applications.

1.5. Objectives

This study is focused on the specific limitations that mobile learning users often have when they access course material from small touch-screen displays, which can be affected by the user’s mobility while walking. The main objective of this research is to develop a set of evaluated guidelines that ensure the usability of m-learning user-interface on handheld devices, taking into account the user mobility as a context which might affect the design of the user interface elements and ultimately learning. Other objectives which were addressed in this thesis are:

- To incorporate the context of use in the design and evaluation of user interfaces for mobile learning applications in a practical and simple way, in order to improve the usability of mobile learning applications, without the need of complex artificial intelligence techniques and adaptation methods.
- To explore the impact of adding the walking context to the process of developing user interface guidelines and the evaluation of these guidelines.
- To investigate the usability of the user interface design, using the proposed guidelines.
- To investigate the perception of using mobile learning for accessing course materials, which were designed using the proposed guidelines, and determine how students think about using the mobile technology as a supportive tool for accessing learning materials.
Jacob Nielson’s (2003) defined usability as “a quality that assesses how easy user interfaces are to use”, comply well with the purpose of this study. He defines usability by five quality attributes (Nielson, 2003):

- **Learnability**: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- **Efficiency**: Once users have learned the design, how quickly can they perform tasks?
- **Memorability**: When users return to the design, after a period of not using it, how easily can they re-establish proficiency?
- **Errors**: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction**: How pleasant is it to use the design?

This thesis is focused on the user’s attitude and satisfaction toward using mobile learning applications, including situations in which the user is experiencing the real mobility use of handheld devices. User satisfaction will be the subjective measure for evaluating the proposed guidelines. The user satisfaction is the quality attribute that is to be measured as an indicator of the user interface easiness of use. User satisfaction is especially important for mobile applications, simply because users will not use these applications if they were not satisfactory for them.

1.6. **Purpose of the Research**

The size of a handheld computer screen will likely not change due to the requirements of mobility. Therefore, interface designer must think about how the interface should be organized to present the information clearly, what information should be presented, what guidelines exist for designing interfaces, how to design for usability and how the users perceive the information presented. However, the main research question addressed in this study is:

- **RQ1**: Do interfaces created using the proposed guidelines produce usable and satisfying m-learning experiences?
To be able to address the main research question in this study, the following interesting questions were addressed in this study:

- **RQ2:** Do the existing m-learning user interface guidelines provide sufficient sources for the design of m-learning applications in different contexts?
- **RQ3:** Are the existing guidelines from different fields related to m-learning applicable to the design of a usable user interface for a m-learning application (module) on touch-screen devices, given the possibility of the user’s mobility as a mobile use context?
- **RQ4:** Can the user mobility, as a mobile use context, be considered in developing user interface guidelines for m-learning, by analyzing the student’s needs in this context?
- **RQ5:** Does the design of a usable user interface for m-learning require using adaptation to cope with the user’s mobility?
- **RQ6:** Can the orientation-aware feature integrated into newer touch-screen devices, be useful for mobile learning applications?

1.7. **Methodology**

The methodology followed in this research is derived from methodologies used in some of the reviewed studies (Gong & Tarasewich, 2004; Hakkila, 2006; Kärkkäinen & Laarni, 2002; Kukulska-Hulme, 2007; O’Malley et al., 2005; Vavoula et al., 2004):

1. Conduct a literature review in the following fields:
   - The current progress and recent advancement in the field of Mobile HCI.
   - Context-aware mobile applications.
   - Mobile Web user-interface guidelines.
   - E-learning and distance education user-interface guidelines.
   - Mobile devices manufacturers’ user-interface guidelines.
   - Mobile applications user-interface guidelines.
   - Mobile commerce usability and user interface guidelines.
   - M-learning user interface guidelines.
   - Mobile applications usability studies, projects, and case studies, while considering the different factors which are expected to affect the usability
of m-learning applications such as: the physical properties of mobile devices, the learning objectives, and the contexts of use.

2. Identify the different context factors, which may affect the user interface on mobile devices.

3. Develop a framework for developing m-learning user interface guidelines for a particular mobile device type, based on the reviewed resources, and the selected context.

4. Recommend a set of user-interface guidelines for effective m-learning design.

5. Develop a prototype using the proposed guidelines, to determine the applicability of these guidelines to the design of a supportive m-learning course material.

6. Test the usability of the developed prototype using heuristic evaluation, to discover the fault usability problems in the prototype.

7. Redesign the prototype, according to the results of step 6.

8. Test the usability of the redesigned prototype with students in real contexts.

9. Analyze the results.

10. Discuss Findings and Recommendations.

This thesis follows a qualitative methodology for both, creating the guidelines and evaluating them. The framework for developing the guidelines relies on a literature review of the available guidelines and an analysis of a number of usability studies that use contextual information to increase user interface usability. These usability studies are used to refine the guidelines and to make them suitable for the mobility context. As mobile learning is a novel field, literature review and analysis was selected as an appropriate method for creating the guidelines, because it allows mobile learning designers to build on the success of the related experiences and to make use of the current practice of mobile learning usability and evaluations.

1.8. **Scope and Limitations**

Motivated by the several factors discussed in section (1.3), the goal of this thesis is to provide a set of user interface guidelines for improving the usability of mobile learning applications, with a particular emphasis on touch-screen devices, and the effect of the user’s mobility while walking, on these guidelines.
Given the wide range of mobile devices and their varying capabilities, it is advisable to individually design input and output for certain device classes (Schmidt, Schröder, & Frick, 2000). In this thesis, the focus will be primarily on handheld devices that fall under Livingston’s (2004) and Weiss’s (2002) definitions and particularly on touch-screen devices. Touch-screen devices were selected for this study, since they are getting more popular recently in the mobile market. By using touch-screens for mobile devices, hardware designers were able to eliminate the need for physical keypad or keyboard, and this helps increase the screen size, without any increase in the size of the mobile device (Chong et al., 2004). This increment in screen size, compared to other mobile devices, could be very beneficial for intensive information mobile applications and especially for m-learning applications, where a practical amount of space is needed for presenting the learning content.

Mobile devices have several limitations that affect the use of these devices for any service or application. This study is focused on overcoming the user interface limitations of handheld devices. Among the three features that affect the user interface design and usability of mobile applications (Hakkila, 2006; Perry, 2003): input, output, and connectivity, only input and output constraints are to be addressed in this study.

Although many innovative ideas about using context-awareness technologies in mobile learning are discussed in the literature, researchers are still coming up with a deep understanding of the notion of context and its benefit for learning. However, this thesis is focused on applying context-awareness to improve the usability of the user interface for mobile learning applications. Context-awareness is considered for the design of the user interface in this study by looking at the effect of the chosen context on the user interface elements and does not include any complex adaptation mechanisms. This method was adopted because of the general dislike of adaptive context-aware user interfaces (Kane, Wobbrock, & Smith, 2008). This thesis is intended for simplifying the design of usable user interfaces, which consider the mobility context of mobile devices without using artificial intelligence techniques for adaptation. Orientation-aware adaptation was only used under the user’s control to switch between the portrait and the landscape presentation. However, context was considered in this study at four levels:
The first level of context considered in this thesis is the device context, i.e., designing for a mobile phone is so different from designing for touch-screen devices.

The second level is the m-learning application context, which is the mobile office context, i.e., the nature of the learning activity does not require the user’s mobility, although the interaction may not be stationary.

The third level is the use context, which is the user’s mobility and in particular walking as it is the most common use context of mobile devices, and a number of recent studies have investigated its effect on the user interface design. Only indoor walking was considered in this study.

The fourth level is the use of the orientation-aware feature for switching the interface between the portrait and the landscape presentations according to the user’s preference and the learning content presented on the screen.

1.9. Thesis Organization

This thesis is organized as follows:

- **Chapter 2**: reviews the mobile technology and its influence on learning.
- **Chapter 3**: presents the field of Mobile Human Computer Interaction to which the point of this research belongs. Also, it describes the different views of the mobile context in general and the mobile learning context in particular. It also highlights the current research in using the context-aware technology in designing usable mobile user interfaces.
- **Chapter 4**: discusses the field of mobile user interface design and the usability of mobile applications
- **Chapter 5**: discusses the methodology followed for developing user interface guidelines for m-learning, introduces the proposed framework for designing usable mobile user interfaces for learning applications, and presents the proposed guidelines.
- **Chapter 6**: discusses the process of developing and testing a m-learning prototype for testing the proposed guidelines.
- **Chapter 7**: presents the results of the prototype testing and discusses the collected data analysis.
• **Chapter 8:** concludes the work that has been done in this study and proposes the work that can be done in the future
Design of a Context-Aware User Interface in Mobile Learning

Uhoud Zamzami

Abstract

The great advancement in wireless communication technologies forms a new learning paradigm that combines the advantages of mobile computing and e-learning practices. As users interact with m-learning applications, usability problems that affect the learning outcomes and the users’ satisfaction with the learning experience were always detected. Considering mobile devices’ limited capabilities, user-interface designers are required to deal with the new computing challenges, introduced by mobility and its dynamically changing context of use. Developing guidelines for m-learning user-interfaces has been an interesting area in the past few years, but until now, these guidelines have not reached a steady state, where a complete set of guidelines are in place.

This research is an attempt to address the complexities of designing context-aware user-interface guidelines for m-learning applications. The mobile context is extremely dynamic and unpredictable, and thus, it is not possible to consider all of the possible variations in context. The objective of this study is to develop a set of evaluated guidelines that ensure the usability of m-learning applications on handheld devices. These guidelines consider the effect of walking, as the most common mobile context of use, on the user interface design of m-learning applications and ultimately learning.

A framework for developing context-aware user interface guidelines was developed in this study. In addition to the existing m-learning guidelines, this framework uses other guidelines from related fields and looks for incorporating the effect of walking on these guidelines. Fifty guidelines were proposed in this study and were verified to be applicable to the design of an m-learning prototype. Thirty-eight guidelines were evaluated using different methods in this study. The walking context was also considered in the guidelines evaluation process. Results obtained from the usability evaluation in this study indicated that the prototype designed in this study was easy to use, enjoyable, and satisfying.
# TABLE OF CONTENTS

Examination Committee Approval
Dedication
Acknowledgment ................................................................. iv
Abstract ..................................................................................... v
Table of Contents ........................................................................ vi
List of Figures ................................................................................ x
List of Tables ................................................................................ xii

## Chapter 1: Introduction
1. Background ........................................................................... 2
1.2. Statement of the Problem .................................................. 3
1.3. Motivations ......................................................................... 7
1.4. Significance of the Study .................................................... 9
1.5. Objectives .......................................................................... 10
1.6. Purpose of the Research ................................................... 11
1.7. Methodology ....................................................................... 12
1.8. Scope and Limitations ...................................................... 13
1.9. Thesis Organization .......................................................... 15

## Chapter 2: The Mobile Technology
2.1. Mobile Technology ............................................................ 17
2.1.1. Handheld Devices ......................................................... 19
2.1.2. Types of Handheld Devices .......................................... 20
2.1.3. Handheld Devices Capabilities .................................... 24
2.2. Mobile Computing ............................................................ 27
2.3. Mobile Learning ............................................................... 30
2.3.1. The Mobile Technology and Learning ......................... 31
2.3.2. Mobile Learning Features ................................................. 35
2.3.3. Mobile Learning Limitations ......................................... 37

Chapter 3: Human Computer Interaction in the Mobile Learning Context  38
3.1. Mobile Human Computer Interaction ..................................... 38
   3.1.1. Device Mobility and Modes of Interaction ...................... 39
   3.1.2. Mobile Devices Challenges of Human Computer Interaction ... 39
   3.1.3. The Mobile Working Context ...................................... 41
3.2. Context-Awareness .............................................................. 42
   3.2.1. Understanding Interaction in the Mobile Context ............ 45
   3.2.2. Importance of Context in Mobile HCI ......................... 50
   3.2.3. Context-Sensing Technologies .................................... 52
   3.2.4. The Mobile Learning Context .................................... 55

Chapter 4: Usability of Mobile User Interfaces ........................... 60
4.1. User Interface Design ....................................................... 60
4.2. Mobile User Interface Design ............................................. 63
   4.2.1. Limitations of Mobile User Interfaces ......................... 65
   4.2.2. Types of Mobile User Interfaces .................................. 67
   4.2.3. Principles of Mobile User Interface Design ................. 70
4.3. M-Learning User Interface Requirements ............................. 74
4.4. M-Learning User Interface Design Guidelines ..................... 77
4.5. Mobile Applications Usability ............................................ 79
   4.3.1. Usability Challenges of M-Learning ............................. 82
   4.3.2. Significance of M-Learning Usability Studies ............... 84
4.6. Mobile Prototyping ............................................................. 86
4.7. Usability Evaluation of Mobile Applications ....................... 89

Chapter 5: Framework for Developing Context-Aware User Interface
Guidelines for Mobile Learning ................................................ 94
5.1. Framework Components ................................................... 95
   5.1.1. M-learning User Interface Guidelines .......................... 96
LIST OF FIGURES

Chapter 1
1.1 Mobile Penetration Rate 2002-2008 2

Chapter 2
2.1 Mobile and Wireless Devices Categories 18

Chapter 3
3.1 Graphical Representation of Context Model 48
3.2 Model of Mobile Application Context 49
3.3 Context of Mobile Interaction 50

Chapter 5
5.1 Framework for Developing Context-Aware User Interface Guidelines for M-learning Applications 108

Chapter 6
6.1 Mobile Hardware and Software Interdependency 143
6.2 Samsung Omnia SGH-i900 146
6.3 Low-fidelity prototyping 147
6.4 The Main Menu Design 148
6.5 The Introduction Design 149
6.6 The Main Memory Design 149
6.7 Connecting CPU and Memory Design 150
6.8 The Practice Questions Design 150
6.9  Screenshot of the Main Menu on Windows Mobile 6.1 Emulator 152
6.10 Screenshot of the Introduction on Windows Mobile 6.1 Emulator 153
6.11 Screenshot of the Main Memory on Windows Mobile 6.1 Emulator 154
6.12 Screenshot of the CPU-Memory Connection on Windows Mobile 6.1 Emulator 155
6.13 Screenshot of the Practice Questions on Windows Mobile 6.1 Emulator 156
6.14 The longest navigation path of four clicks 159
6.15 The maximum scrolling of about three screens 160
6.16 The SCSI Figure Design 161
6.17 The SCSI Figure on Windows Mobile 6.1 Emulator 161
6.18 The Memory Units Table Design 162
6.19 Screenshot of the Memory Units Table on Windows Mobile 6.1 Emulator 162
6.20 The Central Processing Unit Screen on Samsung Omnia i-900 163
6.21 The Memory Units Table Screen displayed in Landscape presentation on Samsung Omnia i-900 164
6.22 The SCSI Figure Screen displayed in Landscape presentation on Samsung Omnia i-900 164
6.23 Screenshot of a Back Menu Screen on Windows Mobile 6.1 Emulator 179
6.24 Mobile Use Purposes 184
LIST OF TABLES

Chapter 3
3.1 Personal Computing Devices Modes of Interaction 39

Chapter 4
4.1 Advantages and Disadvantages of Mobile User Interface Types 68

Chapter 5
5.1 Framework Components and Guidelines References 109
5.2 Guidelines Template 111
5.3 Screen Layout Guidelines 112
5.4 Guidelines for Using Colors 114
5.5 Simplicity Guidelines 115
5.6 Consistency Guidelines 115
5.7 Mobile Basic Screen Layout 117
5.8 Learning Content Selection Guidelines 119
5.9 Text Presentation and Legibility Guidelines 121
5.10 Guidelines for Using Images 125
5.11 Guidelines for Using Tables 127
5.12 Navigation Design Guidelines 130
5.13 Information Structure Guidelines 134
5.14 Guidelines for Using Links 136
5.15 Input Guidelines 138
5.16 Feedback Guidelines 140
5.17 Learner Control Guidelines 141
Chapter 6

6.1 Candidate Devices 144
6.2 Samsung Omnia SGH-i900 Technical Specification 146
6.3 Guidelines that do not need Evaluation 165
6.4 Guidelines that need Heuristic Evaluation 168
6.5 Guidelines that need Usability Evaluation 168
6.6 Tasks and their Purposes 171
6.7 Relating Guidelines to Tasks 174
6.8 Guidelines Checklist 176
6.9 Heuristic Evaluation Problems and Recommendations 178
6.10 Tasks’ Experimental Design 180

Chapter 7

7.1 Users Ratings to Task Difficulty 186
7.2 Overall Opinions about Text Presentation 193
7.3 Users Responses to 'yes' and 'no' Items 193
7.4 Users' Responses to Text Readability Items 194
7.5 Users Ratings to User Interface Elements Clarity 194
7.6 Users' Perceptions about the Interface Elements Easiness of Use 195

Chapter 8

8.1 The Verified Guidelines 217