

***Augmented Reality and Context
Awareness for Mobile Learning Systems***

PhD Thesis

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Abstract

Learning is one of the most interactive processes that humans practice. The level of interaction between the instructor and his or her audience has the greatest effect on the output of the learning process. Recent years have witnessed the introduction of e-learning (electronic learning), which was then followed by m-learning (mobile learning). While researchers have studied e-learning and m-learning to devise a framework that can be followed to provide the best possible output of the learning process, m-learning is still being studied in the shadow of e-learning. Such an approach might be valid to a limited extent, since both aims to provide educational material over electronic channels. However, m-learning has more space for user interaction because of the nature of the devices and their capabilities. The objective of this work is to devise a framework that utilises augmented reality and context awareness in m-learning systems to increase their level of interaction and, hence, their usability. The proposed framework was implemented and deployed over an iPhone device. The implementation focused on a specific course. Its material represented the use of augmented reality and the flow of the material utilised context awareness. Furthermore, a software prototype application for smart phones, to assess usability issues of m-learning applications, was designed and implemented. This prototype application was developed using the Java language and the Android software development kit, so that the recommended guidelines of the proposed framework were maintained. The proposed framework bridge the research gap by unifying the pedagogical aspects, technological aspects and usability of m-learning completely. A questionnaire survey was conducted at the University, with approximately twenty-four undergraduate computer science students.

Twenty-four identical smart phones were used to evaluate the developed prototype, in terms of ease of use, ease of navigating the application content, user satisfaction, attractiveness and learnability.

Several validation tests were conducted on the proposed augmented reality m-learning verses m-learning. Generally, the respondents rated m-learning with augmented reality as superior to m-learning alone.

Declaration

I hereby declare that the material used by me in this thesis for the degree of Doctor of Philosophy, at the Software Technology Research Laboratory, at the De Montfort University, United Kingdom, is original and that no part of the material is included for which a degree has previously been conferred upon anybody by this, or any other, university or college of higher education

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Table of contents

Abstract	2
Declaration	4
Acknowledgments	5
Table of contents	7
List of figures	12
List of tables	13
<i>Chapter 1: Introduction</i>	15
1.1.Introduction	16
1.2.Motivation	18
1.3.Research Questions and Objectives	19
1.4.Contribution	20
1.5.Thesis Organization	21
<i>Chapter 2: Literature Review and Mobile Learning</i>	41
2.1. Overview	42
2.2. Mobile Augmented Reality	47
2.3 A Definition of Mobile Learning	49
2.4 Advantages and Limitations of Mobile Learning	53
2.5 Introduction to the M-learning Generations	55
2.6 The Non-adaptive M-learning Generation	56

2.7 The ‘Learners’ Preferences’-based Adaptive M-learning Generation	58
2.7.1 The Concept of a ‘Learning Style’	62
2.8 LOs and their Applications	67
2.8.1. Advantages of LOs	67
2.8.2 Standards such as Learning Object Metadata (LOM)	68
2.8.3 Learning Object Repositories	69
2.8.4. LO Applications	70
2.9 Contexts and Learning Contexts	71
2.9.1 The Concept of a ‘Context’.	71
2.9.2. The Concept of a ‘Learning Context’	73
2.9.3 Deployment of Learning Contexts within M-learning Applications	80
2.9.4 Advantages of and Challenges to Deploying Learning Contexts	84
2.10 The ‘Learning Contexts’-based Adaptive M-learning Generation	87
2.11 The ‘Learning Contexts’-aware Adaptive M-learning Generation	92
Chapter 3: Methodology	23
3.1 Introduction	24
3.2 AR-Related Methodological Considerations	26
3.3. Current Practices in AR Evaluation	28
3.4. Emerging AR-Specific Applications	33
3.5 Task and Experimental Setup	36
3.5.1. Recruiting the Candidates	36

3.5.2 Semi-Structured Interviews	37
3.5.3. The Survey	37
3.5.3.1. Content and structure of the survey	38
3.5.3.2 Measuring the effectiveness of the AR application	39
Chapter 4: The Proposed Framework	96
4.1. Introduction	97
4.2. Recommendation of Appropriate Learning Materials	98
4.3 Design Modules of the Framework	101
4.4. Strengthening the Context-retrieval Aspect of the Framework	105
4.5 Methods Used for Strengthening the Framework	107
4.6 Incorporation of Learning Objects into the Framework	108
4.6.1. Mobile Learning Metadata (MLM)	108
4.6.2. Incorporation of Los	109
4.6.3 Methods for Converting LOs into MLOs	110
Chapter 5: System Implementation	114
5.1 System Development Environment	115
5.2 System Development Methodology	116
5.3 System Framework	118
5.4 System Development Process	122
5.5 System Implementation	126

<i>Chapter 6: Data Analysis and Results</i>	132
6.1. Direct and Indirect Observation	133
6.1.1. Synchronous and Asynchronous Observation	134
6.1.2. Observations on Participants' Interaction with the AR Application	134
6.2 The First Experiment: Mobile Learning Application	135
6.2.1 The Survey	135
6.2.1.1. Participants' profiles	135
6.2.1.2. Usability of the m-learning application	136
6.2.1.3 Measuring the content effectiveness of the application	137
6.3 The Second Experiment: Mobile Learning AR Application	141
6.3.1 The Survey	141
6.3.1.1. Usability of the AR application	141
6.3.1.2 Measuring the content effectiveness of the application	141
6.4 An Empirical Comparison of the Applications	151
6.4.1. Purpose of the Analysis	151
6.4.2 Preliminary Data Analysis	151
6.4.2.1. Ease of use	152
6.4.2.2 User satisfaction	153
6.4.2.3 Attractiveness	154
6.4.2.4 Learnability	155
6.4.3 Reliability and Validity	156

6.4.3.1 Ease of use	158
6.4.3.2. User satisfaction	158
6.4.3.3. Attractiveness	159
6.4.3.4. Learnability	160
6.4.4 General Validation	161
6.4.5 Association Analysis	162
6.4.6 Analysis and Discussion	165
<i>Chapter 7: Conclusions and Future Work</i>	167
7.1 Summary of the Thesis	168
7.2 Future Work	170
References	172
Appendix A	198
Appendix B	201
Appendix C	207

List of Figures

Figure 1.1 The Structure of M-learning Systems	17
Figure 2.1 Research Methodology	25
Figure 3.1: Milgram's Reality	44
Figure 4.1: The Proposed Framework	101
Figure 5.1 System Development Process	122
Figure 5.2: System Architecture Diagram	127
Figure 5.3: ER Diagram of System Content	130
Figure 6.1: Content Effectiveness	140
Figure 6.2: Usability of AR Application	144
Figure 6.3: Usability of AR Application	145
Figure 6.4: Usability of AR Application	146
Figure 6.5: Comparing the Usability between Mobile Learning and AR in Mobile Learning	150
Figure 6.6: Mean Score of Mobile Learning and Mobile Learning with AR in Ease of Use Sub-category	153
Figure 6.7: The Mean Score of Mobile Learning and Mobile Learning with AR in User Satisfaction Sub-categories	154
Figure 6.8: Mean Score of Mobile Learning and Mobile Learning with AR in Attractiveness Sub-category	155
Figure 6.9: Mean Score of Mobile Learning and Mobile Learning with AR in Learnability Sub-category	156

PAGE NUMBERS AND TITLES MAY HAVE CHANGED PLEASE CHECK

List of tables

<i>Table 3.1: The Dunn and Dunn LS model</i>	<i>44</i>
<i>Table 3.2: The Felder and Silverman LS Model</i>	<i>46</i>
<i>Table 3.3: Wang's Six Dimensions of Contexts in Mobile Learning</i>	<i>56</i>
<i>Table 6.1 Comprehension of available themes</i>	<i>135</i>
<i>Table 6.2: Components of multimedia</i>	<i>136</i>
<i>Table 6.3: Length of multimedia</i>	<i>136</i>
<i>Table 6.4: The quality of the text</i>	<i>136</i>
<i>Table 6.5: The quality of the audio</i>	<i>136</i>
<i>Table 6.6: Duration of the audio</i>	<i>137</i>
<i>Table 6.7: Usability of the Mobile Learning Application</i>	<i>138</i>
<i>Table 6.8: Help of the tutorial</i>	<i>140</i>
<i>Table 6.9: Comprehension of available themes</i>	<i>140</i>
<i>Table 6.10: Application of multimedia</i>	<i>141</i>
<i>Table 6.11: Quality of multimedia in AR</i>	<i>141</i>
<i>Table 6.12: Length of multimedia in AR</i>	<i>142</i>
<i>Table 6.13: Quality of text in AR</i>	<i>142</i>
<i>Table 6.14: Quality of audio in AR</i>	<i>142</i>
<i>Table 6.15: Quality of audio in AR</i>	<i>142</i>
<i>Table 6.16: Average Score for Section Usability of AR Application</i>	<i>146</i>
<i>Table 6.17: Comparison of the Usability between Mobile Learning and AR in Mobile Learning</i>	<i>147</i>

<i>Table 6.18: Comparing the Usability between Mobile Learning and AR in Mobile Learning Utilising a Likert Scale from 1 to 4.</i>	<i>148</i>
<i>Table 6.19: Comparing the Usability between Mobile Learning and AR in Mobile Learning</i>	<i>149</i>
<i>Table 6.20: Statistical Analysis of the Data</i>	<i>151</i>
<i>Table 6.21: Hypotheses for the Usability Sections</i>	<i>156</i>
<i>Table 6.22: Analysis of the Data Using T-Test and F-Test</i>	<i>157</i>
<i>Table 6.23: Analysis of the Data using Pearson and Spearman Correlation Coefficient Methods</i>	<i>163</i>

Chapter 1

Introduction

1.1. Introduction

The mobile device has been a powerful multipurpose tool since its invention in the 1980s. It has become very popular among people from all walks of life since it can be adopted for different functions. Apart from communication, many users employ this cellular device for various functions, which include multi-party conferencing, watching videos and movies, texting, learning and accessing the Internet for materials and services. Because of their portability and affordability, mobile devices can easily be adopted for educational purposes. Today, most learners in various institutions of learning have access to mobile phones. This gives educational planners and other stakeholders the opportunity to deploy educational materials through these devices. According to Wang et al. [6], online educational materials can be deployed to learners in higher institutions through cellular devices. Also suggested that students could learn anything to the extent that the developers appropriately design the materials. Rapid developments in the Internet have opened up new opportunities for learning. For example, the Internet provides a channel for learners who want to access educational materials from anywhere around the world. Methods of learning through the Internet include e-learning (electronic learning), which is further classified into collaborative learning and individual learning. Collaborative learning refers to a situation in which two or more people study together, sharing and exchanging learning resources. Online learning gives students the opportunity to link with their tutors and other peers and interact with them in real time through video conferencing, chat rooms, e-mails, webcasts, etc. E-learners also have the opportunity to access individualised learning materials that meet their educational needs. The accessibility and availability of mobile devices, such as tablets and smart phones, have created mobile learning (m-learning)

opportunities for students who want to acquire learning materials anytime and anywhere. Figure 1.1 (below) shows the format of m-learning applications [12].

E-learners can use their mobile devices to access materials with the help of an Internet connection. Furthermore, Figure 1.1 illustrates that learners can acquire resources that they need through their cellular devices, to the extent that they have access to a communication network and Internet service.

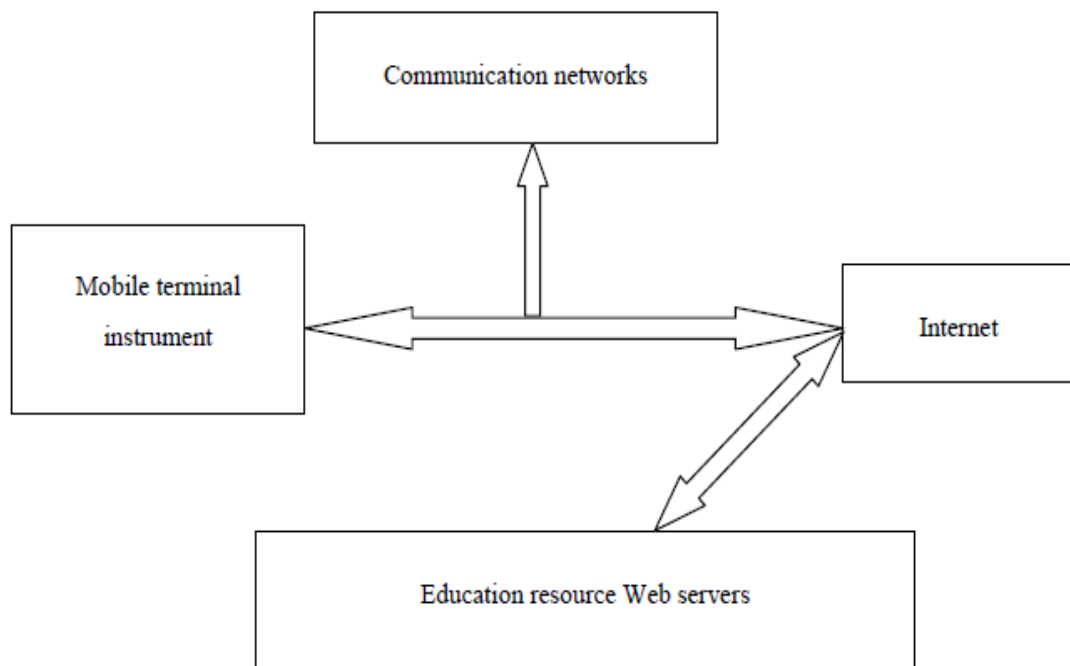


Figure 1.1 The Structure of M-learning Systems

Brevern [14] discussed how learning materials could be organised. According to him, learning should be organised in a way that enables users to interact with their materials. The design of the materials should take into account factors like the introduction and organisation of the knowledge, as well as the behaviour of the learners. The easy accessibility of wireless technology and the development of smart phones with features such as GPS technology, cameras, videos etc. have enhanced the development of educational applications. These educational applications should adhere to high

standards so that they can appeal to and attract a large number of learners and teachers. Various studies have emphasised that there are factors that have to be taken into account when designing m-learning applications. A few research papers have analysed the standards of m-learning applications, but there have been no studies conducted regarding the usability of cellular devices for educational purposes.

1.2. Motivation

Regarding the development of computer applications for learning, there are several usability standards that have been followed, but such guidelines cannot be employed when creating m-learning systems. This is due to the fact that these guidelines do not deal with the limitations of mobile devices, such as the small screen size, processing power and memory capacity. The creation of mobile applications lacks the principles that govern usability standards. E-learning and, particularly, m-learning have generally focused on usability studies and other related factors. Issues related to usability have had less coverage before their comparison with technical issues involving m-learning. Several researchers have shown that usability factors can contribute to the success or failure of m-learning applications, but little or no research has been done about how efficient, learnable, comprehensible, effective and accessible these mobile applications are.

When creating m-learning applications, there are some design factors that have to be taken into account but, as indicated earlier, very few studies have focused on the standards of m-learning applications. No studies have been done about the usability of m-learning systems.

1.3. Research Questions and Objectives

Today, the number of people using cellular phones has outnumbered those who use PCs. This is mainly because mobile phones, particularly smart phones and tablets, can perform most of the functions previously associated with PCs. Apart from telecommunication; mobile devices can be used for deploying educational materials. The usability of these devices is an important aspect of research in the field of m-learning. Hence, when creating learning materials for mobile devices, we have to take into account certain factors, such as the variety of technology, learning capabilities and language aptitude. When these factors are considered, the m-learning systems will greatly appeal to users such as tutors and e-learners. There is the need for evaluation, mainly for the purpose of detecting the limitations and recommending areas of improvement.

The objective of this thesis is to fill the gap that exists to increase the usability of m-learning by answering a number of research questions:

- Does augmented reality and context awareness increase the usability of m-learning and enhance the user's experience?
- Can the proposed framework be used as a guideline when designing and developing mobile applications?

In answering the above research questions, a framework for increasing the usability of m-learning was created, executed and tested regarding a model m-learning system for smart phones.

Accordingly, many important research objectives come into existence:

- Study the effect of augmented reality and context awareness on their usability in an m-learning environment and the range of enhancement of users' expertise.
- Study the requirements of students when they learn in an m-learning environment.
- Study the effectiveness of the proposed framework and its effect on the usability of the mobile application.

1.4. Contribution

Increasing the usability of m-learning devices is a crucial area that requires research. In order to create m-learning applications that would appeal to a variety of users, there is a need to develop a guideline for creating m-learning systems.

Hence, this thesis is intended to make the following contributions to this area of study:

- **Fill the research gap in the area of m-learning usability assessment.**
- **Increase the usability of m-learning:** by using AR in m-learning to make it more interactive and attractive.
- **Integrating AR into m-learning:** interaction in m-learning may be extended by means of AR applications. This is accomplished by melding the virtual with the real, specifically by overlaying computer-generated graphics onto the perceived educational environment.

1.5. Thesis Organisation

This thesis will be structured around two articles that were published and another article that is still a work in progress. Chapter 2 presents a literature review about factors related to the level of standards of m-learning applications. In addition, usability factors of m-learning systems are presented, as well as an extensive literature review about issues regarding m-learning. This chapter also reviews three main issues about m-learning, which include learning style, mobile systems and learning materials. It also presents an introduction to AR, the definition of AR, why it is necessary to build AR applications on mobile devices and application requirements for mobile AR systems, in order to enhance the usability of the systems by increasing their level of interaction. Chapter 3 presents the methodology of the thesis and the methodology of the evaluation and data collection. Chapter 4 presents a framework that makes use of context awareness and AR. Chapter 5 deals with a prototype regarding ‘proof of concept’ or ‘proof of principle’, which is required to ensure that the framework is executable, viable and workable. Chapter 6 presents the state of the art regarding evaluating AR for a mobile setting and proposes a systematic taxonomy for the evaluation of related projects. The project-specific requirements resulting from the AR character of the application are then presented, as well as their impact on the evaluation methodology and the evaluation protocol retained. Based on the proposed evaluation taxonomy, the methodology that shaped the main research questions is presented. The adopted evaluation protocol is then examined before the section presenting in detail the task and experimental setup employed for the on-site experimentations. Chapter 7 presents a conclusion of this research paper by giving a summary of the results, findings and contributions of this study. The chapter also presents further studies that should be conducted in the field of m-learning.

Chapter 2

*Literature Review
and
Mobile Learning*

2.1. Overview

Mobile learning, or m-learning, as it will now be referred to, made its appearance about ten years ago. Quinn (2000) defined this as ‘e-learning through mobile computational devices’. The transfer of e-learning materials onto mobile gadgets enabled learning. Sharples (2006) stated that m-learning was seen as an extension to e-learning by many other researchers. A variety of mobile devices could engage with this system of m-learning, for example mobile phones, smart phones, handheld computers, PDAs and even, on occasion, the smaller laptops. Either by storing the learning materials offline or by accessing them online, these mobile devices provided the medium fundamental to m-learning and studying. Whereas formerly, students had been restricted to certain set locations, such as computer laboratories, libraries or classrooms, these portable devices have freed them to study anywhere and at any time. The latter two aspects of this facility became grounds for the motivation of m-learning. Thereafter, students, no matter where and when they wished to access the materials, could collate a huge pool of information for easy access. The aspects of usability, pedagogy and technology became embodied within the fabric of the design and development of m-learning applications and materials. Because materials had to fit either of two sizes of the mobile-device screens, the layout of these materials had to be considered by technology. Human-computer interaction (HCI) refers to the way in which the user interacts with the device. This contributes to considerations of usability and the design of applications and user interface. From a pedagogical perspective, the enhancing of the learning materials and their educational value was examined to improve the students’ learning experiences. The disciplines of mobile HCI, HCI, computer science, electronic or information systems engineering, psychology and education could all provide m-

learning research. No processes are untouched by technology, which is reforming the world, as we know it. Mostly, the advantages outweigh the disadvantages, which follow in the wake. Learning processes are most significantly affected. The way in which learning, as historically experienced, has been altered can only be described as dramatic. Once storage media had been engaged in the recording and distribution of learning materials, e-learning took over. Following its standardisation, m-learning then came into being. This research focuses on m-learning of a specific kind, featuring communication, assessment and interaction, or traditional learning, which would be accessed by means of smart mobile devices. This research provides an overview of work conducted in the area of m-learning, as well as research, which is still being conducted. It focuses on the two principal technologies of CA (?) and AR. Then, m-learning incorporates these two technologies into a bespoke framework. Results will be taken from courses that apply the new technology, comparing them with m-learning courses without AR. Both technologies previously referred to will be examined in detail.

Augmented reality (AR) is a term recently applied to a variation or extension of virtual reality. In other words, those who use AR may experience virtual objects juxtaposed, composited or superimposed upon the actual world [3]. Instead of replacing the real world, AR becomes a supplement to reality.

Today, AR is evolving speedily, and it is being widely researched. Composite virtual objects in 3D are incorporated into the real world by means of modern technology. AR is interactive and very interesting. It may, therefore, be readily applied to many fields, owing to its enormous potential for use in such areas as, for example, education,

medicine, urban planning, manufacturing, archaeology and architecture. The list is endless. The modern world demands a learning style that depends on mobile and web technology. This explosion of technology has forced the rapid development and progress of computing technologies that harness mobile and web abilities in promoting learning theories. This will be the normal learning style in the future.

Studies that apply AR technologies will provide extra interest and enhancement of a subject for learners. Learning by means of smart phones, palmtops and the like is a relatively new type of behaviour, which is still in its infancy. Pedagogy and technologies à propos these learning modes are rapidly developing [9]. Figure 1 presents the reality-virtuality continuum of Milgram and Kishino [107]. This continuum portrays AR within the broader area of mixed reality. In the technology, the actual area around one is replaced by both virtual and augmented reality; real objects are combined with the virtual. By contrast, AR is able to offer local virtuality. Benford *et al.* [28], took into consideration user transport in addition to artificiality and categorised VR and tele-presence separately from AR (see Figure 2). The AR system [17,19] offers the features that, within the real environment, both virtual and real objects are amalgamated, virtual and real objects are aligned and real and virtual objects can run interactively in real time and in 3D.

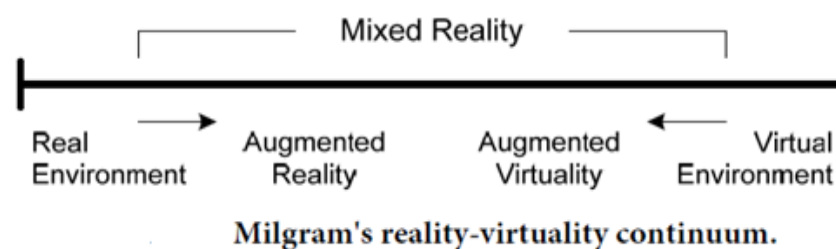


Figure 2.1: Milgram's reality

It is imperative to mention three aspects of the above definition. For one, AR is not just capable of displaying such technology as a head-mounted display (HMD). Because AR can already apply to the sense of sight and will potentially apply to the other senses, the definition is not restricted to sight alone.

Lastly, in overlaying virtual objects over the real, thus removing them from sight, such approaches of diminished or mediated reality are also said to be AR. In the 1960s, Ivan Sutherland, the computer graphics pioneer, together with his students at both the Universities of Utah and Harvard, offered a means of presenting graphics in 3D [151] (151). At the US Air Force's Armstrong Laboratory, a small group of researchers within the NASA Ames Research Center, the University of North Carolina (Chapel Hill) and the Massachusetts Institute of Technology made much progress in this field over the decade from the 1970s to the 1980s. In 1979, the Sony Walkman mobile device was introduced to the world, as were personal digital organisers and digital watches. Shortly afterwards, in the 1990s, wearable computing [103,147] (THESE NUMBERS NOT IN LIST?) arrived in the form of personal computers, which were small enough to be worn all day. The first palmtops included the Palm Pilot (1996), the Apple Newton MessagePad (1993) and the Psion I (1984). Mobile phones, tablet PCs, PDAs (personal digital assistants) and other such mobile platforms are able to support AR. Two scientists, Caudell and Misell [42], in the early '90s, coined the term 'augmented reality' in their development of experimental research on an AR system at the Boeing Corporation. The system was intended to assist workers in connecting wiring harnesses. Although full AR had not yet been achieved, within the next few years [102], a GPS-based system offered outdoor navigational assistance to people with visual impairment. This system made use of spatial overlays. Before long, graphical

overlays could be achieved in mobile settings by means of tracking and computing devices that were both small enough and powerful enough for the purpose. Feiner et al. created an early prototype of an AR system known as MARS [55]. This included 3D graphical tour guide information, complete with buildings and artefacts for the tourist to view.

Towards the end of the 1990s, several conferences began focusing on AR as a distinct research field. These included the Designing Augmented Reality Environments workshop, the International Workshop and Symposium on Augmented Reality and the International Symposium on Mixed Reality. Organisations such as the Arvika Consortium 3 in Germany and the Nottingham MRLab (or Mixed Reality Systems Laboratory) were established. Owing to such freely available toolkits as AR Toolkit, it became relatively simple to build AR applications.

Meanwhile, surveys that provided a general summary of AR advances had arrived. These surveys described the problems found in AR, categorising and summarising its development and progress [17,19,28]. MRLab completed its pilot research in 2001. All symposia were combined in the International Symposium on Mixed and Augmented Reality⁴ (ISMAR). This has now been accepted as the main symposium for research and industry in which problems and solutions may be exchanged.

2.2. Mobile Augmented Reality

Of late, the technique of AR has been adopted in an integrated manner previously unknown on mobile appliances. It is, however, not known what makes mobile devices and applications for AR so well aligned; neither is it clear in exactly which setting it may have the greatest application. For this to be better understood, the origins and exact

definitions of the technique, together with its most appropriate applications and limitations, will be presented.

The late 1960s represents the initial stage in the development of AR, although this advancement was first offered to the consumer only fairly recently. Benderson and Druin (1995) maintained that physical interaction between people and mobile devices occurred then, when researchers began to describe the place and the manner of this technological interaction (p. 39). Virtual and real stimuli are combined in the technology of AR, according to Azuma (1997, p. 356). Thus, stimuli are three-dimensional, interacting in real time. They can be incorporated through physical, as well as sound or visual sensations; in other words, they are multifaceted. Furness (1969) was a pioneer in the field of the application of such blended stimuli, describing it through the example of a fighter plane using computer graphics displayed on the windshield (a head-up), as now provided by the aerospace industry. The graphics enhance and augment the fighter pilot's view. Caudell and Misell (1992) revealed that Boeing's use of goggles that provided AR for engineers assembling wire harnesses sparked the initial term 'augmented reality'. Portales *et al.* (2010) stated that a combined visualisation of real environment and virtual data has been inaugurated in several different sectors. Arenas, such as those of robotics, surgery, entertainment and education were found by Portales *et al.* (2010), as well as other researchers, to be exploiting AR. Milgram and Kishgino (1994) classified augmented reality as that which may incorporate both a virtual and a real environment. In AR, virtual objects are displayed in a real setting and virtual environments can incorporate both people and real objects. In a virtual context, both the environment and the user may be augmented.

Portales et al. (2010) indicated, for instance, that mobile technology in the form of smart phones delivers excellent results, although spatial or head-mounted displays also achieve the experience of AR. Mobile devices combine the exchange of high-speed data, such as WiFi, 3G and 4G, with an increasing ability to process graphics, which appear to be converging on various forms of the current technology in accelerometers, gyro-sensors, inexpensive GPS receivers and high-end camera sensors, all of which may be integrated. Many different and recent technologies have already been incorporated. The result is that the direction of the device, the registration and the speed of the user, as well as the user's location, have all been enabled by combining outside-in and inside-out tracking devices. It now seems entirely possible to present a believable image through the real-time rendering of objects combined with display technology by means of more competent smart-phone display technology, using ever-improving graphical processing ability. Bimber and Raskar (2005), titling this a 'see-through video', added that the camera might be enabled to display the user's environment. It can capture live streams of entertainment, which, before their display, can be overlaid by graphical augmentations. Bimber and Raskar's (2005) AR building blocks combined the above-mentioned elements. Using this single factor, smart phones could be said to be a powerful medium for the application of AR. The ability to move with the user represents a clear, obvious, advantage on the part of the smart phone (or such mobile computing devices) over stationary devices, such as desktop PCs. Díez-(? CHECK NAME) Díez *et al.* (2007) maintained that it seems logical enough that a device which is portable and which is carried around by the user would be the most efficient option when developing an AR application. Thus, the mobile device has the

potential to enhance the user's experience by means of AR at any time convenient for and relevant to the user.

2.3. A Definition of Mobile Learning

Different researchers have used different definitions for m-learning, based on their own perceptions of the phenomenon. A comprehensive definition of m-learning was given as 'the ability to learn independently of place and time, facilitated by a range of mobile devices' by Ufi/learn direct and Kineo (2007), who also outlined five main features of m-learning as: *ubiquitous, bite-sized, on demand, typically blended and collaborative*.

- 'Ubiquitous' refers to the easy accessibility of mobile device learning resources at any time and in any location. Mobile devices are the fastest-growing computing platform in the world; hence, this has given m-learning services a very wide and increasingly ubiquitous presence. The ubiquitous feature of mobile devices comes under the technological perspective of m-learning.
- M-learning applications are designed for use in an environment that is subject to interruptions. The materials should be bite-sized in order to handle likely challenges to concentration as a result of these interruptions. Potential problems relating to interruptions will be discussed under the usability aspect of m-learning.
- The portable nature of mobile devices enables users to have easy and flexible accessibility to m-learning resources that are always available at the learner's convenience. This feature of the portability of mobile devices falls under the technological aspect.

- M-learning devices are not the only main source of delivery of instructional materials to learners. There are other course materials that are used to supplement m-learning services, hence creating a blended approach to learning. ‘Blended learning’ refers to the successful integration of different methods of delivery, models of learning and teaching styles (Heinze & Proctor, 2004). The blended feature of m-learning comes under the pedagogical aspect of m-learning. Boticki *et al.* (2009) presented a context-aware blended m-learning environment.
- Mobile devices have applications that allow people to communicate with one another, hence enabling m-learning to utilise this service in order to enhance peer-to-peer collaboration. This collaborative feature of mobile devices belongs to the pedagogical aspect of m-learning. Traxler (2009) also classified m-learning into the following categories (similar to the ones discussed above): technology-driven m-learning; miniature but portable e-learning; connected classroom learning; informal, personalised, situated m-learning; mobile training/performance support and remote/rural/development m-learning. The viewpoints associated with the various definitions of m-learning can be classified into one of the following three perspectives:
 - *Technological*: this is also called *techno-centric*. The main focus of the technological perspective is mobile devices.
 - *Usability*: the main focus of the usability perspective is learners.
 - *Pedagogical*: the main focus of the pedagogical perspective is also learners.

Velasco *et al.* (2007) gave the following definition of ‘m-learning’ from the technological perspective: a ‘learning methodology which involves the use of small

mobile devices, such as mobile phones or PDAs, that is to say, any handheld device with a wireless connection. Mobile learning solutions allow people to access the information technologies whenever and wherever they need, facilitating the possibility of implementing innovative ways of teaching and learning.'

The various wireless connections used are: 'Wi-Fi, Bluetooth, multi-hop wireless LAN and the global wireless technologies, such as GPS, GSM, GPRS, 3G and satellite systems' O'Malley *et al.* (2005). Traxler (2005) also gave the following definition: 'any educational provision where the sole or dominant technologies are handheld, or palmtop devices'. The various definitions of m-learning mentioned above share one thing in common, which is they consider technology to be the focus of m-learning, instead of the learner or the user. There is a suggestion in these definitions that m-learning was a function of the momentarily available and dynamically changing technology at a specific point in time (Laouris & Eteokleous, 2005a).

When it comes to usability and pedagogical viewpoints, the main focus becomes the user or the learner, rather than the mobile device. According to the usability viewpoint, the centre of focus is mainly the interaction between the mobile devices and the human users; it is called Human-Computer Interaction (HCI) or Mobile HCI. This involved designing course materials in such a way that they could fit into the screen dimensions of the mobile devices. Thus, users could access the materials in a convenient manner.

The following is a definition of m-learning from the pedagogical viewpoint: 'any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of learning opportunities offered by mobile technologies' O'Malley *et al.* (2005). It can be understood from the first part of the above definition that engaging in any kind of learning can be considered

m-learning, with or without the use of mobile devices, provided that the learner is not at a fixed location. These fixed locations may include computer laboratories, libraries, lecture theatres and so on.

According to this viewpoint, m-learning is not defined by mobile technology; rather, it is defined by the mobility of the learner, where the learner can engage in educational activities whilst on the move, using portable and non-portable devices. In view of the above situations, the examples below would also fall under the umbrella of m-learning:

- Learners acquiring a new language or trying to improve their language skills while at home or abroad;
- Learners revising exam papers on the bus while they are on their way to the university;
- Nurses or doctors trying to improve their medical skills while on hospital rounds.

2.4. Advantages and Limitations of Mobile Learning

Some of the advantages of using mobile devices for learning are: *functionality, portability, connectivity, space savings* and *cost*. Most of the functions carried out today by mobile devices can easily be done using laptop computers and desktops and the resource materials saved in them can also be delivered in these mobile devices. As learners can install hundreds of books on their mobile device, it is no longer necessary to carry heavy books. Portable devices are increasingly becoming popular because they are lighter and multifunctional.

They also have Internet connectivity; with them, users can send text messages and emails or make calls. They provide entertainment, such as games and music, and they can be used for educational or commercial purposes. They also have other features, such as a camera, calculator and video-recording functions. Users can download eBooks using their mobile devices. Portable devices occupy less desk space and are generally cheaper than desktop or laptop computers. According to Lockett (2005), related technologies are changing very rapidly. Today, we have mobile devices with large touchscreens and long battery lives. However, there are certain limitations associated with mobile devices when used for academic purposes. These limitations can be divided into three inter-related categories: *technological*, *usability* and *pedagogical*.

Some of the technological limitations of mobile devices are: it is hard to read materials or make an input because of the small screen sizes and keyboards of these devices, respectively. Some portable devices (like the latest smart phones) have certain improvements, such as high screen resolution and better displays, making them appropriate for viewing content like books and magazines, but some users still prefer the traditional desktops and laptops because of their larger screen size. Although many mobile devices have web browsing software similar to desktops and laptops, they may not have all of the functionality of desktop or laptop computers and it might also be difficult to upgrade and expand. Mobile devices are susceptible to damage, loss or theft, hence leading to loss of data. The usability limitations of using mobile devices for learning are mainly concerned with certain constraints associated with accessing materials and engaging with others for the purpose of effective learning. Some of the limitations of usability are: interruptions by people, noise distractions and other factors. Nevertheless, learners can use mobile devices anytime, anywhere.

The interruptions and distractions relating to mobile devices are likely to be greater in areas outside fixed locations (where desktop and laptop computers are used). When developing resource materials for learners in different places, factors such as interruptions and distractions should be taken into consideration. Other limiting factors may involve insufficient working space and lack of comfort, particularly when studying materials on a moving bus or train.

The pedagogical limitations of using mobile devices for the purpose of education mainly centre on distractions. The students are likely to shift their attention from the actual learning materials to other things, such as entertainment.

2.5. Introduction to the M-learning Generations

This section presents a literature review on the design, development and implementation of m-learning, including works that are either completed or are currently in progress. A few years ago, m-learning emerged as a new field of study and several very successful studies have been conducted regarding how to develop the pedagogical aspect of m-learning. M-learning communities have acquired significant knowledge because of these studies. Currently, the majority of researchers realise that m-learning applications should focus on pedagogical elements, whilst addressing usability limitations.

Most researchers are aware of the limitations and drawbacks associated with using a portable device for learning and teaching and, as a result, they try to offset these limitations with enhanced pedagogical value to further support using mobile devices for learning and studying (Parsons *et al.*, 2006). Basing my argument on ongoing studies, m-learning can be categorised into four generations that embody the various m-learning

fields that researchers have created and developed. These four generations arose in order to: a) deal with challenges that exist in the field of m-learning and b) increase academic materials within m-learning applications. The m-learning generations are based on the various differences between the m-learning applications, which have been categorised as follows: '*non-adaptive*', '*learning-preferences*'-based *adaptive*, '*learning contexts*'-based *adaptive* and '*learning-contexts*'-aware *adaptive*. The above four applications form the 'generations' of m-learning. The last two generations use learning contexts in their m-learning applications; hence, before introducing them, the idea of 'context' will be defined. The sections below will describe the main characteristics of the four generations by giving relevant application examples. The challenges regarding these generations will also be reviewed in subsequent sections.

2.6. *The Non-adaptive M-learning Generation*

The design and development of early m-learning applications mainly focused on delivering e-learning resources to mobile devices in order to make it easy for people to carry those learning materials. It was then discovered that the format of the designed e-learning materials was not compatible with the systems of the mobile devices with regard to size, font, quality and scope (Becking *et al.*, 2004); these are also considered to be the technological limitations of m-learning. Although some of the resource materials fulfilled the minimum requirements of m-learning materials, others did not, mainly because they could not fit into the dimensions of the mobile device screen or needed tedious scrolling. The better design of learning resources of later applications in this generation enabled them to be transferred onto a mobile device for educational

purposes. A shared feature of the applications throughout this generation was that the materials that learners accessed were generic. This is called the ‘one-size-fits-all’ approach and indicates that there was no personalisation of learning materials to suit the needs of the learners with regard to their preferences and contexts. The aims of these applications were:

- A. To make learning resources in a mobile format accessible to learners, regardless of their location and time.
- B. Promote the use of mobile devices for learning purposes, particularly in areas where the use of computers is either difficult or unrealistic.
- C. Facilitate collaborative learning between teachers and peers who are at different places by using mobile devices with communication capabilities.

The following are examples of applications.

- In order to assist learners preparing for exams at any time anywhere around the globe, learning materials for revision on desktop computers were synchronised onto a PDA (Bull & Reid, 2004). This is called individual and/or independent learning.
- A language and cultural mobile application was designed for learners who wanted to acquire a foreign language and to assist them in reducing culture shock before, or when, they go overseas for studies (Maniar & Bennett, 2007).
- Collaborative learning was developed between learners on field trips and their classmates through the use of PDAs (Hine *et al.*, 2004). Moura and Carvalho (2008) extensively discussed the effects of collaborative learning between individuals.

2.7. The ‘Learners’ Preferences’-based Adaptive M-learning Generation

‘M-learning is causing educators to rethink how learning happens and how specific learning needs and styles are expanded and enabled with multifunctional hand-held devices’ (Valentine, 2004). The major difference between the applications of this generation and the preceding generation was that an *adaptive learning mechanism* was incorporated into the applications of this generation. This framework defines the customisation of learning materials (designed for mobile devices), in accordance with learners' preferences. Learning preferences refers to the various ways in which a learner wants to study, including the following:

- ***LS (Learning styles?)*** – students’ preferred styles of learning;
- ***Learning strategies*** – students’ preferred strategies for learning;
- ***Learning characteristics*** – this is concerned with the learners' personality and how it might influence their learning preferences.

Examples of these characteristics are: degree of motivation, background, strengths and weaknesses, hobbies, experiences, ambitions and awareness of their obligations. For instance, a diligent student may require detailed learning materials, as opposed to a negligent student.

The following are the objectives of these applications:

- Deliver customised and user-centred learning materials to students.
- Promote the quality of learning and teaching by giving students learning materials that meet their needs and preferences (Laouris & Etekleous, 2005b).

It was believed that learners gain extra pedagogical benefits:

- If they are provided with resource materials that meet their needs and preferences;
- When the design of the material and the content suits the students' LS.

These benefits involve a better understanding of learning materials and the easy acquisition of learning content (Riding, 1996). For instance, active learners are more engaged and, hence, are likely to learn and/or obtain more if given hands-on activities instead of just passively reading learning materials.

The idea of *adaptive learning* is crucial within e-learning or online education. This is mainly because many of the generic learning materials that have been developed may not meet the personal needs of individual or group learners. It is believed that an application that is pedagogically effective should include learning resources that can meet the needs of various learners with different types of LS. Differentiated adaptive learning courses can also be designed to offer extra assistance to learners who are physically challenged (for instance, Muir, 2001).

Distance learning students are more likely to gain from customised materials, mainly for the following two reasons:

1. Learners taking part in a distance-learning program are normally physically located away from where the delivery of instruction is taking place and, in most cases, they work alone. Effective customised learning resources enables learners: (a) to gain a better understanding of their courses, (b) become more engaged and encouraged to learn and (c) acquire better learning experiences and/or quality.

2. Distance learning programs normally involve a diverse array of students. The diversity of learners in distance learning programs is reflected in terms of age, educational background, learning skills, family commitments, responsibilities, proficiency levels, learning styles and needs, physical abilities, etc.

A generic learning course is not likely to be maximally effective, considering the diversity of the students in distance learning. Hence, an adaptive learning course will be more appropriate in this situation (Meisalo *et al.*, 2002).

Creating customised traditional learning resources, such as books and lecture notes, requires much work, but designing personalised learning materials (or, in other words, m-learning materials) is easier and cheaper. The main reason for this is that, once the content has been electronically developed, it can easily be redesigned to meet the needs of learners with different learning preferences (Muir, 2001). Adaptive m-learning is also essential because of the following reasons:

- Technical shortcomings of mobile devices, such as memory and speed;
- Potential interruptions and/or distractions in various areas where mobile devices are used for learning, leading to poor attention for study.

Other studies related to this area include an adaptive m-learning application that designs learning resources that conform to the learners' LS (Park, 2005). There are four conventional phases to developing a '*learning preferences*'-based adaptive m-learning application, which are as follows:

1. The learning style preferences to be taken into account for the application are established. There are various reasons why a specific style of learning, within an LS model, may be chosen for delivery. For instance, the Felder and Silverman LS model (Felder & Silverman, 1988) stated that a range of LS might be

deployed by an application because of the versatility of describing students on a spectrum within four categories.

2. A range of learning resources suitable for learners with different styles/preferences of learning, as indicated in (1), are designed and/or integrated into the m-learning application.
3. The learning preference/style of the learner is identified before the application is used. There are two main methods in identifying a learner's LS:
 - The learner fills in a learning style questionnaire that will identify the LS he or she has (or is most likely to have), or
 - If learners know their learning preferences, all they have to do is enter their data into the application. There are web-based systems that directly ask for learning style information through the Index of LS questionnaire (Felder & Silverman, 1988) from learners, such as in Paredes and Rodriguez (2004). On the other hand, there are systems that automatically identify the learners' learning styles, for instance, Bayesian Networks (Garcia *et al.*, 2005).
4. A process of adaptation is carried out in order to choose suitable learning resources that meet the needs of learners with particular kinds of learning preferences/styles. The ordering of learning resources into the application system can also be adapted and personalised in order to fit the learning styles of the users (Sampson *et al.*, 2002).

This study will analyse two learning style designs: those of Dunn and Dunn and Felder and Silverman. I have chosen to describe the Dunn and Dunn model mainly because it consists of elements formed under the three main learning style categories. A summary of various learning styles will be presented by analysing this model. This discussion

will also review the learning style model of Felder and Silverman, as it is regularly employed within adaptive learning and m-learning applications, such as in Park (2005) and Graf (2007).

2.7.1. The Concept of a ‘Learning Style’

The idea of a ‘learning style’ was originally used in the field of education as a ‘description of the attitudes and behaviours that determine our preferred way of learning’ (Honey, 2001). According to Keefe (1979), a learning style refers to ‘the composite of characteristic cognitive, affective and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment’. Various methods of learning, such as deep, surface or strategic, can be categorised as LS.

A ‘deep’ learner refers to someone who uses analytical skills, such as synthesis and problem solving, in order to gain a deeper understanding of an issue. A ‘surface’ learner refers to someone who memorises materials or information for the purpose of recall, such as during examinations, and does not intend to deeply understand the materials. A ‘strategic’ learner is one who uses both approaches. For example, the learner may use analytical skills when he or she wants to gain a better understanding, or he or she may memorise materials in order to pass an exam. Learning styles (LS) may be classified into three main categories:

- Instructional and environmental learning preferences;
- Information processing learning preferences;
- Personality-related learning preferences (Curry, 1987).

Most of the learning style models fall into the second category: these may include the Felder and Silverman model (Felder & Silverman, 1988), Gardner's Multiple Intelligences (Gardner, 1993), Kolb's Learning Style Theory (Kolb, 1984) and Myers-Briggs Type Indicator (Briggs & Myers, 1977). The Dunn and Dunn LS model (Dunn & Dunn, 1978) is composed of five components that are formed under the above three categories. Table 1 shows the five components together with their factors.

Categories	Components	Factors
Instructional and Environmental	<i>Environmental</i>	Sound/noise level, temperature, light, seating, layout of room/location
Personality-related	<i>Emotional</i>	Motivation, degree of responsibility, persistence, need for structure
Information processing	<i>Physiological</i>	Modality preferences, for example, for visual, auditory, kinaesthetic/tactile learning, intake (food and drink), time of day, mobility
Personality-related	<i>Sociological</i>	Learning groups, help/support from authority figures, working alone/with peers, motivation from parent/teacher
Personality-related	<i>Psychological</i>	Apprehensive/depressed, somatic complaints, hostile attitudes and behaviours, attention disorders, thought problems, delinquency (cheating, insubordination, truancy), social

Table 3.1: The Dunn and Dunn LS model DATE?

The Felder and Silverman model (Felder & Silverman, 1988) falls under the Information Processing Learning Preferences category and classifies students' learning styles/preferences using four dimensions:

- Active/Reflective;
- Sensing/Intuitive;
- Visual/Verbal;
- Sequential/Global.

Table 2 below illustrates these four dimensions. The dimensions can be represented on a numerical scale comprising values from 1 to 10, depending on how learners receive and process information. This model depends on the general inclination of the learner, but there are certain instances in which students may not conform to the general tendencies, particularly if they have a higher preference for a specific behaviour within a certain dimension. For instance, active learners are inclined to like testing and experimenting with new information and, hence, exercises and tests would fit their style. On the other hand, reflective learners may prefer to read and think about the materials before acting, thus, materials that have objects and examples would fit their style (Graf & Kinshuk, 2006; Graf, 2007).

1	<i>Active</i>	Prefer to actively do something with the information for the purpose of processing, such as discussing or testing it.
	<i>Reflective</i>	Prefer to read and think about the learned material.
2	<i>Sensing</i>	Prefer concrete materials, such as facts and data.
	<i>Intuitive</i>	Prefer abstract material, such as theories and their underlying meaning.
3	<i>Visual</i>	Learn best from what they can see or visualise.
	<i>Verbal</i>	Learn best with communication and discussion.
4	<i>Sequential</i>	Prefer to know the details of the sub-topics.
	<i>Global</i>	Prefer to see the ‘big picture’ of the topic before learning the details.

Table 3.2: The Felder and Silverman LS Model (1988?)

We realise that different learning style models may describe a learner’s LS in different ways. Some of them describe LS as a set of fixed characteristics that people have. For instance, a complete visual learner may not want to be a verbal or auditory learner. Stern (2004) stated that few studies have focused on conforming learning styles with specific technologies in order to improve the learner’s experience. M-learning presents an opportunity for providing students with a customised learning system that adapts content according to their level of knowledge and experience. Kinshuk and Lin (2004) designed a web-based intelligent tutoring architecture that comprises a student module, tutorial module, learning style analysis module and access device analysis module. The learning style analysis module, employing the Felder-Silverman learning style theory

(Felder and Silverman, 1988), deals with the student's preferences in learning and communicates with the student module. The access device analysis module detects the access device profile the student is using and then transmits this data to the tutorial module. The tutorial model then produces customised materials for the learner using the student module and access device type. We have established various adaptive web-based learning environments where students are given personalised learning procedures based on their learning styles. But these adaptive web-based environments have either not been created in m-learning applications or they have not been made available at the time of writing (Kinshuk & Lin, 2004).

Studies about the use and implementation of adaptive m-learning have gained tremendous ground in the last few years, for example, the studies of Jung *et al.* (2006) and Guo *et al.* (2008) provide examples of such applications.

2.8. Learning Objects and Their Applications

2.8.1. Advantages of Learning Objects

Learning objects (LOs) are materials and tools that are used for pedagogical purposes. Applications of LOs have a set of rich metadata for describing what is suitable for learners. Yau (2004) stated the following advantages of constructing learning materials as LOs:

1. *Flexibility* of learning materials, because originally, the development LOs was for them to be used in different contexts.
2. Metadata tags promote *easy updates, searches* and *content management*.

3. *Customisation* – The modularity of LOs makes it easy to create customised learning experiences that are specific to each learner.
4. *Interoperability* – LOs are compatible with various types of applications.
5. *Facilitation of competency-based learning* – Metadata tags explain the LOs, hence, students can fill their knowledge gaps by obtaining relevant objects.
6. *Increased value of content* – Whenever LOs are used; the value of the content rises.

Teachers use LOs for various reasons, such as revising a previous concept, encouraging learners, supplying various methods of analysing a concept and presenting or investigating a new concept (Kay *et al.*, 2009).

2.8.2. *Learning Object Metadata (LOM)*

Learning object metadata (LOM) is a data model normally used to describe a learning object. There are various standards for LOs. For instance, LOM was designed using different standards' strategies, such as the Learning Technology Standards Committee (LTSC) (IEEE LTSC, 2005), which established the LOM; Dublin Core Metadata Initiative (dublincore.org), which established the Dublin Core Metadata (DCM); the Instructional Management System Global Learning Consortium (www.imsglobal.org), which established the IMS Learning Resource Metadata (LRM) Specification; and Advanced Distributed Learning (www.adlnet.org), which established the Shareable Content Object Reference Model (SCORM).

These standards and specifications have one thing in common: to promote LOs so they will be adaptable across any web-based learning system. SCORM (?) was written mainly for the purpose of: a) storing, cataloguing and retrieving Shared Content Objects (SCOs) within and from various web-based intelligent learning environments; and b) supporting SCORM-compliant Learning Management Systems (*Ibid.*).

2.8.3. *Learning Object Repositories*

Learning objects are normally stored in global learning object repositories, which are like digital libraries. These repositories are often programmed on a client/server architecture employing brokerage services and offering peer-to-peer access to the local repository of the LOs. For instance:

1. Codewitz (www.codewitz.org) is an international project that was designed to facilitate the better learning of programming skills. The LOs are stored in their Material Bank repository, which is a kernel for sharing and storing resources.
2. Merlot (www.merlot.org) is a multimedia educational resource for learning and teaching. It has about 7,500 LOs in various fields, such as chemistry, business, engineering, geography, mathematics, psychology and world languages.
3. CAREO (www.careo.org) is a repository reference that has about 3,000 LOs.
4. Telecampus (telecampus.edu) has over 66,000 courses and programs for commercial purposes (*Ibid.*).

5. The LORDEC website (www.education.uoit.ca/lorddec/collections.html) has a very useful learning objects repository and, hence, it is regularly used by teachers to access these resource materials. Moreover, people often search and choose learning objects from repositories using Google (Kay *et al.*, 2009).

2.8.4. LO Applications

Various applications that use LOs have been designed. Most of these applications, such as Brennan's (2005), mainly concentrate on teaching programming to students. Brennan suggested a 'development of LOs designed to address the needs of novice programmers' and to enhance teaching, the aim is to make learning programming easier for learners. According to these applications, learners have their own personal preferences on the best way they can learn programming and they have to establish a mental model of the language's constructs so that they can learn the semantics of a programming language. Lee *et al.*, (2005) designed a Java learning object ontology 'for organising LOs of Java courses in an adaptive e-learning environment'. Adamchik and Gunawardena (2003) presented an LO method for teaching programming. Smith (2006) and Bradley *et al.* (2007) also designed applications that enable mobile LOs to be utilised on mobile devices.

2.9. Contexts and Learning Contexts

This section will present the background information regarding the origin of a ‘context’; then, the use of learning contexts within m-learning applications will be reviewed. Eventually, the challenges facing the implementation of these applications will be discussed.

2.9.1. The Concept of a ‘Context’

The idea of context originated from the field of context-aware mobile computing, where it was first used. The term has different meanings for different authors. Dey and Abowd (1999) compiled various definitions of ‘context’ using different perspectives.

These definitions were classified as follows:

- a. Contexts regarding the users’ environment in terms of their situation. Their computers or mobile devices may have information regarding their situation. This information may include users’ characteristics, such as their emotional state, focus of attention, social status and other informational states.
- b. Contexts regarding the application’s environment, surroundings, settings or states, or general information about the environment with regard to the present situation.

Common features of the contexts of the above two categories of definitions may include location, time of day, season, temperature, identities of people and objects around the user and changes to these identities. In addition, two classification systems of contexts have been suggested. Schilit *et al.* (1994) and Chen and Kotz (2000)

proposed the first definition, which consists of four types of contexts. Schmidt *et al.* (1998) proposed the second definition and it contains two types of contexts based on two different perspectives. The following is the first definition.

1. Computing context – this may include network connections, such as IP addresses and ports, communication costs and bandwidth, software modules and other resources such as printers, displays and workstations.
2. User context – this includes the user profile, location, people nearby and current social situation.
3. Physical context – this includes the temperature, lighting, pressure, noise levels, audio, traffic conditions, etc.
4. Time context – this includes time of the day, week, month and season of year. A context history can be formulated using the above three contexts over a period of time. This is significant for specific types of applications.

For instance, if the user's calendar, time and location are known, the application can acquire accurate information about the social situation of the user (whether he or she is in a meeting, at a party or having dinner).

The following is the second classification system:

- Human factors
 - User – personal habits, mental state etc.
 - Social environment – proximity of other people, social relations, collaboration.
 - Task – goal-directed activities or more general objectives.
- Physical environment – location

- Infrastructure – interactive and computing environment.
- Conditions – level of noise, brightness, fixed vs. changeable conditions.

The utilisation of context enhances the development of applications to facilitate the delivery of services/activities suitable to the user's values. For instance, if the application is aware of the user's current location, then a direction can be given to the user. Dey and Abowd (1999) presented a brief synopsis of context that they determined in an effort to simplify the process of identifying contexts for a particular application situation for application designers: 'Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves'.

2.9.2. The Concept of a 'Learning Context'

A 'learning context' is formed from a context; a learning context can also *be* a context. Vice versa is also correct. The main difference between the two terminologies is that a learning context describes the pedagogical aspects that are integrated into the m-learning application design in order to facilitate m-learning services/activities. General learning applications, for example, e-learning also use a learning context in the development of applications in order to provide relevant services/activities that are context-oriented. A comprehensive meaning of a learning context should reflect the circumstances or conditions that surround the learning (Basaeed *et al.*, 2007).

Learning contexts can involve any states that ‘affect the learner’s learning service discovery and access, such as the learner’s profiles and preferences, network channels and devices the learners are using to connect to the Web etc.’ (Yang & Chen, 2006). Just like contexts, we can classify learning contexts according to the perspective surrounding the user and the application. Prekop and Burnet (2003) classified learning contexts as *internal* (surrounding the user) and *external* (surrounding the application) dimensions, as follows.

1. The internal dimension involves:

- *Human factors* (such as the user’s emotional/physical state, personal events, beliefs and previous experiences);
- *Social environment* (work context, business processes and communication) and *activities* (goals, tasks).

2. The external dimension includes:

- The *physical environment* (light, sound, movement, touch, acceleration, temperature, air pressure, proximity to other objects and time);
- *Infrastructure*;
- *Location*;
- *Technological features* (device and product design).

Learning contexts that fall under the internal dimension include: *the activeness of a student according to the time of day* (Bhaskar & Govindarajulu, 2008), *mood and motivation* (Ting, 2005) and *concentration level of a student* (Cui & Bull, 2005). An example of a learning context that falls under the external dimension is the *frequency of interruption level at a location* (Ibid.). Wang (2004) suggested a classification approach

that is composed of six categories of learning contexts. These six categories together form the ‘context space’, as illustrated in Table 3. The six dimensions are: *identity*, *spatio-temporal*, *facility*, *activity*, *learner* and *community*. *Identity* describes the unique characteristics of the learners, such as their login. *Spatio-temporal* is the time and location aspects of the learning process. *Facility* refers to the type of mobile device employed by the user for the purposes of learning and the kind of wired/wireless network that is used for connection. *Activity* refers to the type of learning activity that is happening, such as individual or collaborative. The *learner* dimension describes the learner’s characteristics, such as LS and knowledge level. The sixth dimension, which is *community*, characterises the social interactions between participants, in case there are any. This context space enables researchers/developers to understand the components of different learning contexts and how they can be used to provide various, effective m-learning applications.

Dimension	Explanation
<i>Identity</i>	Specific characteristics of each learner normally recognised through a login system or via special devices, such as smart cards or fingerprint readers.
<i>Space-Time</i>	This is characterised by two elements: <i>time</i> and <i>location</i> . The time can be easily known through the clock on the mobile device and the location can be obtained by using a sensor, such as a Global Positioning System (GPS). Knowledge of these two characteristics gives an indication of an instant or period during which the user will require some information.
<i>Facility</i>	This refers to various kinds of mobile device PDAs, mobile phones, smart phones, tablet PCs, laptops and the capabilities of these devices, such as the CPU power, display size, colour resolution and input method. Knowledge of the facility enables the provision of learning materials according to mobile device.
<i>Activity</i>	It may be hard to identify specific activities suitable for a learning process. Activity context may be acquired through web actions, which are profiles of the learner's access log and discussion records on the Web or by the observation of live actions happening in the classroom.
<i>Learner</i>	This constitutes the intrinsic and psychological characteristics of a learner that are considered to be vital to the success of learning. These characteristics include the learner's emotional

	state, focus of attention and background; however, they are not easy to identify.
<i>Community</i>	The status and interactions among members of the community constitute a complex social context. Various learning activities can be connected across time, place, school, home, expertise; and learning roles are dynamic among the participants.

Table 3.3: Wang's Six Dimensions of Contexts in Mobile Learning (DATE?)

Basaeed *et al.* (2007) also classified learning contexts in a way that is similar to the context space of Wang (2004). Their classification is composed of three categories: *learner*, *device* and *connectivity*. He included more learning contexts, extending Wang's (2004) context space. In the learner category, he added *learning-related information* (which includes the present and previous learning sessions) and *personal preferences* (which includes the desired way of presenting the multimedia and the length and depth of the content). It was realised that the preferred content length was potentially significant to learners, particularly when they must pay for the cost of their own Internet connections. The mobile device and connectivity categories are reflected in the *facility* dimension in the context space of Wang (2004).

Different perspectives of a learning context can be presented by characterising it using the learning settings of an m-learning environment. We must note that the settings in an m-learning environment are not fixed due to the fact that m-learning contexts frequently change, particularly when learners move from one location to another, meeting various peers and services/resources (Chan *et al.*, 2004). According to this perspective, each instantiation of settings is a set of learning contexts (Wang, 2004).

Similarly, a learning context can be regarded as a *situation* and, hence, it can be defined as a ‘complex of environmental and intentional constraints in a given mobile learning setting’ (Becking *et al.*, 2004). Based on this perspective of m-learning activities, Frohberg (2006) proposed five categories of activities relating to the five learning contexts: *free, formalised, digital, physical* and *informal*.

- *Free context activities* – Mobile learning activities that are classified as free context activities consider the context of the learner irrelevant for m-learning activities. For instance, the location of the learner, whether he/she is sitting at home, riding a bus or at the beach, is not relevant to what he/she is currently learning.
- *Formalised context activities* – These are activities taking place in a well-defined educational institution, such as a school, university and college, using a relevant context such as a classroom, lecture hall, auditorium, seminar room or library, possibly also in virtual classrooms or lecture theatres.
- *Digital context activities* – These are activities carried out using a computer or mobile device. There are two main advantages associated with digital context activities: 1 - teachers normally have complete control of the learning environment, and 2 - the computer acts as a playground for learners where they may participate in learning through simulations that replace the physical environment. For instance, the Savannah project (Facer *et al.*, 2004) enables children to learn about animal survival by using various animal simulations and acting out their roles.

- *Physical context activities* – These activities constitute the components of the digital context together with other activities that occur in a situated or real explorative learning environment. For instance, when learners are studying about butterflies, they may be supported by the use of mobile devices giving more information to learners about these insects (Chen *et al.*, 2004).
- *Informal context activities* – These activities support everyday learning, i.e., within a non-formal curriculum. These include relations, emotions and attitudes. Apart from the physical context activities, which use learning contexts? (?)

However, the above are also known as free context, formalised context, digital context and informal context activities. The term ‘context’ was used for these activities mainly because of the literal meaning of the word itself, and it has nothing to do with the description of learning contexts reviewed in this section.

2.9.3. *Deployment of Learning Contexts within M-learning*

Applications

It is not an easy process to deploy learning contexts in m-learning applications. There are many factors to be considered and potential challenges to be addressed before deploying learning contexts in an m-learning application. The advantages and challenges are reviewed in Section 2.4.4. The process of deployment is composed of three stages: (a) retrieval of learning contexts, (b) determining *whether or not* an action is to be performed and, (c) determining *with which approach* an action is to be performed. These stages are discussed below.

1. A retrieval approach is needed for learning contexts to be deployed within an m-learning application. There are two kinds of retrieval approaches – *interactive* and *proactive*, also called *non-automatic* and *automatic*, respectively. *Interactive* applications directly issue requests to the users to input information about their learning contexts. This is likely to cause an intrusion into the current activities of the users and it might take a great deal of time and effort to respond to the request, as they have to manually enter the information required. In *proactive* applications, a retrieval request automatically retrieves information using sensor and/or location-tracking technologies, such as the use of GPS technologies (Jones & Brown, 2002). The automatic process of retrieval is convenient to the users, as they do not have to enter values manually. The interactive m-learning applications can be categorised under the '*learning-contexts'-based adaptive* generation, which is reviewed in Section 2.5.

Proactive applications are categorised into the '*learning-contexts*'-aware *adaptive* generation.

2. When the requested information is received from the learning context, the application then establishes whether to take action. These actions can be either *active* or *passive*, and the learning contexts related to these actions are called *active* and *passive contexts*, respectively. An *active* context directly affects the behaviour of an application. For instance, the handheld learning organiser automatically detects whether requested library books are available when the user walks past the library (Ryu *et al.*, 2007). In a passive context, the system automatically retrieves information, but no action may be required. For instance, in the adaptation mechanism of Martin *et al.* (2006a), if there is a ready activity, their alert module detects whether to interrupt the user. User interruption will only occur if there is an available activity that is urgently important. Apart from such an instance, the user is never interrupted. 'Context-aware application' refers to an application that can sense and recognise contexts by using sensor technologies, eliminating the need to input information manually, for example, a proactive application. Similarly, an active context-aware application is an application that 'automatically adapts to discovered context, by changing the application's behaviour' (Chen & Kotz, 2000), regardless of whether the user is aware of these changes. 'Passive context-aware applications' refer to an application that 'presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later' (*Ibid.*). This implies that the application will not be subjected to any changes unless the user acknowledges or accepts the changes.

3. If it is confirmed that an action is necessary, there are various methods for this action to be implemented. The following are five different approaches that will be reviewed – *proximate selection*, *automatic contextual reconfiguration*, *context information and commands*, *context-triggered actions* (Schilit *et al.*, 1994) and *contextual event notification* (Wang, 2004). Depending on the aims and objectives of the activities and services, one or more of the methods below can be used to promote the deployment of the activities and services in an m-learning application.

- Proximate selection, also called ‘context restriction’, is a user interface approach that enables users to make an appropriate selection of objects found nearby. For instance, an application may employ this method to automatically detect a user’s nearest printer by sensing the location of the user and the closest printer.
- Automatic contextual reconfiguration is an automatic altering of components based on context. The altering can be addition, deletion or any other change of the component. In reference to the previous example, if the user leaves the area nearest to the printer, then the printer will be removed from the application and, hence, it will not be shown as the nearest.
- Contextual information and commands: queries about information or commands may lead to different results (as displayed on the user’s screen), depending on the context of the user. For instance, when a user goes to a different location (i.e., a library), the browser may alter the

displayed directory in order to match the user's location, i.e., giving information about the library.

- Context-triggered actions: these are simple *IF-THEN*-style rules activated by contextual information. For instance, *if* the user is in meeting location A, *then* the application reminds the user of appropriate meeting notes (Schilit *et al.*, 1994).
- A method known as *contextual event notification* may be used to alert the user of significant events and/or deadlines using the information retrieved from the user's calendar.

Apart from the methods discussed above, there are other approaches that can be used to facilitate particular activities/services, once it is confirmed that an action is required to be carried out. The following different adaptation strategies can be deployed, depending on whether it is the *interaction*, *service*, *content* and/or *environment* that should be adapted (Norros *et al.*, 2003).

1. An application may *adapt the interaction* between the user and the device. This is basically obtained through the user interface. For instance, if the application detects that the user is a beginner, and then he/she is provided with a simpler interactive user interface.
2. An application may *adapt the service*, for instance, by giving personalised services, by recommending the user's favourite products, auto-filling in forms for users and giving access to services linked to the location of the user.
3. An application may *adapt the content* that suits the user's context, activities or preferences.

4. An application may *adapt the environment* by changing the physical environment of the user in order to meet his or her preferences (for example, colour, music, etc.).

2.9.4. *Advantages of and Challenges to Deploying Learning Contexts*

The advantages of deploying learning contexts and designing context-aware m-learning applications are based on two principles – *improving the learning/studying situation* and *bringing convenience to the learner*. These are described as follows.

1. *Improve the learning/studying situation* – context-aware m-learning applications can facilitate real-time situated learning to occur in real physical environments. They also have the potential to improve the effectiveness of learning (Basaeed *et al.*, 2007). There are some pedagogical activities/materials that are not suitable for learners within a certain situation and location. Learners' learning opportunities and performance can be improved by scanning the learning materials and choosing those that are best suited to the learners' needs (Cui & Bull, 2005).
2. *Bringing convenience to the learner* – the objectives of context-aware m-learning applications may: (a) enable learners to concentrate more on the learning resources or situation rather than on the technology (Winters & Price, 2004) and, (b) remove the need for users to manually input information into the system, hence enabling them to save time and effort (Schilit *et al.*, 1994; Kaenampornpan & O'Neill, 2004).

A context-awareness m-learning application creates an opportunity for learners to easily receive timely information. Information can be given to students at the right time and location without any difficulty. The mobile device output can be adjusted to match the learner's current situation in order to provide him or her with supplementary benefits if necessary, such as changing the colour, brightness, font size or privacy settings (Schmidt, 2000). The deployment of learning contexts within m-learning applications is associated with two major challenges: difficulties in the detection and retrieval of learning contexts and the dynamic nature of learning contexts.

Retrieving and detecting the learner's internal and external context is difficult for the following reasons:

1. The 'internal context' mainly describes the state of the user, including their emotions, intentions and motivations. Internal context is very difficult to sense because it involves a complicated process, such as attaching a number of wearable sensors to the user to retrieve readings. For instance, machine vision algorithms can detect a learner's facial expressions, and movements in the eye can sense the concentration level of the learner. Such detection processes need intricate analysis and may cause anxiety and discomfort to users. The outcome also may not be totally accurate (Schmidt, 2000; Wang, 2004).
2. The 'external context' describes the state of the environment, such as location, noise level and temperature. The process of sensing an external context is relatively easier. Modern technologies used for sensing the user's location include GPS, Radio Frequency Identification Technology (RFIDT?) and wireless and cellular network services (*Ibid.*). Sometimes,

the GPS data may not be very accurate and available. The strength of the signal of the mobile device will be poor, or completely lost, when the user enters tall buildings, if the location detection sensor is attached or built into a mobile device (Marmasse & Schmandt, 2000). RFID can only function if a writer is attached in the deployed locations and a reader is attached to a mobile device before use. There are inaccuracy issues with both wireless and cellular network services (Wang, 2004). Some users might be worried about their privacy and, thus, may be unwilling to use location-tracking services (Synnes *et al.*, 2003).

3. Internal and external contexts constantly experience change, which therefore, leads to different context values in the same period of time or within the same location (Chan *et al.*, 2004). If, for example, an application chooses suitable learning resources for students using the current level of temperature, what happens when the application suddenly senses a change in the level of temperature in the course of the lesson? To deal with this challenge, there must be an inbuilt system that deals with this dynamic context and that establishes if the change in the context should initiate an action, as well as whether the action should be carried out. If yes, will it be with or without the approval of the user. This means that an application needs to be capable of differentiating between those context changes that should elicit new measures and those that it should record silently (Schmidt, 2005).

In order to establish whether to interrupt and notify the users about newly developed activities whilst they are doing their current tasks, a recommendation process containing a decision mechanism has to be formed (Martin *et al.*, 2006a).

2.10. The ‘Learning Contexts’-based Adaptive M-learning

Generation

The major difference between this generation and the last two generations is that applications within this generation detect the learning materials and activities which are appropriate to the learner by taking into consideration the user’s learning context. The user has to manually enter the values of the learning contexts as required by the application, for example, an interactive method of retrieving contexts. Please note that the proposed mechanisms in this generation are not context-aware. Thus, one realises that a context-based application needs only the addition of an extra property for it to be developed into a fully context-aware application. Application developers normally prefer to develop context-based applications rather than context-aware applications for various reasons, which are reviewed below. The following are three major applications and research works in this generation: TenseITS (Cui & Bull, 2005), CoMoLE (Martin & Carro, 2009) and didactic profiling (Becking *et al.*, 2004); these applications, together with other sundry proposed mechanism applications and frameworks, are discussed below.

The focus of this application was to provide English learning resource materials for Chinese students to learn during their free time. Four learning contexts were taken into

account – *location, available time, concentration level* (at the onset of the course) and *the frequency of interruption* (at that location). In choosing learning resources for students, the learner's user model was also taken into consideration. Some of the characteristics of the user model involved *knowledge level, misconceptions of the English language and difficulties in learning the language*. In the course of their interactions with the application, the users constantly developed the characteristics of the user model. Bomsdorf (2005) developed a system prototype that is almost the same as the above, as it also chooses suitable activities and learning resources using the four learning contexts; the only difference between them was that frequency of disruption was substituted for frequency of interruption.

According to Cui and Bull (2005), there are two reasons for using an interactive multiple-choice method, instead of a proactive approach (such as retrieving information from the electronic diary of the learner). First, the information obtained from the learner's electronic diary may be inaccurate if it is used in retrieving his or her available time and location information at a particular moment in time, as most learners do not regularly follow their schedule (as shown by their absence from lectures and incomplete assignments). Second, proactive approaches were constructed for use in a short period of time and basically in between other activities, which may not be reflected in their electronic diary entry, even if they had kept one. Hence, application developers realised that location may not be sensed correctly, as it has not been recorded. Moreover, the learner's available time cannot be detected. The application works by first requesting the user to enter the values of the four learning contexts, by choosing from multiple choice answers, prior to the beginning of each lesson. There are inbuilt instructions and rules that define the kind of learning resources that are suitable

to the learners, as dictated by the context values and their user model. Thus, learning resources are only recommended to the students when they want them.

In the future, these authors would like to extend their system ‘to other areas of English that Chinese students find difficult, for example: the use of articles’ (*Ibid.*). Moreover, speakers of Russian, Arabic, or other languages, may face problems with tenses and articles. Their system is especially useful for any language or aspect of language that can be tested with multiple-choice questions (because input on a handheld device is difficult) and ‘where students commonly have difficulties [and] could be potentially useful’ (*Ibid.*). The prototype of TenseITS has not yet been tested and the authors have realised that ‘the feasibility of extending the system in different areas and for different target groups, needs to [also] be tested’ (*Ibid.*).

- ***Martin and Carro’s (2009) CoMoLE Suggestion Mechanism***

The CoMoLE suggestion mechanism was created to recommend learning resources to learners where the recommendation procedure relies on both the learner’s internal and external learning contexts. The internal contexts of the user may involve learner preferences, emotions, and experience in using the application, motivation and their LS. The external contexts of the user may involve their location, available time, demographics and the kind of mobile devices they use, together with other devices they have at their disposal. Other factors, such as differences in the user’s physical devices (whether they be cell phones, laptops, PCs or PDAs), are all taken into consideration and, hence, learning materials are designed according to the various kinds of gadgets. It has an option that can interrupt and alert the user to new activities that have been developed, depending on their learning context. The system enables learners to engage

in both personal and collaborative activities. If a student is engaged in collaborative learning, the internal and external contexts of his or her partners are taken into account when choosing suitable learning materials. Various courses have been incorporated into the CoMoLE environment:

- A ‘Boolean algebra’ course was explained in Martin *et al.* (2007), and it illustrates how personal and group learning activities are adapted or recommended to users according to each student’s preferences and learning contexts. This kind of learning activity may involve theoretical examples, interactive examples (simulations), individual tests and collaborative activities.
- Martin and Carro (2009) described two learning environments that used ‘data structures’ and ‘operating systems’. In that situation, two case studies were conducted to evaluate the importance of recommending particular learning activities to students according to their context. A range of learning activities relating to these subjects was incorporated. In order to access and work on the activities, the learners could use various types of gadgets, such as PCs, laptops and PDAs.

- ***The Didactic Profiling Framework of Becking et al. (2004)***

Becking *et al.* (2004) developed a didactic profiling framework, which is a general standardised method that can be used by researchers and developers. It determines various contexts that have to be taken into account when designing different kinds of learning activities that are relevant to the students in different contexts. It focuses on an ascertainment engine and has a set of filtering rules that are formed using the

learner profiles and the LO descriptions. The learning contexts of this mechanism include four categories: *situation*, *learner*, *LOs* and *participation*. However, the precise descriptions of the filtering rules (for the ascertainment engine) are not stated.

- The situation category involves *frequency of interference* (in the course of a lesson), *available time* (approximated or scheduled), *equipment at disposal* (learning tools, aids, books, other learning resource materials that can be employed in this context) and *restriction of action and expression* (for instance, restriction to read, write, listen or speak in that context). Cui and Bull's (2005) application used the first two learning contexts.
- The learner category involves *level of concentration or distraction* (the ability to remain focused in spite of external interventions), *previous knowledge relating to topic* and *previous knowledge relating to technology*. Cui and Bull's (2005) application also used the first two learning contexts.
- The LO category involves *instructional goals* (standards suitable for the contexts of m-learning) and *learning content*.
- The participation (also called 'collaboration with partners') category involves an *individual learning session* (self-paced or supported by a tutor), a *partner session* (working in pairs) and a *group session* (working in groups – self organised or organised by a teacher, informally or formally).

2.11. The ‘Learning Contexts’-aware Adaptive M-learning Generation

Applications from this generation are almost the same as those from the previous generation (thus, the ‘learning contexts’-based adaptive generation). The only difference is that applications from this generation are *proactive* and are called ‘context-aware applications’. This means that there is an automatic retrieval of learning context, where users are not required to input information.

Context-aware m-learning and ubiquitous m-learning applications both focus on the concept of context-awareness and are subsets of computer-supported learning (Wang, 2004). One ubiquitous m-learning application was centred on ‘embedded and invisible computers in everyday life’ (Ogata & Yano, 2004a). Its main aim was to create a network of devices and situations always available in order to promote a ubiquitous learning environment (Nino *et al.*, 2007). Five main features together describe ubiquitous learning – *permanency*, *accessibility*, *immediacy*, *interactivity* and *situating instructional activities* (Ogata & Yano, 2004a). In addition, Hwang (2006) described four features for a ubiquitous learning environment, together with their advantages, as shown below.

- It is context-aware.
- Suitable learning resources are chosen for learners at an appropriate time and location using their internal and external learning contexts.

- Students can learn while they are on the move from one place to another without getting lost or without having problems in connectivity or with learning resources and/or partners at any time or location.
- Even though there are differences between the various portable devices, subject contents are developed to automatically suit the learner's context.

The following are examples of applications:

- ***Application of location independent:*** *JAMIOLAS* (Ogata *et al.*, 2006) is a Japanese language learning application that is designed for foreigners to understand the subtle differences in meaning between Japanese phrases. It is very hard to teach learners the differences in these phrases using traditional teaching methods, mainly because their meanings are based on 'senses such as hearing, vision, touch, taste, smell and spirit' (*Ibid.*). For instance, if one wishes to describe rain, one can use two different words to describe it, depending on whether the rain is heavy or light. It is difficult to know the differences between these phrases without hearing the two different situations. Hence, this application is intended to simulate these scenarios by offering learners extra senses that they can hear, see, touch, taste and smell. In reference to the example above, the learner is presented with a visualisation (with audio) of the two situations and the correct Japanese phrase is provided for learning. The simulated scenarios enable learners to acquire the correct words effectively without sounding strange or uttering them out of context, which can lead to misunderstanding. This is a context-aware application, as it does not need any input of the context information and the design of the situations is based on

specific impressions that relate to specific situations of how they are being used.

The application has to be aware of the various specific situations so that it can choose the correct word for students to learn.

- ***Application of location dependent: Learning Chinese at Taipei Underground*** (Chen & Chou, 2007) is a Chinese language learning application that was designed to facilitate conversation in Taipei's underground stations. Different spots in the underground stations were fixed with RFID writer tags, and the learners used a PDA fitted with an RFID reader to access Chinese language dialogues. The objective of the application was to help foreign students to practice Chinese language in real-life conversations. The application indicates that the dialogues enable the learners to converse with local staff or fellow travellers. The conversations the learners engaged in often involve asking for information about the underground system and for directions about facilities and places like cinemas, restaurants, hospitals and ticket office. A highly skilled language teacher created these materials and they were designed in Macromedia Flash.
- ***Application of situated learning: Butterfly watching*** (Chen *et al.*, 2004) was developed to allow students to watch real butterflies outdoors while receiving specific and detailed information about the butterflies on their mobile devices. The application was developed in a way that allows the learners to take a snapshot of a butterfly using their PDA camera; the photo is then sent to the local server through wireless means. A certain technique is then used to search for a butterfly that matches the one on the photo. The real-time information

received is then transmitted to the learner's device to offer that person detailed information about the butterfly.

Although this literature review has proposed the state of the art issues regarding m-learning, there is no unified theory to cover pedagogical aspects, technological aspects and the usability of m-learning.

The shortcomings of these disciplines are summarized as follows:

- 1- Learning requirements were partially met. For example, studies did not take into account conducting interviews with users, the knowledge level of users and the time availability of learners.
- 2- Technological limitations. For example, some of the resource materials did not fit into a mobile device, such as the size of the screen, which resulted in tedious scrolling. Another example is that the GPS system did not give accurate positions of devices.
- 3- Usability limitation was represented in the poor human-computer interaction. In this regard, no considered work was conducted.
- 4- There is no clear m-learning framework that explains how learning objects were integrated to the application.

Finally, the suggested model unified framework must consider the following:

- 1- A well-defined framework.
- 2- Learning requirements in an m-learning environment.
- 3- Learning contexts, including available time, learning style and knowledge level.
- 4- Refined user requirements.
- 5- Simple retrieval of information related to learners from a database, such as the location and starting time parameters. Learners may adjust these parameters.

- 6- Technological requirements, including reformatting the learning materials according to the device specification.
- 7- Easy adaptability, including the device, the learner and the content.
- 8- Importing off-the-shelf learning objects and incorporating them to different mobile devices.
- 9- Usability by introducing new technologies, such AR, or improving the human computer interaction.

Chapter 3

Methodology

3.1. Introduction

This research analyses a new system for increasing the usability of m-learning by suggesting a framework that utilises AR and CA. A technical questionnaire, observation and interview were carried out at the university using a random sampling method. Twenty-four computer science students were used as a sample. The m-learning prototype employed heuristic assessment as a method to measure the issues related to usability. Heuristic evaluation is a fast and inexpensive usability inspection method utilised in software engineering that assists in detecting usability problems in user interface (UI) design [15]. The main tool used for data collection was a questionnaire distributed to a sample frame of 24 learners at the University. The participants were provided with mobile devices, then they were told to exchange their personal ideas, experiences and impressions about the prototype system. The respondents were asked to rate a number of questions from 1 to 4 on a Likert scale (1 = mostly disagree, 4 = mostly agree). The collected data were then employed to analyse the usability level of the system. In this case, ‘usability’ refers to the ease of m-learning application usage, the ease with which application content is navigated, learnability, satisfaction of the user and the appealing nature of the system. This analysis was then used to find out the effect of AR on the application. Apart from the prototype that was designed, a system for increasing the usability of m-learning was also developed. The framework was employed as a guideline in the design and creation of the prototype application to be introduced and reviewed in Chapter 4. Diagram 2.1 illustrates the research format that

was employed in designing, implementing, testing and assessing the prototype application for smart phones.

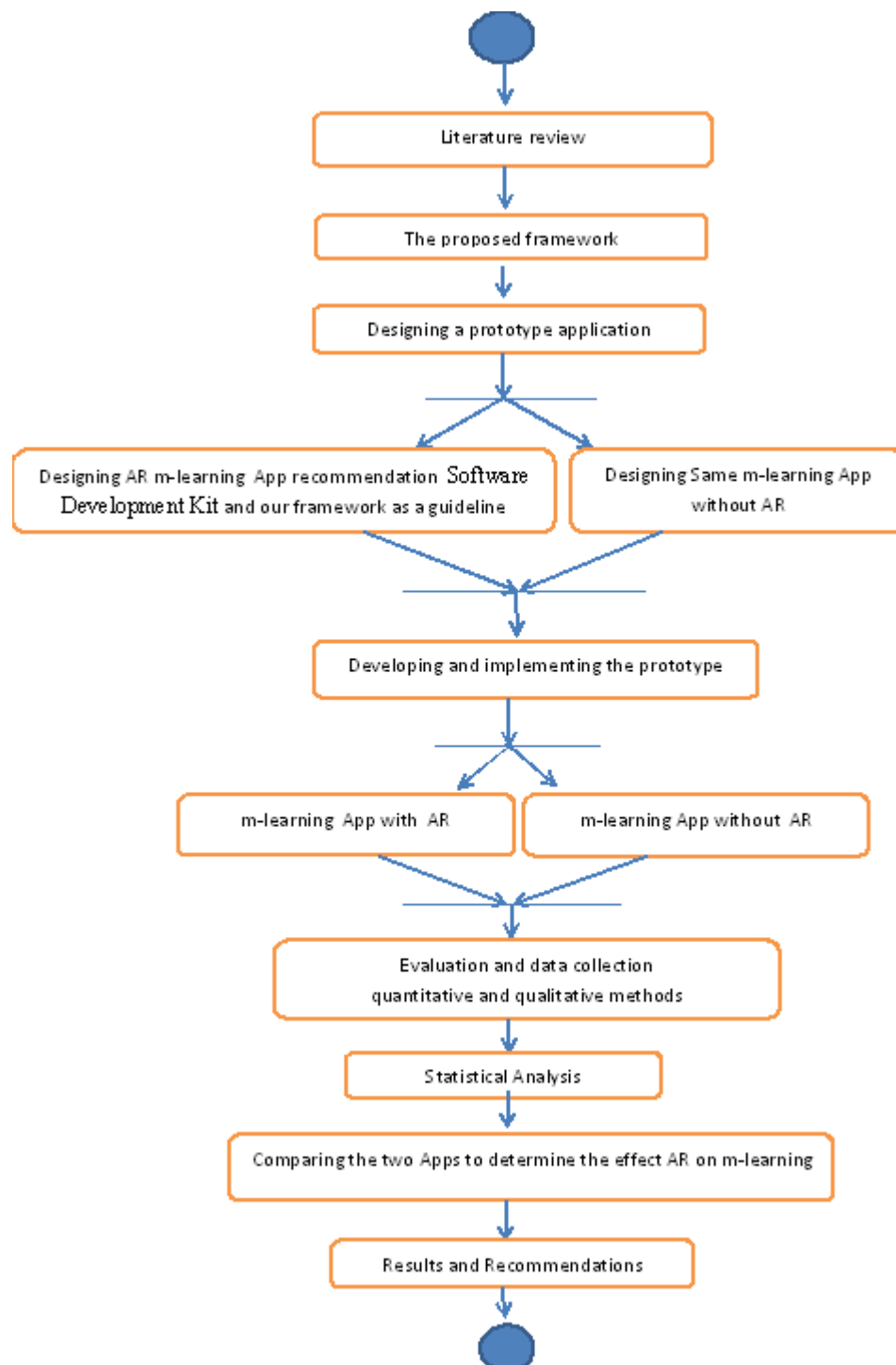


Figure 2.1 Research Methodologies (WATCH FONT SIZE CHANGE)

The standard proposed framework of AR applications integrates AR into m-learning. It focuses on usability and addresses the following problems in AR research fields as well:

1. Poor end-user evaluation in AR;
2. Insufficient education on the evaluation of AR experiences;
3. Difficulty for end-user to articulate his requirements in AR scenarios;
4. Little focus on AR usability compared to technological expertise.

The following sections (3.2- 3.4) show the work in AR applications that has been proposed by other researchers but, moreover, where there is an AR research gap. Section 3.5 shows the methods applied to address these problems in the AR research gap.

3.2. AR-Related Methodological Considerations

Although the subject of AR has been studied for over 40 years, recent research has begun to focus on the issues of HCI and evaluation (Dunser *et al.*, 2008; Swan & Gabbard, 2005; Dunser *et al.*, 2007; Grasset *et al.*, 2007b). (PLEASE BE CONSISTENT WHETHER YOU ARE GOING TO ITALICISE ET AL OR NOT) AR has been identified, most probably because of this, as ‘technology-driven’ (Anastassova *et al.*, 2007b; Dunser *et al.*, 2007), and AR systems as being ‘technology-centric’ (Swan & Gabbard, 2005). Of the many reasons for this, the principal one would be that AR is an emerging technology (Anastassova *et al.*, 2007a, 2007b; Gabbard & Swan, 2008; Haller *et al.*, 2007), which lays no claims to fixed or well-accepted metaphors, established application of design or heuristics. Up to now, AR has not established any set or standardised interfaces (Dunser *et al.*, 2007; Wagner, 2007). Owing to the proliferation of interfaces and devices used in AR applications, some researchers feel

that this is never likely to take place (Bowman *et al.*, 2005; Dunser *et al.*, 2007). To illustrate this point, as yet, no proposal for an AR system has resulted in market success (Wagner, 2007). In the field of AR technology, the absence of dedicated delivery platforms and standardised design application does not present the full range of problems.

There are also no advanced, dedicated, authoring tools for creating content, tracking and pose-estimation (Haller *et al.*, 2007). The difficulty is that, while engineers and developers apply themselves to the creation of a single platform that can be properly tested and assessed, until all the technology has been installed and a robust and relevant platform established on which content is authored, this cannot be evaluated (Dunser *et al.*, 2007). This leads to the prohibition of an iterative design and rapid prototyping, such as is employed by other disciplines of interaction design and software (Gandy *et al.*, 2007). However, end users risk underperformance, should low- or mid-fidelity AR prototypes be used for the purpose of evaluation (Anastassova *et al.*, 2007a). Such situations of impasse have caused AR and HCI communities to sit up and take notice.

Two published studies in the field of AR, i.e., human-centred design and evaluation, offer a summation of related practices, both present and past. In 2005, the first study was published by Swan and Gabbard (2005). A representative sample comprising 266 publications relating to AR published between 1998 and 2004 was examined by these two researchers. They discovered in their reviewing of these filtered articles that only 21 (~8%) described a formal user-based study, and 38 (~14%) tackled an issue relating to HCI. The second study was published in September 2008 by HITLab in New Zealand (Dunser *et al.*, 2008). Of 557 AR-related publications published between 1993

and 2007, only an estimated 10% were found to include some type of user evaluation. The state of the art is illustrated by these percentages, where applications and technologies are concerned; they also partly explain why in most cases end-user integration comes in the final stage of the project (Dunser *et al.*, 2007). There is also the factor of AR applications being proposed as a result of incorrect motivation (Dunser *et al.*, 2008), insufficient education on the evaluation of AR experiences and lack of comprehending the need for evaluation. Thus, it is unsurprising that actual, empirical results, even in the very popular AR-specific domains of, say, assemblage or industry, do not uniformly mention the benefits of AR vis-à-vis more conventional job aids (Anastassova *et al.*, 2007a).

However, other reasons exist. In the initial stages of AR design applications, although the end users had been involved early enough in the design process, the participants found it difficult to articulate their requirements à propos AR scenarios (Damala *et al.*, 2008), being insufficiently informed of the potential of the applications (Anastassova *et al.*, 2007b) because the phrase ‘augmented reality’ is little known. ‘Ill-defined’ is the term that best describes the user task-analysis process of AR applications (Anastassova *et al.*, 2007b; Haller *et al.*, 2007; Sandor & Klinker, 2007). A vicious circle has resulted from these issues. This does not bode well for the long-term adoption of AR applications viewing usability engineering in the light of AR. In an article in 2002, dealing with usability engineering as applied to AR, Gabbard and Swan (Gabbard *et al.*, 2002) emphasised that the usability of AR applications is as important as those of any other interactive system. For a system to achieve high usability, it has to be both usable and useful; however, limits have been experienced in certain experiments with AR systems, due to either one or another of these factors. Thus, the degree of usability,

rather than technological expertise, becomes of paramount importance.

3.3. Current Practices in AR Evaluation

The main reasons for AR applications being underutilised evaluation-wise have been revealed and are now understood. However, it would still be useful to review the evaluation trends of AR applications, which would allow one to pinpoint the direction of potential future research. An overview of the methods and evaluation techniques à propos AR is illustrated in three interesting articles. The first paper examined is that of Anastassova *et al.* (2007a). In their first paper, the authors reviewed 48 articles relating to user-focused evaluation and design in industrial applications of AR. They incorporated empirical results in dealing with any human-centred design aspect. Only a relatively small number of research studies focus on user-centred designs and the issues of evaluation, and this explains the examination and publication of the same study articles that engage task analysis and user needs together with an evaluation of usability. According to the account of Anastassova *et al.*, it seems that most articles, i.e., 83%, focus on issues of usability, as opposed to 17% focusing on the analysis of user needs. The researchers also discovered that, in the latter group, the focus was normally on the so-called ‘conscious’ needs of the user (~63%), as opposed to their ‘unconscious’ needs.

In the methodology of Anastassova *et al.*, it is evident that studies focusing on specific user needs offer a hasty field analysis of the activities of the users (interviews with task experts and questionnaires). In probing the more obscure requirements of users, evaluations of scenarios and prototypes are focused on. The 83% normally aim to

evaluate the ease of working with interfaces and assess their value in the training of students, although this latter aim seems to take precedence over the former. The average number of participants was 15, although the actual numbers ranged from 1 to 75. A pertinent remark made was that the experimental tasks were too short, too simple and too artificial. Only 18% of the studies made an effort to position the users in an experimental environment using real-time conditions. The researchers close by remarked that there has to be an evaluation of existing technological solutions and that user analysis needs, which is ‘a challenge for emerging technologies...because innovation is upcoming and in search of potential applications’, and lacks a structured methodology (Anastassova *et al.*, 2007).

Gabbard and Swan (2008) also highlighted the importance of creating interactive experiences and AR applications. Their article, published in May 2008, emphasised from the outset that much valuable insight may be acquired for emerging technologies from studies based on user needs. In this way, as in AR, humans may well alter their perception of the world as they now know it.

Gabbard and Swan maintained that integrating user-based studies with usability engineering in the AR research agenda will not only provide the opportunity for research, but offer a crucial challenge. These researchers suggested a system of classifying user-based experiments aligned with AR (Gabbard *et al.*, 2002). Three complementary axes were defined:

- User-based studies dealing with human perception issues of AR, such as speed of task performance, hand-eye coordination and depth of perception;
- User-based studies aligned with task performance with specific application

classifications of AR, such as number of task errors, target finding and completion time for the task;

- User-based studies aligned with computer-supportive cooperative work and collaborative AR environments.

Although the authors speak of these axes as complementary, for practical purposes, it is extremely difficult to place any of the AR experiments on AR applications in any given category. In an effort to remedy this failing, Dunser *et al.* (2008) suggested that a fourth category be added to the list, one titled ‘does not necessarily involve measurement of user task-performance, but other ways of identifying issues with system usability’ (Dunser *et al.*, 2008). The category proposed by these researchers offers a more relevant framework for the sort of experiments that would be conducted in order to align them with the application under discussion. Of paramount interest is that 25.4% of the 161 articles categorised by this study fell into the fourth group, whereas only 13 articles, or 8%, provided formal evaluations of users. Although the researchers achieved valuable insights into AR applications, generalising the data became extremely problematic because of the informal way in which the data were collated.

Dunser *et al.* (2008) also offered a taxonomy based on the employed evaluation methodology, thus providing a fourth research axis for user-based studies and AR evaluation. They defined the five categories thus:

1. Objective measurements, where measures should be interpreted in the strict sense of a term (e.g., accuracy, error rates and task completion time).
2. Subjective measurements, or perceived user ratings, usually gathered by means of questionnaires.

3. Qualitative analysis, which includes formal user observations, formal interviews or classification, or coding of user behaviour, such as gestures or speech.
4. Usability evaluation techniques employing expert-based evaluation, heuristics, task analysis or the ‘think aloud’ method.
5. Informal evaluations, including observations, or other types of feedback, or informal collection of data.

The authors admitted to a glaring difficulty of this taxonomy, namely, that a wide variety of methods were employed by researchers. It is not easy to draw lines under each category. For instance, an informal evaluation, which was video-recorded and based on observations analysed *a posteriori*, in which the ‘think-aloud’ method was encouraged, would be difficult to place in a tailor-made category. For the purpose of this study, it suffices to concentrate on the traditional distinctions between quantitative and qualitative methods.

Finally, despite the fact that the literature on the experiences and applications related to AR is not plentiful or rich, the need for the evaluation of user-based studies has increasingly become of interest to researchers. Formative evaluation, or that of an advanced level, is more frequently conducted in a laboratory than in a real-life context, as is the application of tasks, which tend to be simple and of short duration. User-needs analysis, as well as evaluation in the real application context are uncommon, and are most frequently conducted by experts in the domain. A paradox may be seen in that more evaluation studies centre on ‘objective measures’, which are not easy to apply in our application context, such as applications for edutainment, which are difficult, if not impossible, to apply in formal evaluations or experimentations. The resulting troubled and blurred scenery relating to design application, especially regarding culture and AR

edutainment, becomes progressively more unpredictable.

3.4. *Emerging AR-Specific Applications*

Although suggestions may at this stage be somewhat attenuated, they could, in the light of the present state-of-the-art evaluation in the field of AR, offer a good opportunity for conversion to AR-specific applications. Current gaps in (and limitations of) HCI in AR applications, only tenuously previously examined in the context of AR, will now be presented, as in the previous section (Dunser *et al.*, 2007). When applications for AR systems are under discussion, the initial question that must be posed is: can general GUI applications be applied to AR systems? Dunser *et al.* (2007) maintained that this approach presents the difficulty that GUI evaluation applications usually require a screen, keyboard and mouse to allow for user interaction. AR suggests many other and varied means of interacting, input and output with an application (Dunser & Hornecker, 2007). These aforementioned researchers proposed, as a direction, virtual reality-derived knowledge. This, compared with AR, has up to the present focused more on evaluation (Roussou, 2004, 2008).

Conversely, it is believed that virtual reality (VR), as with GUI, is strikingly different in nature from AR. VR is totally absorbed in an artificial, 3D setting. In order to affirm this, an initial definition applying to VR must be relied upon. Supposing that the definition is sufficiently elastic to incorporate such contexts as Second Life, it would be possible to apply certain existing applications to the applications of AR.

Gabbard *et al.* (2002) examined the issues of usability and usability engineering for AR systems. They insisted that a product with high usability must be both usable and

useful. Furthermore, they defined ‘usability’ in terms of user-oriented traits, as found in other interactive applications. They suggested that the following characteristics are the most imperative:

- Ease of learning
- Speed of user task performance
- User error rate
- Subjective user satisfaction
- User retention over time

The researchers demanded, in the initial stages of the project, an analysis of the domain for AR applications. In other words, they attempted to distinguish the users from the tasks with which they will engage. This contrasts markedly with the promotion of engineers in developing AR prototypes and new technologies, seeking only *a posteriori* to find showcases of interest to a specific ‘invention’, not taking into account the solution to a specific problem (Dunser *et al.*, 2007). As far as the application of overall HCI application is concerned, little has been contributed that would close the large gaps in the domain. Dunser *et al.* (2007) proffered, as applicable to AR, these general applications:

- **Affordance:** this term, coined by Donald Norman in his book *The Design of Everyday Things*, has since become very widely used (Norman, 1990). It refers to the connection between an interface and its physical and functional traits.
- **Reducing Cognitive Overhead:** this characteristic is closely linked with affordance. If this trait is provided by a system, a low cognitive overhead will be needed in order to interact with the application.

- **Low Physical Effort:** a minimum number of steps is needed to accomplish a task.
- **Learnability:** the system must be easy to learn and, therefore, consistency is a high priority.
- **User Satisfaction:** in using a system, one monitors the satisfaction of the user, with the usability not only relying on objective measurements.
- **Flexibility of Use:** the differing preferences and abilities of users should be noted and catered to. One could personalise a name or customise, for instance, a mobile museum guide.

Estimation and tracking is one of the foremost difficulties faced by AR. Poor tracking performance should be avoided and the design should provide for the elimination of this feature. Dunser *et al.* (2008) acknowledged in closing that there is too little knowledge of AR systems' design to generate generic rules. They maintained that their efforts were an initial effort to close the existing gap in this domain. They demanded that there should be a multi-disciplinary approach to research in this field, enabling not only the engineering or 'hard sciences', but also differing areas of expertise (Dunser *et al.*, 2008). It may be seen from this overview that AR evaluation is a new field of research. The affective (EFFECTIVE?) experience factor in the use of an AR system is of great significance and has (as yet) to be thoroughly investigated (Bickmore & Picard, 2000; Dierking, 2005; Zhang & Li, 2005). Despite the limits to the scale of evaluation sessions, many issues that arise as the result of experimentation will be scrutinised. Contributions will begin to shape the informal design application to be more widely adopted by the scientific community; nevertheless, at present, AR researchers are still forced to follow an explorative approach, which is 'error-fix' in nature (Gabbard &

Swan, 2008).

Interest in the outcome will be inherent in applying suitability to the methodology, the overall planning of the evaluation session in a real-world context and retaining the protocol, the permission to experiment, in the context of real objects and in applying AR in experimenting with real students.

3.5. Task and Experimental Setup

In this section, the process of experimentation, the environment and the experiment variables (as concepts) are introduced. The evaluation protocol, in terms of the setup, and the experimental conditions are described in chronological order. We conducted two experiments; the first one aimed to investigate the overall ease of the m-learning application usage, the ease of navigation vis-à-vis application content and the ease of learning. The second one dealt with AR applications. Both experiments were conducted on the same conditions and settings.

3.5.1. Recruiting the Candidates

Twenty-four participants were recruited for the experiments. Their common feature was that they were all enrolled at university. A detailed, written presentation of the study, together with experimentation protocols, was emailed to them, while a brief outline of the goals and the scope of the study were presented verbally to them. The consent forms were available in printed form on-site at the end of the briefing session; however, these were also mailed to the potential participants (See Appendix VIc).

3.5.2. Semi-Structured Interviews

Live interviews were held in order to gain first impressions of the applications. This proved helpful in establishing the main issues aligned with user experience. Participants were first asked ‘warm-up’ questions focusing on their personal details, moving on to their impressions of the application’s usage. As it turned out, little reference was made to AR and AV; more attention was paid to the general look and feel of the application. It emerged fairly quickly from the interviews that the initial hypothesis, notwithstanding the limited size of the sample, was confirmed in that a survey would be of great assistance in formalising the results while preparing for the following evaluation sessions.

3.5.3. The Survey

During the interviews it was interesting that input was received on the topics to be included in the survey, together with the level of detail for each evaluation key point investigated. This meant that the survey, being exploratory in nature, would complement the interviews and the observations. Although the interviews were flexible, the questionnaire set questions in an orderly framework, to be answered in the same order as given. The significance of the survey, however, was that it emphasised the user experience of AR as it applied to education by means of a mobile device. This was the first time that light had been shed on this important aspect. Special attention had to be paid to the formulation of statements regarding the AR aspect of the mobile application, considering the sample had no experience either with mobiles or the concept of AR. Because of the highly contextual nature of the experimental intervention, the survey

also comprised questions applicable to the overall user experience and the satisfaction with using a mobile application in the area of education. The collaboration involved in the project added value to the creation of the survey materials; input and feedback on the questionnaire was supplied by all stakeholders concerned.

3.5.3.1 Content and structure of the survey

The first section of the five-part survey included a welcome note and a total of forty-six questions (see Appendix VI), which took between 7 and 10 minutes to complete. General questions were set to assist in shaping and formalising the profiles of the participants, especially with reference to the use of IT and the learning habits of the students. The second section was titled, ‘Questions regarding the use of the application’. This comprised questions aligned with application usability, with particular reference to the AR learning context. The questions were posed in such a way that they did not necessitate prior knowledge of the terminology used. The third section comprised questions probing the effectiveness of the content. This related to the interpretive material, including traits pertinent to the effectiveness of the presentation of the content. The questions avoided the term ‘interface’, which may have puzzled the students. The fourth section set the objective of exploring a sensitive topic. This topic would be common to the AR-based conception of the application; it would also apply to the principle of a learning concept being assisted by a mobile device, together with the interaction of the student with the AR application. The fifth and final section comprised questions relating to post-effect use. Although it was not intended to formalise the evaluation as impacting on cognitive aspects, it was deemed imperative to set a few questions on this issue. The survey had to be as comprehensive as possible.

With this in mind, ‘tricky’ questions were sometimes formulated in various ways, later placing these either under one section or another. The completed survey may be found in Appendix VI; the results appear in the following chapter.

3.5.3.2 Measuring the effectiveness of the AR application

Although open-ended questions were presented in order for the participants to articulate their views freely on some occasions, the majority of the survey questions were of the ‘closed’ type. At times, it seemed more appropriate to make statements with which the students could agree or disagree, giving the scale of their agreement or disagreement. A four-point scale along the lines of a Likert scale was preferred to a five-point scale. This was because the latter scale includes a statement of neutrality. Students could misunderstand the word ‘neutral’, mistaking this for having no opinion (Albaum, 1997). In terms of the analysis, for this reason the presented scale comprised ‘Mostly Agree’, followed by ‘Somewhat Agree’, ‘Somewhat Disagree’ and ‘Mostly Disagree’ statements, on a scale of 1 – 4. The ‘acquiescence effect’ was allowed for in alternating statements, which were worded either positively or negatively. This prevented participants from repeating the same answer too many times (Kuniavsky, 2003; Love, 2005). If the preceding statement was negative, the 1 – 4 score was reversed. An extra benefit of using a Likert-like scale is that the calculation of usability scores may be combined with percentages, not only for the research questions, but also for each individual participant.

The standard proposed framework of AR applications integrates AR into m-learning. It focused on usability and addressed the following problems in AR research fields as

well:

1. Poor end-user evaluation in AR.
2. Insufficient education on the evaluation of AR experiences.
3. Difficulty for the end-user to articulate his requirements in AR scenarios.
4. Little focus on AR usability compared to technological expertise.

Chapter 4

The Proposed

Framework

4.1. Introduction

Integrating AR technologies into m-learning is a complex and complicated affair. Identifying needs and establishing requirements must be undertaken before designing any new interactive application or product (Cheng & Atlee, 2007). As far as the research hypothesis is concerned when dealing with the integration of mobile AR within the m-learning framework, it is of paramount importance in providing a successful product, to approach and comprehend the nature of the ‘problem space’ (or ‘action space’). This is also defined as ‘understanding and conceptualising what is currently the user-experience product and how this is going to be improved or changed’ (Preece *et al.*, 2007).

Three kinds of feasibility studies were deployed in determining the potential of the framework for intended users as an m-learning application. Firstly, a pedagogical study was conducted. Using interviews of learners, it explored: (a) their learning requirements when studying in an m-learning environment; (b) the potential of the framework to support their studies; (c) the refined user requirements of the system by means of user-centred understanding. Secondly, a technological study involved how the learning materials could be displayed so that the content would easily fit into the dimensions of the various mobile screen sizes. Thirdly, usability involved the user interface design of the software application of mobile devices, as well as physically interacting with those gadgets, in other words, human-computer interaction (HCI).

4.2. Recommendations of Appropriate Learning Materials

In selecting the most applicable learning contexts appropriate to the learning materials, these researchers perused studies conducted by Cui and Bull (2005) and Martin *et al.* (2006b). From these most significant works regarding the framework, we chose three learning contexts to be integrated into it, which were: available time, LS and knowledge level.

Martin *et al.* (2006b) spoke of the available time, knowledge level and LS, while Cui and Bull (2005) provided research on both knowledge level and concentration level, as well as on LS and frequency of interruption. The three learning contexts mentioned were integrated into the framework for the following reasons:

LS: authors such as Prekop and Burnett (2003) and Beale and Lonsdale (2004), along with many others, have stressed the necessity for the incorporation of cognitive learning contexts into the design and development of context-aware m-learning applications. The cognitive learning context includes personality, traits, LS strategies and preferences, user goals and knowledge level, which has all too frequently been overlooked by those designing and developing learning applications. Parsons *et al.* (2006) emphasised that, during m-learning, one must consider the various learning styles of the learners, as well as their psychological traits and their preferred learning styles. Beale and Lonsdale (2004) maintained that correctly adjusting the level of information to the preferred style of the learner would provide him or her with the most effective and enjoyable learning experience. In contrast, Coffield *et al.* (2004) stated

that those critical of this suggestion feel that, whether or not the best-suited material was offered to the student, this had no effect on his or her level of ability to learn or to study.

It is the view of the author, however, that the majority of learners can, in fact, greatly benefit from well-chosen learning materials, as indicated by their LS; therefore, the incorporation of this learning context should indeed take place. The extensive research of Graf (2007), which involved two evaluative studies, promoted the existence of a relationship between the working memory capacity of the student and his or her LS, as defined by the dimensions of the Felder and Silverman LS model (1988). Learners all have different goals as well as learning styles; these must be specifically catered to in any m-learning application.

Knowledge level: researchers have emphasised the importance of correctly chosen materials, i.e., those that suit the knowledge level of the student, in increasing the efficacy of the learning/studying materials (Cui & Bull, 2005; Martin *et al.*, 2006c; Becking *et al.*, 2004; Bouzeghoub *et al.*, 2007); this is because the students:

- Are inclined to become demotivated and bored if the material provided is work already known to them or is repetitive;
- Cannot make progress if the material is too advanced for them. This will simply add to the stress felt by the students, therefore, rendering their studies ineffectual.

Using the student's knowledge level as a yardstick makes sense in that students then progress from their personal level, not having to cope with problems that are too

advanced. Moreover, they will not have to re-learn work that they have already absorbed.

Available time: one of the bases for recommending the choice of appropriate m-learning materials for the student is his or her available time. Once this factor has been established, the amount of material may be tailored to each student (Cui & Bull, 2005; Becking *et al.*, 2004; Martin *et al.*, 2006c). In adaptive e- and m-learning situations, the knowledge level and the LS have often been used (Grigoriadou *et al.*, 2006). It is important to user learning that these learning contexts be applied. These contexts may also be replaced by learning strategies or by a model of another style. This would not affect the validity of the framework.

4.3. Design Modules of the Framework

The technical details and design of the framework components are illustrated in the architecture of the system. There are ten components, each of which is described below, the framework having been logically divided thus:

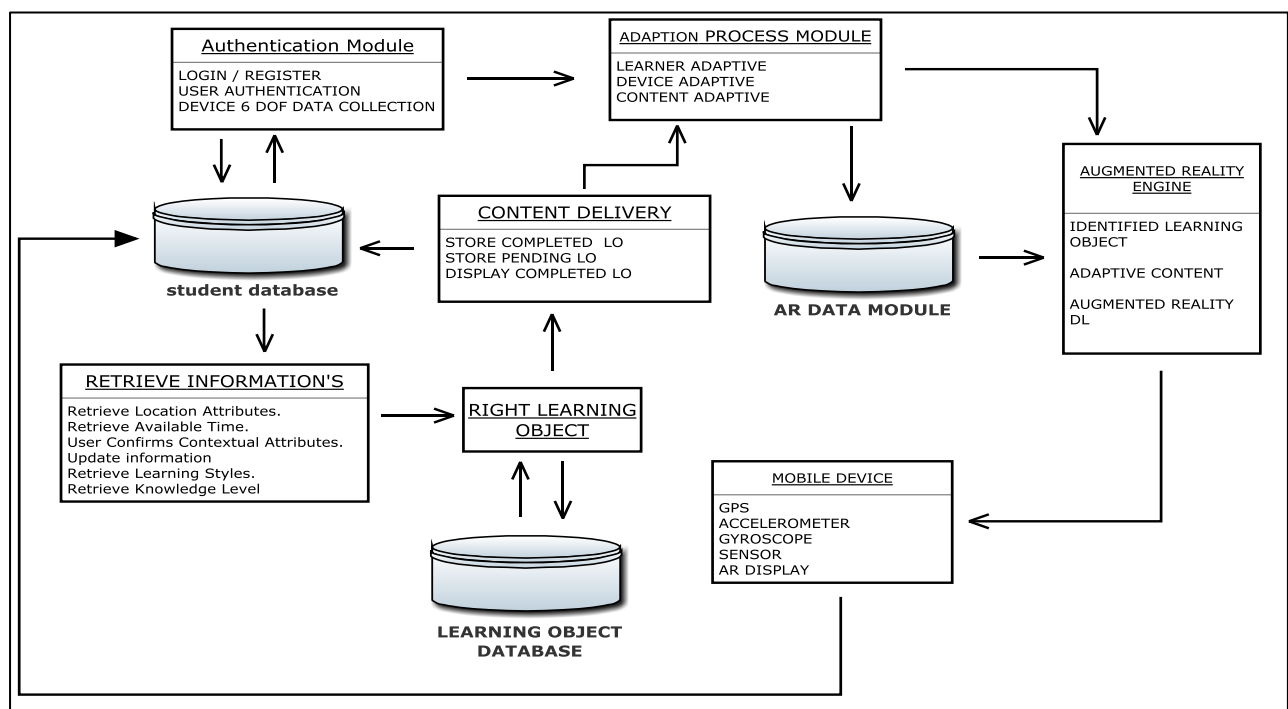


Figure 4.1: The Proposed Framework

UNABLE TO EDIT – PLEASE CHANGE INFORMATION'S TO INFORMATION

Student database: the learner's personal information includes the unique identifier that will record his or her first name and surname, birthdate and the modules or degrees that he or she is studying. It will also comprise the location and the student's preferred

learning style. A simple test establishes the level of knowledge each student has on the learning object. The student database records and stores all this information. Parsons *et al.* (2006) stressed the importance of this learner profile, in that various user types in their learning may require m-learning devices.

Learning object database: all the learning objects are stored in this database. These may be of various types, comprising revision activities, for instance, reviews, compulsory activities (such as assessments) and non-compulsory activities (such as exercises). The attributes of each learning object include: the unique identifier, subject, title, description, objective of the activity, duration for the completion of the activity, priority of the activity to be undertaken (i.e., low, medium or high) and the status of the activity (i.e., finished or unfinished). Should the activity be unfinished, the activity that remains is recorded. Learning objects comprise information, examples, tests and exercises based on multiple-choice questions. In facilitating the various learning styles related to the learning objects, these might be integrated into the framework and offered for potential selection by the student.

Retrieval of information: this facility retrieves information relating to the available time and location of the student from the student database, translating these elements into approximate values, which may be drawn on by the suggestion mechanism in recommending learning objects to the student (based on individual contexts and learner profiles). The student database yields such attributes as location, starting time and time of completion. By means of a predetermined method, the student is able to view and confirm, or even to change, the attribute values, should this be desired. By means of this method, contextual information may also be updated as and when necessary. Available time, learning style and knowledge level comprise the parameters entered

into the suggestion mechanism, which then indicates apposite learning objects to the students.

Right learning objects: recommended learning objects for the students are stored together with information regarding the task's completion – whether or not this has been attained. When dealing with an exercise or a test, one may ascertain whether this has been correctly completed. All such information is relayed to the student database. As the accuracy of the student increases, the knowledge level is concomitantly raised. In supporting the updating of the knowledge level of the learner, three steps are taken: Pending learning objects are stored, completed learning objects are stored, and completed learning objects are displayed.

Augmented reality engine: this feature augments the reality flow of the m-learning system. The server using the engine's definition language, which displays the objects, provides the objects. The engine also notes any markers in case the installed AR is based on markers. The engine detects, by means of available sensors, the present device orientation, the direction and the location.

Augmented reality DL: Definition Language (or DL) is the language used in defining those virtual objects that will afford the experience of AR. This language is XML-based, meaning that it will comprise the method of hosting and managing the display of LOs on the mobile device.

Content delivery: the database of the device has information available to this module, which can reformat content in accordance with the device specifications. This implies that the dimension or size of a video file could be altered to fit the requesting device's

screen size. Equally, the module could, depending on the channel connection used in sending the request, change the quality of the video.

The AR interactive learning module: here, the AR technique is used in order to show the various learning contents to the users on their devices, as given in the 6DoF information. The adaptive module results and the personalised LO list are also displayed. One of the several ways in which the interactive learning process may be achieved is by means of the above-mentioned knowledge-level assessment. Moreover, once the student launches the application, the module will identify each LO, marking it with an identification tag.

The adaptive module: this module comprises three objectives, namely, providing the right content on the right device to the right person. Once the module has accessed the personal information and 6DoF of the learner from the learner-data model, the LOs will be recognised by the system as seen from the information.

Device adaptive: all mobile devices operate on different systems, varying in software, screen size and capabilities, for instance, media players or web browsers. These features make a huge difference to the learning experience of the student. For this reason, it is imperative in ensuring effective learning, to make devices compatible with the learning content.

Learner adaptive: the learner adaptive represents the adaptation for the various levels of learner knowledge. In this system, the learner's knowledge level is assessed in two ways. Several questions were put to the learner when he or she first participated in the learning scenario of each learning object. Three knowledge levels comprised each learning object. The learners must answer questions in the form of challenges. The

second way in which the knowledge level of the learner was assessed was on the completion of a topic or a unit. The learner was required by the system to take several tests covering a comprehensive unit or topic to evaluate that person's knowledge level of that specific unit or topic.

Content adaptive: this is the last of the adaptive mechanism models. The content-adaptive model queries and filters the adaptive model, thereby retrieving all content in accordance with the adaptive results obtained in the previous three models. The content-adaptive model then offers this content to the student.

4.4. Strengthening the Context-retrieval Aspect of the Framework

❖ Overview of technologies used for location retrieval

GPS technologies: these are used for establishing the whereabouts of students by means of a GPS receiver, as in Fithian *et al.* (2003), Ogata and Yano (2004a, 2004b) and Ryu and Parsons (2008). The recording of travelling GPS data, for instance, when the device moves from location A to B, has proven GPS technology to be inaccurate and unreliable (Kochan *et al.*, 2006). The transition period of any change in location, however, is not deemed in this research to be of great importance; what is important is the location of the student and the time available at the start of the learning session. A separate Bluetooth GPS device, for instance, GlobalSat BT-338, may be attached to the device if it does not have a built-in GPS receiver. The mobile device may then be

connected by Bluetooth to a Bluetooth GPS receiver, as set out in the research of Ryu and Parsons (2008). When signals from the WLAN are being retrieved, location retrieval in both indoor and outdoor settings may be achieved by means of the WLAN positioning technique. Once a student is connected to a station or access point, his or her location may readily be implied. Because WLAN is commonly available within educational institutions, this may be effortlessly implemented; there is built-in wireless access capability in most modern mobile devices.

WLAN: this offers the most accurate signal strength in positioning technologies (Li *et al.*, 2006). Chen *et al.* (2007b) used this technique in their language learning application in order to pinpoint the situation of a student in a school playground; this enabled the suggestion of an English vocabulary lesson. Chen *et al.* (2002, 2004) used WLAN in their butterfly- and bird-watching applications, respectively. Rather than being used as a positioning tool, WLAN enabled learners and instructors to transmit messages to and from (TO AND FRO? OR TO AND FROM EACH OTHER?). The local server was a WLAN card, either built in or inserted into a laptop, which then allowed students to use a device equipped with WLAN. The students acted as clients, transmitting wirelessly between their devices and the local server.

4.5. Methods Used for Strengthening the Framework

The following measures have been enacted to ensure that accuracy of location and available time are both achieved and to counter the possibility of students not maintaining their stated schedules:

- Location-retrieval methods, making use of GPS and WLAN;
- A direct request method, which has been incorporated into the framework.

Location retrieval: it is proposed that WLAN be used for retrieving the indoor location of a student, whereas GPS technology should be applied for the retrieval of a student's outdoor location. The information retrieved regarding the location alerts the system, should the retrieved locations not match. It also identifies the correct location of the student, enabling confirmation that he or she is adhering to the stated schedule.

The WLAN positioning technique and the use of GPS technology are easily implemented and are reliable for indoor and outdoor methods, respectively (Wang *et al.*, 2003). It is for this reason that these two technology types have been adopted by this research. If the mobile device does not have a built-in GPS receiver, a Bluetooth GPS may readily be affixed, thereby achieving the same capability. If a WLAN is available, therefore, the location of the student may be retrieved. It is suggested that GPS technology be deployed when WiFi signals cannot be achieved. Given the robust and wide availability of WLAN, the WLAN positioning technique should successfully retrieve the location of a student within any university campus building.

Direct request method: in this method, students are requested to confirm the accurate retrieval of their available time. This reminds the student, before he or she begins the learning session, to check and then indicate the accuracy of his or her available time status; this information will be used when an update of the schedule is deemed necessary. Students are all requested to supply their available time, inputting it into the system, where necessary.

4.6. Incorporation of Learning Objects into the Framework

4.6.1. Mobile Learning Metadata (MLM)

Chan *et al.* (2004) proposed an extension to the LOM and IMS Learner Information Profile, or LIP standards, which would apply to all informal and m-learning scenarios. This would be known as Mobile Learning Metadata (MLM). This proposal was required to include in the present usage of LOM, and other such standards, and the forms of learning that had previously focused on web-based learning using laptop and/or desktop computers. The three top-level categories of MLM are: learner, learning object and settings (which describes the context in which the learning is taking place, such as the location of the student or of the learning object). Two sub-categories comprise the student classification: the learner model, which comprises dynamic information on the student's learning and knowledge history and the learner profile, which includes static information concerning the student and his or her preferences.

The apposite LO is located by the context engine of the m-learning system by means of information given by the settings and learner categories, accessing the metadata of the

LO. The present values of the context information are dynamically generated by means of information within the settings category.

4.6.2. Incorporation of LOs

Learning style and knowledge level may be integrated by means of the LOM. However, because the MLM comprises extra metadata tags used when describing information about m-learning aspects of LOs, MLM has been deployed.

There are two ways to assess students' knowledge level so that the most appropriate LOs may be selected. Students are obliged to have knowledge on the LO topic before continuing with the next topic; these prerequisites have been defined by Lee *et al.* (2005). Various paths and/or learning strategies were allowed by the ontology to be used in facilitating the adaptive learning. Yau (2004) expressed the levels of difficulty found in the introductory LO topics. Learners' perceived difficulty levels of basic LOs, ranging from the very easy to the very difficult, were established. Once the student's introductory LO knowledge level has been obtained, this may be used to decide on the LOs appropriate for him or her.

4.6.3. Methods for Converting LOs into MLOs

The research methodology incorporates the scrutiny of current LOs designed for use on specific mobile devices and generic mobile phones. Criteria and guidelines needed to make mobile devices reusable in m-learning settings, where devices have differing specifications, were scrutinised and presented. Learning objects have been used more

frequently in web-based learning environments, owing to the reusable nature of these LO learning materials. LOs have, for instance, been used to teach science (Dumbraveanu & Balmus, 2006) and programming (Brennan, 2005; Adamchik & Gunawardena, 2003). In addition, learning objects that may be used on mobile phones have been designed, developed and evaluated by Bradley *et al.*, (2009). The metadata of these LOs are LOM (IEEE LTSC, 2005), or a subset thereof.

Chan *et al.* proposed an MLM that is an extension of IEEE (?) LOM. This comprised three top-level groups, as follows:

- Learner: this includes metadata describing the learner;
- Settings: this metadata indicates the context state of the learning setting – resources relevant to the learner or LO, location of learner or LO and any information regarding time available;
- Learning Object: this group comprises the learning resources described by the metadata. M-learning metadata have not been further researched or described by any author.

The integration of LOs for use on mobile devices has been researched and published. By extending SCORM for m-learning environments by Nakabayashi and Hoshide (2007) and in using Can Core to implement LOM for mobile devices (McGreal, 2006), such metadata have been personalised. In the research of Nakabayashi and Hoshide (2007), the authors extended the SCORM 2004 specification. This enables students to view offline learning materials on their mobile phones.

Students may also share learner tracking details, as well as the structure of the course for their learning activities, using both mobile phones and PCs. A common content

format was proposed for the learning content, which could then be uniformly distributed to the various browsers. This was to counter the differing application programming settings of mobile phones, which differed in make and model. Further aspects had to be satisfactorily worked through before the mobile phones were able to implement SCORM 2004. A recognised limitation was the ‘inability to run JavaScript (ECMAScript), which the SCORM runtime environment (RTE) specification relies on for communication between LMS and the sharable content object (SCO)’ (*Ibid.*). A further limitation took the form of the problem of delivering to the mobile phone browsers any rich media content, owing to the absence of plug-in software and the small size of the screen. Therefore, three design principles were applied:

- The ‘Manifest File’, which describes content course structure and sequencing rules for learner adaptation, is shared for learning from both mobile phones and personal computers.
- The ‘RTE Specification’ for LMS-SCO communication will be extended to mobile phones.
- ‘Two types of SCOS and assets, one for mobile phones and one for personal computers, are prepared. During learning, a suitable type of content is selected by checking the type of terminal device’ (*Ibid.*).

One way of retrieving content for use on mobile phones is to employ a built-in browser. One may also consider ‘implement[ing] learning content using an application program downloaded and run on the mobile phone’ (*Ibid.*). Installing a browser that displays general purpose content on a mobile phone provides a third possibility. ‘This browser will download and display learning content compliant to a specified format. Although it

is necessary to implement multiple content browsers, each of which runs in the different carriers' programming environments, a standardised content format that is independent of the carriers' formats can be introduced' (*Ibid.*). Alkouz (2006) suggested using a generator that allows web-based learning objects on different devices to be displayed for the use of m-learning applications.

In the work of McGreal (2006), CanCore, an application profile for LOM that used a subset of the IEEE LOM elements, provided simplified guidelines for describing pedagogical metadata. The IEEE LOM is considered 'complicated for effective implementation'. CanCore has been:

‘...specifically developed and adapted to facilitate the description of rich, bandwidth-intensive multimedia resources, and is particularly appropriate for supporting implementations that are to be accessed using a wide variety of technological and pedagogical environments, including mobile devices. CanCore specifications allow for greater reuse and portability of resources, systems and content of many kinds across applications and operating systems. Educators implementing m-learning environments can take advantage of a wide variety of international standards-based resources already available online in learning object repositories.’ (*Ibid.*)

In much the same way, Moulin and Piras (2006) suggested the use of additional geo-referenced metadata for LOs that would enhance m-learning.

Chapter 5

System Implementation

5.1. System Development Environment

❖ Hardware Environment

This system, an offshoot from Apple Macbook 2013 with Intel dual core 5i CPU 2.4 GHz and 128 GB of RAM, offers the client a learning application mode that incorporates a client server designed and developed from Apple iPhone 4GS or from its more recent models. Because built-in hardware is necessary for launching the application, one must supply a minimum of one iPhone 4GS, which offers a camera for AR viewing. This would include a GPS chip for sensing location, an accelerometer by means of which to adopt guidance ability, an electronic compass and a 3R adaptive mechanism. Also included would be a complete WiFi network connection ability, together with a cellular network.

❖ Software Environment

Apple Macintosh OSX 10.6 Snow Leopard is the source of both client- and server-side software applications. Apple's official Integrated Development Environment (IDE) Xcode 6.0, combined with the official iOS Software Development Kit (SDK) 7.0, provides the environment for the programming. Objective C 2.0 is the chief object-oriented programming language, while the SQLite framework has supplied the data development applicable to the developing of embedded mobile device applications. iOS 7.0, or more recent versions, are necessary for the client application.

5.2. System Development Methodology

This system's m-learning application is based on the iPhone making use of Apple Xcode IDE 5.0, with Objective-C programming language,. The Model, View and Controller (MVC) design architecture has been embraced, so that the Apple iOS application development should be met by its object-oriented principles.

1. The Data Model

The model layer of the MVC design architecture comprises objects such as learning contents, learning progress, learner profile, 6DOF information etc., which represents the data managed by the application. The six-data model provides an example of the way in which objects in this layer should be arranged, so that the most sense is made of the data. A well-defined set of interfaces facilitates data-model objects with external interaction. Such interfaces guarantee the ongoing integrity of the underlying data.

2. The Interface View

The appearance and presentation format of the client application are defined by the View layer, which comprises controls, window and views in the client application. The AR View, the Login View, the Personal Main Page View and the Register Table View are all examples of this layer. The Functions View (comprising such features as custom views, for example, or Launch the System, Get Contents and Back to Personal Main Page) could severally be accepted as standard system views, as could the Navigation

AR and Learning Contents AR. Both types of view are configured to display the data from the system's data model objects in such a way as to be both adaptive and appropriate to the client. The viewed objects also need to generate notifications in response to learner interactions and events relating to that data.

3. The Controller

The Controller Layer provides the bridge between the Interface View layer and the Data Model. It receives the notifications generated by the View Layer, forwarding them to the Controller Layer, which uses them to perform complementary changes to the Data Model. For instance, if for any reason, the data in the data layer changes (perhaps because of some internal computation loop), it would alert the appropriate controller object, which would immediately update the views. A notification would be forwarded to the Controller by the data model, requesting the new AR contents to be displayed by the Interface Views.

5.3. System Framework

❖ The Authentication Module

Once the client's application has been installed on their iPhone devices and the learners have launched it, they will be required to use a specific ID number (e.g., a Student ID number) and password to log in to the system. The Learner Data Model will be accessed by the server for the retrieval of personal information, such as the learner's name, ID, programme, course ID and grade, together with any previous knowledge level, so that the learner authentication process may be achieved. On successful

completion of this step, a personal main page will be displayed to the learner containing all the above-mentioned information. This page would be divided into three sections: Profile, Progress and Last Evaluation Result. The system will guide the learner through the registration process, requesting the provision of his or her personal information should the learner not already be registered in the system. Once login has been achieved, the learner will press the AR button at the bottom of the personal main page and launch the system, which will then proceed to access the learner's location information. This will achieve the 6 DOF progress for the Adaptive Modules.

❖ *The Adaptive Modules*

Three objectives are included in the system's adaptive modules. These function to furnish the 'right contents to the right device for the right people'. Once the learner data model has been accessed for personal information, the system will begin, according to the information, to recognise the learning scenario so that the device may receive the learner's 6DOF information.

❖ *Device Adaptive*

The various mobile devices each have different capabilities, operating systems, software and screen sizes. Media players and web browsers both create differences to the experience of the students' learning. Therefore, it is imperative that the presentation of the learning contents be adapted to the individual devices so that effective learning can be guaranteed. By mapping the combinations of the mobile device features to a few stereotypes and by displaying information according to the appropriate stereotype, a

common solution can be provided. Content adaptation within the system is broken down into three fundamental stereotypes: web page, text and multimedia. Based on the available functionality to display certain types of contents, such contents are furnished to the device.

❖ *Learner Adaptive*

The Learner Adaptive Model represents the adaptation for the various levels of learner knowledge. In this system, the learner's knowledge level is assessed in two ways. Several questions are put to the learner when he or she first participates in the learning scenario of each learning object. Three knowledge levels comprise each learning object. The learners must answer questions in the form of challenges. The system moves on to the next knowledge level challenge once the learner has met the first challenge. The system provides contents apposite to each particular knowledge level, should the learner fail the challenge. Once the learner has passed a challenge, a grade from 'A plus' to 'D minus' is supplied by the system, according to the difficulty of the question and depending on the correctness of the answer and the length of time taken to answer the question. The second way the knowledge level of the learner is assessed is by the completion of a topic or a unit. The learner will be required by the system to take several tests covering a comprehensive unit or topic to evaluate his or her knowledge level of that specific unit or topic.

❖ *Content Adaptive*

The last model of the adaptive mechanism is the Content Adaptive Model, which uses the system to query and filter the data model so that contents may be retrieved according to all the adaptive results gained in the previous models. These contents are passed on to the learner.

❖ *The AR Interactive Learning Module*

In this module, the AR technique is used by the server to present various learning contents on the learner's iPhone device, in compliance with the 6DOF information, the Adaptive result and the personalised learning object list from the Adaptive modules. There are several ways in which the interactive learning process may be achieved; one such way is the above-mentioned knowledge level. Moreover, the application will begin to display objects once the learner has launched it. The learner may click on a tag for which he or she wishes to receive more contents. The tag, displaying detailed contents about that object, will then advance a full-screen semi-transparent view. Use is made of a semi-transparent display with which the learner can view both object scene and contents simultaneously.

5.4. System Development Process

Eleven principal processes make up the entire process of architecture and system development, each divided into three modules, as described in the design of the system framework.

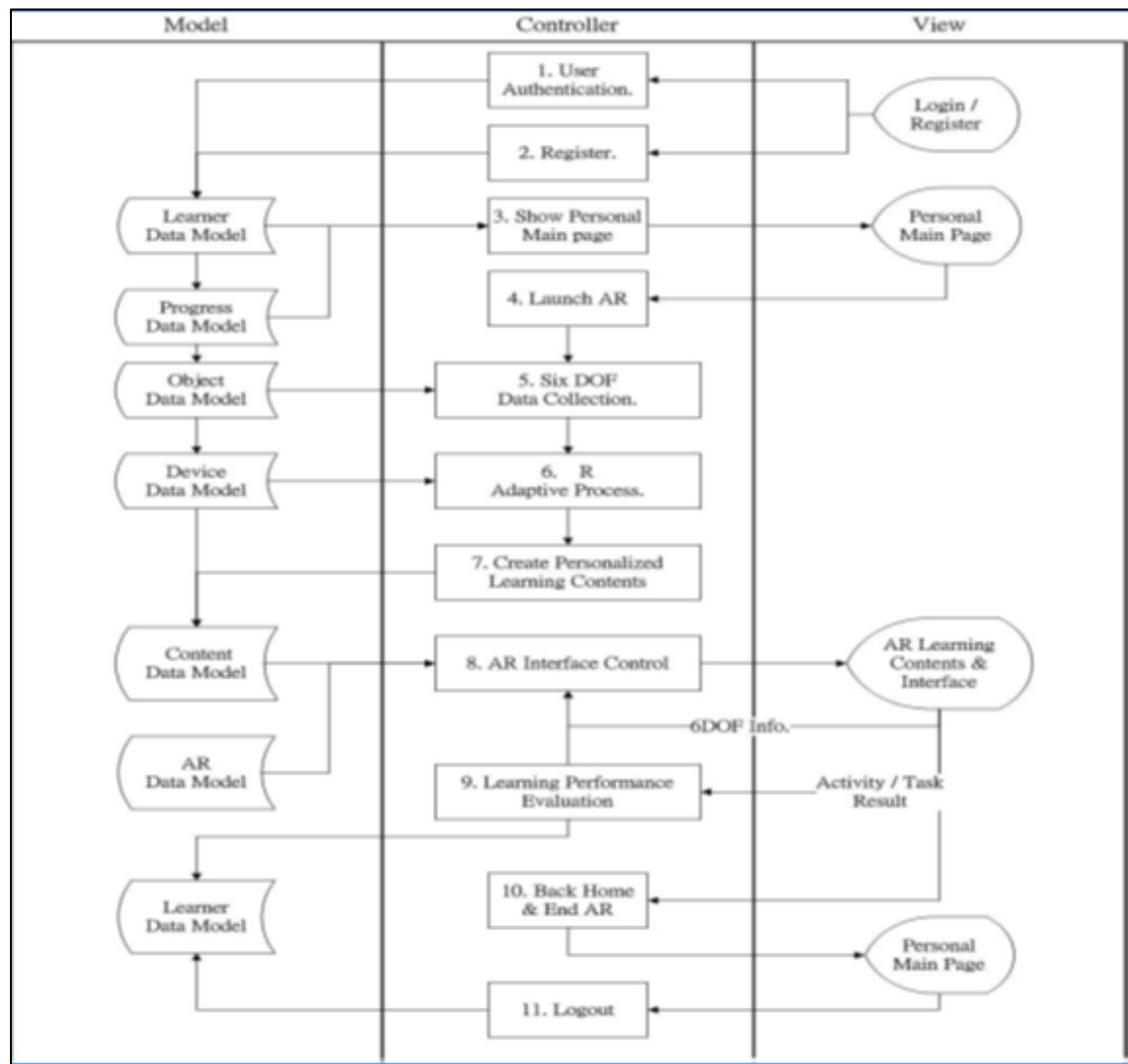


Figure 5.1 System Development Process

VERY POOR IMAGE QUALITY

❖ *The Authentication Process*

The objective of the adaptation mechanism is ‘the right contents for the right device to the right person’, requires that the learners first log in to register with the system, thus providing personal profile details through the client application on their iPhone device. This would include items such as student ID, learning interests, enrolled courses, programmes, etc. To this end, once the first View layer displays the main interface containing options for Login and Register, the launching of the client application takes place. Learners who have already registered can log in directly by typing in their learner ID and password. Three processes follow:

Process 1: in this process, the Learner Authentication will notify the Learner Data Model of the login information, which must match the learner ID to retrieve a specific learner profile as a key in the data model. Conversely, there is ***Process 2*** for the new learner: the Register, as mentioned above, to supply a registration interface will require the Interface View. The new learner profile will thereafter be saved. The Controller will send a notification to the Model Layer so that the Learner Data Model can be updated.

Process 3: is the result of both the Register and the Learner Authentication: Show Personal Main Page on the View layer. Personal information, current location, learning progress, together with two buttons – Launch AR and Logout – will be shown on the iPhone devices.

❖ *The Adaption Process Adaptive Process?*

The Adaptive Process, which aims to achieve the m-learning goals, comprises three critical processes. The Launch AR button, once clicked on, initiates **Process 4: Launch the Application**. This is the start of the first adaptive process.

Process 5: The 6DOF Data Collection, as the first step towards retrieving the current location of the learner, acquires GPS information. Learning contents may be furnished according to the 6DOF process. The 6DOF information, furthermore, is used by the system to achieve and support **Process 6**.

In Process 6: Learner Data Model, the model is asked by the Controller to forward the learner profile. Personal information is then matched with suitable contents and learning objects are taken from the Content Data Model and the Object Data Model. Thereafter, the server creates a personalised learning object list comprising learning contents and objects relating to the individual learner.

Process 7: Create Personalised Learning Contents completes the adaptive process by utilising the Adaptive Data Model.

❖ *The AR Interactive Learning Process*

Once all adaptive processes have been conducted, the system begins providing interactive, personalised AR learning contents via **Process 8: AR Interface Control**. Here, two possible ways exist for students to learn using the system. Firstly, two AR tag boxes showing the learning object's name will be shown to the learners, together with the learning object's tag box as an interactive button. The learner may simply click on any tag box to discover the details of the learning contents provided on the learning

object in question. On receipt of the touch event, thereafter notifying the Interface View layer, the Controller will flip up the detailed contents view to offer more adaptive learning contents suited to the learner's progress.

Whilst undergoing the learning process, the student must interact with each learning object by successfully completing the challenge through a series of quizzes. Designed for assessing the learners' knowledge levels, this challenge mechanism assists the learner in performing the aforementioned Adaptation. Once the student has conducted the tasks and activities set for each learning object, the results are forwarded to the Controller of **Process 9: Learning Performance Evaluation**. Should the results meet the goals as elucidated by the course instructor, the system will revert to the AR Interface Control process, shepherding the student to the next learning object. If the goals were not met, the AR Interface Control process will continue to provide the same learning contents to the learner for remedial study until these goals are achieved. Once the AR interactive learning progress has been accomplished, all of the learning information and the results of the evaluation are stored in the Learner Data Model. The Adaptive Progress will thereby be enhanced. By clicking on the Back Home button, students can discontinue their AR interactive learning, returning to the personal main page. In such a case, the View Layer will notify the Controller, requesting Process 3. To complete the full interactive learning process, users can then click on Logout.

5.5. System Implementation

The implementation of the system, together with the algorithm and core elements, is tackled in this section, which consists of three modules: Learner Authorisation, Adaptive and AR Interactive Learning. An overview of system operations is provided in the initial section of this chapter, focusing particularly on the way the three modules interact. Data model details follow in the next section – the adaptive mechanism, as well as the query. The third and final section considers the algorithm of the learning object identification.

❖ System Process Overview

AR provides an intuitive learner interface, designed for visualisation in a mobile computing application. In this way, such information is provided intuitively (Reitmayr & Schmalstieg, 2004). The system is an m-learning application that provides learning objects. Learning contents adapted to various personal learning statuses are afforded by the system through an AR display technique.

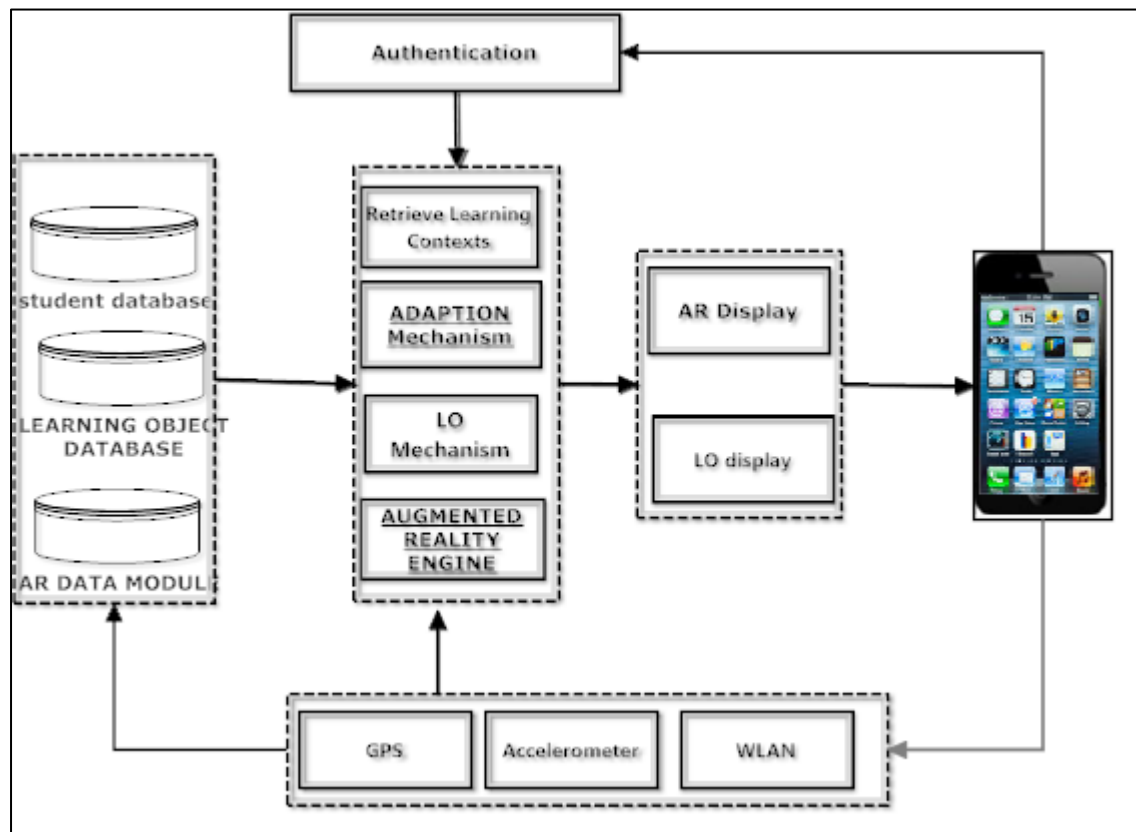


Figure 5.2: System Architecture Diagram

The Data Synchronisation Process, as depicted in the system architecture diagram, will be included in future research; however, it has not yet been implemented. This implies that the system functions by utilising the database of an off-line local SQLite type because the current research intends to focus on content adaptation concomitantly with the AR technique. The system is designed on client mobile software design principles, as mentioned in Tan and Kinshuk (2009). This would translate to the built-in local database requiring significantly less resource usage. It would also require only a small data communication bandwidth, needing no redundant human/device interaction.

Learning contents are afforded for three programmes, as developed in the research scenario that demonstrates the application. Learning contents would also be provided for LO. Profiles of students would be stored in the local database. The following

section elaborates on other details of the data model. Once login to the application has taken place, the system will authenticate the learner profile according to the database record. This will display the personal learning status of the student, such as the course and unit that they are currently enrolled in, together with any known knowledge level. Pertinent to the personal learning status, an AR data model will be generated by the system. This model will comprise all objects and related contents to be displayed on the screen. The adaptive mechanism process has then been completed.

Once a learner has clicked on an object identification tag, detailed contents on a particular object are displayed in the view. Contents of Interest is important in that not only is the displayed content related to the learning object, but it is also related to an individual student's learning status. When clicking on a specific learning object, students enrolled in different programmes, at different knowledge levels and in different units will receive learning contents that are different because they are learner-specific. The following section reviews details of the Contents of Interest concept.

❖ *Adaptive Mechanism*

Contents of Interest, the rationale behind implementing the Adaptive mechanism, are discussed in this section; this is followed by a review of the Personal Learning Status, the Adaptive Data Model and the Query Mechanism.

❖ *Personal Learning Status*

This aspect, the personal learning status, is a most significant element of the Adaptive mechanism. Programmes, units, courses and knowledge level, as applied individually to

each learner's status, are identified by the Adaptive mechanism. This includes the related contents the learner will be interested in and will be happy to study, not just the learning objects. Students with different personal learning statuses can, for the same learning object, receive contents that are totally different. Learners will receive different contents should they be at different levels of knowledge, even when working on the same unit and when enrolled on the same course.

❖ *3R Data Model and the Query Mechanism*

Six critical data models make up the system, for example, the learner's personal profile, (name and student ID) is stored by the Learner Data Model. Information concerning the courses the learner is registered for under a specific learner ID is stored by the Personal Learning Status Data Model. Similarly, progress details, such as related knowledge level and unit ID for each registered course, are also stored in the PLS Data Model. Details of each unit and knowledge level provided by the course are stored in the Progress Data Model. The Introduction to Maths course, for instance, has six units, each comprising three levels. The names of the learning objects are stored within the RLO Data Model. Content appropriate to all learning objects is stored in the Content Data Model, which includes various learning profiles. The AR Data Model, the output of the Adaptive Mechanism, is the final data model. Figure 5.3 shows the Entity–Relationship (ER) Diagram of the system.

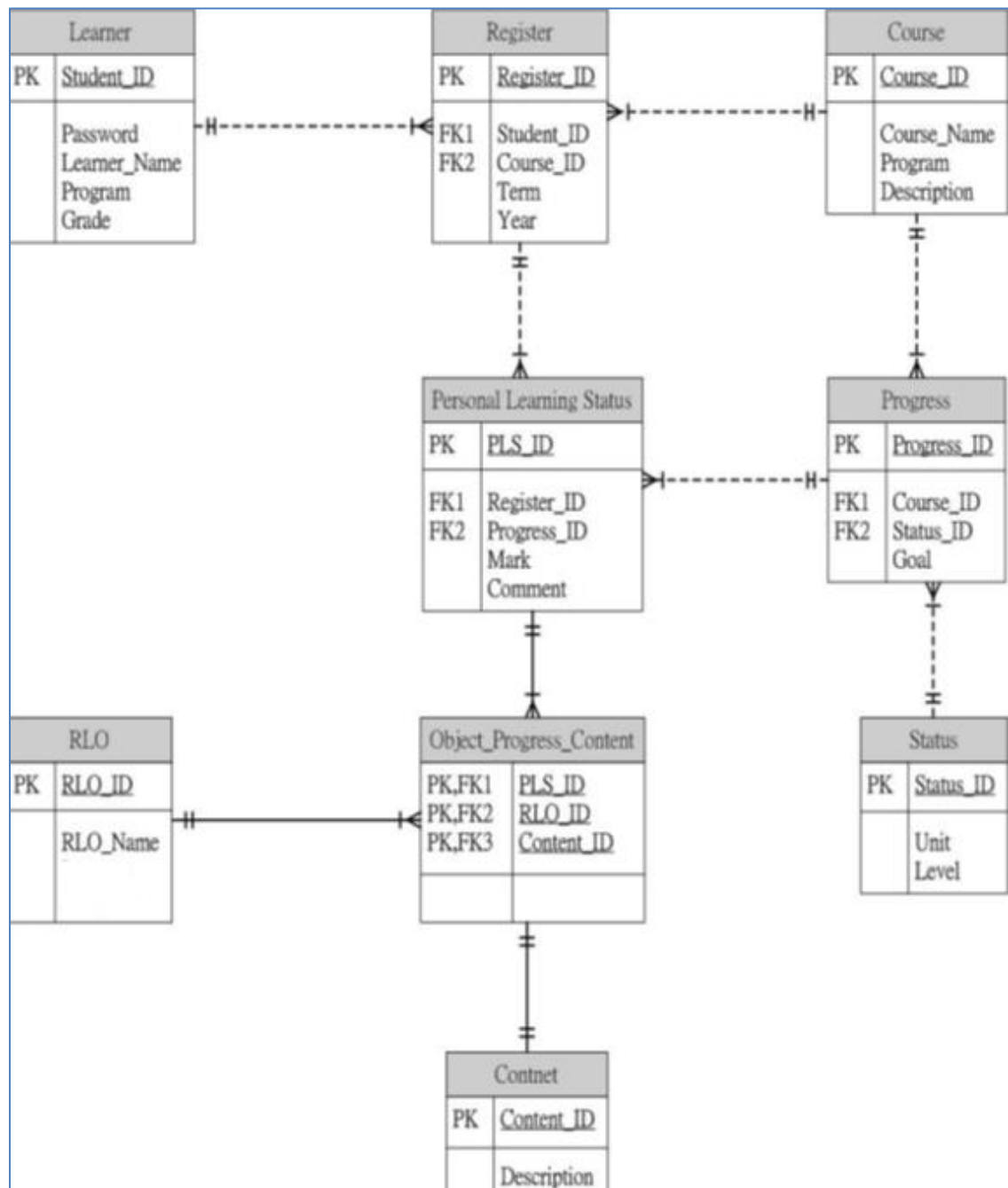


Figure 5.3: ER Diagram of System Content POOR QUALITY

Once a learner has logged in to the system, the Adaptive Mechanism query selects the learner's profile table first and the course register table second. This enables the system to ascertain which course/s the learner is currently taking. It then decides on the personal learning status, as indicated by the course register ID. This will reveal the

learner's progress in each course, which he or she is currently registered in. According to the Personal Learning Status (PLS) ID, the mechanism then matches and chooses objects suited to the learning contents and the progress ID, as also the object ID. The key table in the Adaptive Data Model, the 'Object_Progress_Content' table, is of key importance, because it holds together the other three tables.

Chapter 6

Data Analysis and Results

6.1 Introduction

Chapter 3 specified the groups of data to be collected and the type of questions to be addressed in the research, recruitment of the candidates, research methods, whether the majority of the survey questions were of a closed type or an open-ended type, and the five-part survey was included. In the data collection, quantitative and qualitative methods were applied.

This chapter considers the data analysis. Moreover, it pursues the research methodology illustrated in Figure 3.1 in Chapter 3. Section 6.2 focuses on direct and indirect observation approaches. Section 6.3 considers the experiment of m-learning applications without AR. In contrast, section 6.4 considers the experiment of m-learning applications with AR. As shown in Diagram 3.1, for both experiments it was noticed that:

- 1- Interviews and questionnaires were applied in evaluation and data collection.

Therefore, quantitative and qualitative methods were followed.

- 2- Statistical analysis of usability was applied and summarised in Tables 6.7 and 6.16.

- 3- A comparison of usability of m-learning and AR m-learning is shown in Table 6.17.

In section 6.4, an empirical comparison of application, m-learning and m-learning and AR was carried out. This comparison includes: ease of use, user satisfaction, attractiveness and learnability. Generally, respondents preferred m-learning with AR to m-learning.

Finally, the research methodology applied in this work helps to develop a unified approach that covers pedagogical aspects, technological aspects and usability of m-learning, as follows:

1- The pedagogical aspect was improved by:

- Conducting interviews with learners for the sake of exploring:
 - i. Their learning requirements;
 - ii. The potential of the framework to support their studies;
 - iii. The refined user requirements of the system by means of user-centered understanding.
- Selecting the most important learning contexts regarding the framework:
 - i. Available Time;
 - ii. Learning style;
 - iii. Knowledge level. A simple test establishes the level of knowledge each student has regarding the learning object.
- The adaptive module: this module comprises three objectives, namely, providing the right content on the right device to the right person.

2- Technological aspects:

- Methods used for strengthening the framework:
 - i. Location-retrieval methods, making use of GPS and WLAN;
 - ii. Direct request method.
- Device adaptive. All mobile devices operate on different systems, varying in:
 - i. Software;
 - ii. Screen size and capabilities.

3- The introduced framework was employed as a guideline in the design and creation of the prototype application. This prototype used a heuristic assessment as a method to measure the issues related to usability. Usability issues include:

- Making it easy to end-users to articulate their requirements;
- End-user evaluation. A questionnaire was distributed to analyse the usability level of the system and to find out the effect of AR on the application;

- Integrating AR to the proposed framework increased the usability of m-learning dramatically.

6.2. Direct and Indirect Observation

The participants' observation was not just a choice; it was a necessity. The device used was a generic UMPC. The battery of the UMPC had to be replaced after about 60 minutes of use. For these reasons, 'participatory' direct observation was considered necessary in addition to the indirect observation that would occur later by watching the video recordings. Another advantage of the direct observation approach was that it encouraged communication and discussion with the participants. In addition to this 'real-time' observation, the interaction of the participants with the application and the environment – including the observer – was recorded by a digital video camera set on a tripod and manipulated by another member of the research team. Finally, as the use of logs was not retained for technical reasons, all details of the interactions of the students with the application were captured and recorded using an ARCHOS multimedia player, equipped with a head camera worn by the students.

The observation started directly after a participant had been told to use and navigate the application content. Despite our fears that shadowing might perturb or intimidate participants, no particular problems were observed, and students seemed to feel at ease with the researcher's presence. The double recordings of the interaction of the participant with the device itself, as well as with the surrounding environment, were daily archived for further analysis.

6.2.1. Synchronous and Asynchronous Observation

Twenty-four students were observed during the time span of approximately one week. Despite the fact that all sessions were recorded both by the video camera and the ARCHOS recorder, extensive notes were taken. After the experiments ended, the records from the digital camcorder and the ARCHOS multimedia player were viewed, analysed and coded. No particular software was used for this video analysis; instead, all incidents that occurred were noted, tagged and categorised. Two main categories of findings resulted from this analysis: observations on participants' interaction with the mobile AR application and the environment, as well as incidents with a potential influence on the overall user experience.

6.2.2. Observations on Participants' Interaction with the AR Application

The issue of interaction with the mobile AR application is far more complex than the issue of interaction with fixed or mobile interactive multimedia applications. This section aims to shed some light on the observed interactions of the learners with the mobile AR application and the content of the application. After adjusting all the material needed for the experimentations, participants were asked to follow a short tutorial regarding the manipulation of the application and the function of the application controls. The users were asked to freely navigate the content according to their preferences. Despite how well the tutorial prepared each participant, the best introduction turned out to be using the application. All participants demonstrated a much better understanding of the application. A common incident was that some users needed time to understand the entire content. Most of the participants showed the ability to identify the application in a time span of 1 to 7 seconds. Only two participants

met some difficulties in using the application. The overall duration of the use ranged between 25 and 60 minutes. Despite the fact that participants were advised to investigate only the themes in which they were interested, the majority chose to watch most or all of the available multimedia sequences. A pleasant surprise was that participants were very careful in what they looked at and heard. Therefore, synchronous and asynchronous observation gave interesting feedback. A major usability issue was related to the users' satisfaction. Students were observed to be comfortable when they used the application and showed a clear interest and passion for discovery with the application.

6.3. The First Experiment: Mobile Learning Application

6.3.1 The Survey

6.3.1.1 Participants' profiles

The average age of the University students was 20.75 years, although ages ranged from 18 to 23. All participants had owned a mobile phone from the age of 13 or 14, with some having had one from the age of 11 or 12. Sixteen students, or 66.67% (?), used their computers frequently, usually every day; six students, or 25%, said that they used theirs at least several times per week. Two students said that they seldom used their computers, perhaps a few times per month.

6.3.1.2. Usability of the m-learning application

This most crucial section, comprising two open-ended and five closed-ended questions,

focused on the principal of m-learning. Statements found in this section were phrased to study the overall ease of m-learning application usage, the ease of navigating application content and the ease of learning the objects. Lastly, it was stated that the help was provided by the attenuated tutorial provided prior to the experimentations. This statement was designed to affect the evaluation answers and was included to complement the previous two statements, focusing on ease of orientation and navigation regarding the use of the application. This section, in addition to the preceding questions, included two open-ended, complementary questions. These were: *'Is there anything you wish the application didn't do?'* And: *'Is there anything that you need the application to do?'* Ten of the twenty-four students replied to these questions (41.7%).

6.3.1.3. Measuring the content effectiveness of the application

Part three of the survey comprised questions à propos the effectiveness of the content. The first statement addressed the intuitive comprehension of the available themes, namely, the themes of *'Context'*, *'Description'*, *'Analysis'* and *'Technique'*.

<i>The Statement: the intuitive comprehension of the available themes, namely, the themes of 'Context', 'Description', 'Analysis' and 'Technique'.</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
58.33%	33.33%	8.33%	0	3.4

Table 6.1 Comprehension of Available Themes

A particularly interesting question included in this section referred to the way in which participants used the application 'components' of the multimedia.

<i>Audio</i>	<i>Text</i>	<i>Multimedia</i>	<i>Video</i>
66.7%	41.33%	33.3%	25%

Table 6.2: Components of multimedia

The length of the multimedia presentations		
<i>Not Long Enough</i>	<i>Satisfactory</i>	<i>Much Too Long</i>
8.33%	91.67%	0%

Table 6.3: Length of multimedia presentations

Two other sets of questions related to the quality and the length of the text, as well as the audio, were provided in the application.

The Statement: <i>'The quality of the provided text was what I would expect'.</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
25%	12.5%	0%	20.83%	2.29

Table 6.4: The quality of the text

The Statement: <i>'The quality of the audio comments corresponded to what I would expect from a multimedia presentation'.</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
12.5%	45.83%	33.33%	8.34%	2.63

Table 6.5: The quality of the audio

The Statement: <i>'The duration of the audio comments was neither too short</i>	The Likert
---------------------------------------------------------------------------------	------------

<i>nor too long</i> ’.				Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
37.5%	37.5%	8.33%	16.67%	2.92

Table 6.6: Duration of audio comments

The Statements	Likert Scale								The Score
	Number of Participants								
	Mostly Agree		Somewhat Agree		Somewhat Disagree		Mostly Disagree		
Learning was easy.	4	16.67%	6	25%	8	33.33%	6	25%	2.35
Navigating the content of the application was easy.	1	4.16%	8	33.33%	14	58.33%	1	4.16%	2.33
Using the application was easy.	6	25%	4	16.66%	12	50%	2	8.33%	2.58
The tutorial at the beginning helped me to understand how to use the application.	10	41.66%	14	58.33%	0	0%	0	0%	3.42
The quality of the multimedia presentations was what I would expect.	6	25%	13	54.16%	0	0%	5	20.83%	2.83
The quality of the provided text was what I would expect.	6	25%	3	12.5%	7	29.16%	8	33.33%	2.29
The quality of the audio comments corresponded to what I would expect.	3	12.5%	11	45.83%	8	33.33%	2	8.33%	2.63
The duration of the audio comments was neither too short nor too long.	9	37.5%	9	37.5%	2	8.33%	3	12.5%	2.92
I find that using the application helped me to better comprehend and appreciate the objects.	3	12.5%	6	25%	9	37.5%	6	25%	2.25
I learned more than I would have learned had I not used the application.	0	0%	11	45.83%	13	54.16%	0	0%	2.46
Using the application was playful.	4	16.66%	6	25%	12	50%	2	8.33%	2.75
Would you use such an application, were it available at university?	2	8.33%	6	25%	12	50%	4	16.66%	2.50
Need training to use mobile learning?	12	50%	8	33.33%	3	12.5%	1	4.16%	3.29
Need more time to find information?	10	41.66%	9	37.5%	3	12.5%	2	8.33%	3.13

Table 6.7: Usability of the Mobile Learning Application

Statements found in this section analysed the overall ease of the m-learning application usage, the ease of navigating the application content and the ease of learning.

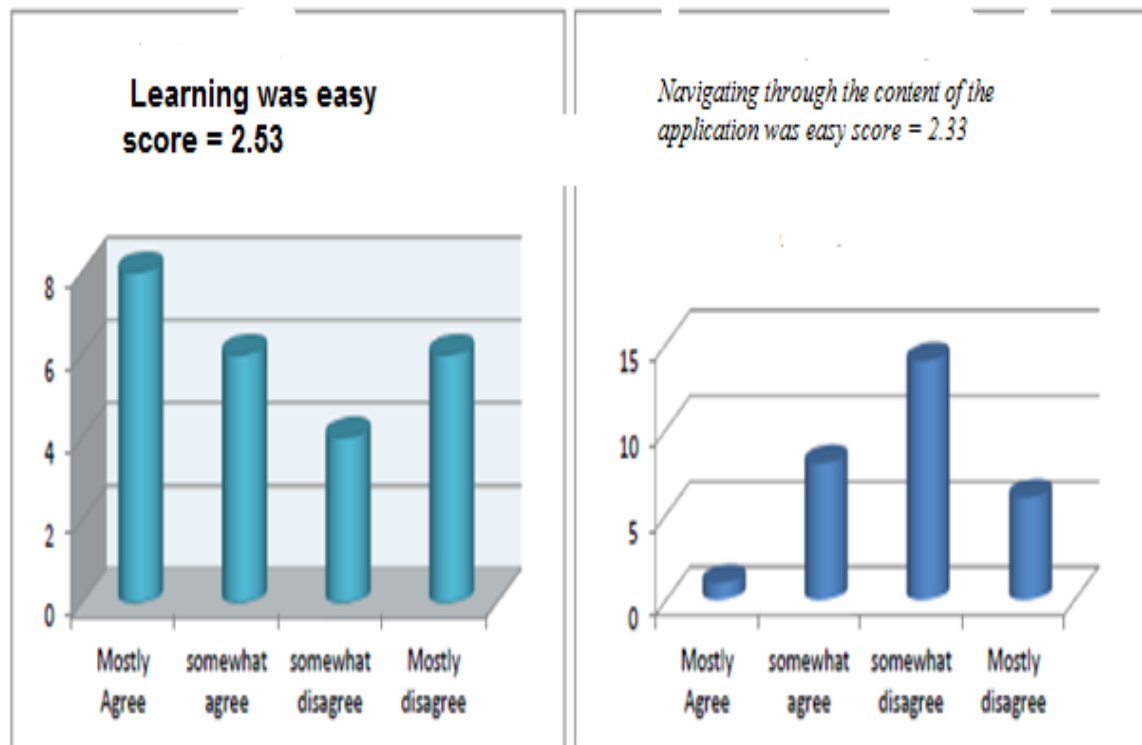


Figure 6.1: Content Effectiveness

6.4. The Second Experiment: Mobile Learning AR Application

6.5.1. The Survey

6.4.1.1. Usability of the AR application

This most crucial section, comprising two open-ended and five closed-ended questions, focused on the principal AR aspects of the prototype being tested. Statements found in this section gauged the overall ease of AR application usage, the ease of navigating application content and the ease of identifying the objects. Last, help was provided by the attenuated tutorial before the experimentations.

The Statement: <i>‘The tutorial at the beginning helped me to understand how to use the application.’</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
0%	58.83%	33.33%	8.33%	3.2

Table 6.8: Tutorial help

6.4.1.2. Measuring the content effectiveness of the application

Part Three of the survey included questions about the effectiveness of the content.

The first statement addressed the intuitive comprehension of the available themes, namely, the themes of ‘Context’, ‘Description’, ‘Analysis’ and ‘Technique’.				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
58.33%	33.33%	8.33%	0%	3.4

Table 6.9: Comprehension of available themes

A particularly interesting question included in this section referred to the way in which participants applied the application components of the multimedia.

<i>Audio</i>	<i>Text</i>	<i>Multimedia</i>	<i>Video</i>
66.7%	41.33%	33.3%	25%

Table 6.10: Application of multimedia

This question provided students with the opportunity of expressing their own feelings, as to whether the options provided did not accommodate them. Twelve participants (50%) answered that the images were of assistance to them; six (25%) participants said that the images interfered rather than helped them to appreciate the objects. Six participants (25%) chose the option 'Other', specifying that they were helped in some cases, while not in others. This section posed four questions relating to the presentations' use of multimedia.

The Statement: <i>'The quality of the multimedia presentations was what I would expect.'</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
33.33%	50%	16.67%	20.83%	3.4

Table 6.11: Quality of multimedia AR

Another question dealt with the length of the multimedia presentations.

The Length of the Multimedia Presentations:		
<i>Not Long Enough</i>	<i>Satisfactory</i>	<i>Much Too Long</i>
8.33%	91.67%	0%

Table 6.12: Length of multimedia presentations in AR

Two other sets of questions were related to the quality and the length of the text, as well as the audio provided in the application.

The Statement: <i>'The quality of the provided text was what I would expect.'</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
70.8%	29.2%	0%	20.83%	3.7

Table 6.13: Quality of text in AR

The Statement: <i>'The quality of the audio comments corresponded to what I would expect from a multimedia presentation.'</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
58.3%	25%	8.34%	0%	3.7

Table 6.14: Quality of audio in AR

The Statement: <i>'The duration of the audio comments was neither too short nor too long.'</i>				The Likert Score
<i>Mostly Agree</i>	<i>Somewhat Agree</i>	<i>Somewhat Disagree</i>	<i>Mostly Disagree</i>	
50%	50%	0%	0%	3.6

Table 6.15: Quality of audio in AR

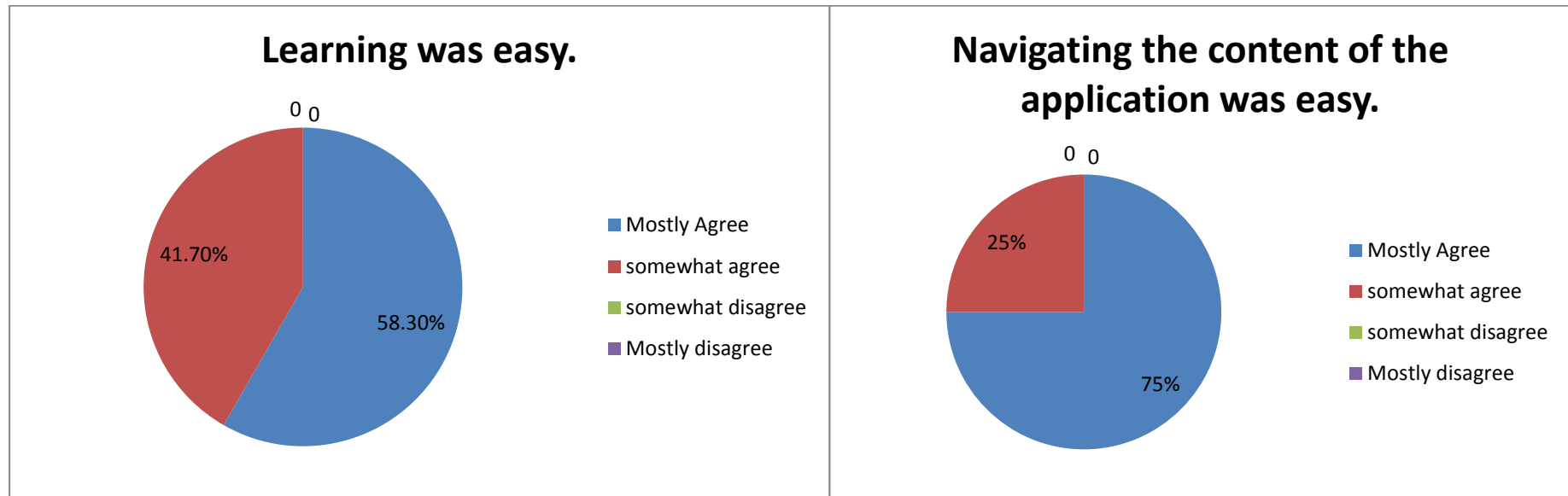


Figure 6.2: Usability of AR Application

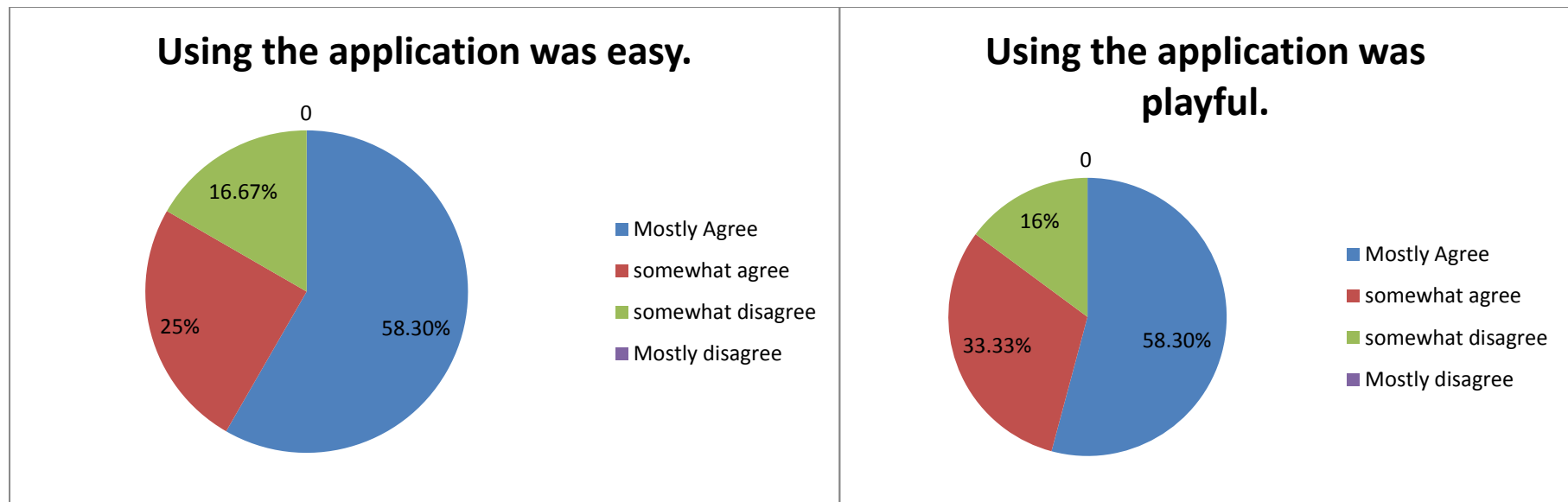


Figure 6.3: Usability of AR Application **USE OF CAPITAL LETTERS IN THE KEY NOT CONSISTENT**
NOT SURE IF THE WORD “PLAYFUL” IS THE RIGHT ONE HERE – THINK YOU MEAN ENTERTAINING?

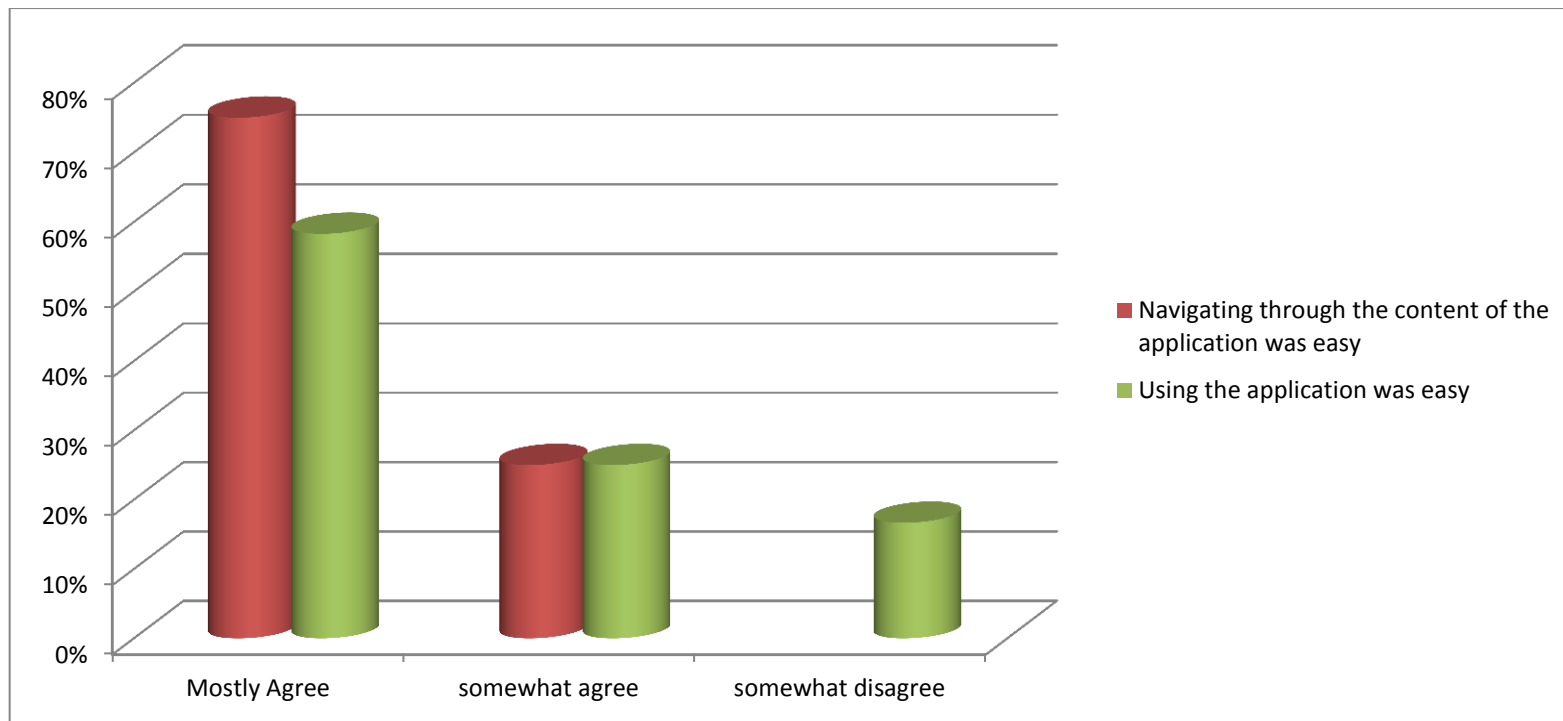


Figure 6.4: Usability of the AR Application (USE OF CAPITAL LETTERS NOT CONSISTENT ON AXIS LABEL)

Table 6.16: Average Score for Section Usability of the AR Application

Table 6.16: Average Score for Section Usability of the AR Application					
The Statements	Likert Scale (1 to 4)				Average Score (1 to 4)
	Number of Participants				
	Mostly Agree	Somewhat Agree	Somewhat Disagree	Mostly Disagree	
Learning was easy.	14	10	0	0	3.58
Navigating the content of the application was easy.	18	6	0	0	3.75
Using the application was easy.	14	6	4	0	3.42
The tutorial at the beginning helped me to understand how to use the application.	8	14	2	0	3.25
The quality of the multimedia presentations was what I would expect.	2	4	13	5	2.13
The quality of the provided text was what I would expect.	17	7	0	0	3.71
The quality of the audio comments corresponded to what I would expect.	14	6	2	2	3.33
The duration of the audio comments was neither too short nor too long.	12	0	12	0	3.00
I found that using the application helped me to better comprehend and appreciate the objects.	18	4	2	0	3.67
I learned more than I would have learned had I not used the application.	12	7	3	2	3.21
Using the application was playful .ENTERTAINING?	14	8	2	0	3.50
Would you use such an application, were it available at university?	12	6	3	3	3.13
Do you need training to use the application?	5	7	7	5	2.50
Do you need more time to find information?	3	9	7	5	2.42

Table 6.17: Comparison of the Usability between Mobile Learning and AR in Mobile Learning

M_LEARNING						AR				
The Statements	Likert Scale (1 to 4)				SCORE	Likert Scale (1 to 4)				SCORE
	Number of Participants					Number of Participants				
	MA	SA	SD	MD		MA	SA	SD	MD	
Learning was easy.	8	6	4	6	2.67	14	10	0	0	3.58
Navigating the content of the application was easy.	1	8	14	1	2.33	18	6	0	0	3.75
Using the application was easy.	6	4	12	2	2.58	14	6	4	0	3.42
The tutorial at the beginning helped me to understand how to use the application.	10	14	0	0	3.42	8	14	2	0	3.25
The quality of the multimedia presentations was what I would expect.	2	4	13	5	2.13	2	4	13	5	2.13
The quality of the provided text was what I would expect.	6	3	7	8	2.29	17	7	0	0	3.71
The quality of the audio comments corresponded to what I would expect.	3	11	8	2	2.63	14	6	2	2	3.33
The duration of the audio comments was neither too short nor too long.	9	9	2	3	2.92	12	0	12	0	3.00
I found that using the application helped me to better comprehend and appreciate the objects.	3	6	9	6	2.25	18	4	2	0	3.67
I learned more than I would have learned had I not used the application.	0	11	13	0	2.46	12	7	3	2	3.21
Using the application was playful .ENTERTAINING?	4	6	12	2	2.50	14	8	2	0	3.50
Would you use such an application, were it available at university?	2	6	12	4	2.25	12	6	3	3	3.13
Do you need training to use mobile learning?	12	8	3	1	3.29	5	7	7	5	2.50
Do you need more time to find information?	10	9	3	2	3.13	3	9	7	5	2.42

Table 6.18: Comparing the Usability between Mobile Learning and AR in Mobile Learning Utilising a Likert Scale from 1 to 4.

<i>Elements</i>	<i>Mobile Learning</i>	<i>AR Mobile Learning</i>
<i>Learning was easy.</i>	<i>2.67</i>	<i>3.58</i>
<i>Navigating the content of the application was easy.</i>	<i>2.33</i>	<i>3.75</i>
<i>Using the application was easy.</i>	<i>2.58</i>	<i>3.41</i>
<i>Need training to use the application?</i>	<i>3.29</i>	<i>2.57</i>
<i>Need more time to find information?</i>	<i>3.13</i>	<i>2.44</i>
<i>The quality of the provided text was what you would expect.</i>	<i>2.29</i>	<i>3.7</i>
<i>The quality of the audio comments corresponded to what I would expect.</i>	<i>2.63</i>	<i>3.33</i>
<i>Using the application was playful. ENTERTAINING?</i>	<i>2.50</i>	<i>3.5</i>
<i>Would you use such an application, were it available at university?</i>	<i>2.25</i>	<i>3.2</i>

Table 6.19: Comparing the Usability between Mobile Learning and AR in Mobile Learning

<i>Elements</i>	<i>Mobile Learning</i>	<i>AR Mobile Learning</i>
<i>Learning was easy.</i>	33.33%	58.30%
<i>Navigating the content of the application was easy.</i>	37.5%	75%
<i>Using the application was easy.</i>	41.6%	58.33%
<i>Need training to use the application?</i>	50%	42.76%
<i>Need more time to find information?</i>	41.7%	39.77%
<i>The quality of the provided text was what you would expect.</i>	37.5%	70.8%
<i>The quality of the audio comments corresponded to what I would expect.</i>	45.8%	58.3%
<i>Using the application was playful. ENTERTAINING?</i>	50%	88.76%
<i>Would you use such an application, were it available at university?</i>	33.4%	56.42%

Notably, according to the results of the comparison, the use of AR in m-learning increases its usability by 33%.

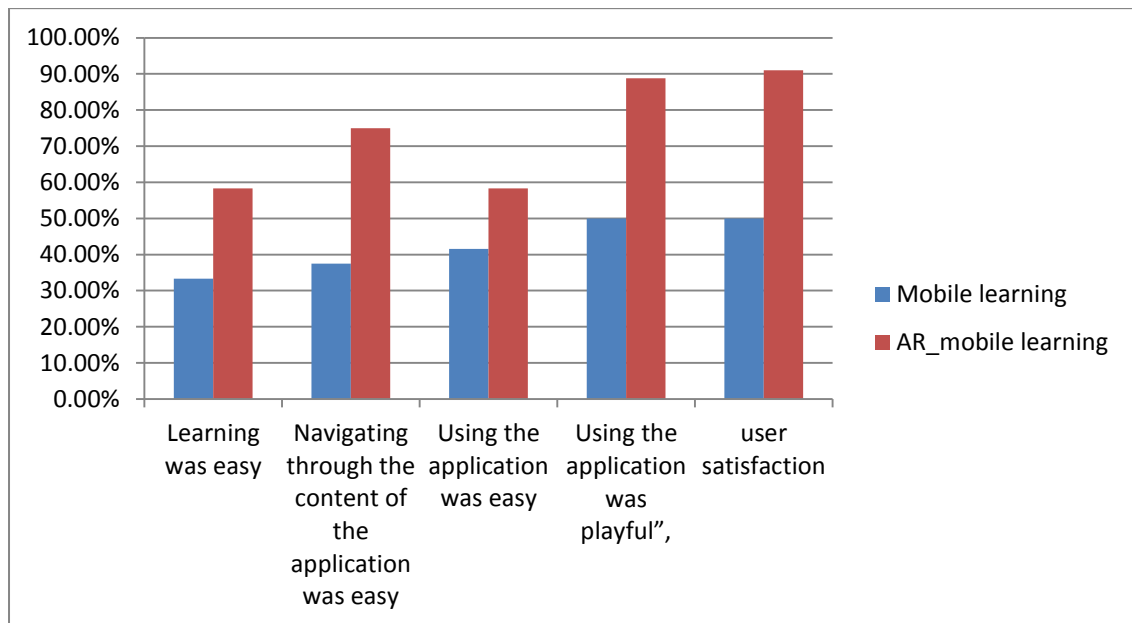


Figure 6.5: *Comparing the Usability between Mobile Learning and AR in Mobile Learning*

6.5. *An Empirical Comparison of the Applications*

An empirical analysis of the gathered data was carried out in order to compare and contrast the two applications.

6.5.1. *Purpose of the Analysis*

The main purpose of analysing the data was to compare the two smart phone applications (m-learning and m-learning with AR). The main features to be compared were as follows:

- Ease of use;
- User satisfaction;
- Attractiveness;
- Learnability.

The procedure for analysing the data will be as follows:

- Cleansing of preliminary data;
- Reliability test and association relationship test.

6.5.2. Preliminary Data Analysis

The data collected about m-learning and B (?) were compared using four main criteria: ease of use, user satisfaction, attractiveness and learnability (see Table 6.20, below). The questionnaire was designed in a way that captured feedback from the users on different perspectives of the two applications. The questions were well distributed and covered all aspects of the applications to be evaluated. The study assumed that equal weight was given to all the questions for the general assessment since several questions were used in every category for the users to evaluate the applications.

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

Table 6.20: Statistical Analysis of the Data

6.5.2.1. Ease of use

The data analysis that was carried out regarding the ease of use of the two applications concluded that m-learning with AR had an average score of 1.74, regarding ease of usability, while m-learning had an average score of 2.74 (see Table 6.20). It can be

concluded from the result of the data analysis that users have given a favourable rating to m-learning with AR, in terms of ease of usability when compared to m-learning. Similarly, m-learning with AR has a standard deviation of 0.14, while m-learning is 0.37, indicating that the consistency and variability of m-learning with AR is better than simply m-learning. The survey in this study was carried out on the paired experiment; hence, the diagram in Figure 5.1 shows a side-by-side comparison of m-learning and m-learning with AR.

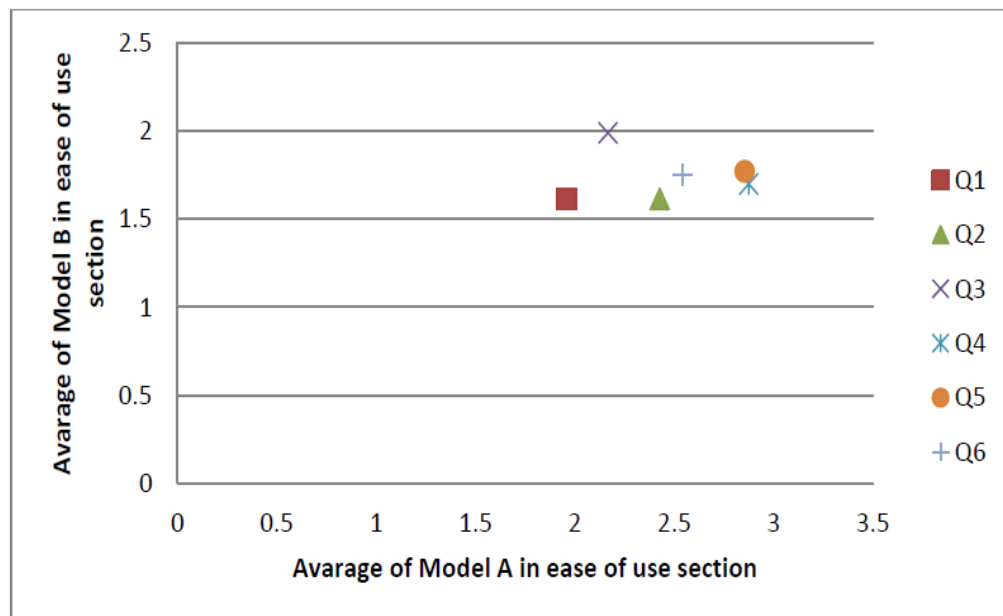


Figure 6.6: Mean Score of Mobile Learning and Mobile Learning with AR in Ease of Use Sub-category

CHANGE AVERAGE TO AVERAGE

6.5.2.2. *User satisfaction*

User satisfaction is one usability criterion that was analysed in this study. A statistical analysis of the data indicated that m-learning had an average score of 1.76, while m-learning with AR earned a 2.23 in user satisfaction (refer to Table 6.20). This analysis showed that users have expressed a higher satisfaction rate regarding m-learning with AR than m-learning alone.

Similarly, m-learning with AR had a standard deviation of 0.19, while m-learning was 0.27, indicating that the consistency and variability of m-learning with AR was better than m-learning. The study used a paired experiment in the survey, hence, the diagram in Figure 6.7 shows a side-by-side comparison of m-learning and m-learning with AR.

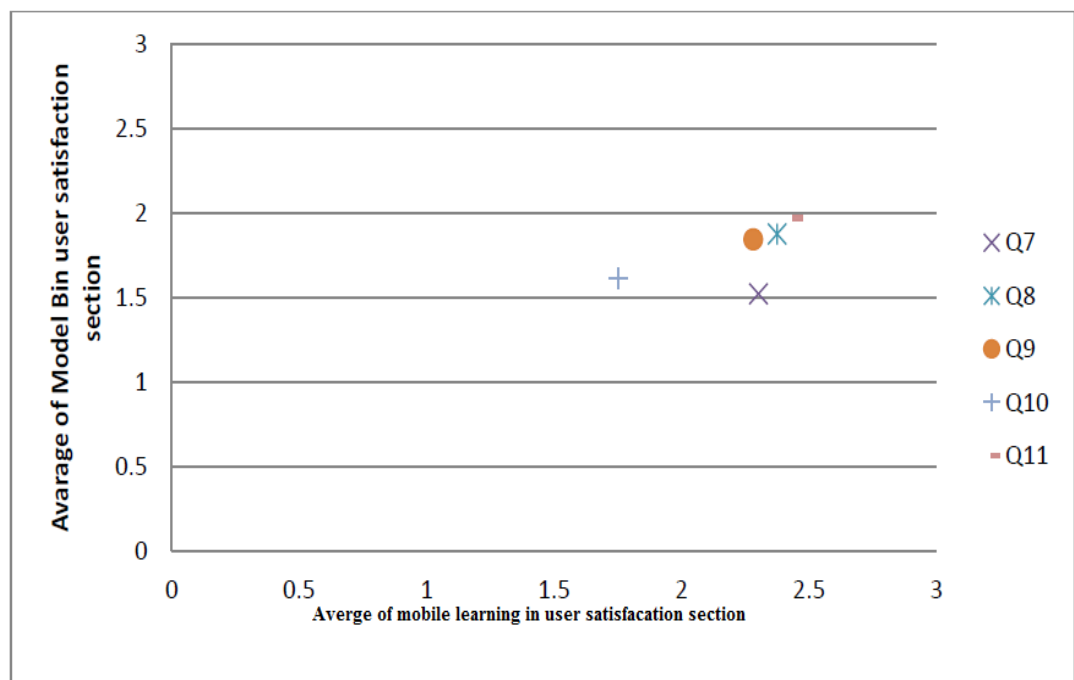


Figure 6.7: The Mean Score of Mobile Learning and Mobile Learning with AR in User Satisfaction Sub-categories CHANGE AVERAGE TO AVERAGE AND MODEL BIN TO MODEL BIN ?

As the above graphic indicates, users gave a higher satisfaction rating to m-learning with AR than to m-learning alone.

6.5.2.3. *Attractiveness*

The study conducted an analysis of the attractiveness of the two applications. The result of the statistical analysis in Table 6.20 shows that, in terms of attractiveness, m-learning had an average score of 2.05, while m-learning with AR had an average score of 3.16. This analysis showed that m-learning with AR had a higher favourability rating among the users in terms of attractiveness when compared to M-learning, which scored a lower favourability rating. Similarly, m-learning with AR had a standard deviation of 0.13, while m-learning had a standard deviation of 0.27, indicating that the consistency and variability of m-learning with AR was better than m-learning. The study used a paired experiment in the survey. Figure 5.3 shows a side-by-side comparison of the two applications.

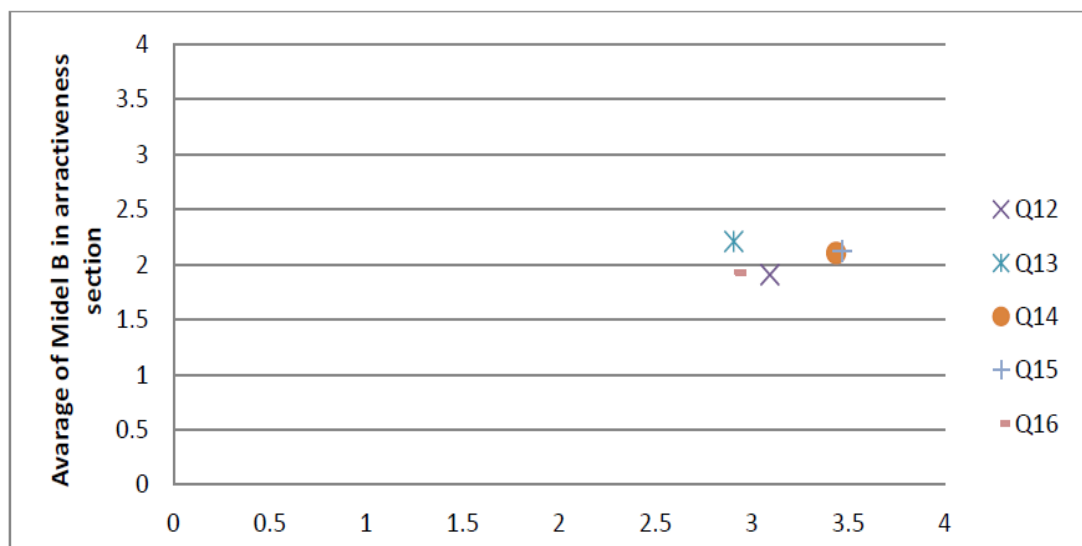


Figure 6.8: Mean Score of Mobile Learning and Mobile Learning with AR in Attractiveness Subcategory

The feedback from users indicates that m-learning was less attractive than m-learning with AR.

6.5.2.4. *Learnability*

The study conducted an analysis of the learnability of the two applications. The statistical analysis in Table 6.20 shows that, in terms of learnability, m-learning had an average score of 2.17, while m-learning with AR had a lower average score of 1.71. This analysis showed that m-learning with AR had a higher favourability rating among the users in terms of learnability when compared to m-learning. Similarly, m-learning with AR had a lower standard deviation of 0.09, when compared to m-learning with a standard deviation of 0.1, indicating that the consistency and variability of m-learning with AR was better than m-learning. The study used a paired experiment in the survey; Figure 6.9 shows a side-by-side comparison of the two applications in terms of learnability.

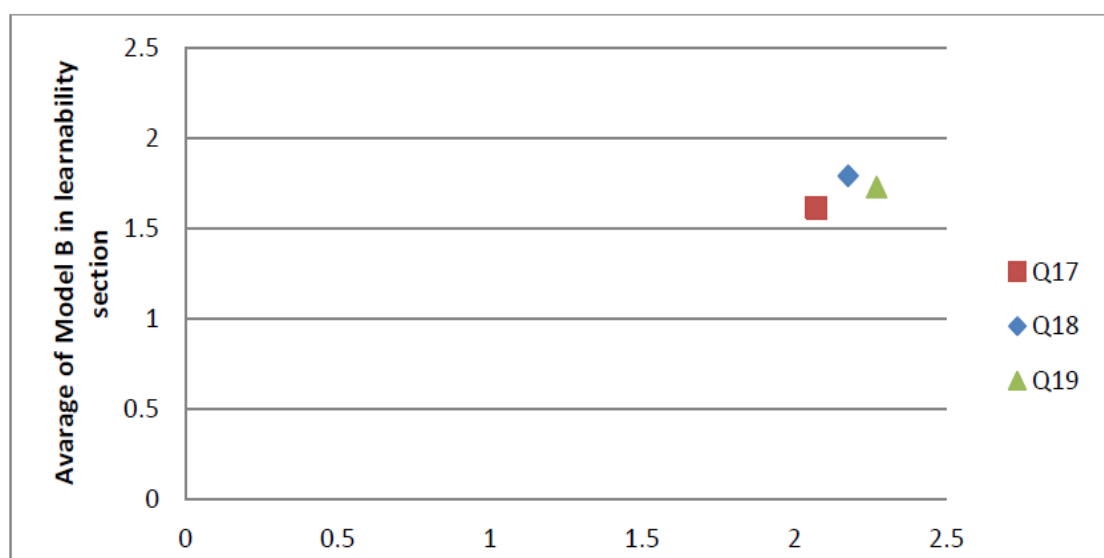


Figure 6.9: Mean Score of Mobile Learning and Mobile Learning with AR in Learnability Sub-category

AVERAGE

The feedback from users indicated that m-learning with AR was easier than m-learning.

6.5.3. *Reliability and Validity*

In order to compare the validity and reliability of m-learning and m-learning with AR, the paired T-test and F-test were used to assess the differences in scores and variance between the two applications.

As indicated in Table 6.21, the study hypothesised that, in view of the four usability criteria (ease of use, user satisfaction, learnability and attractiveness), there will be no difference between m-learning and m-learning with AR.

Hypothesis	Statement
Ease of Use	<i>Model B performs the same as Model A.</i>
User Satisfaction	
Attractiveness	
Learnability	

Table 6.21: Hypotheses for the Usability Sections

The following are the results of the hypothesis:

Hypothesis	Paired T- Test		Paired F -Test	
	Test Statistics	Confidence Interval ($\alpha=0.05$)	Test Statistics	Confidence Interval ($\alpha=0.05$)
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.

Table 6.22: Analysis of the Data Using T-Test and F-Test

6.5.3.1. *Ease of use*

The study hypothesised that there will be no difference in the ease of use between m-learning and m-learning with AR (see Table 6.22). This hypothesis has been disproved because the P-value was statistically significant at <0.05, showing that there was a significant difference between m-learning and m-learning with AR in terms of ease of use. In addition, Table 6.22 also shows that the T-test confidence interval, for the average difference between m-learning and m-learning with AR, was (0.64, 0.82). It can be observed that the scores in the lower bound and upper bound were greater than zero, showing that the score for m-learning with AR was less than that of m-learning, hence confirming our assumption that m-learning with AR is superior to m-learning.

In terms of variance and consistency, the study hypothesised that there is no significant difference between m-learning and m-learning with AR. The result of the data analysis showed that the P-value was <0.05, thus disproving our hypothesis. It can be concluded

from the result that there is a significant difference between m-learning with AR and m-learning in terms of variance. In addition, the confidence interval, which is (1.12, 1.57), shows that the lower bound score is greater than 1. We can, therefore, conclude that m-learning with AR has better consistency than m-learning alone.

6.5.3.2 User satisfaction

The study hypothesised that there will be no difference in the user satisfaction category between m-learning and m-learning with AR (see Table 6.22). This hypothesis has been disproved because the P-value was statistically significant at <0.05 , showing that there was a significant difference between m-learning and m-learning with AR in terms of user satisfaction. The confidence interval also showed that the difference between m-learning and m-learning with AR was (0.38, 0.55). It can be observed that the scores for the lower bound and upper bound (?) are greater than zero, showing that the score for m-learning with AR was less than that of m-learning. Therefore, our assumption is confirmed, that m-learning with AR is superior to m-learning alone.

In terms of variance and consistency, the study hypothesised that there is no significant difference between m-learning and m-learning with AR in terms of user satisfaction. The result of the data analysis shows that the P-value was <0.05 , hence disproving our hypothesis. It can be concluded from the results that there was a significant difference between m-learning with AR and m-learning. In addition, the confidence interval, which was (1.09, 1.55), shows that the score for the lower bound was greater than 1. We can, therefore, conclude that m-learning with AR has better consistency than m-learning.

6.5.3.3. *Attractiveness*

The study hypothesised that there will be no significant difference in attractiveness between m-learning and m-learning with AR (see Table 6.22). This hypothesis has been disproved because the P-value was statistically significant at <0.05 , showing that there was a significant difference between m-learning and m-learning with AR, in terms of attractiveness. In addition, the difference between the two applications, in terms of confidence interval, was (1.0, 1.21), indicating that the lower bound and upper bound scores were greater than zero. We can, therefore, conclude that m-learning with AR has better consistency than A(?) since the score for m-learning with AR was less than the score for m-learning. The result of the data analysis showed that the P-value was <0.05 , hence disproving our hypothesis, which indicated that there is no significant difference between the two applications in terms of consistency. It can be concluded from the results that there was a significant difference between m-learning with AR and MODEL? A, in the sense that m-learning with AR is superior to m-learning with regard to consistency in attractiveness.

On the other hand, it can be realised that the level of confidence interval in this category was (0.58, 0.83) (BRACKETS?) with an upper bound score that was smaller than 1. Thus, it can be concluded that the level of consistency for m-learning was higher than m-learning with AR. The major justification for this could be attributed to the subjective attitude of the respondents regarding attractiveness. The samples that were taken mainly focused on the assessment of m-learning. Half of the questions posed to the respondents in this category inquired about the users' views about the various colours in the applications. The dominant colour that was employed in m-

learning with AR was red. Most of the respondents did not like this colour and recommended that it not be used.

6.5.3.4. *Learnability*

The study hypothesised that there will be no significant difference in learnability between m-learning and m-learning with AR, as indicated in Table 6.22. This hypothesis has been disproved because the P-value was statistically significant at <0.05 , showing that there was a significant difference between m-learning and m-learning with AR in terms of learnability.

In addition, the confidence interval for the difference between m-learning and m-learning with AR was (0.38, 0.58) BRACKETS?. The scores for the lower bound and upper bound are greater than zero, illustrating that the score for m-learning with AR was less than m-learning. We can, therefore, conclude that m-learning with AR has better consistency than m-learning, since the score for m-learning with AR was less than the score for m-learning.

In terms of variance and consistency, the study hypothesised that there is no significant difference between m-learning and m-learning with AR in terms of learnability. The results of the data analysis showed that the P-value was <0.05 , disproving our hypothesis. It can be concluded from the results that there was a significant difference between m-learning with AR and m-learning. Regarding the confidence interval of (1.09, 1.73), with the lower bound greater than 1, it indicates that m-learning with AR had better consistency than m-learning.

6.5.4. General Validation

The study hypothesised that there will be no significant difference in general validation between m-learning and m-learning with AR, as indicated in the General Validation category of Table 6.22. This hypothesis has been disproved because the P-value was statistically significant at <0.05 . This shows that there was a significant difference between m-learning and m-learning with AR in terms of general validation.

In addition, the confidence interval for the difference between the two applications was (0.67, 0.77). The scores for the lower bound and upper bound were greater than zero, illustrating that the score for m-learning with AR was less than m-learning. Therefore, we can conclude that m-learning with AR has better consistency than m-learning, since the score for m-learning with AR was less than the score for m-learning.

In terms of variance and consistency, the study hypothesised that there is no significant difference between m-learning and m-learning with AR in terms of variance. The results of the data analysis showed that the P-value was <0.05 , disproving our hypothesis. Considering the confidence interval of (1.19, 1.44) with the lower bound greater than 1, m-learning with AR had better consistency than m-learning.

6.5.5. Association Analysis

The assessments of the two applications, A (?) and m-learning with AR, were carried out at the same time. There was a need to test the association levels of the two applications (m-learning and m-learning with AR) to find out if the respondents assessed m-learning and m-learning with AR as being independent of each other. The

hypotheses of the study from H1 to H4 can be tested using the Pearson correlation coefficient, which is employed in parametric statistics for evaluating the association level between two or more applications, such as m-learning and m-learning with AR. ‘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].

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.

Table 6.23: Analysis of the Data using Pearson and Spearman Correlation Coefficient Methods

While the Pearson correlation coefficient is used in analysing parametric data, the Spearman correlation coefficient is used in analysing non-parametric data that measures the correlation between the two applications. Table 6.23 illustrates the statistical analysis of the Pearson correlation coefficient and the Spearman correlation coefficient. The following are the results of the analysis:

1. In the ease of usability category, the findings of the association between the two applications were contradictory. The results of the data analysis showed that the Pearson correlation coefficient test was positive (0.06) at a P-value of >0.05, therefore, confirming our hypothesis. However, the result of the data analysis of

the Spearman correlation coefficient was (0.09), at a P-value of <0.05 . This result disproves our hypothesis. This contradictory result could be attributed to an error in the evaluation because the Spearman correlation coefficient test was significant at (0.027), which is very near 0.05. Another reason is that our survey used a sample of only 96 learners. The small sample size used in the data analysis affected the accuracy of the results since the Spearman coefficient was used in the approximation of non-parametric associations. The result of the Pearson coefficient in Table 6.23 illustrates that the assessment of m-learning and m-learning with AR are independent.

2. In the category of user satisfaction, the results of the data analysis showed that the Pearson correlation coefficient test between the two applications was 1, or positive (0.20) (P-value <0.05). Similarly, the data analysis showed that the Spearman correlation coefficient test was positive (0.21) (P-value <0.05). The statistical analysis of both the coefficients illustrated positive P-values, disproving our hypothesis. It can be concluded from the results in Table 6.23 that the association between the two applications was positive in the sense that the respondents who gave positive feedback about m-learning with AR similarly gave positive feedback about m-learning.
3. In the category of attractiveness, the results of the data analysis showed that the Pearson correlation coefficient test and the Spearman coefficients of the two applications indicated negative values of (-0.010, -0.008), with a P-value of >0.05 . The findings of these results confirmed the null hypothesis, that m-learning and m-learning with AR are independent. The opinions of the respondents about the attractive nature of the applications are subjective; hence,

the assessment of the two applications will be independent. The opinions expressed by the users included wanting a change of the colour red and the incorporation of more feature options like 'Help, Back and Forward' buttons. Moreover, the users expressed their views that they did not like the use of the scroll bar function in the m-learning applications.

4. In the learnability category, the results of the data analysis showed that the Pearson correlation coefficient test between the two applications was positive (0.22), at a P-value of <0.05 . Similarly, the Spearman correlation coefficient test was positive (0.24), at a P-value < 0.05 . Since the P-value for the Pearson coefficient and the Spearman coefficients were both positive, our hypothesis has been disproved. It can be concluded from the results in Table 6.23 that the association between the two applications was positive in the sense that respondents who gave positive feedback about m-learning with AR similarly gave positive feedback about m-learning.
5. The results of the data analysis in the general validation category indicated that the Pearson correlation coefficient between m-learning and m-learning with AR was positive (0.16), which is significant at a P-value of <0.05 . Similarly, the Spearman correlation coefficient test was positive (0.17), which is significant at a P-value of <0.05 . Thus, the P-values for the two coefficients disproved our hypothesis. It can be concluded from the results in Table 5.4 that the association between the two applications was positive in the sense that respondents who gave positive feedback about m-learning with AR similarly gave positive feedback about m-learning.

6.5.6. Analysis and Discussion

The initial analysis of the data indicated that m-learning would be more distributed than m-learning with AR. Generally, the respondents rated m-learning with AR as superior to m-learning. A validation test was conducted on the two applications. The paired T-test was selected to assess differences in averages between the two applications for every question and general situation because the assessment of m-learning and m-learning with AR is paired together. The F-test was employed to see if there was a significant difference between the variance of the two applications. The findings of the data analysis indicated that the P-values for the T-test and F-test were less than 0.05. These findings disproved our null hypothesis, which stated that there is no significant difference between the two applications. In addition, the confidence interval of the two applications is greater than zero, illustrating that if the average of m-learning is subtracted from the average of m-learning with AR, the result will be less than zero. We can conclude from this result that the users had a more positive view of m-learning with AR than m-learning. Statistical methods, such as the Pearson correlation coefficient and the Spearman correlation coefficient, were used to evaluate the association between the users' assessment of m-learning and m-learning with AR. The results also showed that users evaluated the two applications independently in certain questions. Generally, there is a positive relationship between the associations of the two applications in the sense that respondents who gave positive feedback about m-learning with AR similarly gave positive feedback about m-learning. The study concludes that m-learning with AR is better than m-learning in terms of user satisfaction, ease of use, learnability and attractiveness.

Chapter 7

*Conclusions
and
Future Work*

7.1. Summary of the Thesis

This study proposed a framework that utilises augmented reality (AR) and context awareness into an m-learning system to increase the level of interaction and the usability of such systems. This research has developed a standard framework for AR applications.

The research gap was identified by surveying the multi-disciplinary literature regarding m-learning. The survey concentrated on the technological perspective and learners as well. Accordingly, the proposed work brought together pedagogical, technological and usability aspects of m-learning.

The research methodology in this work began by surveying AR and m-learning to determine the state of the art. The standard proposed framework of AR applications integrates AR into m-learning. It focused on usability and addressed the following problems in AR research fields as well:

1. Poor end-user evaluation;
2. Insufficient education on the evaluation of AR experiences;
3. Difficulty of the end-user to articulate his requirements;
4. Little focus on usability, rather than technological expertise.

Taking the framework into account as a guideline, two designs of the m-learning App were proposed; one design with AR and the second without. Accordingly, two prototypes were developed and implemented. In both cases, the experiments were aimed to investigate the overall ease of the m-learning application usage, the ease of navigation through the application content and the ease of learning.

Data collection included both methods, quantitative and qualitative. The data collected was analysed and we 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 was a

relationship between two applications when students evaluated m-learning and m-learning with AR. Overall, we discovered that there was some positive correlation between the evaluation of m-learning and m-learning with AR, indicating that students who evaluated m-learning higher will also tend to evaluate m-learning with AR higher. The major statistics we used in our study were the Pearson correlation coefficient and the Spearman correlation coefficient. We also developed a prototype application for smart phones using the Java language and an Android software development kit by following the proposed framework as a guideline. According to the results of the comparison, the use of AR in m-learning increases the usability of m-learning by 33%.

7.2. Future Work

- ***Development of the Prototype***

Based on the prototype that has been scrutinised and assessed, novel algorithms of a sturdier nature will be developed and integrated. Regarding content, the new prototype will also include animated 3D avatars and objects. Novel research avenues could then be emphasised, contributing in some small way to this new experimentation phase.

- ***Improving the Graphics and Interaction Design***

The interaction and graphics application design proved to be an important part of the feedback offered in the evaluation process. The feedback illustrated that there were issues with functionalities, such as the absence of audio controls and graphic design being unclear and unattractive. When designing a more up-to-date version of the prototype, one of these

factors can be taken into account.

- ***Incorporating the Target Group Earlier in the Interaction Design Process***

While evaluating the new applications and modes of interaction, although the validation sample for the mobile AR prototype was small (owing to the exploratory character of the study and its use of under-developed technologies), certain interesting and novel modes of interaction emerged. From the results of the assessment, it appeared that the test group was very demanding, albeit critical and attentive. In the future, it would seem expedient to involve chosen representatives of the sample group in the technology design during the initial phase in order to offer insightful comments and to improve the acceptability of the latest prototype.

- ***Experimenting with New Functions***

However, it will still be feasible to embed new functions in the AR prototype by collaborating at length and closely with the new recruits to AR. Certain new functions are already set to be included in the AR prototype.

- ***Validating and Further Delving into the Results of the First Experiments***

- ***This study was limited to small and limited sample, this sample can***

References

- [1] Lobo, D. *et al.* 'Web usability guidelines for smart phones: a synergic approach', *International Journal of Information and Electronics Engineering*, vol. 1, no. 1, pp. 33-37, 2011.
- [2] Wang, S. and Dey, S. 'Adaptive mobile cloud computing to enable rich mobile multimedia applications', *IEEE Transactions on Multimedia*, accepted, pp. 1-14, 2013.
- [3] Black, M. and Edgar, W. 'Exploring mobile devices as grid resources: using an x86 virtual machine to run boinc on an iPhone', *10th IEEE/ACM International Conference on Grid Computing*, Washington, DC, USA, pp. 9-16, 2009.
- [4] Prensky, M. 'What can you learn from a cell phone? Almost anything!' vol. 1, no. 5, 2010. Available online at http://www.innovateonline.info/pdf/vol1_issue5/What_Can_You_Learn_from_a_Cell_Phone_Almost_Anything!.pdf.
- [5] Traxler, J. and Leach, J. 'Innovative and sustainable mobile learning in Africa', *4th IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education*, Los Alamitos, USA, pp. 98-102, 2006.
- [6] Wang, M., Shen, R., Tong, R., Yang, F. and Han, P. 'Mobile learning with cell phones and pocket-PCs', Springer-Verlag Berlin Heidelberg, New York, pp. 332- 339, 2005.
- [7] Parsons, D. and Ryu, H. 'A framework for assessing the quality of mobile learning', *11th International Conference for Process Improvement, Research and Education (INSPIRE)*, UK, Southampton Solent University, pp. 17-27, 2006.
- [8] Kukulska-Hulme. 'Mobile usability in educational contexts: what have we learnt'? *International Review of Research in Open and Distance Learning*, vol. 8, no. 2, pp. 1-16, 2007.
- [9] Honeyman, M. 'A valid alternative for higher education'? *20th Annual National Agricultural Education Research Meeting*, University Park, PA: The Pennsylvania State University, Department of Agricultural and Extension Education, pp. 67-73, 1993.
- [10] Kristoffersen, S. and Ljungberg, F. 'Making place to make it work: empirical explorations of HCI for mobile CSCW', *International ACM SIGGROUP Conference on Supporting Group Work*, New York, 276-285. 1999.
- [11] DiCerbo, K., Kovac, R., West, P. Frezzo, D., Behrens, J. and Sehnalakova, J. 'Individual practice and collaborative inquiry: instructional configurations in a simulation environment', *6th International Conference on Networking and Services (ICNS)*, pp. 335-339, 2010.
- [12] Jin, Y. 'Research of one mobile learning system', *International Conference on Wireless Networks and Information Systems*, Guiyang University, China, pp. 162-165, 2009.
- [13] Han, M. 'New technology of distance learning in China', *International Conference on Computer Science and Service System (CSSS)*, Nanjing, China, pp. 517-519, 2011.

- [14] Brevern, H. 'Cognitive and logical rationales for e-learning objects', *Journal of Educational Technology and Society*, vol. 7, no. 4, pp. 2-25, 2005.
- [15] Ting, R. 'The advanced mobile learning practices: learning features and implications,' *7th IEEE International Conference on Advanced Learning Technologies, (ICALT)*, Taipei, Taiwan, pp. 718-720, 2007.
- [16] Chang, V. 'Web service testing and usability for mobile learning', *International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies, (ICN/ICONS/MCL)*, University of Southampton, UK, pp. 2-21, 2006.
- [17] Chang, C. and Sheu J. 'Design and implementation of ad hoc classroom and eschoolbag systems for ubiquitous learning', *IEEE International Workshop on Wireless and Mobile Technologies in Education*, Växjö, Sweden, pp. 8-14, 2002.
- [18] Hoppe, U., Lingnau, A., Machado, I., Paiva, A., Prada, R. and Tewissen, F. 'Supporting collaborative activities in computer integrated classrooms-the NIMIS approach,' *6th International Workshop on Groupware*, Duisburg University, Germany, pp. 94-101, 2000.
- [19] Liu, T., Wang, H., Liang, J., Chan, T. and Yang, J. 'Applying wireless technologies to build a highly interactive learning environment', *IEEE International Workshop on Wireless and Mobile Technologies in Education*, Center for Teacher Education, National Central University, Chung-li, Taiwan, pp. 63-70, 2002.
- [20] Seppala, H. and Alamaki, P. 'Mobile learning in teacher training', *Journal of Computer Assisted Learning*, vol. 19, no. 3, pp. 330-335, 2003.
- [21] Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., Randell, C., Muller, H., O'Malley, C., Stanton, D., Thompson, M. and Weal, M. 'Ambient wood project: designing new forms of digital augmentation for learning outdoors', *Proceedings of IDC*, ACM Press, College Park, Maryland, USA, vol. 1, no. 8, pp. 3-10, 2004.
- [22] Ryu, H., Brown, R., Wong, A. and Parsons, D. 'Personal learning organiser: designing a mobile learning experience for university students', *presented at the Conference on Mobile Learning Technologies and Applications (MoLTA)*, New Zealand, pp. 20-23, 2007.
- [23] Evans, C. 'The effectiveness of m-learning in the form of podcast revision lectures in higher education multimedia', *International Journal of Computers and Education*, vol. 50, no. 2, pp. 491-498, 2008.
- THERE IS A VERTICAL LINE DOWN THE SIDE OF THE PAGE?
- [24] Hashim, A., Ahmad, W. and Ahmad, R. 'Mobile learning course content application as a revision tool: the effectiveness and usability,' *International Conference on Pattern Analysis and Intelligent Robotics (ICPAIR)*, Computer and Informatics Science Department, University of Teknol, Tronoh, Malaysia, pp. 184-187, 2011.

- [25] Bitesize: Available: <http://www.bbc.co.uk/schools/gcsebitesize/>, last accessed on December 12, 2012.
- [26] Zhang, D. and Adipat, B. 'Challenges, methodologies, and issues in the usability testing of mobile applications', *International Journal of Human-Computer Interaction*, vol. 18, no. 3, pp. 293-308, 2005.
- [27] Ziefle, M. and Bay, S. 'How to overcome disorientation in mobile phone menus: a comparison of two different types of navigation aids', *International Journal of Human-Computer Interaction*, in press, vol. 21, no. 4, pp. 393-433, 2006.
- [28] Jarvela, S., Naykki, P., Laru, J. and Luokkanen, T. 'Structuring and regulating collaborative learning in higher education with wireless networks and mobile Tools', *International Journal of Educational Technology and Society*, vol. 10, no. 4, pp. 71-79, 2007.
- [29] Shen, R., Wang, M. and Pan, X. 'Increasing interactivity in a blended classroom through a cutting-edge mobile learning system', *British Journal of Educational Technology*, vol. 39, no. 6, pp. 1073-1086, 2008.
- [30] Huang, Y., Jeng, Y. and Huang, T. 'An educational mobile blogging system for supporting collaborative learning', *International Journal of Educational Technology and Society*, vol. 12, no. 2, pp. 163-175, 2009.
- [31] Ziefle, M. and Bay, S. 'How older adults meet complexity: aging effects on the usability of different mobile phones', *International Journal of Behavior and Information Technology*, vol. 24, no. 5, pp. 375-389, 2005.
- [32] Wahab, A., Osman, A. and Ismail, H. 'Engaging children to a science subject: a heuristic evaluation of mobile learning prototype', *2nd International Conference on Computer Engineering and Applications (ICCEA)*, Shah Alam, Malaysia, pp. 513-516, 2010.
- [33] Brown, T. 'The role of mobile learning in the future of e-learning in Africa'? *Presentation at the 21st International Conference on Distance Education and Technology (ICDE): Issues and Practice*, Open University of Hong Kong, Hong Kong, China, 2004.
- [34] Riggs, R. and Vandenbrink, M. 'Programming for wireless devices with the Java platform,' Micro Edition. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2001.
- [35] Parsons, D. and Ryu, H. 'A framework for assessing the quality of mobile learning', *11th International Conference for Process Improvement, Research and Education (INSPIRE)*, Southampton Solent University, UK, pp. 17-27, 2006.
- [36] O'Malley, C., Vavoula, G., Glew, J., Taylor, J., Sharples, M., Lonsdale, P., Naismith, L. and Waycotte, J. 'Guidelines for learning in a mobile environment', *2nd IEEE International Workshop on Wireless and Mobile Technologies in Education*, Jhongli, Taiwan, pp. 173-76, 2005.
- [37] Yuan, J., Xing, R. and Wang, J. 'Applying research of m-learning mode in teaching',

International Forum on Information Technology and Applications (IFITA), Nanchang, China, pp. 417-420, 2010.

[38] Cavus, N. and Ibrahim, D. 'Mobile learning: an experiment in using SMS to support learning new English language words', *British Journal of Educational Technology*, vol. 40, no. 1, pp. 78-91, 2009.

[39] Zhao, Y. and Zhu, Q. 'Influence factors of technology acceptance model in mobile learning', *4th International Conference on Genetic and Evolutionary Computing (ICGEC)*, Shenyang, China, pp. 542-545, 2010.

[40] Li, H. and Qiu, F. 'Analysing theory characteristic and studying application mode about mobile learning', *International Conference on Electrical and Control Engineering (ICECE)*, Hangzhou, China, pp. 6327-6330, 2011.

[41] Capretz, L. 'Clues on software engineers learning styles', *International Journal of Computing and Information Sciences*, vol. 4, no. 1, pp. 46-49, 2006.

[42] 'Learning and teaching styles in engineering education', [Online]. Available: <http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/LS-1988.pdf>

[43] 'Index of learning style questionnaire', [Online]. Available at: <http://www.engr.ncsu.edu/learningstyles/ilsweb.html>

[44] Basaeed, F., Berri, J., Zemerly, J. and Benlamri, R. 'Learner-centric context aware mobile learning', *IEEE Multidisciplinary Engineering Education Magazine*, vol. 2, no. 2, 2007.

[45] Johnson, G. and Johnson, J. 'Dimensions of online behavior implications for engineering e-learning', *Technological Developments in Education and Automation*, Springer Science+Business, Heidelberg, London, New York, pp. 61-66, 2010.

[46] Junqi, W., Lili, Q. and Hu, Z. '3g phone-based mobile learning for improving k-12 teachers' educational technology in rural areas', *2nd International Workshop on Education Technology and Computer Science (ETCS)*, Wuhan, China, pp. 821-825, 2010.

[47] Attewell, J. 'Mobile technologies and learning: a technology update and mobile learning project summary', *Learning and Skills Development in Technology Enhanced Learning Research Centre*, 2005, [Online] Available at: <http://www.mlearning.org/archive/docs/The%20m-learning%20project%20-%20technology%20update%20and%20project%20summary.pdf>.

[48] Naismith, L., Lonsdale, P., Vavoula, G. and Sharple, M. 'Literature review in mobile technologies and learning', *National Endowment for Science Technology and the Arts*, Bristol, UK 2004.

[49] Palazzi, C. and Maggiorini, D. 'From playgrounds to smart phones: mobile evolution of a kid's game', *IEEE in Consumer Communications and Networking Conference (CCNC)*, Padova, Italy, pp. 182-186, 2011.

[50] Deponti, D., Maggiorini, D. and Palazzi, C. 'Droidglove: an android-based application for wrist rehabilitation', *International Conference on in Ultra Modern Telecommunications Workshops (ICUMT)*, St. Petersburg, Russia, pp. 1-7, 2009.

[51] Li, X., Ortis, P. *et al.* 'Smartphone evolution and reuse: establishing a more sustainable model', *39th International Conference on Parallel Processing Workshops (ICPPW)*, California, USA, pp. 476-484, 2010.

[52] Hoppe, U., Lingnau, A. *et al.* 'Supporting collaborative activities in computer integrated classrooms-the NIMIS approach', *Proceedings 6th International Workshop on Groupware*, Duisburg University, Germany, pp. 94-101, 2000.

[53] Chien, C. and Xu, Z. 'Topics in integrated circuits for communication' in *IEEE Journals and Magazines*, vol. 50, no. 10, pp. 106–107, 2012.

[54] 'Better living through software: Microsoft advances for the home highlighted at consumer electronics show 2002', [Online], Available: <http://www.microsoft.com/en-us/news/features/2002/jan02/01-08msces.aspx>

[55] 'Smartphone evolution: from IBM Simon to Samsung Galaxy s3', [Online] Available: <http://www.ibtimes.com/smartphone-evolution-ibm-simon-samsunggalaxy-s3-697340#>

[56] iPhone 5 [Online] Available at: http://en.wikipedia.org/wiki/IPhone_5

[57] Pieterse, H. and Olivier, M. 'Android botnets on the rise: trends and characteristics', *Information Security for South Africa (ISSA)*, Pretoria, South Africa, pp. 1-5, 2012

[58] 'ISO/IEC 9126 in practice: what do we need to know'? [Online] Available at: <http://www.essi.upc.edu/~webgessi/publicacions/SMEF%2704-ISOQualityModels.pdf>

[59] Fetaji, M. Dika, Z. and Fetaji, B. 'Usability testing and evaluation of a mobile software solution: a case study', *Proceedings 30th International Conference on Information Technology Interfaces*, Cavtat, Croatia, pp. 501-06, 2008.

[60] Ab Hamid, S. and Fung, L. (2007) Learn programming by using mobile edutainment game approach. *International Workshop on Digital Game and Intelligent Toy Enhanced Learning*, pp. 170-172.

WHY ARE SOME OF THE REFERENCES NUMBERED AND OTHERS NOT? YOU HAVE A REF TO 107 IN THE TEXT?

Bibliography

A-RAGE.COM (2008) (last accessed November 2, 2008) A-Rage: Augmented Reality Gaming Engine. <http://www.a-rage.com/>.

ACOUSTIGUIDE (2008) (last accessed November 2, 2008)

<http://www.acoustiguide.com/new/index.html>.

Adamchik, V. and Gunawardena, A. (2003) *A LOs approach to teaching programming*. International Conference on Information Technology: Computers and Communications.

Albaum, G. (1997) The Likert scale revisited: an alternate version. *Journal of the Market Research Society*, 39, 331-343.

Albertini, A., Brunelli, R., Stock, O. and Zancanaro, M. (2005) *Communication User's Focus of Attention by Image Processing as Input for a Mobile Museum Guide*. 10th International Conference on Intelligent User Interfaces IUI '05. San Diego, California, USA, New York, NY, 299-301.

Alkouz, A. (2006) *Web services-based LOs generator for device-independent m-learning*. International Conference on Mobile and Collaborative Learning, vol. 1, no. 2, pp. 1-3.

Allert, J. (2004) *Learning style and factors contributing to success in an introductory computer science course*. International Conference on Advanced Learning Technologies, pp. 385-389.

Ambrose, T. and Paine, C. (2006) *Museum basics*. London and New York: Routledge.

Anastassova, M. (2006) *L'analyse ergonomique des besoins en amont de la conception de technologies émergentes: Le cas de la Réalité Augmentée pour la formation à la maintenance automobile*. PhD Thesis. Paris, Université René Descartes – Paris 5.

Anastassova, M., Burkhardt, J.-M. and Megard, C. (2007a) User-Centered Design and Evaluation of Augmented Reality Systems for Industrial Applications. In RICHIR, S. (Ed.) *VRICLaval Virtual Proceedings 2007*, Laval, France, 215-224.

Anastassova, M., Megard, C. and Burkhardt, J.-M. (2007b) Prototype Evaluation and User-Needs Analysis in the Early Design of Emerging Technologies. *Human Computer Interaction 2007*. Beijing, China, Springer-Verlag, 383-392.

Anastopoulou, S. and Sotiriou, S. (Eds.) (2005) *Connect: Designing the classroom of tomorrow by using advanced technologies to connect formal and informal learning environments*. Implementation Guide, Athens, Greece, Epinoia S.A.

Assemblée Nationale (2000), Archives de la XIème Législature, N° 2418, Constitution du 4 Octobre 1958, Onzième législature, Enregistré à la Présidence de l'Assemblée nationale le 25 Mai 2000.

Aoki, M., Woodruff, A., Hurst, A. and Szymanski, M. H. (2001) Electronic guidebooks and visitor attention. In *International Cultural Heritage Informatics Meeting (ICHIM 2001)*, Milan, Italy.

Aoki, M.P. and Woodruff, A. (2001) Improving electronic guidebook interfaces using a task-oriented design approach. In *Symposium on Designing Interactive Systems, Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods and Techniques*, (2000), ACM Press, 319-325.

ARTAG (2008) (last accessed February 27th 2009), ARTag Homepage, <http://www.artag.net/>.

ARTOOLKIT (2008) (last accessed February 27th 2009), ARToolkit Homepage. <http://www.hitl.washington.edu/artoolkit/>.

Arvanitis, K. (2005) 'Imag(in)ing the everyday: using camera phones to access the everyday meanings of archaeological monuments', In Perrot, X. (Ed.) *Digital Culture and Heritage, ICHIM 2005*. Paris 21-23 Sept. 5, Archives and Museum Informatics, available at http://www.archimuse.com/publishing/ichim05/arvanitis_paper.pdf

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

Attewell, J. Technology Enhanced Learning Research Centre, *From Research and Development to Mobile Learning: Tools for Education and Training Providers and their Learners* PUBLISHER? DATE?

Attewell, J. and Savill-Smith, C. (2004) Mobile learning and social inclusion: focusing on learners and learning. *LSDA Learning with Mobile Devices: Research and Development*, pp. 3-12.

Avellis, G., Scaramuzzi, A. and Finkelstein, A. (2003) Evaluating non-functional requirements in mobile learning contents and multimedia educational software. *World Conference on mLearning*, University of Wolverhampton, UK.

Azuma, R. (1993) Tracking Requirements for Augmented Reality. *Communications of the ACM*, 7 (Jul. 1993), 50-51.

Azuma, R. (1997) A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments*, 6, 355-385.

Bachmair, B., Pachler, N. and Cook, J. (2009) Mobile phones as cultural resources for learning – an analysis of mobile expertise, structures and emerging cultural practices. *Zeitschrift für Theorie und Praxis der Medienbildung* ISSN 1424-3636.

Baseed, E. I., Berri, J., Zemerly, M. J. and Benlamri, R. (2007) Web-based contextaware m-learning architecture. *International Journal of Interactive Mobile Technologies*, vol. 1, no. 1, pp. 1-6.

Back, M., Cohen, J., Gold, R., Harisson, S. and Minneman, S. (2001) Listen reader: an electronically augmented paper-based book. In *Conference on Human Factors in Computing Systems, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Seattle, Washington, United States, 2001), 23-29.

Balog, A. (2007) Augmented Reality in Schools: Preliminary Evaluation Results from a Summer School. *Proceedings of World Academy of Science, Engineering and Technology*, 24, 114-117.

Baron, S., Patterson, A. and Harris, K. (2006) Beyond technology acceptance: understanding consumer practice. *International Journal of Service Industry Management*, 17, 111-135.

Bartneck, C., Masuoka, A., Takamashi, T. and Fukaya, T. (2006) The Learning Experience with Electronic Museum Guides. *Psychology of Aesthetics, Creativity and the Arts*, 5 (1), 18-25.

- BBC (2008) (last accessed November 15th, 2008) Take One Museum. http://www.bbc.co.uk/sn/tvradio/programmes/take_one/.
- Beale, R. and Lonsdale, P. (2004) Mobile context-aware systems: the intelligence to support tasks and effectively utilise resources. *Lecture Notes in Computer Science: Mobile HCI*, pp. 240-251.
- Becking, D., Betermieux, S., Bomsdorf, B., Birgit, F., Heuel, E., Langer, P. and Schlageter, G. (2004) Didactic profiling: supporting the mobile learner. In *G.Richards (Ed.), World Conference on E-learning in Corporate, Government, Healthcare, and Higher Education*, Chesapeake, VA: AACE, pp. 1760-1767.
- Been-Lirn Duh, H., Tan, G. C. B. and Chen, V. H.-H. (2006) Usability Evaluation for Mobile Device: A Comparison of Laboratory and Field Tests. In *Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services* (Helsinki, Finland, September 12–15, 2006). MobileHCI '06, vol. 159. ACM, New York, NY, 181-186.
- Bellotti, F., Berta, A., De Gloria, A. and Margarone, M. (2003) Supporting efficient design of mobile HCI. *Mobile HCI 2003, Conference on Human Computer Interaction with Mobile Devices. (MobileHCI)*, September 2003, Udine, Italy. Springer Verlag, 241-255.
- Bellotti, F., Berta, R., De Gloria, A., Ferretti, E. and Margarone, M. (2004) Microgames for a compelling interaction with cultural heritage. In *International Cultural Heritage Informatics Meeting, ICHIM 2004*, Berlin, Archives and Museum Informatics.
- Bellotti, F., Berta, R., De Gloria, A. and Margarone, M. (2002) User Testing a Hypermedia Tour Guide. *Pervasive Computing*, 1, 2 (Apr. 2002), 33-41.
- Benko, H., Ishak, E. and Feiner, S. (2004) Collaborative Mixed Reality Visualisation of an Archaeological Excavation. In *Proceedings of the 3rd IEEE/ACM international Symposium on Mixed and Augmented Reality (November 02–05, 2004). Symposium on Mixed and Augmented Reality. IEEE Computer Society*, Washington, DC, 132-140.
- Berger, M. (2004) *Museums of tomorrow: a virtual discussion*, New York: Distributed Art Publishers
- Chalk, P. and Qi, M. (2005) Java LOs: a cross-cultural perspective. *Conference on Java and the Internet in the Computing Curriculum*.
- Berk, R. and Berk, S. (1979) *Labor and leisure at home: content and organisation of the household day*. Beverley Hills, CA: Sage.
- Bhaskar, N. and Govindarajulu, P. (2008) A design methodology for acceptability analyser in context-aware adaptive mobile learning systems development. *International Journal of Computer Science and Network Security*, vol. 8, no. 3, pp. 130-138.
- Bird, P. (2009) Methodological Issues in a Study of Mobile Learning as a Disruptive Innovation. Project report available at: www.edamba.eu/userfiles/file/Bird%20Peter.pdf.

- Bisignano, M., Modica, G. and Tomarchio, O. (2005) Dynamic user interface adaptation for mobile computing devices. *Symposium on Applications and the Internet Workshops*, pp. 158-161.
- Bloom, B.S. (Ed.) (1956) Taxonomy of educational objectives: the classification of educational goals: handbook I, cognitive domain. *New York; Toronto: Longmans, Green*.
- Bomsdorf, B. (2005) Adaptation of learning spaces: supporting ubiquitous learning in higher distance education. *Dagstuhl Seminar Proceedings 05181. Mobile Computing and Ambient Intelligence: The Challenge of Multimedia*.
- Boticki, I., Hoic-Bozic, N. and Budisak, I. (2009) A system architecture for a context-aware blended mobile learning environment. *Journal of Computing and Information Technology*, vol. 17, no. 2, pp. 165-175.
- Bouzeghoub, A., Do, K. N. and Lecocq, C. (2007) Contextual adaptation of learning resources. *IADIS International Conference Mobile Learning*, pp. 41-48.
- Boyatt, R., Brose, F., Hansen, S. and Skepper, C. (2003) Online Computer Teaching Aid Project Report. *Unpublished MEng Dissertation, University of Warwick*.
- Bradley, C., Haynes, R., Boyle, T., Cook, J. and Smith, C. (2007) Multimedia LOs for mobiles. *IADIS International Conference Mobile Learning*, pp. 65-72.
- Bradley, C., Haynes, R., Cook, J., Boyle, T. and Smith, C. (2009) Design and development of multimedia LOs for mobile phones. *Mobile learning: transforming the delivery of education and training*, pp. 157-182.
- Brennan, M. (2005) Teaching undergraduate programming using LOs. *EU Minerva funded project paper*.
- Briggs, K. and Myers, I. (1977) *Myers-Briggs Type Indicator*. Palo Alto, CA: Consulting Psychologist Press, Inc.
- Brown, B. and Crawshaw, T. (1998) Electronic diaries: how they are used, advice for implementation and a review of products. *JISC Technology Applications Program: Report 20*.
- Brown, J.S. (1999) Learning, working and playing in the digital age. *Conference on Higher Education of the American Association of Higher Education*.
- Brown, P. J. The stick-e document: a framework for creating context-aware applications, *Electronic Publishing*, vol. 8(2 and 3), 259–272 (June and September 1995)
- Burrell, J., Gay, G. K., Kubo, K. and Farina, N. Context-Aware Computing: A Test Case JOURNAL? PUBLISHER? DATE?
- Bull, S. and Reid, E. (2004) Individualised revision material for use on a handheld computer. *Learning with Mobile Devices: Research and Development*, pp. 35-42.

- Chan, T., Sharples, M., Vavoula, G. and Lonsdale, P. (2004) Educational metadata for mobile learning. *International Workshop on Wireless and Mobile Technologies in Education*, pp. 197.
- Chandler, P. and Sweller, J. (1992) The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology*, vol. 62, pp. 233-246.
- Cheah, H. (2002) Anywhere, anytime, any kind. Towards a sustainable learning system. *International Conference on Computers in Education*, pp. 1518.
- Chen, G. and Kotz, D. (2000) A survey of context-aware mobile computing research. *Dartmouth Computer Science Technical Report TR2000-381*.
- Chen, C. H. and Chou, H. W. (2007) Location-aware technology in Chinese language learning. *IADIS International Conference Mobile Learning*, pp. 189-193.
- Chen, C. M., Li, Y. L. and Chen, M. C. (2007a) Personalised context-aware ubiquitous learning system for effectively supporting English vocabulary learning. *International Conference on Advanced Learning Technologies*, pp. 628-630.
- Chen, C. M., Huang, T. C., Li, T. H. and Huang, C. M. (2007b) Personalised e-learning system with self-regulated learning assisted mechanisms for promoting learning performance. *International Conference on Advanced Learning Technologies*, pp. 637-638.
- Chen, Y. S., Kao, T. C., Sheu, J. P. and Chiang, C. Y. (2002) A mobile scaffolding-aid based bird-watching learning system. *International Workshop on Mobile Technologies in Education*, pp. 15-23.
- Chen, Y. S., Kao, T. C., Yu, G. J. and Sheu, J. P. (2004) A mobile butterfly-watching learning system for supporting independent learning, *International Workshop on Mobile Technologies in Education*, pp. 11-18.
- Cheverst, K., Davies, N., Mitchell, K., Friday, A. and Efstratiou, C. Developing a Context-Aware Electronic Tourist Guide: Some Issues and Experiences, Proc. CHI, The Hague, Netherlands, April 2000
- Cheverst, K., Davies, N., Mitchell, K. and Smith, P. (2000) Providing tailored (context-aware) information to city visitors. *Lecture Notes in Computer Science, Springer-Verlag*, vol. 1892, pp. 73-85.
- Claessens, B. (2004) Perceived control of time: time management and personal effectiveness at work. *PhD Thesis. Technical University of Eindhoven, Netherlands*.
- Code, J. R., MacAllister, K., Gress, C. L. Z. and Nesbit, J. C. (2006) Self-regulated learning, motivation and goal theory: implications for instructional design and elearning. *International Conference on Advanced Learning Technologies*, pp. 872-874.
- Coffield, F., Moseley, D., Hall, E. and Ecclestone, K. (2004) LS and pedagogy in post-16 learning. A systematic and critical review. *Learning and Skills Research Centre*, ref no. 041543.

- Cohen, L., Manion, L. and Morrison, K. (2007) Research methods in education. *Routledge Taylor and Francis Group. London and New York.*
- Colbert, M. (2001) A diary study of rendezvousing: implications for position-aware computing and communications for the general public. *International Conference on Supporting Group Work*, pp. 15-23.
- Conde, M., Munoz, C. and Garcia, F. (2008) mLearning: first step in the learning process revolution. *Journal of Interactive Mobile Technologies*, vol. 2, no. 4, pp. 62-64.
- Cooley, M., Whitaker, N. and Coombs, P.H. (1985) The world crisis in education: a view from the eighties. *New York: Oxford University Press.*
- Cooney, G. (2008) Voice: the killer application of mobile learning. *The ECAR Study of Undergraduate Students and Information Technology*
<http://www.upsidelearning.com/blog/index.php/2009/11/02/top-50-mobile-learningresources/>
- Cope, A. and Jorgenson, M. (2009) Overview of location technologies. JANET Network Access Programme. PUBLISHER?
- Corlett, D., Sharples, M., Chan, T. and Bull, S. (2004) A mobile learning organiser for university students. *International Workshop on Wireless and Mobile Technologies*, pp. 35-42.
- Corlett, D., Sharples, M., Bull, S. and Chan, T. (2005) Evaluation of a mobile learning organiser for university students. *Journal of Computer Assisted Learning*, vol. 21, no. 3, pp. 162–170.
- Costa, P., Almeida, J., Pires, L. Guiszardi, G. and Sinderen, M. (2006) Towards conceptual foundations for context-aware applications. *Artificial Intelligence for Interactive Digital Entertainment Conference.*
- Cui, Y. and Bull, S. (2005) Context and learner modelling for the mobile foreign language learner. *Science Direct, System 33 (2005)*, pp. 353-367.
- Curry, L. (1987) Integrating concepts of cognitive or LS: a review with attention to psychometric standards. *Ottawa: Canadian College of Health Service Executives.*
- Dawson, F. and Stenerson, D. (1998) Internet calendaring and scheduling core object specification (iCalendar). *The Internet Society.* <http://tools.ietf.org/html/rfc2445> [11/08/09]
- Deci, E. and Ryan, R. (1985) *Intrinsic motivation and self-determination in human behaviour.* New York, NY: Plenum.
- Defude, B. and Farhat, R. (2005) A framework to design quality-based learning objects. *International Conference on Advanced Learning Technologies*, pp. 23-27.
- DeLongis, A., Hemphill, K. J. and Lehman, D. R. (1992) *Methodological issues in applied psychology.* Edited by Bryant et al. Plenum Press, New York.

- Dey, A. and Abowd, G. (1999) Towards a better understanding of context and context awareness. *Lecture Notes in Computer Science*, Springer-Verlag, vol. 1707, pp. 304-307.
- Dey, A.K. Context-Aware Computing: The CyberDesk Project. AAAI 1998 Spring Symposium on Intelligent Environments, Technical Report SS-98-02 (1998) 51-54.
- Dochev, D. and Hristov, I. (2006) Mobile learning applications – ubiquitous characteristics and technological solutions. *Cybernetics and Information Technologies*, vol. 6, no. 3, pp. 63-74.
- Drury, A. (1999) Report on the use of electronic diaries and personal digital assistants on the Salford Royal Hospitals NHS Trust academic network system. *Salford Royal Hospitals NHS Trust*.
- Dumbraveanu, R. and Balmus, N. (2006) Using LOs in teaching science. *Proceedings of IMCL'06*. Amman, Jordan.
- Dunn, R. and Dunn, K. (1978) *Teaching students through their individual LS: A practical approach*. Reston, VA: Prentice-Hall.
- El-Sofany, H. and El-Seoud, S. (2009) Towards the development of an m-learning system: a new stage to enhance higher education. *International Journal of Interactive Mobile Technologies*, vol. 3, no. 3, pp. 4-9.
- Eraut M. (2000) Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, vol. 70, pp. 113-136.
- Facer, K., Joiner, R., Stanton, D., Reid, J., Hull, R. and Kirk, D. (2004) Savannah: mobile learning and gaming? *Journal of Computer Assisted Learning*, vol. 20, pp. 399-409.
- Felder, R. and Silverman, L. (1988) LS and teaching styles in engineering education. *Engineering Education*, vol. 78, no. 7, pp. 674-681.
- Fithian, R., Iachello, G., Moghazy, J., Pousman, Z. and Stasko, J. (2003) The design and evaluation of a mobile location-aware handheld event planner. *International Conference on Human Computer Interaction with Mobile Devices and Services*, pp. 145-160.
- Frohberg, D. (2006) Mobile learning is coming of age – what we have and what we still miss. *DELFI: 4. e-learning Fachtagung Informatik der Gesellschaft für Informatik*, pp. 327-338.
- Frohberg, D. (2008) Mobile learning. *Phd thesis. University of Zurich*. (in German)
- Gang, Z. and Zongkai, Y. (2005) Learning resource adaptation and delivery framework for mobile learning. *IEEE Frontiers in Education Conference*, pp. 18-24.
- Garcia, P., Amandi, A., Schiaffino, S. and Campo, M. (2005) Using Bayesian networks to detect students' LS in a web-based education system. *Simpósio Argentino de Inteligencia Artificial*, pp. 115-126.

- Gardner, H. (1993) *Multiple intelligences: the theory in practice*. New York: Basic Books.
- Gillham, R. (2005) Diary studies as a tool for efficient cross-cultural design. *Amberlight Human Computer Interactions White Paper*.
- Goh, D., Sun, A., Zong, W., Wu, D., Lim, E., Theng, Y., Hedberg, J. and Chang, C. (2005) Managing geography LOs using personalised project spaces in G-portal. *Research and Advanced Technology for Digital Libraries*, pp. 336–343.
- Goh, T., Kinshuk and Lin, T. (2003) Developing an adaptive mobile learning system. *International Conference on Computers in Education*, pp. 1062-1065.
- Graetz, K. (2006) Learning spaces. *An Educause e-book*.
<http://www.educause.edu/books/learningspaces/10569> [30/06/09]
- Graf, S. and Kinshuk (2006) An approach for detecting LS in learning management systems. *International Conference on Advanced Learning Technologies*, pp. 161-163.
- Graf, S. (2007) Adaptivity in learning management systems focusing on LS. *PhD thesis. Vienna University of Technology, Austria*.
- Graham, C., Cagiltay, K., Craner, J., Lim, B. and Duffy, T. (2000) Teaching in a web-based distance-learning environment: an evaluation summary based on four courses. *CRLT Technical Report No. 13 00*.
- Grasso, A. and Roselli, T. (2005) Guidelines for designing and developing contents for mobile learning. *International Workshop on Wireless and Mobile Technologies in Education*, pp. 123-127.
- Grigoriadou, M., Papanikolaou, K. A., Tsaganou, G., Gouli, E. and Gogoulou, A. (2006) eCompetence skills for adaptive learning environments in higher education. *The Challenge of eCompetence in Academic Staff Development*.
- Hartnell-Young, E. and Jones, P. (2004) Mobile Law and e-Portfolios, *The Knowledge Tree*,
<http://www.flexiblelearning.net.au/knowledgetree/edition06/download/Hartell-YoungandJones.doc> [19/8/2010].
- IEEE LTSC (2005) WG12 – Learning object metadata. <http://ltsc.ieee.org/wg12/> [12/08/09]
- Jones, G. and Brown, P. (2002) Challenges and opportunities for context-aware retrieval on mobile devices. *ACM Conference on Research and Development in Information Retrieval*.
- Jones, Q., Grandhi, S., Whittaker, S., Chivakula, K. and Terveen, L. (2004) Putting systems into place: a qualitative study of design requirements for location-aware community systems. *ACM Conference on Computer Supported Cooperative Work*, vol. 6, no. 3, pp. 202-211.
- Joy, M., Muzykantskii, B., Rawles, S. and Evans, M. (2002) An Infrastructure for Web-based Computer-Assisted Learning. *ACM Journal on Educational Resources in Computing*, vol. 2, no. 4, pp. 1-19.

- Jung, H., Park, S. and Chung, K. (2006) An architecture for adaptive mobile learning. *International Conference on Advanced Information Networking and Applications*, pp. 219-223.
- Kaenampornpan, M. and O'Neill, E. (2004) An integrated context model: bringing activity to context. *Advanced Context Modelling, Reasoning and Management: UbiComp*.
- Karagiannidis, C. and Sampson, D. (2004) Adaptation rules relating learning style research and learning object metadata. *Workshop on Individual Differences in Adaptive Hypermedia. International Conference on Adaptive Hypermedia and Adaptive Web-based Systems*.
- Kay, R. (2007) A systematic evaluation of LOs for secondary school students. *Journal of Educational Technology Systems*, vol. 35, no. 4, pp. 411-448.
- Hartner, M., Amon, C. and Peschl, M. (2003) Qualitative expert interview study for identifying factors to promote the innovation potential of employees. http://www.greenfield.at/pdf/abstract_expert_interviews.pdf [06/09/09]
- Harvey, A. and Singleton, J. (1989) Canadian activity patterns across the life span: a time budget perspective. *Canadian Journal of Age*, vol. 8, no. 3, pp. 268-285.
- Heinze, A. and Procter, C. (2004) Reflections on the use of blended learning education. *Education in a Changing Environment*, University of Salford, UK.
- Hellman, D. (2007) Working with IMAP and iCalendar. *Python Magazine*. <http://www.doughellmann.com/articles/mailbox2ics/> [12/08/09]
- Herrington, A., Herrington, J. and Mantei, J. (2009) Design principles for mobile learning. *New technologies, new pedagogies: Mobile learning in higher education*, pp. 129-138.
- Hine, N., Rentoul, R. and Specht, M. (2004) Collaboration and roles in remote field trips. *LSDA Learning with Mobile Devices: Research and Development*, pp. 69-72.
- Honey, P. and Mumford, A. (1992) *The manual of LS*. Berkshire: Honey, Ardingly House.
- Honey, P. (2001) Honey and Mumford LS Questionnaire. <http://www.peterhoney.com/product/learningstyles> [08/03/06]
- Houser, C., Thornton, P. and Kluge, D. (2002) Mobile learning: cell phones and PDAs for education. *International Conference on Computers in Education*, pp. 1149-1150.
- Hwang, G. J. (2006) Criteria and strategies of ubiquitous learning. *International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing*, pp. 72-77.
- Hwang, H. A., Lim, Y., Lim, H. and Kim, J. T. (2006) An individualised and self-regulated e-learning system. www.ucmss.com/books/LFS/CSREA2006/EEE3127.pdf
- Koumpis, A., Karagiannidis, C. and Stephanidis, C. (1996) Adaptations of the text media type:

- addressing the user's perspective. *International Workshop on Multimedia Software Development*, pp. 160.
- Kristine, P. (2005) Learning on the move – mobile technologies in business and education. Australian Flexible Learning Framework. LOCATION?
- Kukulska-Hulme, A. and Traxler, J. (2005) *Mobile learning – a handbook for educators and trainers*. F. Lockwood, Ed. London: Routledge.
- Kukulska-Hulme, A. (2007) Mobile usability in educational contexts: what have we learnt? *International Review of Research in Open and Distance Learning*, vol. 8, no. 2, pp. 1-16.
- Laouris, Y. and Eteokleous, N. (2005a) We need an educationally relevant definition of mobile learning. *World Conference on mLearning*. Cape Town, South Africa.
- Laouris, Y. and Eteokleous, N. (2005b) Successful implementation of m-learning depends on well-defined requirements. *IADIS International Conference Mobile Learning*.
- Laroussi and Derycke (2009) Extending LIP to provide an adaptive mobile learning. *International Journal of Interactive Mobile Technologies*, vol. 3, no. 1, pp. 22-31.
- Lee, M. C., Ye, D. Y. and Wang, T. I. (2005) Java learning object ontology. *International Conference on Advanced Learning Technologies*, pp. 538-542.
- Leeder, D., Boyle, T., Morales, R., Wharrad, H. and Garrud, P. (2004) To boldly GLO – towards the next generation of LOs. In G. Richards (Ed.), *Proceedings of World Conference on E-learning in Corporate, Government, Healthcare, and Higher Education* (pp. 28-33). Chesapeake, VA: AACE.
- Lelouche, R. (2002) Communication is not easy! Can the computer help second language learners and teachers? *International Conference on Computers in Education*, pp. 419-420.
- Leung, C. (2002) Extensive reading and language learning: a diary study of a beginning learner of Japanese. *Reading in a Foreign Language*, vol. 14, no. 1, pp. 66-81.
- Li, B., Salter, J., Dempster, A. and Risos, C. (2006) Indoor positioning techniques based on wireless LAN. *International Conference on Wireless Broadband and Ultra Wideband Communications*, paper 113.
- Lieberman, H. and Selker, T. Out of Context: Computer Systems That Adapt to, and Learn From, Context, MIT Media Laboratory, August 2002.
- Lockett, B. (2005) *Mobile learning*. 3T Productions Limited.
- Lonsdale, P., Beale, R. and Bryne, W. (2005) Using context-awareness to enhance visitor engagement in a gallery space. *People and Computers XIX — The Bigger Picture*: Springer London, pp. 101-111.
- Lozanov, G. (1979) *Suggestology and outlines of suggestopedy*. Gordon and Breach Science Publishers, New York.

- Luckin, R. and du Boulay, B. *et al.* (2005) Using Mobile Technology to Create Flexible Learning Contexts. *Journal of Interactive Media in Education* 2005 (22).
- Mac Labhrainn, I., Hall, B. and Pittman, J. (2005) The effectiveness of knowledge technologies in accommodating LS. *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, pp. 972-977.
- Magal-Royo, T., Peris-Fajarnes, G., Montanana, I. and Garcia, B. (2007) Evaluation methods on usability of m-learning environments. *IEEE Interdisciplinary Engineering Education Magazine*, vol. 2, no. 2, pp. 34-37.
- Mahmud, Z. and Rahim, R.A. (2002) Investigating patterns of interview conversations among lecturers in the Malaysian institutes of higher learning on the teaching of statistics at the introductory level. *International Conference on Teaching Statistics*.
- Maiden, N. and Rugg, G. (1996) ACRE: selecting methods for requirements acquisition. *Software Engineering Journal*, May 1996, pp. 183-192.
- Maniar, N. (2007) Media influence on mobile learning. *VideoFunet Conference*.
- Maniar, N. and Bennett, E. (2007) Overcoming ‘culture shock’ using a mobile learning application. *IADIS International Conference Mobile Learning*, pp. 159-162.
- Marmasse, N. and Schmandt, C. (2000) Location-aware information delivery with *comMotion*. *Lecture Notes in Computer Science, Springer-Verlag*, pp. 157-171.
- Martin, E., Carro, R. and Rodriguez, P. (2006a) Recommending activities in collaborative m-learning. *International Conference on Adaptive Hypermedia and Adaptive Web-based Systems*.
- Martin, E., Andueza, N. and Carro, R. (2006b) Architecture of a system for context-based adaptation in m-learning. *International Conference Advanced Learning Technologies*, pp. 252-254.
- Martin, E., Carro, R. and Rodriguez, P. (2006c) A mechanism to support context-based adaptation in m-learning. *European Conference on Technology Enhanced Learning*, pp. 302-315.
- Martin, E. and Carro, R. (2009) Supporting the development of mobile adaptive learning environments: a case study. *IEEE Transactions on Learning Technologies*, vol. 2, no. 1, pp. 23-36.
- Mayer, R. and Moreno, R. (2007) A cognitive theory of multimedia learning: implications for design principles. *Handbook of Applied Cognition*, Wiley.
- Max, M. (2006) iCalendar Packages for Python. <http://codespeak.net/icalendar/> [12/08/09]
- McAlpine, I., Wilson, K., Russell, C. and Cunningham, M. (2004) An online diary as a research and evaluation tool for first-year physics. In R. Atkinson, C. McBeath, D. Jonas-Dwyer and R. Phillips (Eds), pp. 616-622.

- McDonald Legg, C., Schneckenberg, D., Wildt, J., Galway: CELT.Guo, H., Gao, G., Ma, J., Li, Y. and Huang, R. (2008) Research of an adaptive system in mobile learning environment. *International Conference on Computers in Education*, pp. 659-663.
- McGreal, R. (2006) Implementing learning object metadata for mobile devices using CanCore. *Proceedings of the International Conference on Internet and Web Applications and Services*, Guadeloupe, French Caribbean.
- Meawad, F. E. and Stubbs, G. (2006) Towards large-scale deployment of adaptive mobile learning. *International Conference on Mobile and Collaborative Learning*.
- Meek, J. (2006) Adopting a life cycle approach to the evaluation of computers and information technology. *PhD Thesis. The University of Birmingham, UK*.
- Meek, J. and Sharples, M. (2001) A life cycle approach to the evaluation of learning technology. *Conference on Computer Assisted Learning*, pp. 195-196.
- Meisalo, V., Torvinen, S., Suhonen, J. and Sutinen, E. (2002) Formative evaluation scheme for a web-based course design. *Conference on Innovation and Technology in Computer Science Education*, pp. 130-134.
- Melis, E. and Andres, E. (2003) Global feedback in active math. *World Conference on E-learning in Corporate, Government, Healthcare, and Higher Education*, pp. 197-220.
- Meyer, B., Haywood, N., Sachdev, D. and Faraday, S. (2008) Independent learning: literature review. *Learning and Skills Network Research Brief*.
- Microsoft (2003) Module 1: Introduction to mobile device application development. *Msdn training*. <http://download.microsoft.com/download/1/0/c/10c18e4a-f88f-4c7eb40f-9abc80388620/course-2556-module-1.pdf> [13/08/09]
- Miller, H. (2007) On the move – how mobile employees are changing the workplace. http://www.hermanmiller.com/MarketFacingTech/hmc/research_summaries/pdfs/wp_MobileWorkers.pdf [19/08/10]
- Mirisaei, S. and Zin, A. (2009) A context-aware mobile organiser for university students. *Journal of Computer Science*, vol. 5, no. 12, pp. 898-904.
- Montalvo, F. and Torres, M. (2004) Self-regulated learning: current and future directions. *Electronic Journal Research in Educational Psychology*, vol. 2, no. 2, pp.1-34.
- Moshell, J. M. and Hughes, C. E., University of Central Florida, Virtual Environments for Academic Learning
- Moulin, C. and Piras, A. (2006) Enhancing mobile learning with geo-referenced LOs. *IADIS International Journal on WWW/Internet*, vol. 4, no. 2, pp. 16-30.
- Moura, A. and Carvalho, A. (2008) Mobile learning: teaching and learning with mobile phones and Podcasts. *International Conference Advanced Learning Technologies*, pp.631-633.

- Muir, D. (2001) Adapting online education to different LS. *National Educational Computing Conference, 'Building on the Future'*, pp. 1-15.
- Mungunsukh, H. and Cheng, Z. (2002) An agent-based programming language-learning system. *International Conference on Computers in Education*, pp. 148-152.
- Murphy, A. (2006) Designing mobile learning. *International Conference on Internet and Web Applications and Services*.
- Nakabayashi, K. and Hoshide, T. (2007) Design and implementation of a mobile learning environment as an extension of SCORM 2004 specifications. *International Conference on Advanced Learning Technologies*, pp. 369-373.
- Naismith, L., Lonsdale, P., Vavoula, G. and Sharples, M. (2004) Literature review in mobile technologies and learning. *NESTA Futurelab Series, Report 11*.
- Najjar, J., Ternier, S. and Duval, E. (2004) Interoperability of learning object repositories: complications and guidelines. *IADIS International Journal on WWW/Internet*, vol. 2, no. 1, pp. 1-16.
- Nesbit, J. C., Belfer, K. and Leacock, T. (2003) *Learning object review instrument (LORI)*. E-learning Research and Assessment Network.
- Nokia (2003) Optimising the client/server communication of mobile applications, part 1. www.forum.nokia.com/.../Optimising_client_server_part3.pdf [08/09/09]
- Nino, C. P., Marques, J., Barbosa, D. N. F., Barbosa, J. L. V., Geyer, C. F. R. and Augustin, I. (2007) Context-aware model in a ubiquitous learning environment. *International Conference on Pervasive Computing and Communications*, pp. 182-186.
- Nissel, M. and Bonnerjea, L. (1982) Family care of the handicapped elderly: who pays? *London: Policy Studies Institute*.
- Norros, L., Kaasinen, E., Plomp, J. and Rämä, P. (2003) Human-technology interaction research and design. *VTT Roadmap, VTT Research Notes 2220*.
- O'Malley, C., Vavoula, G., Taylor, J., Sharples, M., Lefrere, P., Lonsdale, P., Naismith, L. and Waycott, J. (2005) D4.1 guidelines for learning in a mobile environment. *MOBIlearn/UoB.OU/wp4/d4.1/1.2*
- Ochoa, X. and Duval, E. (2006) Use of contextualised attention metadata for ranking and recommending LOs. *International ACM Workshop on Contextualised Attention Metadata*.
- Ogata, H. and Yano, Y. (2004a) Context-aware support for computer-supported ubiquitous learning. *International Workshop on Mobile Technologies in Education*, pp. 27-35.
- Ogata, H. and Yano, Y. (2004b) Knowledge awareness map for computer-supported ubiquitous language learning. *International Workshop on Mobile Technologies in Education*, pp. 19-26.

- Ogata, H., Yin, C. and Yano, Y. (2006) JAMIOLAS: supporting Japanese mimicry and onomatopoeia learning with sensors. *International Conference on Hybrid and Information Technology*, pp. 111-115.
- O'Malley, C. *et al.* Guidelines for Learning/Teaching/Tutoring in a Mobile Environment, 10/6/200, MOBIlearn <http://trainandgo.blogspot.com/2010/01/mobile-learning-in-cortina.html>, retrieved Mar. 3, 2012.
- Palmbald, M. and Tiplady, B. (2004) Electronic diaries and questionnaires: designing user interfaces that are easy for all patients to use. *Quality of Life Research*, vol. 13, pp. 1199-1207.
- Paredes, P. and Rodriguez, P. (2004) A mixed approach to modelling LS in adaptive educational hypermedia. *Special Issue on 'Innovations in Advanced Technology for Learning: Authoring for Adaptive Educational Hypermedia' of the ACTA Press' Advanced Technology for Learning'*.
- Park, H. (2005) Design and development of a mobile learning management system adaptive to learning style of students. *International Workshop on Wireless and Mobile Technologies in Education*, pp. 67-69.
- Park, H. (2008) The effect of information visualisation and structure on mobile learning. *Journal of the Research Center for Educational Technology*, vol. 4, no. 1, pp. 39-48.
- Parsons, D., Ryu, H. and Cranshaw, M. (2006) A study of design requirements for mobile learning environment. *International Conference on Advanced Learning Technologies*, pp. 96-100.
- Pedrazzoli, A. (2009) OPUS One – OLAT (An artificial intelligence – multi-agent-based adaptive learning system). *World Congress on Engineering and Computer Science*, pp. 567-573.
- Petrelli, D. and Not, E. (2005) User-centred design of flexible hypermedia for a mobile guide reflection on the hyperaudio experience. *User Modelling and User-Adapted Interaction: Springer Netherlands*, pp. 85-86.
- Pollock, E., Chandler, P. and Sweller, J. (2002) Assimilating complex information. *Learning and Instruction*, vol. 12, pp. 61-86.
- Pouzevara, S. and Khan, R. (2007) Learning communities enabled by mobile technology: a case study of school-based, in-service secondary teacher training in rural Bangladesh. *Asian Development Bank Project Report*.
- Prekop, P. and Burnett, M. (2003) Activities, context and ubiquitous computing. *Computer Communications* 26, pp. 1168-1176.
- Proctor, N. and Burton, J. (2004) Tate modern multimedia tour pilots 2002-2003. *Learning with Mobile Devices: Research and Development*, pp. 127-130.
- Quenter, A., Bludau H. B, Friederich H. C., Schild, S., Riepe, T. and Zipfel, S. (2009) Use of electronic diaries within treatment of obesity and binge eating disorder: first experiences. *Lecture*

Quinn, C. (2000). M-Learning: mobile, wireless, in-your-pocket learning. *LiNE Zine. Fall*. <http://www.linezine.com/2.1/features/cqmmwiyp.htm> [3/3/08]

Rapport d'information déposé en application de l'article 145 du Règlement par la commission des affaires culturelles, familiales et sociales sur les musées et présenté par M. Alfred Recours, Député.

Rarau, A., Pusztai, K. and Salomie (2005) Multi-facet item based context-aware applications. *International Journal of Computing and Information Sciences*, vol. 3, no. 2, pp. 10-18.

Raymond, S. and Ross, R. (2000) Electronic subject diaries in clinical trials. *Applied Clinical Trials*.

Riding, R. (1996) LS and technology-based training. *Department for Education and Employment: Sheffield*.

Rieman, J. (1993) The diary study: a workplace-oriented research tool to guide laboratory efforts. *INTERCHI, IOS Press*, pp. 321-326.

Ross, M. (1990) Time use in later life. *Journal of Advanced Nursing*, vol. 15, pp. 394- 399.

Ross, M., Rideout, E. and Carson, M. (1994) The use of the diary as a data collection technique. *Western Journal of Nursing Research*, vol. 16, no. 4, pp. 414-425.

Ryu, H., Brown, R., Wong, A. and Parsons, D. (2007) Personal learning organiser: designing a mobile learning experience for university students. *Conference on Mobile Learning Technologies and Applications*, pp. 23-30.

Ryu, H. and Parsons, D. (2008) A learner-centred design of a location-aware learning reminder. *International Journal of Mobile Learning and Organisation*, vol. 2, no. 2, pp. 187-200.

Sampson, D., Karagiannidis, C. and Kinshuk (2002) Personalised learning: educational, technological and standardisation perspectives. *Interactive Educational Multimedia*, no. 4, pp. 24-39.

Schilit, B. and Theimer, M. Disseminating Active Map Information to Mobile Hosts. *IEEE Network*, vol. 8, no. 5 (1994), pp. 22-32.

Schilit, B., Adams, N. and Want, R. (1994) Context-aware computing applications. *Workshop on Mobile Computing Systems and Applications*, pp. 88-90.

Schmidt, A., Beigl, M. and Gellesen, H. W. (1998) There is more to context than location. *International Workshop on Interactive Applications of Mobile Computing*, pp. 893-901.

Schmidt, A. (2000) Implicit human computer interaction through context. *Personal Technologies*, vol. 4, no. 2, pp. 191-199.

Schmidt, A. (2005) Potentials and challenges of context-awareness for learning solutions. *Workshop of the SIG Adaptivity and User Modelling in Interactive Systems*.

- Sedano, C., Laine, T., Vinni, M. and Sutinen, E. (2007) Where is the answer? – The importance of curiosity in pervasive mobile games. *Future Play 2007*.
- Shao, Y., Cook, C. and Koleva, B. (2007) Designing a mobile group blog to support cultural learning. *World Conference on mLearning*.
- Sharples, M. (2006) Big issues in mobile learning. *Kaleidoscope Network of Excellence Mobile Learning Initiative – Workshop Report*.
- Sheehy, K., Kukulska-Hulme, A., Twining, P., Evans, D., Cook, D., Jelfs., A., Ralston, J., Selwood, I., Jones, A., Heppell, S., Scanlon, E., Underwood, J. and McAndrew, P. (2005) Tablet PCs in schools – a review of literature and selected projects. *Becta ICT Research Report*.
- Shih, K. P., Kao, T. C., Chang, C. Y. and Chen, H. C. (2007) Development and evaluation of a self-regulatory-learning-cycle-based system for self-regulated e/mlearning. *International Conference Advanced Learning Technologies*, pp. 396-397.
- Shirota, Y. (2004) A metadata framework for generating web-based learning materials. *International Symposium on Applications and the Internet*, pp. 249.
- Siadat, M., Torniai, C., Gasevic, D., Jovanovic, J., Eap, T.M. and Hatala, M. (2008) m-LOCO: An ontology-based framework for context-aware mobile learning. *International Workshop on Ontologies and Semantic Web for E-learning*.
- Smith, B. L. and MacGregor, J. T. (1992) What is collaborative learning? *Collaborative Learning: A Sourcebook for Higher Education*, A. S. Goodsell, M. R. Maher and V. Tinto ed., Univ. Park, PA, National Center on Postsecondary Teaching, pp. 10-29.
- Smith, S. (2006) Creating mobile learning...? *Conference on Handhand Learning – Education on the Move*.
- Song, Y. (2007) Educational uses of handheld devices: what are the consequences? *Journal of Tech Trends*, vol. 51, no. 5, pp. 38-45.
- Song, Y. and Fox, R. (2008) Affordances of PDAs: undergraduate student perceptions. *Journal of the Research Center for Educational Technology*, vol. 4, no. 1, pp. 19-38.
- Stern, B. (2004) A comparison of online and face-to-face instruction in an undergraduate foundations of American education course. *Contemporary Issues in Technology and Teacher Education*, vol. 4, no. 2, pp. 196-213.
- Sun Microsystems (2009) Sun: Java-enabled devices top 1.5 billion. <http://www.java.net/pub/n/JavaTops1.5BDevices> [08/09/09]
- Sweller, J. (1994) Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, vol. 4, pp. 295-312.

- Swenson, P. (2002) Handheld computers and the standards, assessment, accountability movement. *International Conference on Computers in Education*, pp. 666-667.
- Sykes, E. (2003) An intelligent tutoring system prototype for learning to program Java. *International Conference on Advanced Learning Technologies*, pp. 485.
- Sykes, E. (2005) Qualitative evaluation of the Java intelligent tutoring system. *Journal on Systemics, Cybernetics and Informatics*, vol. 3, no. 5, pp. 49-60.
- Synnes, K., Nord, J. and Parnes, P. (2003) Location privacy in the Alipes platform, *International Conference on System Sciences*, pp. 10-19.
- Syvanen, A., Nokelainen, P., Pehkonen, M. and Turunen, H. (2004). Mobile Learning Future Views. In L. Cantoni and C. McLoughlin (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2004* (pp. 2112-2118). Chesapeake, VA: AACE.
- Takayama, K. (2003) Getting students to think like scientists: integration of science-specific graduate attributes into the curriculum. http://www.ltu.unsw.edu.au/content/userDocs/fye_2003_cooley.pdf [05/08/09].
- Taylor, H., Löber, J., Frohberg, A., Mwanza, D. and Murelli, E. (2003) Establishing user requirements for a mobile learning environment. *Conference Proceedings of Eurescom 2003*.
- Taylor, J., Mistry, V., Sharples, M., Bo, G. and Ahonen, M. (2002) D2.2 evaluation methodology. *MOBIlearn/OU/D2.2/1.0*.
- Tetard, F. and Patokorpi, E. (2004) Design of a mobile guide for educational purposes. *Conference on Mobile Human-Computer Interaction*.
- Ting, R. (2005) Mobile learning: current trends and future challenges. *International Conference on Advanced Learning Technologies*, pp. 603-607.
- Tiplady, B., G. K. Crompton and D. Brackenridge (1995) Electronic diaries for asthma. *BMJ*, 1995. 310 (6992): p. 1469.
- Traxler, J. (2005a) Defining mobile learning. *IADIS International Conference Mobile Learning*, pp 261-266.
- Traxler, J. (2005b) Strategic aspects of mobile and wireless learning. *Landscape Study in Wireless and Mobile Learning in the Post-16 Sector*.
- Traxler, J. (2009) Current State of Mobile Learning. *Mobile Learning – Transforming the Delivery of Education and Training*, pp. 9-24.
- Tsai, I., Young, S. and Liang, C. (2005) Exploring the course development model for the mobile learning context: A preliminary study. *International Conference on Advanced Learning Technologies*, pp. 437-439.

- Twining, P., Evans, D. *et al.* (2005) Tablet PCs in Schools – Case Study Report. Becta ICT Research Report. Ufi/learn direct and Kineo (2007) Mobile learning reviewed.
http://www.kineo.com/documents/Mobile_learning_reviewed_final.pdf [27/01/09]
- University of Warwick (2009) WiFi wireless hotspot locations.
<http://www2.warwick.ac.uk/services/its/servicessupport/campusnetwork/wifi/locations> [12/08/09]
- Valentine, E. (2004) Unplugged learning. *A report on the rise of mobile technology in learning.*
- Vargo, J., Nesbit, J. C., Belfer, K. and Archambault, A. (2003) Learning object evaluation: computer-mediated collaboration and inter-rater reliability. *International Journal of Computers and Applications*, vol. 25, no. 3, pp. 198-205.
- Vavoula, G. (2004) KLeOS: knowledge and learning organisation system in support of lifelong learning. *PhD Thesis. The University of Birmingham, UK.*
- Vavoula, G., Meek, J. *et al.* (2006) A lifecycle approach to evaluating MyArtSpace. *International Workshop on Wireless, Mobile and Ubiquitous Technology in Education*, pp. 18-22.
- Vavoula, G., Kukulska-Hulme, A. and Pachler, N. (2007a) Research methods in mobile and informal learning – how to get the data we really want. *Kaleidoscope Workshop.*
- Vavoula, G., Sharples, M., Rudman, P., Lonsdale, P. and Meek, J. (2007b) Learning bridges: a role for mobile technologies in education. *Journal of Educational Technology*, vol. 47, no. 3, pp. 33-36.
- Researching Mobile Learning Frameworks, tools and research designs (Eds.) (2009) Researching Mobile Learning Frameworks, tools and research designs. *Peter Lang.*
- Velasco, A., Carabias, J., Conde, M. A. and Garcia, F. J. (2007) Claynet: content adaptation in mobile learning. *IADIS International Conference Mobile Learning*, pp. 269-272.
- Wang, S. (2002) A study of designing a communication-technology course to facilitate English-learning. *International Conference on Computers in Education*, pp. 454-455.
- Wang, Y. (2004) Context-awareness and adaptation in mobile learning. *International Workshop on Mobile Technologies in Education*, pp. 154-158.
- Wang, Y., Jia, X. and Lee, H. K. (2003) An indoors wireless positioning system based on wireless local area network infrastructure. *International Symposium on Satellite Navigation Technology Including Mobile Positioning and Location Services. LOCATION?*
- Wattinger, C., Nguyen, D., Fornaro, P., Guggisberg, M., Gyalog, T. and Burkhart, H. (2006) Problem-based learning using mobile devices. *International Conference on Advanced Learning Technologies*, pp. 835-839.
- Waycott, J. (2004) The appropriation of PDAs as learning and workplace tools: an activity theory perspective. *PhD thesis. Open University, UK.*

Wentzel, P. (2005) Mobile learning in the Netherlands: possibilities of use of real-time database access in an educational fieldwork setting. *World Conference on Learning*. LOCATION?

Wentzel, P., van Lammeren, R., Molendijk, M., de Bruin, S. and Wagtendonk, A. (2005) Using mobile technology to enhance students' educational experiences. Case Study from Educause Center for Applied Research. LOCATION?

Wessel, D., Zahn, C. and Hesse, F. (2007) A mobile application to satisfy situational interest and support memory in informal settings. *Workshop 'Learning in Museums: International Positions'*. Knowledge Media Research Center, Tübingen.

Whitelaw, C., Sears, M., Law, D. and Campbell, K. (2002) Learning Technologies in Higher Education: Supporting Transformative Practice. *International Conference on Computers in Education*, pp. 705-706.

Wild, P. J., McMahon, C. A., Culley, S., Darlington, M. J. and Liu, S. (2005) A diary study in the engineering domain. *International Workshop on Understanding Designers*, pp. 181-196.

Wingkvist, A. and Ericsson, M. (2009) A meta-model describing the development process of mobile learning. *M. Spaniol et al. (Eds.): ICWL 2009, LNCS 5686*, pp. 454-463.

Winnie, P., Nesbit, J.C., Kumar, V., Hadwin, A., Lajoie, S.P., Azevedo, R. and Perry, N.E. (2006) Supporting self-regulated learning with g ? Study software: the learning kit project. *Technology, Instruction, Cognition and Learning*, 3.

Winters, N. and Price, S. (2004) Mobile HCI and the learning context: an exploration. *International Workshop on Context in Mobile HCI*. LOCATION?

Wu, T. T., Yang, T. C., Hwang, G. J. and Chu, H. C. (2008) Conducting situated learning in a context-aware ubiquitous learning environment. *International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, pp. 82-85.

Yang, S., Shao, N. and Sue, A. (2004) Personalised Metadata Mechanism Applied to Adaptive Mobile Learning. *International Workshop on Wireless and Mobile Technologies in Education*, pp. 168.

Yang, S. and Chen, I. (2006) Universal access and content adaptation in mobile learning. *International Conference Advanced Learning Technologies*, pp. 1172-1173.

Yang, M. C. (2007) An adaptive framework for aggregating mobile learning materials. *International Conference Advanced Learning Technologies*, pp. 180-182.

Yao, C. (2009) Context-aware customisation e-learning system with intelligent online examination mechanism. *International Conference on Interaction Sciences*, pp. 502-507.

Yau, J. (2004) LOs and the teaching of Java programming. *MSc thesis. University of Warwick, UK*.

Yau, J. (2010) Java LOs Experiment. Available at:

Yau, J. and Joy, M. (2004) Introducing Java: A Case for Fundamentals-first. *International Conference on Education and Information Systems, Technologies and Applications (EISTA)*, pp. 229-234.

Yau, J. and Joy, M. (2006a) Application of LS for Effective Mobile Learning. *IADIS International conference on Mobile Learning*, pp. 409-411.

Yau, J. and Joy, M. (2006b) Context-aware and adaptive learning schedule for mobile learning. *Mobile and Ubiquitous Learning Workshop, International Conference on Computers in Education*.

Yau, J. and Joy, M. (2007a) A context-aware and adaptive learning schedule framework for supporting learners' daily routines. *Mobile Communications and Learning Workshop, IEEE ICONS Conference*, pp. 31-37.

Yau, J. and Joy, M. (2007b) Architecture of a context-aware and adaptive learning schedule for learning Java. *International conference on Advanced Learning Technologies*, pp. 252-256.

Yau, J. and Joy, M. (2008) A self-regulated learning approach: a mobile context-aware and adaptive learning schedule (mCALS) tool. *International Journal of Interactive Mobile Technologies*, vol. 2, no. 3, pp. 52-57.

Yau, J. and Joy, M. (2009a) A mobile and context-aware learning schedule framework from a pedagogical perspective – an interview study. *IADIS International Conference Mobile Learning*, pp. 189-196.

Yau, J. and Joy, M. (2009b) A mobile context-aware framework for managing learning schedules – data analysis from an interview study. *International Journal of Mobile and Blended Learning*, vol. 1, no. 4, pp. 29-55.

Yau, J. and Joy, M. (2009c) A mobile and context-aware adaptive learning schedule framework from a usability perspective – a 'diary: diary-questionnaire' study. *International Conference on Computers in Education*, pp. 512-519.

Yau, J. and Joy, M. (2009d) A mobile context-aware framework for supporting self-regulated learners. *IADIS International Conference Cognition and Exploratory Learning in Digital Age*, pp. 415-418, Rome, Italy.

Yau, J. and Joy, M. (2010a) Designing and evaluating the mobile context-aware learning schedule framework: challenges and lessons learnt. *IADIS International Conference Mobile Learning*, pp. 85-92.

Yau, J. and Joy, M. (2010b) A context-aware personalised m-learning application based on m-learning preferences. *International Conference on Wireless, Mobile and Ubiquitous Technologies in Education*, pp. 11-18.

Yau, J., Joy, M. and Dickert, S. (2010c) A mobile context-aware framework for managing learning schedules – data analysis from a DIARY study. *Special Issue' Innovations in Designing Mobile*

Learning Applications' of the Journal of Educational Technology and Society, to appear.

Yin, C., Ogata, H. and Yano, Y. (2005) Ubiquitous-learning system for the Japanese polite expressions. *International Workshop on Wireless and Mobile Technologies in Education*, pp. 269-273.

Zawacki-Richter, O., Brown, T. and Delport, R. (2006) Mobile learning – a new paradigm shift in distance education? *World Conference on mLearning*.

Zhang, F. (2002) Implementing computer technology into the language learning process: what difference does it make? *International Conference on Computers in Education*, pp. 734.

Zhao, X. and Okamoto, T. (2008) A personalised mobile mathematics tutoring system for primary education, *Journal of the Research Center for Educational Technology*, vol. 4, no. 1, pp. 61-67.

Zimmerman, D. and Wieder, D. (1977) The diary: diary-interview method. *Urban Life*, vol. 5, no. 4, pp. 479-498.

Zimmerman, B.J., Bonner, S. and Kovach, R. (1996) Developing self-regulated learners: beyond achievement to self-efficacy. *American Psychological Association (APA)*.

Stamford, Conn., September 28, 2009. Augmented reality: a practical guide, pragmatic bookshelf introduction to Augmented Reality on smart phones

Appendix A

Some Interview Questions

Interviewer: Would you mind telling me how old you are and which year of studies you are attending at the university?

Student: *STUDENT COMMENTS?*

Interviewer: Let me write that down, first year...

Interviewer: So, how was it?

Student:

Interviewer: Was it easy or hard to locate the subjects?

Student:

Interviewer: OK. Do you think that the structure of the content was clear enough? I mean, the different thematic axes present for each item of content?

Student:

Interviewer: Was there anything that caused particular problems or a kind of presentation that was not easy to follow?

Student:

Interviewer: Do you think that it (the application) helped you to approach the subject, or did it, rather, distract you from contemplating the content or both at the same time?

Student:

Interviewer: It is very interesting for us to have all points of view and receive positive and negative comments for the system...so as to see what goes fine and what may be not so fine...

Student:

Interviewer: Was there any content that you enjoyed more than others?

Student:

Interviewer: Speaking generally, would you say that you like using the application often, regularly, a lot?

Student:

Interviewer: Is there any interpretative material that you prefer among others? Like text, audio?

Student:

Interviewer: How is your relationship with new technologies, like the Internet, mobile phones and similar gadgets?

Interviewer: Let's say that an application like that is available. Do you finally think that this is something that could help you to understand the context of the objects a bit better? Or do you think, on the contrary, that it would rather distract you? It's the one or the other? Or, maybe, both at the same time?

Student:

Interviewer: We feared that it might not be visible enough... We would really like to discuss other aspects like these with you in the workshop. But otherwise, do you think themes were comprehensible?

Interviewer: In terms of the structure of the content, were things clear enough?

Student:

Interviewer: Trying to make an abstraction, do you think that using the

guide was easy or too complicated?

Interviewer: And in terms of navigation in the information in this case and identification of information, with the combination of image and text, was it more or less difficult to go through the content?

Appendix B

- ***The Structure of the Interview Study***

The structure of the interview study will be designed and organised according to three coherent topics and collectively contain 30 interview questions.

Topic 1 – Significance of the proposed learning contexts

Participants will be asked whether they are aware of any learning preferences that they may have, whether it is important for them to learn according to these preferences and to give their opinions on having materials selected for them based on their learning preferences, their knowledge level, their current concentration level, the frequency of interruption at the location and their available time for the learning session.

Topic 2 – M-learning preferences – locations, mobile devices, learner characteristics

Participants will be asked about the locations where they normally study. Participants will then be asked if they sometimes have to study in undesirable places and what effects that had on their learning activities, which factors in a location affected their abilities to concentrate and how distractions or interruptions affected them during their studies. They were asked:

- About the computing devices and software that they utilised for their studies;
- Whether they would use a mobile device for engaging in learning/studying in different locations;
- Whether they would feel it was an intrusion and/or object to the use of GPS technologies for tracking their locations;

- To choose from a set of pre-defined scales to best describe their learner characteristics relating to how hard-working they are, how much they enjoy their studies, how conscientious they are, how soon they complete their work and how self-disciplined, organised and routine-structured they are.

A learner characteristics scale was created and participants were asked to choose between the given values to select the one that described them best, in their opinion, as follows:

☐ 1 – Very hard-working, 2 – Hard-working, 3 – Not so hard-working, 4 – Lazy

☐ 1 – Enjoys studies very much, 2 – Enjoys studies, 3 – Doesn't enjoy studies, 4 – Hates it

☐ 1 – Very conscientious, 2 – Conscientious, 3 – Careful, 4 – Careless

☐ 1 – Complete work ASAP, 2 – Last-week, 3 – Last-day, 4 – Last-minute

☐ 1 – Very self-disciplined, 2 – Quite self-disciplined, 3 – Not so self-disciplined

☐ 1 – Very organised, 2 – Quite organised, 3 – Not organised at all

☐ 1 – Very routine-structured, 2 – Semi-routine-structured, 3 – Spontaneous

Topic 3- Usability of the AR application

This section, comprising five closed-ended and two open-ended questions, is one of the most crucial regarding the main AR aspects of the prototype tested. More particularly,

the statements included in this section were intended to examine the overall ease of use of the application, the easiness of identifying the commented-upon works and the easiness of navigating the content.

- ***Interview Invitation***

Title (Augmented Reality and Context Awareness in M-learning)

You are invited to take part in the research project identified above.

Nouf Alotaibi (School of Computer Science) is conducting the research as part of her PhD under the supervision of Dr Jordan from the School of Electrical Engineering and Computer Science, Faculty of Technology at the University of DMU, United Kingdom.

Why is the research being done?

This research aims to study the effect of adopting context awareness and augmented reality in mobile learning system to increase the system usability. The research will proceed by studying if a more usable m-learning system increases learner engagement, which should lead to a better outcome of the learning process.

Who can participate in the research?

Only students of the course will take part in the research. Only half the number of students in the class will join.

What choice do you have?

Participation in this research is entirely your choice. Only those people who give their informed consent will be included. Whether or not you decide to participate, your

decision will not disadvantage you in any way. If you decide to participate, you may withdraw at any time without giving us a reason.

How will your privacy be protected?

All the collected data will be anonymous. Since the research group consists of peers, no personal data will be collected as the group members share the same characteristics. The questionnaire will be electronically filled and anonymously submitted.

How will the information collected be used?

Data will be analysed and used only for the purpose of constructing the questionnaire. It will contribute towards my PhD thesis.

What do you need to do to participate?

If you would like to participate, please complete the attached Consent Form and return it. We will then contact you to for further details.

Thank you very much for considering this invitation.

Augmented Reality and Context Awareness in M-learning Consent Form

Issue	Respondent's initial
I have read the information presented in the information letter about the	

study 'Augmented Reality and Context Awareness in M-learning.'	
I have had the opportunity to ask any questions related to this study and received satisfactory answers to my questions, and any additional details I wanted.	
I understand that the collected usage information will be used in publications and relevant discussions. I also understand that the collected data will be anonymous.	
I understand that correspondence to questionnaire will be anonymously collected and publicly shared.	
I understand that individuals may look at relevant sections of the data collected during the study from DMU University, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.	

With full knowledge of all the foregoing, I agree to participate in this study.

I agree to being contacted again by the researchers if my responses give rise to interesting findings or cross-references.

☐ No

☐ Yes

If yes, my preferred method of being contacted is:

☐ Telephone

☐ Email

☐ Other

Participant Name:		Consent taken by	
Participant Signature:		Signature	
Date		Date	

Appendix C

Part 1: Basic Information

1. Please select the learning object you studied:*
2. Date of Completion:*
3. Time of completion: (Hours:Minutes)*
4. Location of completion (such as lab, library, home, cafe, park, etc):*
5. Length of time required for completion (approx. in minutes):*
6. Please rate your motivation level during this study session:*

Part 2: Feedback of the Learning Object

Relating to the chosen set of parameters for the study of the learning object:

1. Please rate how useful the studying of this learning object was in the set of parameters (i.e. particular motivation level, amount of time required and Java knowledge level) that were chosen for it to be
2. Please rate how enjoyable your learning experience was:*
- Please provide a brief reason, if possible:
3. Was your learning experience more enjoyable or enhanced as a result of studying it in the proposed set of parameters:*
- Please provide a brief reason, if possible: