Automatic Detection of Learner-Style for Adaptive eLearning

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Abstract

The advent of modern wireless technologies has seen a shift in focus towards the design and development of educational systems for deployment through mobile devices. The use of mobile phones, tablets and Personal Digital Assistants (PDAs) is steadily growing across the educational sector as a whole. Mobile learning (mLearning) systems developed for deployment on such devices hold great significance for the future of education. However, mLearning systems must be built around the particular learner's needs based on both their motivation to learn and subsequent learning outcomes.

This thesis investigates how biometric technologies, in particular accelerometer and eye-tracking technologies, could effectively be employed within the development of mobile learning systems to facilitate the needs of individual learners. The creation of personalised learning environments must enable the achievement of improved learning outcomes for users, particularly at an individual level. Therefore consideration is given to individual learning-style differences within the electronic learning (eLearning) space. The overall area of eLearning is considered and areas such as biometric technology and educational psychology are explored for the development of personalised educational systems.

This thesis explains the basis of the author's hypotheses and presents the results of several studies carried out throughout the PhD research period. These results show that both accelerometer and eye-tracking technologies can be employed as an Human Computer Interaction (HCI) method in the detection of student learning-styles to facilitate the provision of automatically adapted eLearning spaces.

Finally the author provides recommendations for developers in the creation of adaptive mobile learning systems through the employment of biometric technology as a user interaction tool within mLearning applications. Further research paths are identified and a roadmap for future of research in this area is defined.

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Faithless is he that says farewell when the road darkens.
(J.R.R. Tolkien, The Fellowship of the Ring).

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Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institution of learning.

Signed:
Tracey Mehigan

Contents

List of Tables

List of Figures

Acronyms

ABL	Activity Based Learning
AI	Artificial Intelligence
AOI	Area of Interest
CAI	Computer Aided Instruction
CBT	Computer Based Training
CBI	Computer Based Instruction
CTM	Cognitive Traits Model
dLearning	Distance Learning
eLearning	Electronic Learning
ET	Eye-Tracking
FD/FI	Field Dependant / Field Independent
FFM	Five Factor Model
FSILS	Felder Solomon Index of Learner Style
FSLSM	Felder Silverman Learner Style Model
GBT	Game Based Learning
GUI	Graphical User Interface
HCI	Human Computer Interaction
HBD	Hermann Brain Dominance
HMLSM	Honey and Mumford Learning Style Model
HTML	Hyper Text Mark-up Language
IBT	Internet Based Training
IDE	Integrated Development Environment
IQ	Intelligence Quotient
IPIP	International Personality Item Pool

ITS	Intelligent Tutoring Systems
KBT	Knowledge Based Tutors
LCMS	Learning Content Management System
LMS	Learning Management system
LSDA	Learning and Skills Development Agency
LSI	Learning Style Inventory
LSQ	Learning Style Questionnaire
MAPLE	Mobile Adaptive Personalised Learning Environment
MBTI	Myer-Briggs Type Indicator
MI	Multiple Intelligences
MMS	Multimedia Messaging Service
MLMS	Mobile Learning Management System
mLearning	Mobile Learning
OS	Operating System
PC	Personal Computer
PDA	Personal Digital Assistant
SAT	Standard Assessment Tests
SMS	Short Messaging Service
VARK	Visual Auditory Reading/Writing Kinaesthetic framework
WAP	Wireless Application Protocol
WBT	Web Based Training
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network
WMC	Working Memory Capacity
3G	Third Generation
4G	Fourth Generation

Part I

Introduction

Chapter 1

Introduction

1.1 Mobile Devices for eLearning

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser 1991) [241].

This has very much been the case with the modern mobile phone, as is highlighted through a high global penetration rate (Comreg 2011) [48]. The uptake of mobile telephony could enable mLearning systems to be successfully employed for education in the school classroom, the university and the corporate office. Every imaginable subject could be covered with potentially every student included. This potential of ubiquitous education can be further enhanced through the development of adaptive and personalised mLearning systems for the achievement of increased motivation and improved learning outcomes for students.

The advent of modern wireless technologies has seen a shift in research and practice towards the design and development of educational systems for deployment through such mobile devices. This use of mobile phones and PDAs is steadily growing across the educational sector. Emerging learning systems hold great significance for the future of education.

There are many advantages provided by mobile devices for learning. These advantages are created through the relationship that exists between the device and its owner. *"This relationship is one-to-one, always on, always there, location aware and personalized"* (Motiwalla & Qin 2007) [177]. There is potential to extend the relationship, through wireless connection, to one-to-many and many-to-many, for collaborative learning purposes and inclusion with classmates in ubiquitous environments. This potential is increased by the importance of the mobile phone to teenage identity and the

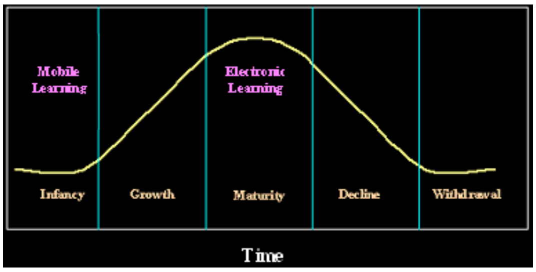

Figure 1.1: Mobile Learning Life Cycle

development of social friendship networks (Eldridge & Grinter 2001) [67].

While the use of these devices is steadily growing across the educational sector as a whole, the implementation level of mLearning systems remains in its infancy. Figure 1.1 highlights the life-cycle position of mLearning in relation to that of eLearning. The life-cycle is used to determine the current stage in a technology's development. mLearning is currently at the infancy stage. As research, development and implementation continues, mLearning will move to the growth stage and will become more integrated into the educational field. As with any emerging and diverse field, there will always be gaps and overlaps evident in the diffusion of systems.

A wide diversity still exists within both mLearning research and practice, mainly between the types of systems that have been developed and deployed to date. Such diversity is evident in the diffusion that is currently taking place between different types of learning categories used in mLearning research projects. This diversity is reflected from situated learning right through to intelligent systems. Simultaneously, a fusion of systems is also occurring. This fusion is represented by the overlap of learning system categories. For example, there exists a potential move away from immersive, game-based learning, represented in traditional eLearning simulation systems, toward the advancement of situated mLearning environments (Dede 2009) [58].

Other issues also exist, for example, the diversity in devices employed and the lack of consideration given towards device compatibility and usability. In such a personalised learning environment, there is also a lack of consideration given to the needs of the individual learner in respect of improved learning outcomes and motivation as they interact with systems.

1.1.1 eLearning vs. mLearning

eLearning or electronic learning is a broad term, *"covering a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and* *digital collaboration. It includes the delivery of content via Internet, intranet/extranet (LAN/WAN), audio and videotape, satellite broadcast, interactive TV, CD-ROM, and more"* (Karrer 2007) [128].

eLearning can also be defined as *"education via the Internet, network, or standalone computer. E-learning is essentially the network-enabled transfer of skills and knowledge. E-learning refers to using electronic applications and processes to learn. e-learning applications and processes include Web-based learning, computer-based learning, virtual classrooms and digital collaboration. Content is delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, and CD-ROM"* (Ellis 2004) [69]. Although eLearning can be either synchronous or asynchronous as indicated by the latter definition, in most cases eLearning occurs through asynchronous communication, in that simultaneous participation by students is not required.

mLearning differs from eLearning. The term mLearning refers to the employment of wireless, portable, handheld devices, for teaching and learning practices and purposes. Within mLearning, educational support, services and specific learning applications are delivered through many different categories of mobile device. mLearning can be synchronous or asynchronous in nature. School-based learning has always been mobile in nature. In the early 1800s the association of chalk and slate facilitated the ability to 'move' material, thus giving learning a mobility factor. This increased with the widespread production of printed textbooks. This natural mobility is enhanced through school field trips and outings which also require the student to move beyond a fixed classroom location. The mobile device offers a means to put learning back into its own sphere of mobility, providing ubiquitous learning in the classroom, the museum and on fieldtrips.

1.1.2 The Popularity of Mobile Phones

There are many devices available for use in mLearning systems including tablets, laptops and ultrabooks. Many existing mLearning systems rely on the use of traditional PDAs for application deployment, but with a drop of 43.5% in world shipments of traditional PDAs (not including Apple's iPod Touch) from 2006 through 2007 (Hruska 2007) [115], mLearning could see an increase in mobile phone usage. This is especially the case with the continued technological advancement of devices such as Apple's iPhone, and the capabilities such advancement brings to the device.

In the majority of Western European countries the mobile phone penetration rate is above 100%, greatly exceeding the early uptake of the internet. Europe has seen an overall penetration rate of 125% on average (Comreg 2011) [48]. In the United States 61.5 million people owned smart-phones in the last quarter of 2010. Emerging economies including China, Indonesia and Africa have seen a continuation in the growth of their mobile market (Mansfield 2010) [151]. As the technology associated with mobile phones improves, and we see increased capabilities of mobile phones and wireless technologies, the sales of PDAs fall. It was estimated that worldwide sales of touch-screen mobile phones would hit 200 million by the end of 2011 (Hruska 2007) [115] however, this figure has to be revised upwards as 2009 alone saw 75 million touch screen handsets sold (James 2010) [120]. These statistics show an immense potential for the future growth of mLearning, especially through the use of mobile phones.

1.1.3 Adaptive Systems for eLearning Environments

Research in eLearning has moved toward the inclusion of adaptive features to enable more personalised and successful learning outcomes for students. The aim of adaptive systems is the adjustment of the learning process to suit an individual learner. This can be achieved by taking account of an individual's personal learning-style. Learning-style represents the student's fit within the specific scales of learning-style and / or personality models. Within this research there is a heavy reliance on the use of questionnaires to model the learner. In recent years efforts have been made to avoid the use of questionnaires through automatic user modelling based on user interaction behaviour with a system (Graf 2008) [94] and Baysian networks (Garcia 2005) [85] and feed-forward neural networks (Villevarde *et al.* 2006) [236].

Work by Spada *et al.* (2008) [218] investigated the possibility of determining an individual's learning-style directly from their interaction with a web-based learning system. This research found a high degree of correlation between the way in which an individual uses a mouse and their learning-style (as determined using questionnaires). Spada *et al.* were able to detect scores on the Global/Sequential dimension of the Felder-Silverman Learning Style Model (FSLSM) [77] with a high level of confidence based on measurements of mouse acceleration. Their research presents a new approach to predict Global/Sequential learning-styles that makes use of mouse movement patterns in a website. Whilst Spada's research approach offers great potential for eLearning, it cannot be employed on systems which do not use a mouse, such as mobile devices.

1.1.4 Research Questions

Based on the current state of mLearning and the limits to which adaptive features have been represented in mLearning environments, the focus of this thesis is the potential to provide a non-intrusive solution for the provision of intelligent and adaptive systems for mLearning environments. This is based on the extension of Spada's work for use in mLearning applications and environments. As Spada's work focuses on the use of mouse movement patterns, this research uses behaviour-based biometric technology for the purpose, including accelerometer and eye-tracking devices. These devices can be used either individually or combined.

Based on this, the research in this thesis asks the following questions:

- To what extent will mlearning play a part in eLearning in the future?
- To what extent are adaptive features represented in mLearning?
- Is it possible to detect learning-style through user interaction patterns in mLearning environments?
- Can biometric technologies, such as accelerometers and eye-trackers, be used to detect learning-style in mLearning environments?

1.1.5 Contribution to the Field

Building on work presented at EdMedia 2009 [160], EdTech 2009 [161], Irish HCI 2009 and 2011 [159] [165] and ICME 2011Meh11 and work published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163], IJGBL (2012) [167] and *Tools for Mobile Multimedia Programming and Development*, Tjondronegoro (2013) [168], this thesis discusses a number of contributions made within the field of adaptive learning systems for mobile environments.

A theoretical model has been designed to distinguish between eLearning and mLearning and to evaluate the current and future placement of mLearning systems in relation to eLearning systems.

Behaviour-based biometric technologies, particularly accelerometer devices and eye-tracking technology have been used as the basis of a number of studies to explore their potential use in relation to:

- The automatic detection of Global/Sequential and Visual/Verbal learners (as described in the FSLSM) based on interaction with systems through accelerometer devices.
- The automatic detection of Global/Sequential and Visual/Verbal learners (as described in the FSLSM) based on interaction with systems through eye-tracking technology.

A content management model called MAPLE (Mobile Adaptive Personalised Learning Environment) has been designed for use with any mLearning platform to facilitate the detection of user learning-styles (based on dimensions of the FSLSM) from user interaction for the automatic provision of adapted content display to suit the learning-style needs of the user.

The accelerometer device, now standard in high-end mobile devices such as the iPhone, has been employed in the development and implementation of a prototype mLearning application using the MAPLE model. The mLearning application intelligently detects Visual/Verbal learners (as outlined in the FSLSM) through the application user's accelerometer interaction with the system and adapts displayed content presented to the user based on the application's assessment of its user's learning-style on both the Visual/Verbal and Global/Sequential dimensions of the FSLSM.

1.2 Thesis Outline

This thesis is structured as follows:

Part II - Background

Chapter 2 - Evolution of eLearning. Chapter two looks at the evolution of eLearning to date. The emergence of handheld and wearable technologies for learning is also examined.

Chapter 3 - Learning-Styles. Chapter three introduces the learning-style and personality models currently used within the field of eLearning for the development of adaptive learning systems. The chapter focuses on the FSLSM, discussing the model dimensions in detail. The relationships between the FSLSM and other such models are highlighted. The Felder-Solomon Index of Learning Styles (FSILS) is outlined and its validity as a measurement instrument for student placement on the FSLSM dimensions is examined according to the literature, with a focus on the distribution of learners across the dimensions. A critique of the FSLSM is also provided.

Part III - Modeling Mobile Learning

Chapter 4 -Modeling Mobile Learning. Chapter four builds on work published in Mobile Learning; Pilot Projects and Initiatives (Guy 2010) [167]. This chapter outlines the differences between eLearning and mLearning. Current mobile phone statistics are examined. This chapter puts forward a model that highlights current mLearning systems, for example, Learner Centred Systems, ITS (Intelligent Tutoring Systems), Situated Learning Systems and Collaborative Systems (See section *4.2 Categorising Mobile Learning Systems*). The use of game-based and immersive learning elements from traditional eLearning within situated mLearning environments is considered. A definition and examination of the future placement of mLearning in relation to eLearning is a requirement before it is possible to move mLearning towards its growth stage. The chapter also looks at the level of adaptivity within both eLearning and mLearning, with a focus on how adaptive systems can be improved for future mLearning systems based on user learning-style. The MAPLE content management model is outlined.

Part IV - Biometric Devices - User Studies

Chapter 5 - Detecting Learning-Style through Accelerometer Technology. Chapter five builds on work presented at EdMedia 2009 [160], EDULearn 2009 [161] and work published in Mobile Learning; Pilot Projects and Initiatives (Guy 2010) [167]. This chapter introduces accelerometer technology, now a standard feature in modern mobile devices. The term accelerometer is defined. Two studies conducted to assess the potential use of accelerometer technology for the detection of user learning-styles are outlined and results presented.

A prototype application was developed based-on the MAPLE model (outlined in chapter 4) as an example adaptive mLearning system. The system assesses the user's learning-style on the Global / Sequential and the Visual / Verbal dimension of the FSLSM and subsequently provides the user with appropriate learning content based on this measurement. The application makes use of the mobile device's built in accelerometer sensor to facilitate the main user interaction function.

Chapter 6 - Detecting Learning-Style through Eye-Tracking Technology. Chapter six builds on work presented at Irish HCI 2009 [159], ICME 2011 [162], iGBL 2012 [164] and work published in Mobile Learning; Pilot Projects and Initiatives (Guy 2010) [167]. This chapter introduces eye-tracking technology, outlining its use within eLearning to date. The term eye-tracking is defined. Two studies conducted to assess the potential use of eye-tracking technology for the detection of user learning-styles are outlined and results presented. The potential use of eye-tracking technology with mobile devices and the extension of the MAPLE-based prototype to include eye-tracking -based data for mLearning is considered.

Part V - Conclusion & Future Work

Chapter 7 - Conclusion and Future Work. Chapter seven presents an overview of the research, listing the contributions to the field highlighted in this thesis. An overview of the privacy and ethical issues relevant to this work is highlighted. Conclusions are drawn and an outline of future work related to this work is also provided.

Part II

Background & Review

Chapter 2

The Evolution of eLearning

"It is self evident that the history of technology in education extends back to the clay tablets, slate drawing boards, and handmade paper of pre-Gutenberg education" (Garrison & Anderson 2003) [89].

Bush, generally known as *'the grandfather of hypertext'* [104], wrote an article in 1945 for the July edition of the Atlantic Monthly, describing a theoretical hypertext MEMory EXtender called Memex. This is significant for eLearning in that it recognises that the human mind selects by association rather than in the manner of structured indexing systems applied in most libraries. Memex foreshadowed a mechanised private file and library system where an individual could store books and documents, creating links both within them and between them. Through Memex, Bush anticipated the use of system types such as windows, speech recognition, online encyclopaedias and the internet (Haas 2007) [104].

The history of the modern computer is relatively brief. With a period of approximately 60 years, computers have facilitated a change in the philosophy of education across the globe toward the provision of education for all. The last forty years have seen the most progress, with the greatest developments in the field emerging in the last decade of the 2nd millennium.

This chapter examines the development of eLearning to date, from the introduction of Computer Aided Instruction (CAI) through to mLearning. The chapter highlights technological advances that have facilitated the development of the field, including the development of the Microcomputer, Supercomputer, Graphical User Interface (GUI) and the Mouse. The development of the Internet and its use for learning purposes is discussed. The emergence of handheld and wearable technologies for learning is also outlined.

2.1 eLearning

Whilst there is still no generally accepted definition of eLearning, there are many definitions under debate. This is also the case surrounding the definition of eLearning theories. In 2003, Nichols [181] argued that the field of eLearning has advanced as a group of applications without developing a strong theoretical background of its own, suggesting that the bulk of literature on the field is practice-based. eLearning relies heavily on the theories that developed alongside traditional learning (Nichols 2003) [181]. This is partly due to the development of Computer Aided Instruction (CAI) in the early years of the 1960s, when both psychologists and educators saw an opportunity for computers to act as a supplement to teaching as an existing field. This prompted a continuum for the lack of specific theory development as the field of eLearning advanced.

2.1.1 CAI and Programmed Instruction

The first suggestion for instructional technology comes from Pressey, who, in 1920, offered the first learning machine allowing drill and practice education and multiple choice questions (Deutsch 2007) [60]. His work was followed by Lazerte, who developed a cylindrical type problem tester, offering students problems to answer, checking that their answers were correct and in the right order (Kantowski 1977) [126].

The work of Skinner on Operant Conditioning in the 1950s established learning task performance analysis through small, easily attainable learned repertoires of behaviour (Frase 1975) [84]. The very first teaching system of this type was programmed and designed by Anderson, Brainard & Rath, to teach binary arithmetic, setting the initial focus on mathematics. As with all early systems the program was hindered by lack of computer memory (Rath 1967; Buck & Hucka 1995) [197] [33].

The publication by Wiley, of a book entitled *"Programmed Learning and Computer-Based Instruction"* by Coulson (1962) [51], initiated the first real efforts at actually using the computer to teach (Rath 1967; Coulson 1962; Buck & Hunka 1995) [197] [51] [33]. Focusing on CAI for mathematics and reading, Suppes & Atkinson provided the student with an opportunity to take an active role in the learning process and employ 'drill and practice' to master tasks.

It was not until the mid 1980s that people began to realise that it was not necessary to be able to write computer programs to make effective use of a computer. This led to the introduction of courses in computer application literacy. The computer was now a productivity tool and an aid to problem solving; there was a shift in focus towards Computer Integrated Instruction.

An Early Adaptive Learning System

SAKI (Self-Adaptive Keyboard Instructor), the first commercial adaptive teaching system, was introduced by Pask & McKinnon-Wood in the 1950s. The system was designed to teach people how to increase their speed and accuracy in typing alphabetic and numeric symbols using a 12-key keyboard. The difficulty of the tasks issued was contingent on the student's performance level. SAKI was the first system to mimic the relationship between the human teacher and the student through conversation theory (Pask 1982)[187].

Conversation Theory

Conversation theory was developed by Gordon Pask and originates from his work in cybernetics. Conversation theory attempts to explain learning in both living organisms and machines. The fundamentals behind the theory are that learning occurs through conversations which can be conducted at different levels as follows:

- Natural language (general discussion)
- Object languages (discussing the subject matter)
- Metalanguages (discussions about learning)

Conversations (interactions) lead to the "construction of knowledge" and serve to make knowledge explicit.

In order to facilitate learning, Pask argued that subject matter should be represented in the form of entailment structures which show what is to be learned. Entailment structures exist at a variety of different levels depending upon the extent of relationships.

The critical method of learning according to conversation theory is "teachback" in which one person teaches another what they have learned. Pask identified two different types of learning strategies: serialists, who progress through an entailment structure in a sequential fashion, and holists, who look for higher order relations (Pask 1975) [186].

Conversation theory applies to the learning of any subject matter and is an important element in the development of mobile learning (Sharples 2005; Hague 2007; Glanville 2008) [105] [91] [212].

2.1.2 Computers in Education

In the 1940s, the Harvard MARK 1 and the University of Pennsylvania's ENIAC were the main operational computers put into use for educational purposes (Molnar 1997; Myers 1985) [174] [178]. The size and financial cost of the machines limited their potential for possible applications.

In the 1960s there was an increased investment in computers for schools, particularly in the United States (US). The US National Science Foundation (NSF) supported the set up and development of 30 regional computing networks spanning over 300 higher education institutions and post-primary schools (Molnar 1997) [174].

The role of computers in education was transformed by Kemeny & Kurtz at Dartmouth College of Computation (Downes 2005) [62]. The production of a time-share system, using the GE-235 and Datanet-30 computers, enabled many undergraduate students to interact with a computer through remote consoles. This placed computers into education on a larger scale then seen before. The system was also used for research purposes by General Electric Advanced Systems Lab (General Electric 1965; Molnar 1997) [174] [68]. Dartmouth off-campus terminals were also placed in local post-primary schools (DTSS 2008) [246].

The University of Alberta set up an educational research services division resulting in the installation of the IBM 1500 system on campus. The system was used to run medical courses in cardiac training for students until the 1980s (Kay 1993) [130].

By 1975 the use of computers in classroom teaching had increased from 1% to 23% of US classrooms. Due to this increase, 55% of students in US-based classrooms had access to a computer. By 1985 the US provided access to one computer for every sixty children in schools across the country (Papert 1980; Molnar 1975) [184] [174]. This was facilitated by the advent of a low-cost microcomputer which enabled the break away from expensive systems and time share. The 1990s witnessed a rapid rise in investment in the advocacy of technology in schools. This was seen in particular with many countries across the globe issuing their first national educational technology plans and standards containing specific goals to increase access to technology in schools. Countries as diverse as Italy, Mexico, Japan and Canada engaged in remarkably similar programs to provide computers and internet connections to schools. In Britan, over £1 Billion was spent on the National Grid for Learning and associated schools technology initiatives. Ireland invested IR£107.92 million in its 2001 plan (Lei *et al.* 2007) [145]. The rate of computer use in Irish post-primary schools doubled from 24% to 47%

between 2003 and 2006. In 2009 the Irish Government committed a €150 million investment in computers for schools. Currently, computers are openly available and inexpensive; however there is still a lack of access particularly in the formal school setting where there remains more than one child per computer (Donnolly 2009) [61].

2.2 Technological Advances

There have been a number of technological advances since the inception of the computer. These have led to developments in the field of eLearning and improvements in the provision of eLearning systems.

2.2.1 The Microcomputer

In the 1970s the Altair and the Mark 8 came into production. The Apple I, developed by Jobs & Wozniac, was the most significant break-through in personal computing due to the built-in computer terminal circuitry which was distinctive. The IBM PC (which was introduced in 1981) also took on a command-line approach. Following this, Apple introduced their Macintosh model in 1984 (Lei *et al.* 2007) [145].

The introduction of the microcomputer was the first step in making computers openly accessible for educational purposes.

2.2.2 GUIs, Graphical Icons and the Mouse

The advent of the GUI and the mouse had great implications for the development of eLearning through the provision of easier access and user-friendly systems.

The Mouse

Engelbart, a pioneer in Human Computer Interaction (HCI) is credited with the development of the mouse commercially debuted by Xerox in their 8010 Star model (Myers 1985) [178] and later Apple's Lisa 1 model, in conjunction with a prototype for their GUI (Myers 1985) [178]. The initial introduction of these systems was unsuccessful due to their financial cost, it would not be seen again commercially until the introduction of the Apple Macintosh. The mouse was developed in cooperation with English from Stanford Research Institute (SRI). The mouse received a patent in 1970 (Bellis 1997; Myers 1985) [26] [178].

The GUI & Graphical Icons

A GUI uses graphical icons and a pointing device to control a computer. Sketchpad, the first Graphical User Interface (GUI) was developed by Sutherland, at Massachusetts Institute of Technology (MIT) in 1963 (Sutherland 2001) [224]. This system, as with other early Cathode-Ray-Tube (CRT) systems, used a light-pen device for pointing.

In 1973, Xerox PARC developed the non-commercial Alto personal computer. The Alto had a bitmapped screen and demonstrated a graphical user interface (GUI). It was used at PARC XEROX offices, and at several universities for many years. It influenced the design of personal computers during the late 1970s and early 1980s, including both the Apple Lisa and Macintosh. The Alto project led to the commercial release of the Xerox Star 8010 Document Processor in 1981. Its pointing device (mouse) couldn't move diagonally, it didn't have overlapping windows and its operating system required keyboard commands. The Star 8010 was unsuccessful commercially.

A learning research group was set up at Xerox PARC. The group, led by Kay, who would advance the use of GUIs to include Graphical Icons, resulting in a computer for teaching and learning called KiddiKomputer. It was envisaged that the system would be used in four main projects looking at the development of thinking skills, modeling through simulations, interface skills and iconic programming.

Apple's Lisa model launched with a prototype GUI (Myers 1985) [178] but failed commercially. The Macintosh, released in 1984, was the first commercially successful product to use a multi-panel window GUI. File directories looked like file folders. A set of desk accessories including a calculator, notepad, and alarm clock (that the user could place around the screen as desired) were included. The user could delete files and folders by dragging them to a trash-can icon on the screen.

In the mid 1980s, the introduction of the Microsoft Windows User Interface software provided an even more user friendly approach to software than Apple's Machintosh (Myers 1985) [178]. The advances in micro-computer technology or personal computers (PC), and their reduced cost, now established the computer as a necessity for schools and universities. Ownership of a computer was now a requirement for freshmen entering universities in the US (Molnar 1997) [174]. The advent of personal computing was a major factor in the formation of eLearning.

Apple's Macintosh included the use of a GUI, icons and mouse device and was an early portable computing (Lei *et al.* 2007) [145].

2.2.3 The Supercomputer

The introduction of the supercomputer was key for the ability to provide access to information and knowledge throughout the world. In the 1980s, the NSF in the US established interconnected supercomputer centres. This was achieved through the merger of these powerful computers with high bandwidth communication networks, through distributed technologies. A US national Network (NSFNET) was established in 1985 in the US making large systems available to all universities. The "infosphere" was established, facilitating the dissemination of knowledge through the interaction of people, technologies, and information (Molnar, 1997) [174].

2.2.4 The Internet

The 1960s saw the beginnings of the Internet when the US Department of Defence commissioned the development of Arpanet. A four node network was established between University of California, Los Angeles (UCLA), SRI, University of Utah and University of California, Santa Barbra (UCSB) (Zakon 1993) [248]. In 1989 Berners-Lee of CERN in Switzerland, circulated a proposal for an in-house online document-sharing system which he described as a *"web of notes with links"*. His proposal was approved by his superiors; the system would later emerge as the World Wide Web.

It was the introduction of graphical web browsers such as Mosaic and Netscape Navigator that allowed for the development of fast information access and inexpensive communication. There was an explosion in usage of the internet by the general public, with usage figures standing at 14 million globally at the end of 1995, with all users accessing information, news and conducting research. Uptake of the internet surpassed 10% of US households in 1995. The introduction of internet software tools such as Authorware, Multimedia Toolbook, Director, and IconAuthor began in 1996. *"There was a new frontier in learning"* (Zhang & Nunamaker 2003) [250].

2.3 Learning through Internet Technologies

Reflecting its connections with the internet, eLearning was initially called "Internet-Based Training" (IBT) and later "Web-Based Training" (WBT).

Online university courses were seen as the way forward. Universities took hold of the opportunity. New York University (NYU), for example established online courses such as NYU Online.

In the 1990s there was a surge in the establishment of popular online learning companies such as click2Learn.com, which would become leaders in enterprise productivity solutions. There was a surge in expectations and discovery in the late 1990s. This heightened interest, particularly by remote and adult learners, led to the development of eLearning (Green & Gilbert 1995) [96]. There was a high level of investment in research and the development of systems leading to the provision of thousands of courses online from universities worldwide (Alexander 2001) [18]. The number of adults seeking higher education exploded, with the percentage of older students in college programs rising sharply to 59% by 1999 from 32% a generation earlier (Gunasekaran *et al.* 2002) [101]. Many corporations adopted eLearning systems to facilitate their staff training programs in particular, DELL, CISCO and Hewlett Packard used such IBT systems in their staff training (Zhang & Nunamaker 2003) [250].

2.3.1 eLearning 2.0

"Ideas are constantly evolving, as technology, pedagogy, and student needs change" (Karrer 2007) [128]. Elearning is an approach to learning that has evolved alongside the advent of web 2.0 and the increased capability of small handheld devices such as mobile phones and tablets.

eLearning 2.0 is used to refer to a new way of thinking about eLearning. There is an emphasis on social learning, where the learning content is socially constructed rather than accessed. There has been a shift from traditional didactic learning towards a more learner-centred model that emphasises a more active learner role. The way that learning is seen has also changed, allowing for user- and socially-generated content. The way in which people view and use the internet has also changed. 'Digital Natives', people who were born during or after the introduction of digital technology, use technology (including the internet) in a different way than their 'Digital Immigrant' counterparts. Digital Natives have interacted with digital technology from an early age and therefore have a greater understanding of its concepts. Digital Immigrants are people who were born before the existence of digital technology and adopted it to some extent later in life (Prensky 2001) [193]. Therefore it is not only the technology that has changed but the user has changed also.

Downes (2005) [62] stated that *"the Web was shifting from being a medium, in which information was transmitted and consumed, into being a platform, in which content was created, shared, remixed, repurposed, and passed along. And what people were doing with the Web was not merely reading books, listening to the radio or watching TV, but having a conversation, with a vocabulary consisting not just of words but of* *images, video, multimedia and whatever they could get their hands on. And this became, and looked like, and behaved like, a network".*

People started to Blog (a contraction of the term Web log) through the use of content creation tools such as Blogger and Wordpress. RSS (Really Simple Syndication) was to follow, leading to the development of networked blog readers and website followers. Wikipedia was born from the use of the collaborative writing tool wiki. Audacity, a free audio recording tool, when combined with RSS saw the beginning of user generated Podcasting.

All of these social developments have moved education away from the classroom, with students discussing classroom topics for reviews with global online peers (Downes 2004) [63]. Online learning has become a platform and is no longer a content consumption tool but an online authoring tool. The content is generated by students and is conversational in nature. ELearning content has become *syndicated, aggregated and disseminated by students themselves* (Downes 2005) [62].

2.4 Games, Tutors and Projects

2.4.1 The Advent of Game-Based Learning

In the 1970s, Piery conducted research into the effectiveness of 22 simulations based training games. Piery found that student interest in instructional games was higher than their interest in traditional and conventional instruction (Garris *et al.* 2002) [88]. Between 1978 and 1983, educators began to look beyond replication of existing educational practices, producing simplistic colourful programs to engage and challenge the student in the classroom. Programs like Gertrude's Puzzles and Muppets on Parade were created to provide problem-solving learning experiences for students, facilitating the development of thinking skills (Johnson 2003) [123].

Educational games have started to enter mainstream education (Williamson *et al.* 2005) [243]. There is a scenario emerging where the learner plays an active part in the design of the game and its processes. Papert (1980) [184] stated *"The most important learning skills that I see children getting from games are those that support the empowering sense of taking charge of their own learning"*. Simulation and immersive learning environments employing augmented reality and Artificial Intelligence (AI), have been seen in the development of training systems for the US Military (Prensky 2001) [193].

Many empirical studies have been carried out to examine the effects of game based instruction programs. Work in 1993 by Whitehall & McDonald and in 1996 by Ricci *et al.* found that instruction employing game features led to improved learning (Garris *et al.* 2002) [88]. Ryland, a classroom teacher at the Chew Magna primary school in the UK has taken the initiative to employ games in his classroom schedule with very positive results. The UK average attainment of level four literacy levels for boys aged 9 through 11 years was 75% in 2004. At Chew Magna primary school, the number attaining level four went up from 76.5% in 2000 to 93% in 2004. The British Educational Communications and Technology Agency (BECTA) award winning method has seen Ryland's students excel in creative thinking. The students have seen improved Standard Assessment Tests (SAT) scores.

Teachers have used commercial off the shelf (COTS) titles such as Sim City, MYST and Age of Empires to encourage learning. Other titles, which are specifically educational, have also been used. The FutureLab-funded project Savannah, an ecological system using Global Positioning Systems (GPS), has also been used in the classroom (Gee 2003; Krotoski 2005) [90] [140].

2.4.2 Tutoring Systems

Tutor systems began to emerge as early as the 1960s. A portable or mobile tutor device called the 'Auto Tutor' was developed for nursing students to present a series of information frames and questions, which were branched to other frames depending on the button pressed by the learner. The intrinsic system was developed by Crowder. The system offered an alternative to the type of systems proposed by Skinner (Seedor 1963) [208]. The Empirical Tutor had the ability to *"use film sequences, slide projectors, tape recorders or even real apparatus, which the student may use to help him to decide how to answer the question in the frame"* (Sim 1963) [214].

A new focus on the development of intelligent tutors emerged in the 1970s in an effort to overcome the issues encountered with earlier learning systems. A Computer-Based Instruction (CBI) system named SOPHisticated Instructional Environment (SOPHIE) was designed by Brown [32] to enable students to both debug and articulate their own ideas and reasoning strategies.

Other CAI tutors were also developed in this period for algebra, geometry and the teaching of programming languages. Carnegie Mellon University were active in the use of this type of system to improve student grade levels (Molnar 1997) [174].

In more recent times, mobile intelligent tutoring systems have emerged (Bull *et al.* 2004; Ketamo 2002) [34] [134], facilitating mobile learners to increase their skill levels in a variety of subjects including, for example, geometry. These systems will be discussed in more detail in chapter 4.

2.4.3 Project-Orientated Education

The idea of project-oriented education began in the 1980s with the development of a National Geographic KidsNet in the US. The network was an effort to bring inquiry based education to elementary school children. The system allowed for experiments through data gathering on topics of social, geographic and scientific interest such as acid rain. Electronic mail was used to allow students to communicate with each other and with practicing scientists in a collaborative manner. 'Tinker's network led to a number of instances where the children's tests provided valuable information on the failure to meet standards, particularly related to air pollution and school drinking water (Molnar 1997) [174]. Another project of Tinker's in the early 1990s, the 'Global Laboratory Network', saw 11-18 year old students measuring environmental factors such as air temperature and bird population through the use of low-cost devices to provide a 'snapshot' of the planet in a major seasonal event. This type of project saw the teacher in a new role as a consultant, a global 'classroom' was created and a new social infrastructure was established for education (Molnar 1997) [174].

2.5 The Emergence of Handheld Technologies

2.5.1 The First Notions of Mobile Learning

Aldiss (1963) [17], in a science fiction article, envisaged the concept of mLearning alongside the development of personal computing in the 1970s. Aldiss states that in the 1960s *"computers had been invented, and they were getting smaller, but it wasn't until the great developments in micro technology in the seventies that portable computers were made"* (Vavoula *et al.* 2007) [235].

Kay (1972) [129], interested in tracking what students would do with the computers outside school, developed the DynaBook, a book-sized computer that would run dynamic simulations for learning. Kay (1972) stated that *"it is now within the reach of current technology to give all the Beths and their Dads a DynaBook to use anytime, anywhere as they may wish"*. Kay highlights the potential for communicative devices and acknowledges the belief, drawing on the work of Dewey, Piaget & Papert, that children learn by doing (Kay 1972) [129]. These systems were the first initiative in mLearning through portable devices.

2.5.2 The Development of Mobile Technologies for Learning

The most significant advancements in the area of mLearning rely on technology. The development of handheld and wearable technology is currently playing an important role in the extension of eLearning toward ubiquity. mLearning *"defines new relationships and behaviours among learners, information, personal computing devices, and the world at large"* (Wagner 2005) [239].

In 1978 the Japanese company NTT launched the first commercial mobile phone. The development of the mobile device would not, however, play a role in education until the advent of 2.5G and later 3G technology in the late 1990s and early 2000s. In many cases, mLearning systems such as the LMS relied on mobile internet connections through Wireless Application Protocol (WAP) applications. The very first mobile phone that facilitated wireless internet connections and email was the Nokia 'Communicator' which was preceded by the first commercial mobile internet service launched by NTT DoCoMo in Japan under the iMode service a few years earlier.

Nokia embedded the black and white snake game, the first ever mobile game, into its 6110 model in the late 1990s. Although the game was not specific to learning, it contributed to a revolution in the gaming world. Games have evolved alongside the improvements to device capabilities. In the first years of the 21^{st} century coloured screens entered the mobile world. The Apple iPhone has a 24-bit colour display (up to 16,777,216 colours). Memory size also played a part in the advancement in game development. Memory can be extended by gigabytes through the use of Micro-Secure Disk (M-SD) technology. Development technologies have also improved.

The introduction of GPRS, WiFi, Bluetooth and 3GP technology has further enhanced the development of mLearning systems. Advancements in networking technology have been equally important to mobile gaming. Nokia's snake game actually had a multiplayer addition which employed the use of an infrared interface. While mLearning has focused on the provision of varying learning systems such as the LMS and Intelligent Tutors, game-based learning has been most widely used in the area of situated learning, particularly museum guides. This type of game has placed an emphasis on the idea of collaborative learning which has been extended into the classroom, facilitated by the conversational and ubiquitous aspects of the mobile device.

The 1990s saw a surge in research by universities across Europe into the use of mLearning for students. The Palm Corporation under their Palm Education Pioneers Project offered grants for corporations and universities, to test and create mLearning content specific to their PalmOS Platform (Pryer 2001) [195]. These grants were followed by the European Commission funding provided to many mLearning projects, in particular the MOBI learn project and the Leaonardo Da Vinci Projects (Leonardo da Vinci Project 2008; Attewell *et al.* 2005) [5] [20]. mLearning companies emerged with a focus on authoring and publishing, delivery and tracking and content development. Conferences and trade fairs emerged specific to mLearning and handheld education.

Mobile technology is advancing at a strong pace. Mobile phone capabilities are predicted to equal that of current PCs. According to Google's head of online sales who foresees that by 2014, *"desktops will give way to mobiles as the primary screen from which people will consume information and entertainment ...In Japan, most research is currently done on smart-phones, not PCs"* (Kennedy, 2010) [132].

This combined with their connectivity potential offered through technologies such as IrDA (Infra-red Data Association), Bluetooth 4.0 and the emergence of 4G technology included in the handset, offers benefits for collaborative and ubiquitous learning through varying types of systems.

There is also the economic factor as these devices are inexpensive in terms of technological equipment and their penetration rate into society is high. Europe has seen an average penetration rate of 125% overall. Mobile phones are currently the most widely spread and available electronic device in the world (Comreg 2011) [48].

High-end mobile devices (including the iPhone / iPad and Android devices) now have more capacity, larger screens, greater resolution and 4G (Fourth Generation) technology. The mobile device is becoming a major player in the field. The introduction of Apple's iPad has facilitated the provision of digital textbooks by many publishers (Robyn 2011) [202]. The iPad is currently being used in the classroom in schools across Europe and the US (Sudo, 2011) [222].

2.6 Traditional v.s. Technology-based Learning Environments

The emergence of new technology-based learning has empowered the student. eLearning, facilitated through new technologies, allows for learning that is student-centred. There is a reduced focus on teacher-centred instruction as seen in traditional learning environments. Information exchange between students through multimedia-based technologies is evident, particularly through social networking and collaborative environments. Activity and inquiry-based learning can now be achieved. This leads to enhanced critical-thinking skills for informed decision-making. Further comparisons between traditional and new learning environments are given in Table 2.1.

Table 2.1: Comparison between Traditional and New Learning Environments (adapted from the International Society for Technology in Education (ISTE) NETS Project 1998)[116]

Traditional Learning Environments	**New Learning Environments**
Teacher-centric Instruction	Student-centred learning
Single-sense instruction	Multi-sensory stimulation
Single-path progression	Multi-path progression
Single media	Multimedia
Isolated work	Collaborative work
Information delivery	Information exchange
Passive learning	Active, exploratory, inquiry-based learning
Factual, knowledge-based	Critical thinking, informed decision-making
Reactive response	Proactive, planned action
Isolated, articficial context	Authentic, real world context

Today, students of almost any age, prefer to access subject information on the Internet, where it is more abundant, more accessible and more up-to-date, Lei *et al.* 2008 [145]. *"A laptop computer holds the answer to many of today's challenges. Such a portable tool is something a student could not only work with, but also feel empowered by. With laptop computers, students can access thousands of textbooks electronically and collaborate with any number of other students"* (Jacobson 2005) [119]. *"Laptop computers have been a dominant device for most large one-to-one computing projects"*, however, these are not the only viable device (Lei *et al.* 2008) [145]. Indeed, laptop devices in many cases can be restrictive in their portability. Mobile phones and tablet PCs can also be used. Such low-cost devices increasingly popular devices can facilitate many functions for learning activities. This combined with their higher level of portability makes them a good choice for mLearning.

2.7 Conclusion

The advent and rapid growth of elearning has lowered barriers to education. Since its advent in the early 1950s the computer has played a role in the advancement of educational practice and methods. They have provided access to education to those who previously were outside the loop. The dissemination of rich educational information and knowledge has been simplified, enabling education to reach everyone, anytime, anywhere in a variety of favourable and engaging formats. ELearning, whilst still closely associated with the internet, has engaged new technologies whilst at the same time enhancing its internet capabilities. The current methods applied to eLearning provide a social conversational aspect to learning that can only lead to increased benefits and efficiencies for learners. These methods can be further enhanced as the computer becomes smaller and more powerful. This growth continues with the movement toward ubiquitous and mLearning which is evident through the emergence of iPad within schools projects across the globe.

This chapter has examined the development of eLearning to date. Technological advancements have been considered alongside their influence on eLearning systems. The emergence of handheld and wearable technologies for learning has also been considered.

Chapter 3 will look at learning-style and personality models which are popular in the development of eLearning systems with a particular focus on the FSLSM. The FSILS, the main measurement instrument associated with the FSLSM will be examined in relation to its reliability and validity. The relationships and parallels that exist between the FSLSM and other learning-style, personality models and theories, will be examined. A critique of learning-style models will also be provided.

Chapter 3

Learning-Styles

This chapter introduces the different learning-style and personality models currently used within the field of eLearning for the development of personalised learning systems. The chapter focuses on the FSLSM explaining the model dimensions in detail. The relationship between the FSLSM and other such models are highlighted. The FSILS is explained and its validity as an instrument for measuring student placement on the FSLSM dimensions is examined according to the literature. Particular focus is placed on the distribution of learners across the dimensions of the model. The effects of gender on the FSLSM are considered. A critique of the FSLSM is provided.

3.1 Learning-Styles Defined

Learning-styles reflect the way that a student characteristically and collectively acquires, retrieves and retains information. A learning-style is the approach a student takes to achieve a learning-outcome. *"Students preferentially take in and process information in different ways: by seeing and hearing, reflecting and acting, reasoning logically and intuitively, analysing and visualising, steadily and in fits and starts"* (Felder 1988) [77]. Learning-style is defined by the traits and characteristics of an individual learner. While this is the case at the individual level, there are within the wider population groups of students who share similar characteristics and traits in relation to their approach to learning. A student's learning-style is a division of the larger concept of personality. Learning-styles have been defined as follows;

"Distinctive and observable behaviours that provide clues about the mediation abilities of individuals and how their minds relate to the world and, therefore, how they learn" (Gregorc 1984) [98],

"An individual's characteristics and preferred way of gathering, organising and thinking about information" (Fleming, 2001) [82],

"The ways in which individuals begin to concentrate on, process, internalise, and retain new and difficult information" (Dunn & Dunn, 1974) [65],

"A range of constructs from instructional preferences to cognitive style" (Sadler-Smith 2001) [205],

"The characteristic strengths and preferences in the ways individuals take in and process information" (Felder & Silverman 1988) [77].

3.2 Learning-Style and Personality Models Commonly used in Adaptive Systems

A wide spectrum of both learning-style and personality models have been employed to date for the development of learning systems. In many cases, these systems leave the choice of the learning-style model to the teacher. Such systems include the AHA! System (De Bra and Calvi, 1998; Stash, Cristea, and de Bra, 2006) [57] [220], and the IDEAL system (Shang, Shi, and Chen, 2001) [210]. The Myer Briggs Type Indicator (MBTI) was used by Bachari *et al.* (2003) [21] in their LearnFit system, an extension to the Moodle LMS. Examples from these systems will be given in chapter 4 (section *Adaptive Systems in eLearning*).

Other systems relate to specific learning-style models, including the iWeaver System (Wolf 2003) [245] which employs the Dunn & Dunn model (1974) [65] and the INSPIRE system (Papanikolaou *et al.* 2003) [183] which uses Honey & Mumford's model.

Due to its links to both personality models and other learning-style models, the FSLSM (Felder and Silverman 1988) [77] has emerged as a popular learning-style model for the development of adaptive eLearning systems. While originally intended for use with engineering students, it is widely used in many fields. The FSLSM comprises four dimensions, the Active/Reflective, the Sensitive/Intuitive, the Visual/Verbal and the Global/Sequential dimensions. Each of the dimensions will be explained in further detail later in this chapter. The dimensions of the model can be seen in singular use or combined use in many systems (Graf *et al.* 2008) [94]. The CS383 system (Carver, Howard and Lane 1999) [114] uses three dimensions of the FSLSM, including the Global/Sequential, Visual/Verbal and the Sensitive/Intuitive dimensions. The MASPLAG system (Pena, Marzo, and de la Rosa, 2004) [188], and the TANGOW system (Carro, Pulido, and Rodriguez, 2001) [38] both use the FSLSM, the latter particularly looks at two dimensions, the Sensitive / Intuitive and the Global / Sequential dimension, of the FSLSM. The LSAS system (Bajraktarevic, Hall, and Fullick, 2003) [22] uses the Global / Sequential dimension of the model. All mentioned systems employing the FSLSM, rely on the FSILS to pre-assess students.

3.2.1 Personality Models

"Psychologists agree that a person can be viewed as a unique configuration of internal attributes and that he or she behaves primarily as a consequence of this pattern of internal attributes" (Boekaerts 1996) [28]. It is generally accepted that aspects of a student's personality (as a whole) can play a dominant part in their behaviour in relation to learning and achievement, and that this can be measured in a reliable fashion. There are many personality models available which are employed by researchers and educators in the measurement of student personality for educational purposes. The Myer-Biggs Type Indicator (MBTI) and the Five Factor Model (FFM) are two such models.

Myer-Briggs Type Indicator (MBTI)

Developed in 1962, the MBTI is a self-report questionnaire based on Jung's theory of psychological types (Lawrence 1993) [142]. It was designed to quantify non-psychopathological personality types (Boyle 1995) [31].

The model classifies people based on 16 personality types as a four letter code according to their preference on the four dichotomies where a preference is indicated for one component or the other (Felder 1996) [74]. The four dichotomies are Extroversion-Introversion, Sensing-Intuition, Thinking-Feeling and Judgment-Perception. Based on the four dichotomies, a personality could be represented as ESFJ, ENFP or INTP etc to define specific tendencies, behaviours, attitudes orientation and decision making style (Boyle 1995) [31]. The dichotomies are outlined in further detail below.

The 93-item MBTI Form (Myers and McCaulley, 1998) [178] is comprised of forced choice questions and is the current standard instrument to assess the four bi-polar dichotomies of MBTI.

"Although a personality model, MBTI profiles are known to have strong learning-style implications" (Felder 1996 [74]; Pittenger 1993; Felder and Brent 2005) [189] [76]. The personality of a learner can influence the way in which they learn and therefore, according to Graf (2007) [95], *"MBTI includes important aspects for learning. Besides,*

other learning-style models are based on considerations of MBTI". For example, aspects of the FSLSM such as the Sensitive/Intuitive dimension, are directly linked to MBTI (Felder & Silverman 1988) [77]. The MBTI Dichotomies comprise the following;

Extroversion-Introversion (E-I) deals with the orientation of a person.

- **Extroverts (E)** - try things out, focus on the outer world of people (their preferred focus involves surrounding themselves with people or things).
- **Introverts (I)** - think things through, focus on the inner world of ideas (their own thoughts or ideas).

Sensing-Intuition (S-N) the way in which people prefer to perceive data is the focus of this dichotomy.

- **Sensors (S)** - practical, detail-oriented, focus on facts and procedures, these people prefer to perceive data from their five senses.
- **Intuitors (N)** - imaginative, concept-oriented, focus on meanings and possibilities, these people prefer to use their intuition (sixth sense) to perceive data from their unconscious.

Thinking-Feeling (T-F) represents judgment based on perceived data can be distinguished between thinkers and feeling based on rational considerations.

- **Thinkers (T)** - sceptical, tend to make decisions based on logic and rules, judgment is based on logical connections such as true or false and if-then.
- **Feelers (F)** - appreciative, tend to make decisions based on personal and humanistic considerations, judgment refers to more-less and better-worse evaluations.

Judgment-Perception (J-P) looks to see is a person is introverted or extroverted in their judgment functions (T-F) and their perception functions (S-N).

- **Judgers (J)** - set and follow agendas, seek closure even with incomplete data therefore like step by step approaches or structure and quick closure.
- **Perceivers(P)** - adapt to changing circumstances, resist closure to obtain more data. Like to keep all their options open and are more flexible and spontaneous.

The model provides a basis not only for the prediction of human behaviour but its four dichotomies *"can be correlated to learning preferences and information seeking* *strategies in the information system"* (Felicia and Pitt 2009) [80].

Five Factor Personality Model (FFM)

First presented by the president of the American Psychological Association (APA), L.Thurstone, in 1933, and refined in a later version with NEO-PRI by McCrae and Costa (1989)[156], the model is also referred to as the Big Five Model. The International Personality Item Pool (IPIP) is the measurement instrument applied in assessing personality under this model. The IPIP employs a set of 50 questions to measure an individual's personality traits. The FFM differs from the MBTI in that the traits are not bi-polar; each trait can however be present at a high or low level. The FFM's traits comprise the following:

Openness to Experience - Represents people with imagination and insight. People in this trait category hold a broad range of interests and are intelligent, sensitive and open minded.

Conscientiousness - This trait reflects thoughtful people who are organised, careful and responsible. They show goal directed behaviour, highly conscientious and mindful of detail.

Extroversion - Extroverts are highly excitable, social, talkative, and assertive showing high emotional expressiveness. This trait also reflects high activity levels.

Agreeableness - Good natured, compliant and cooperative, people who show this trait are very trustworthy, kind, affectionate modest and gentle.

Neuroticism - Neurotics can experience emotional instability, are usually anxious, moody, irritable and sad. They can be very insecure and suffer from depression.

The FSLSM scales relate directly to the Extroversion, Conscientiousness and Agreeableness traits of the FFM.

3.2.2 Learning-Style Models

Based on personality theory, numerous learning-style models have emerged over the last 25 years (Hawk and Shah, 2007) [108]. This has drawn increased attention to the diversity that exists between students relating to the manner in which they learn.

Hawk and Shah (2007) [108] state that *"within the last three decades, the proposition that students learn and study in different ways has emerged as a prominent pedagogical issue"*. Most learning models highlight that a varied approach to teaching is also important to ensure that the needs of all students are met in the learning environment. This is highlighted particularly by Felder and Silverman (1988) [77] who suggest that a mismatch between student learning-style and the teaching style employed within the learning environment can have a detrimental effect on learning. In 1984, Gregorc *"found that individuals learned with ease when the learning environment was compatible with their learning-style, but learning was thought of as 'a challenge, hard or distasteful' when there was a mismatch"* (as cited by Millar 2005) [172].

Kolb's Learning-Style Model

In 1984 Kolb based his learning-style model on experimental learning theory and look in particular at the learning process and the role of experience within the learning process. According to Kolb (1994) [138] *"learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping experience and transforming it"*. Kolb's model proposes a holistic approach to learning based on continuous processes. Kolb places less importance on learning-outcomes than is the case with other learning-style models. Kolb's cycle of Learning Stages are based on four process cycles in which learning occurs. These include how students take in information comprising:

How students take in information

- Concrete Experience (CE) - Feeling
- Abstract Conceptualism (AC) - Thinking

How students process information

- Reflective Observation (RO) - Watching
- Active Experimentation (AE) - Doing

Kolb suggests that learning is most effective when it occurs across all four modes, but dependant on the style of the individual learner the learning-style may commence within any of the process cycles. The four resulting learning-styles include Diverger (CE/RO), Assimilator (AC/ RO), Converger (AC / AE) and Accommodator (AE/CE).

Diverger (CE/RO). The imaginative Diverger is based around Concrete Experience and Reflective Observation. This learner is aware of values and meanings and is interested in people. They view concrete situations from many perspectives and adapt by observation rather than through action. They respond well to course material that relates to their interests and experience but need to be motivated.

Assimilator (AC/ RO). Abstract Conceptualism and Reflective Observation are the main focus for the Assimilator. For effective learning outcomes this category prefers the instructor to maintain the role of the expert. They appreciate the presentation of data in a logical, ordered fashion and are better when given time to reflect on information.

Converger (AC / AE). Rely on Abstract Conceptualism and Active Experimentation. The Converger appreciates the practical application of ideas and theories, these learners are good problem solvers, but prefer technical problems over interpersonal problems. They show great control over the expression of emotions. Practical application of ideas is important here. They are generally good decision makers.

Accommodator (AE/CE). Concrete Experience and Active Experimentation best represent the Accommodator. Problem based learning would best suit this type of learner. The instructor should pose open-ended questions and take a step back allowing the learner the opportunity to discover possibilities for themselves inductively and through trial and error. These learners like to carry out plans. This category of learner can be impatient and over assertive but are good at adapting to new situations and can take the opportunity this gives them to solve problems in real situations.

The Learning-Style Inventory (LSI) was originally introduced in 1976 (revised in later versions) to assess learning-styles based on this model. In 2005 Kolb introduced the current version of the LSI. The current version employs a forced choice ranking method in its assessment process of the CE, RO, AC and AE modes of learning [138].

Honey and Mumford's Learning-Style Model (HMLSM)

Building on the model offered by Kolb, having direct ties to the dimensions of the FSLSM, Honey and Mumford further develop the four styles. Their model strongly relies on the Active / Reflective and Concrete / Abstract dimensions of Kolb's model in their definition of types.

Activists are similar to Kolb's Accommodators. The activist is always open to anything new and always ready to take action. However their tendency to rush into the most immediately obvious action without looking into the consequences sufficiently can lead them into difficulties. **Reflectors** are similar to Kolb's Divergers. They are generally methodical, good listeners and information assimilators, but tend to hold back from direct participation, are not assertive, and are slow to come forward.

Theorists in Honey and Mumford's model are similar to Kolb's Assimilator. These disciplined learners are very logical in their thought processes. They are rational and objective. Theorists are mostly vertical thinkers and therefore can show difficulty in situations where it is necessary to show lateral thinking skills. **Pragmatists** reflect Kolb's Convergers. These learners are practical and realistic, they are eager to try things out, they get straight to the point and are very orientated toward technique, they have a tendency to reject anything that doesn't have an obvious application. Honey and Mumford (1992) [111] state that *" in relation to Kolb's model the similarities between his model and ours are greater than the differences"*.

A self report inventory, the Learning-Style Questionnaire (LSQ) developed by Honey and Mumford in 1982 and revised by Honey and Mumford (1992, 2000) [111] [112] ,is the current and standard means of assessing a person's learning-style using this model. An 80 item version and a 40 item version of the LSQ are available for this purpose, each with its own advantages/disadvantages as follows:

The 40-item Questionnaire:

- Suitable as an introductory test for new users
- Suitable to an assorted audience
- Shorter questionnaire - 10 items per style
- Less time consuming - students remain focused
- Faster completion and scoring

The 80-item Questionnaire:

- Suitable for extracting more in-depth analysis of learning-styles
- More suitable to a business-related audience
- Longer questionnaire - 20 items per style
- More time consuming - students can lose focus

3.2.3 Other Theories of Learning and Intelligence

The review of personality and learning-style models detailed here does not purport to be conclusive, there are many other models and theories available for the analysis of student learning-styles, personality and intelligences. These include (for example) the Dunn & Dunn model (1974) [65], the Herrmann Brain Dominance (HBD) Model (1989) [109], the Field Dependence - Independence Model (Witkin *et al.* 1977) [244] and Gardner's theory of Multiple Intelligences (1983, 1999) [86] [87]. These models and theories will be examined in terms of their linkages to the FSLSM later in the chapter.

3.3 The Felder-Silverman Learning-Style Model (FSLSM)

The FSLSM (Felder & Silverman, 1988) [77] is a widely employed model for inferring learner characteristics in the area of adaptive eLearning. For example, the model is used in the CS383 System (Carver, Howard and Lane 1999)[114] and by Graf and Kinshuk (2008) [94] for their adaptive LMS system (see chapter 4).

The FSLSM was formulated in 1988 to provide the best basis for instructors in the engineering field for the delivery of educational content. The model attempts to capture the most important learning-style differences among students to enable the delivery of content in a manner that suits all students. Felder and Silverman's work was based on the belief that the matching of a student's learning-style with the teaching style of their professor would lead to better learning-outcomes for students. Where a mismatch occurs, Felder & Spurlin (2005) [79] suggest that students are likely to lose interest, leading to an inferior educational outcome.

The 1988 version of the FSLSM indicated 2^5 learning-styles (32), however, they later (2002) dropped the Inductive / Deductive dimension. Consequently the model now allows for 2^4 learning-styles (16). *"Learners are characterised by values on the four dimensions. These dimensions are based on major dimensions in the field of learning-styles and can be viewed independently from each other"* (Graf 2007) [95]. The measurement instrument associated FSILS, develops the preference profile of a student on four of the learning-style dimensions. Based on the original Felder & Silverman paper (1988), there is a discrepancy between the FSLSM and the FSILS, in that the FSILS, in assessing preferences on the four scales of the FSLSM provides for a higher number of possible combinations when considering the high, moderate and balanced style levels across a scale. The FSILS is looked at in further detail later in the chapter.

3.3.1 FSLSM Dimensions

Preferred Learning Style		*Corresponding Teaching Style*	
sensory intuitive	perception	concrete abstract	content
visual auditory	input	visual verbal	presentation
inductive deductive	organization	inductive deductive	organization
active reflective	processing	active passive	student participation
sequential global	understanding	sequential global	perspective

Figure 3.1: Felder Silverman Learning-Style Model (Adapted from Felder and Silverman 1988)

As stated, the FSLSM distinguishes between learning-styles based on four dimensions which focus on how students process, perceive, understand and stress inputs. Based-on these dimensions a learning-style can be Active or Reflective, Sensing or Intuitive, Visual or Verbal, and Sequential or Global. Students can reflect a balance within a single dimension, in that they are considered to have no preference for either end of the scale. Students can also show a moderate leaning toward, or a strong preference for, one side of the scale or the other. To enable teachers to reach all students in a single session, Felder & Silverman also propose a teaching model for use in parallel with the learning-style model. The model aims to classify instructional methods according to their corresponding learning-style.

The Active / Reflective Dimension

The Active / Reflective dimension of the FSLSM reflects the way in which a student preferentially processes information.

- **Active learners** tend to be experimentalist, that is, people who feel more comfortable with, or are better at, active experimentation than reflective observation. They retain and understand information best when doing something active with it. For example, doing something in the external world with the information. They like to discuss or apply information to a task and explain information to others.

- **Reflective learners** are usually theoreticians, and prefer reflective observation, that is, they prefer to think about information before applying it to the external world (Felder & Silverman 1988) [77].

Teaching-Style Associated with the Active / Reflective Dimension

The corresponding teaching-style specifies the type of student participation that is facilitated by relative presentation. For Active learners it is necessary to include a brief discussion session and or practical problem solving sessions. For Reflective learners it is appropriate to include the occasional pause for thought and the presentation of material that requires fundamental understanding (Felder & Silverman 1988) [77].

The Sensitive / Intuitive Dimension

The Sensitive / Intuitive dimension is representative of the type of information that a student would preferentially perceive.

- **Sensing (or Sensory) learners** are patient with detail, like learning facts and data and they also like experimentation. They like problem solving where standard methods are employed. In general, according to Felder-Silverman, they are not open to surprises. Sensors are careful and slow and therefore may not do well in timed situations.

- **Intuitive learners** prefer principles and theories and like discovering possibilities and relationships. They are good at grasping new concepts. They are favourable to repetition. They are bored by detail and challenged by complications. They like innovative situations. Intuitive learners can be impatient and careless and their quickness in this regard can lead them into trouble in timed tests (Felder & Silverman 1988) [77].

Teaching-Style Associated with the Sensitive / Intuitive Dimension

The corresponding teaching-style specifies the type of information that should be emphasised by the instructor in the presentation of material to students. For Sensitive learners, *"concrete information, facts, data and observable phenomena"* (Felder & Silverman 1988) [77] should be included. *"Abstract information should be included to reach Intuitive learners, including principles and theories and is appropriate mathematical models"* (Felder & Silverman 1988) [77].

The Visual / Verbal Dimension

The Visual/Verbal dimension reflects the sensory channel that is preferential to the student for the receipt of external information.

- **Visual learners** remember best what they see, and learn best through images and diagrams. Pictures, diagrams and flowcharts, timelines, films and demonstrations are all suitable for this learner category.
- **Verbal learners** gain more from text and auditory explanations. They also benefit from discussion and favour verbal explanations (Felder & Silverman 1988) [77].

Felder and Silverman originally referred to Auditory learners in the 1988 paper but Felder changed this to Verbal learners in the 2002 Author's preface to the same paper. His reasoning is that, although textual prose is perceived visually, it cannot be categorised as auditory. Textual prose cannot be categorised as visual either, that is in a similar manner as a picture for transmitting information. Felder notes that cognitive scientists have established that our brains generally convert written words into their spoken equivalents and process them in the same way that they process spoken words. Written words are therefore not equivalent to real visual information: to a visual learner, a picture is truly worth a thousand words, whether they are spoken or written. Making the learning-style pair visual and verbal solves this problem by permitting spoken and written words to be included in the same category (verbal) (Felder-Silverman 1988) [77].

Teaching-Style Associated with the Visual / Verbal Dimension

The corresponding teaching-style reflects the type of presentation that should be stressed relative to the learning-style of individual learners on this dimension. Felder & Silverman suggest that as lectures contain auditory content, and hand-outs are usually textual, they work best for Verbal learners. In order to adjust the lecture to accommodate Visual learners, *"visual material, pictures, diagrams, sketches, process flow charts, network diagrams, and logic or information flow charts should be used to illustrate complex processes or algorithms; mathematical functions should be illustrated by graphs; and films or live demonstrations of working processes should be included"* (Felder & Silverman 1988) [77].

The Global / Sequential Dimension

The Global / Sequential dimension of the model differs from the other three model dimensions as it looks in particular at how learners progress toward an overall understanding of a topic or subject area.

- **Sequential learners** usually follow a line of reasoning. They achieve a more effective learning-outcome where learning topics are presented in small incremental steps of complexity.

- **Global learners** are usually unable to explain how they arrive at solutions, achieving a learning-outcome in large leaps and bounds, absorbing the learning materials almost randomly without seeing the connections and then suddenly seeing the whole picture (Felder & Silverman 1988 [77]).

Teaching-Style Associated with the Global / Sequential Dimension

The associated teaching-style proposed by Felder-Silverman addresses the type of perspective that should be provided on the information presented. According to Felder & Silverman (1988), Sequential learners are currently facilitated fully in education as curricula are sequential, course syllabi are sequential, textbooks are sequential, and most teachers teach sequentially. In order to progress Global learners toward understanding the instructor should provide the big picture or goal of a lesson before presenting the steps, doing as much as possible to establish the context and relevance of the subject matter and to relate it to the students' experience. Applications and "what ifs" should be liberally furnished. The students should be given the freedom to devise their own methods of solving problems rather than being forced to adopt the professor's strategy, and they should be exposed periodically to advanced concepts before these concepts would normally be introduced (Felder & Silverman 1988) [77].

The Inductive / Deductive Dimension

Initially the FSLSM also focused on organisation including a fifth dimension, Inductive / Deductive learners. The Inductive / Deductive dimension represented the student's preferred organisation of information.

- **Induction**, according to Felder & Silverman is a reasoning progression that proceeds from particulars (observations, measurements, data) to generalities (governing rules, laws, theories) and is the natural learning-style.
- **Deduction** proceeds in the opposite direction and is the natural teaching-style (Felder & Silverman 1988) [77].

In the Author's preface in 2002 of the earlier 1988 paper, Felder omitted this dimension from the model. While Induction and Deduction are indeed different learning and teaching preferences and approaches, Felder (2002) [77] highlights that based on the results from additional samplings, his earlier speculation that more students prefer induction, is refuted. Felder (2002) [?] states *"I don't want instructors to be able to determine somehow that their students prefer deductive presentation and use that result to justify continuing to use the traditional but less effective lecture paradigm in their courses and curricula"*.

It is important to note that while a student may present on one side of any learning-style dimension, Felder & Silverman (1988) [77] state that it is possible to include content for the opposite style to 'train' the user toward the other style.

3.3.2 The Felder-Solomon ILS Questionnaire (FSILS)

The FSILS [78] is the main method used to measure the learning-style of an individual user in relation to the FSLSM. The FSILS was initially published in 1991. The index was updated in 1994 after further analysis based on responses. The online version became available for use as a non-commercial instrument in 1997 (Felder & Spurlin 2005 [79]).

Assessing Questionnaire Results

The 44 questions included in the online questionnaire rate a student on each of the four dimensions of the FSLSM. A total of 11 questions are posed for each dimension (see Appendix 1). The instrument does not provide a metric for the Inductive / Deductive dimension however metrics are provided for the remaining four of the five dimensions. The exclusion of the Inductive / Deductive dimension is a reflection of its exclusion by Felder from his model in 2002 [77].

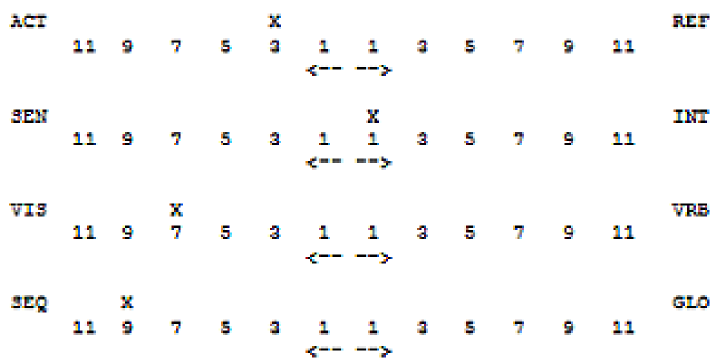

Figure 3.2: Individual FSILS Questionnaire Results (Felder and Solomon [78])

Each question offers two potential answers to the user. For example, each question is answered either with a value +1 (where answer 'A' is selected by the user) or -1 (where answer 'B' is selected). These values are totalled in respect of the dimension score.

Preferences are expressed for students as between values +11 and -11 to indicate the total score achieved on either side of the dimension scale.

- A learner placed between a score of 1 and 3 on a single dimension of the results screen is deemed to be balanced on that particular dimension.
- A learner placed between 5 and 7 on one side of a dimension, will be shown to have a moderate leaning in favour of the relevant side of that dimension scale.
- A learner placed between 9 and 11 on a dimension scale, will have a high leaning toward the relevant side of the dimension scale.

A sample results screen from the online questionnaire is shown in Figure 3.2. The learner whose questionnaire result is presented is balanced on the Active / Reflective dimension with a score of +3. This balanced score implies that the learner is equally Active and Reflective, and does not show a leaning toward one extreme of the scale over the other. He is also balanced on the Sensitive / Intuitive dimension with a score of +1. The student is moderately Visual on the Visual / Verbal dimension with a score of +7. The student shown is highly Sequential, scoring +9 on the Sequential side of the Global / Sequential dimension scale.

The FSILS is currently the only validated instrument for the FSLSM (Graf and Kinshuk 2006) [93].

3.3.3 Validity and Reliability of FSILS

The literature indicates that the validity and reliability of the FSILS has been successfully tested using four different measures including test-retest, internal consistency, inter-scale reliability and construct validity.

Felder & Spurlin (2005) [79], Seery *et al.* (2003) [209], Livesay *et al.* [148] and Zywno (2003) [252], assess the reliability of the FSILS by retesting subjects after specific intervals. The results of their studies indicate that, while it is necessary to provide large enough intervals between retesting to ensure that subjects cannot remember their responses on earlier tests, the intervals should not be so large that the quantity being assessed might change to a significant extent in the natural course of events. This is evident in the results of the three studies. Zywno employed an interval of eight months, Livesay *et al.*, seven months while Seery *et al.* employed a smaller interval of just four weeks. Felder and Spurlin suggest that the four week interval employed by Seery represents the ideal interval period for this purpose as their study results indicated higher correlations and statistical significance over the other two studies, concluding that test-retest reliability of the FSILS is satisfactory.

Internal consistency and inter scale reliability refers to the homogeneity of items intended to measure the same quantity or the extent to which responses to items are correlated. Cronbach's alpha is a measure of internal consistency, for example, it measures how closely related a set of items are in a group. Cronbach's coefficient alpha is an average of all possible split pair correlations (Felder & Spurlin 2005) [79]. A high level of internal consistency between items, thus a high Cronbach alpha, is expected in a valid instrument. Tuckman (1999) [232] suggests that an alpha of 0.50 or greater is acceptable for attitude and preference assessments.

Felder & Spurlin (2005) [79] assessed the internal consistency and reliability of the FSILS. Based on five studies, that of Livesay *et al.* (2003) [148], Zywno (2003)[252], Van Zwanenberg (2000) [234], Viola *et al.* (2006) [237] and Spurlin (2002) [219] as cited by Felder & Spurlin (2005) [79], results indicate that all alpha values exceed the criterion value of 0.5 excluding one instance, that of the Global / Sequential dimension where an alpha of 0.41 was achieved in the Van Zwanenberg study. According to Felder & Spurlin (2005) this is reflective of the consistently lower dimension values achieved in the Van Zwanenberg study across all dimensions in comparison to all other studies reported in the literature. Litzinger *et al.* (2005) [147] tested 572 subjects from across three colleges including engineering, education and liberal arts to assess the internal consistency and reliability of the FSILS scores achieved. The Cronbach alpha coefficient was calculated for each of the four dimensions. The values obtained correspond with the studies conducted by Felder & Spurlin (2005), showing a comparable magnitude to the results of three of the four studies (test-retest validity, internal consistency reliability and inter-scale orthogonality and construct validity). Litzinger *et al.* found that both the Sensitive/Intuitive and the Visual/Verbal dimension scales had a reliability in excess of 0.7, while the Active/Reflective and the Global / Sequential dimension scale had Cronbach alphas of 0.6 and 0.56 respectively. These results are also in accordance with Tuckman's criteria for attitude and preference assessments. It must be noted that Viola *et al.* (2006) [237] state that in general the alpha coefficients are not high, even if greater than the threshold 0.5 recommended by Tuckman (1999) [232].

Felder & Spurlin also examine the Pearson Correlation coefficients for preferences on different FSILS scales achieved across the four studies mentioned. While they report that three of the scales are reasonably orthogonal, their findings indicate that the Sensitive / Intuitive and the Global / Sequential preferences are correlated. This was further corroborated through the results achieved when factor analysis was conducted on the FSILS responses within three of the four studies (Livesay *et al.*, Zywno and Van Zwanenberg *et al.*) when using a rotated principle component method. All three studies conclude that the Active / Reflective, Visual / Verbal and Sensitive / Intuitive dimensions can be considered relatively independent. However results show that a moderate degree of association exists between the Global / Sequential and the Sensitive / Intuitive dimension, particularly evident between the Sensitive and Sequential scales (Van Zwanenberg *et al.* 2000; Zywno 2003) [234] [252]. This correlation between Global / Sequential and Sensitive / Intuitive dimensions is expected and supports the construct validity of the FSILS as its principle intended purpose is designing instruction suited to include all learners. Felder & Spurlin state that *" one would anticipate a moderate correlation between the sensing/intuitive and sequential/global scales. Sequential learners, who acquire understanding in logical connected steps, could be either sensors or intuitors, but global learners, whose thinking processes tend to be nonlinear and who acquire understanding holistically, would seem much more likely to be intuitive than sensing"* (Felder & Spurlin 2005) [79]. Viola *et al.* (2006) [237] also find a correlation between Sensitive and Sequential dimensions. It must be noted that Viola *et al.* (2006) [237] also state that, based on Pearson's correlation, their study's findings when using Multiple Correspondence Analysis (MCA), are higher than findings shown in the literature and indicate that many dependencies exist between styles belonging to the same FSILS dimension including the Active / Reflective dimension and the Sensing / Intuitive dimension.

Felder & Spurlin (2005) [79] state that construct validity reflects the instrument's level of accuracy in measuring the trait that it attempts to measure. There are two main types of construct used for this purpose. Convergent construct validity, where instrument scores correlate with quantities with which they should correlate, and Divergent / Discriminant Construct Validity, where instrument scores fail to correlate with quantities with which there is no reason to expect a correlation. Felder and Spurlin indicate that the results from several studies provide evidence addressing one or both of these forms of validity.

In general it is expected that learning-style preferences influence a student's educational path towards particular fields of study, for example, civil engineers tend to be sensitive learners while intuitive learners might gravitate toward mathematics. Consequently, it would be reasonable to expect that undergraduates attracted to a specific field would have similar profiles from year to year and that their profiles would differ from undergraduates in different fields.

Findings from Felder & Spurlin's [79] assessment of 10 engineering populations from the literature indicate that undergraduate engineering students across a variety of different institutions (including Ryerson, Limerick, Iowa State and Michigan), are consistently more Active than Reflective, more Sensitive than Intuitive, more Visual than Verbal and more Sequential than Global, supporting the convergent validity.

Studies conducted by Lopez (2002) [149] confirm that students in humanities are proportionally more Verbal than their counterparts in the Sciences, while Litzinger *et al.* 2005 [147] found that engineering students tend to be more Sequential and Sensing and more Verbal than their liberal arts counterparts, thus supporting discriminant validity.

Consequently, based on the findings of the research discussed above, including the research conducted by Felder & Spurlin (2005) [79], to assess the FSILS based on the four measures (test-retest, internal consistency, inter-scale reliability and construct validity), it is concluded that the FSILS can be accepted as a valid instrument for the assessment of Learning-style preference based on The FSLSM.

3.3.4 Gender and the FSLSM

As originally intended for use with engineering students Fowler *et al.* (2001) [83], in an effort to attract and retain a higher level of female students to engineering, assessed the learning-style of female candidates as compared to their male counterparts. In testing 69 engineering students, the FSILS scores indicated that in relation to engineering courses there was a greater mismatch with the traditionally associated learning-styles for female students. It must be noted that their results could potentially have been influenced by the small number of female candidates (9) assessed on the FSILS when compared to the male candidates in the sample (60). Therefore the sample population was highly gender imbalanced (Table 3.1).

Gunduz and Ozcan (2010) [102], testing a sample population of 450 students (300 male and 150 female), report no significant differences between genders when comparing learning-style preferences based on the FSLSM. Again, it is important to note that their sample was gender imbalanced.

Litzenger *et al.* (2005) [147] report significant mean differences between genders on all scales of the FSLSM except the Active / Reflective dimension in an essentially gender-balanced sample population of 572 FSILS respondents. Litzenger *et al.* conclude however that a significant result but further study is warranted as it is stated to be the first report of significant gender differences relating to the FSILS within the literature.

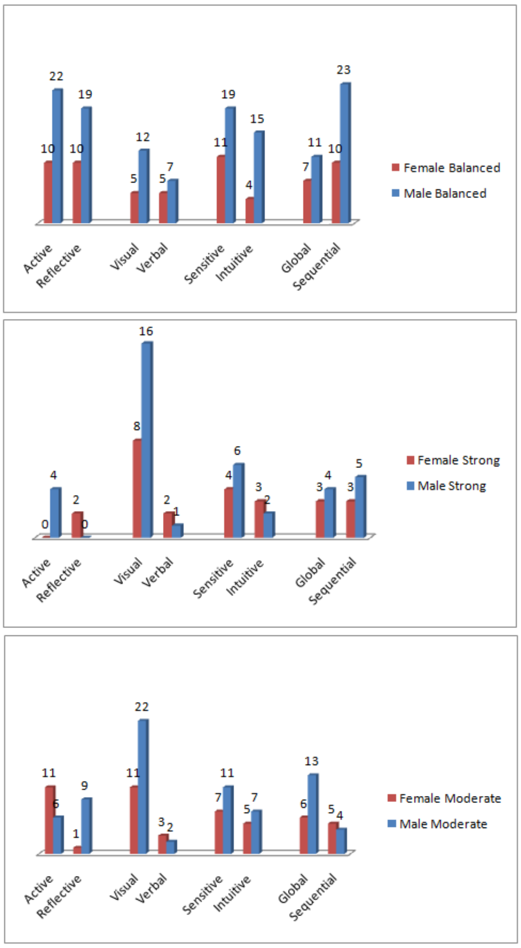

Figure 3.3: Gender Differences between Male and Female Students across FSLSM Dimensions Including Balanced, Strong and Moderate

Author's Contribution

The sample population data gathered in preparation of this thesis also reflects a gender-imbalance (34 females and 60 males). Consequently no definite conclusion can be drawn as to any differences occurring in learning-style preference based on gender from the sample. However it is noted that in general, the imbalance is reflected in the sample population where FSILS scores are moderate and strong across the dimensions of the FSLSM. This indicates that in general, while a difference is observed between male and female students across the dimensions, no conclusion can be drawn as to the differences between genders (Figure 3.3).

Table 3.1: Learning-Style Preference Diversity between Genders in Engineering (Fowler *et al.* 2001) [83]

	Act / Ref	Sen / Int	Vis/ Ver	Glo / Seq	*N*
Male	Act=55%	Sen=65%	Vis=87%	Glo=38%	60
	Ref=45%	Int=35%	Ver=13%	Seq=38%	
Female	Act=78%	Sen=67%	Vis=56%	Glo=56%	9
	Ref=22%	Int=33%	Ver=44%	Seq=44%	

3.3.5 Relationships and Parallels between FSLSM and other Learning and Personality Models

The benefit of the FSLSM goes beyond those posed by the model itself. The relationship that exists between the model dimensions and other learning-style and personality models offer a unique combination (Felder & Spurlin 2005) [79]. These linkages and relationships give a greater emphasis and backing to the use of this model when modeling students for adaptive personalised electronic and mobile learning systems. Felder & Silverman (1988) [77] admit that their learning-style dimensions are neither original nor comprehensive. The literature indicates many relationships between the FSLSM and other models. Some of the relationships have been examined based-on the FSLSM's dimensions (table 3.1). There is a certain degree of overlap between the concepts used in the model and those used in others learning-style models (Popescue 2009) [191]. The FSLSM has also been linked with a number of learning-style, personality and intelligence models as highlighted in Figure 3.4.

Linking the Sensitive Intuitive Dimension to Other Models

The Sensitive / Intuitive dimension is, according to Felder & Silverman (1988) [77], directly related to one of the four dimensions of Jung's theory of psychological types. The dimension is stated as being related to MBTI by Felder & Brent (2005) [76]. According to the results of a study conducted by Felder & Brent, preferences for Sensitive and Active learning measured on the FSILS were found to correlate with preferences for Sensing and extroversion measured on the MBTI. They also indicate cross correlations achieved by others studying comparable models against the FSILS. Rosati & Felder (1995) [204], as cited in Felder & Spurlin (2005) [79], found that sensing students on the FSILS were also sensing on the MBTI where students are tested on both instruments. The dimension also has parallels with the Concrete / Abstract dimension of the Kolb model (Felder & Brent 2005) [76]. The dimension has been linked with Witkin (1977) [244] Field Dependence - Independence Model by Graf *et al.* (2008) [94] who suggest that the Field-Dependent dimension of Witkin's model has close ties to the Sensitive dimension of the FSLSM while Intuitive learners are most likely to be Field-Independent.

Linking the Active / Reflective Dimension to Other Models

The Active / Reflective dimension is closely related, if not identical to, the Introvert / Extrovert dimension of the MBTI and Jung's earlier model (Lawrence 1993, Felder & Silverman 1988; Felder & Brent 2005) [142] [77] [76]. Rosati & Felder (1995)[204] as cited in Felder & Spurlin (2005)[79] found that Active learners are more Extroverted and Perceiving where students are measured on both the FSILS and the MBTI. A correlation was also found between Active learning preferences and Extroversion on the MBTI. The dimension also relates to the processing component of both Kolb's and Honey and Mumford's models (Felder & Spurlin 2005; McCarthy 1987; Popescue 2009; Hawk & Shah 2007) [79] [155] [191] [108]. The dimension has also been associated with the Impulsive / Reflective dimension of the Dunn & Dunn model (Hawk & Shaw 2007) [108]. The dimension also has analogues in the visual auditory kinaesthetic formulation of modality theory and neuro-linguistic programming (Felder & Brent 2005) [76].

Linking the Visual / Verbal Dimension to Other Models

The Visual / Verbal dimension is similar to Fleming's Visual Auditory Reading/Writing Kinaesthetic framework (VARK) [81]. Felder and Silverman's Visual learners, as described earlier in the chapter, are characterised by a preference for learning from demonstrations, pictures, diagrams and graphs, whereas Verbal learners prefer opportunities to explore new material through language-based processes such as talking writing

FSLSM	Active	Reflective	Global	Sequential	Visual	Verbal	Sensitive	Intuitive
MBTI	Feeling / Extroversion	Thinking Feeling Introversion	Intuition	Sensors Intuition	Extroversion	Introversion	Sensing	Intuition
KOLB	Active Experimentation Converging Accommodator	Reflective Observation Assimilator			Accommodating	Accommodating	Concrete Experience Converging Assimilator	Abstract Conceptualism Diverging
FD / FI	FD	FI	FD	FI	FI	FD	FD	FI
GSLM			Random	Sequential				
MI	High Spatial Body Kinesthetic Interpersonal	High Intrapersonal	Spatial		Spatial	logical		
VARK	Kinesthetic		Visual	Auditory Read / Write Kinesthetic	Visual	Auditory Kinesthetic		
FFM	Extroversion	Conscientious Introversion					Agreeableness	
H&M	Active Experimentation Activists	Reflective Observation Reflectors					Concrete Experience Pragmatist	Abstract Conceptualization Theorists
CTM	Low WMC	High WMC	Low WMC	High WMC	Low WMC	Low WMC High WMC	Low WMC	High WMC
HBD	Right		Right	Left	Right	Left		

Figure 3.4: Cross-Comparisons between Learning, Personality and Other Theories

explaining and discussing. VARKs formulation of modality theory and neuro-linguistic programming also has parallels in cognitive studies of information processing (Tanner & Allen 2004) [225]. Hawk & Shah (2007) [108] also tie this dimension to the the Dunn & Dunn model. Visual learners have also been linked to Herrmann Brain Dominance Instrument's right brain dominance. Visual learners are represented by the spatial intelligence while Verbal learners are logically intelligent, that is they have the ability to detect patterns, reason deductively and think in a scientific and mathematical manner (Felder & Brent 2005) [76]. Graf *et al.* (2008) [94] also link the dimension with Witkin (1977) [244] Field Dependence-Independence model indicating that Visual learners are Field-Dependent while Verbal learners are Field-Independent.

Linking the Global / Sequential Dimension to Other Models

The Global / Sequential dimension is the most significant dimension of the FSLSM in relation to cognitive style (Schmeck 1988; Das 1988) [207] [54]. This dimension has many links with other learning-style models. Sequential learners have strong parallels with the sequential dimension of the Gregoric learning-style model (Hawk & Shah 2007) [108]. The dimension is linked to Pask's Serialist and Holistic style (Popescue 2009) [191] and Dunn & Dunn's Analytic and Auditory-sequential dimensions (Hawk & Shah 2007) [108]. Global learners are Holistic (Popescue 2009) [191], and are linked to the random dimension of the Gregoric model (Hawk & Shah 2007) [108]. Graf *et al.* (2008) [94] suggest that the difference between the Holistic and Global learning-styles is nominal. In their published study where students are measured on both the FSILS and the MBTI, Rosati & Felder (1995) [204] as cited in Felder & Spurlin (2005) [79] indicate that students who are clearly more Sequential on their FSILS were significantly more likely to be Sensors than Intuitors on the MBTI. This supports the conjecture of Lawrence (1993) [142] that Sensors are more inclined to think sequentially and that Intuitors will be balanced on the the Global / Sequential dimension scale. Sequential learners tend to be field independent on Witkin's (1977) Field Dependence-Independence model, while Global learners tend to be Field Dependant (Graf *et al.* 2008) [94].

FSLSM and the Cognitive Traits Model

The Cognitive Traits Model (CTM) (Riding 2002; Lin *et al.* 2003) [201] [146], profiles learners according to one of three cognitive traits, Working Memory Capacity (WMC), Inductive Reasoning Ability (IRA) and Associative Learning Skills (ALS).

FSLSM is linked to the WMC trait of the CTM on all four dimensions as shown by Kinshuk & Graf (2007) [136], based on the literature. WMC is the trait that allows individuals to keep an active amount of limited information for a short period of time

(Millar 1956) [171]. WMC facilitates both storage and operational subsystems (Kinshuk & Graf 2007) [136]. WMC is potentially an important factor for consideration in the development of adaptive systems as there is a need to assist students in the avoidance of cognitive overload when working within personalised systems.

According to Kinshuk & Graf (2007) [136], learners linked with low WMC are generally Active, Visual, Sensitive and Global in their learning-styles while Reflective, Verbal, Intuitive and Sequential learners show high WMC. In an effort to maintain manageable levels of WMC it is necessary to consider that low WMC students can be facilitated through more concrete and media presentation. In the case of learners with high WMC, the level of abstract content in presentations can be increased.

FSLSM and Gardner's Theory of Multiple Intelligences (MI)

Howard Gardner *"questioned the idea that intelligence is a single entity, that it results from a single factor, and that it can be measured simply via IQ tests. He has also challenged the cognitive development work of Piaget. Bringing forward evidence to show that at any one time a child may be at very different stages for example, in number development and spatial/visual maturation, Howard Gardner has successfully undermined the idea that knowledge at any one particular developmental stage hangs together in a structured whole"* (Smith 2008) [216]. Gardner proposed the theory of Multiple Intelligences in 1983 (Gardner 1983) [86], initially formulating a provisional list of seven intelligences. There are currently nine intelligences associated with the theory. These are given Figure 3.5.

Although not a learning-style or a personality model, Gardner's Multiple Intelligences have been linked to the FSLSM by Tanner and Allen (2004) [225] and Nilson (2009) [182].

Felder & Silverman's Visual learners are Spatial; *"they process, store and retrieve information in 2D spatial arrangements/organisation, shapes graphics, diagrams, flowcharts, pictures and scenes"* (Nilson 2009) [182]. Verbal learners are logically intelligent, that is, they have the ability to detect patterns, reason deductively and think in a scientific and mathematical manner.

Active learners are said to have high interpersonal skills, they are spatially intelligent and bodily kinaesthetic (see Figure 3.5). This implies that these students have the ability to understand the feelings and intentions of others (interpersonal). They can manipulate and create mental images and can solve problems based on this intelligence (spatial). This ability is not confined to sighted learners (Nilson 2009) [182] and is also evident in blind learners (Silverman 2000) [213]. As these learners are also bodily kinaesthetic (see Figure 3.5), they can use their mental abilities in cooperation with their physical movements. This gives these individuals the ability to understand their own feelings and motivation. *"Active learners in Felder and Silverman's framework might possess high interpersonal intelligence, whereas reflective learners might excel in the domain of interpersonal intelligence"* (Tanner & Allen 2004) [225].

Global learners are also said to possess spatial intelligence. Visuals also help the *"Global learner because they give the big picture"* (Nilson 2009) [182]. Sequential learners are logical and mathematical (Dagez & Hashim 2005) [52].

Intelligence	**Description**
Linguistic intelligence	Sensitivity to the spoken and written language. The ability to learn languages, and the capacity to use language to accomplish certain goals.
Logical-mathematical intelligence	Consists of the capacity to analyze problems logically, carry out mathematical operations, and investigate issues scientifically.
Musical intelligence	Involves skill in the performance, composition, and appreciation of musical patterns.
Bodily-kinesthetic intelligence	Entails the potential of using one's whole body or parts of the body to solve problems. It is the ability to use mental abilities to coordinate bodily movements.
Spatial intelligence	Involves the potential to recognize and use the patterns of wide space and more confined areas.
Interpersonal intelligence	Is concerned with the capacity to understand the intentions, motivations and desires of other people.
Intrapersonal intelligence	Entails the capacity to understand one self, to appreciate one's feelings, fears and motivations.
Existential intelligence	The ability to understand religious and spiritual ideals. A strong understanding of things that are not visual to the eye but through faith and belief.
Naturalist intelligence	Enables human beings to recognize, categorize and draw upon certain features of the environment

Figure 3.5: Gardner's Multiple Intelligences

3.3.6 The Distribution of Learning-Styles Across the FSLSM

Results from the literature have been compiled by Felder & Spurlin 2005 [79] to highlight the distribution of learning-style preference across the sample populations of studies that have used the FSILS. These are provided in Figure 3.7. In most cases the studies have been based-on samples comprised of undergraduate students. The preferences are represented by the highest score on each dimension, for example, 63% of sampled students at Iowa State were Active learners, as a consequence the remaining percentage (37%) were Reflective learners. The results from some of these studies have been further broken down by Felder & Spurlin to highlight the distribution within some of the sample populations based on the strength achieved for each score on each dimension of the scale as indicated in table 3.3.

Str./ mod. active	Balanced	str./mod. reflective	str./mod. sensing	Balanced	Str./mod. intuitive	str./mod. visual	balanced	str./mod. verbal	str./ mod. sequent.	balanced	Str./mod. global
24%	61%	15%	29%	53%	17%	64%	33%	3%	16%	68%	16%

Figure 3.6: Strengths of Preference (Adapted from Graf *et al.* 2007)

Results cited by Graf *et al.* (2007) [95] correspond with the results indicated by Felder & Spurlin (2005). Graf *et al.* show that, based on 207 participants chosen from courses in web engineering, information management and information systems at the Massey University in New Zealand (122 participants) and the Vienna University of Technology in Austria (87 participants - including students at Bachelors level right through to PhD level), 57% of students who took part in the study had an Active preference, 58% of the students had a Sensitive preference, 87% of the students had a Visual preference and 56% of the students had a Global preference. The results from some of these studies can be further broken down as indicated in Figure 3.7.

Contribution

In the development of this thesis, a total of 94 participants took part in studies conducted to assess biotechnology as a means of detecting learning-style (see chapters 5 & 6). The participants were all students ranging from Leaving Certificate to PhD level. A total of 51 students were from the Department Computer Science at UCC, 19 students participated from the School of Education at UCC, while eight students participated from the Department Microbiology. 16 participants comprised teaching staff and students from the Department of Computing, Maths and Physics at Waterford Institute of Technology. Four Leaving Certificate students from local secondary schools, two students from the School of Business at Cork Institute of Technology and two others also participated. The resulting sample is supportive of the distribution reported by

SAMPLED POPULATION	A	S	Vs	Sq	N	Reference
Iowa State, Materials Engr.	**63%**	**67%**	**85%**	**58%**	**129**	**Constant**
Michigan Tech, Env. Engr.	**56%**	**63%**	**74%**	**53%**	**83**	**Paterson**
Oxford Brookes Univ. , Business	64%	70%	68%	64%	63	De Vita
British students	**85%**	**86%**	**52%**	**76%**	**21**	
International students	52%	62%	76%	52%	42	
Ryerson Univ., Elec. Engr.						
Students (2000)	**53%**	**66%**	**86%**	**72%**	**87**	**Zywno & Waalen**
Students (2001)	**60%**	**66%**	**89%**	**59%**	**119**	**Zywno**
Students (2002)	**63%**	**63%**	**89%**	**58%**	**132**	**Zywno**
Faculty	**38%**	**42%**	**94%**	**35%**	**48**	
[a]**Tulane, Engr.**						
Second-Year Students	**62%**	**60%**	**88%**	**48%**	**245**	**Livesay *et al.***
First-Year Students	**56%**	**46%**	**83%**	**56%**	**192**	**Dee *et al.***
Universities in Belo Horizonte (Brazil)[b]						
Sciences	65%	81%	79%	67%	214	Lopes
Humanities	52%	62%	39%	62%	235	
Univ. of Limerick, Mfg. Engr.	**70%**	**78%**	**91%**	**58%**	**167**	**Seery *et al.***
Univ. of Michigan, Chem. Engr.	**67%**	**57%**	**69%**	**71%**	**143**	**Montgomery**
Univ. of Puerto Rico-Mayaguez						
Biology (Semester 1)	65%	77%	74%	83%	39	Buxeda & Moore
Biology (Semester 2)	51%	69%	66%	85%	37	Buxeda & Moore
Biology (Semester 3)	56%	78%	77%	74%	32	Buxeda & Moore
Elect. & Comp. Engr.	47%	61%	82%	67%	?	Buxeda *et al.*
Univ. of São Paulo, Engr.[b]	60%	74%	79%	50%	351	Kuri & Truzzi
Civil Engr.	69%	86%	76%	54%	110	
Elec. Engr.	57%	68%	80%	51%	91	
Mech. Engr.	53%	67%	84%	45%	94	
Indust. Engr.	66%	70%	73%	50%	56	
Univ. of Technology Kingston, Jamaica	**55%**	**60%**	**70%**	**55%**	**?**	**Smith *et al.***
Univ. of Western Ontario, Engr.[c]	69%	59%	80%	67%	858	Rosati
First year engr	66%	59%	78%	69%	499	Rosati
Fourth year engr.	72%	58%	81%	63%	359	Rosati
Engr. faculty	51%	40%	94%	53%	53	Rosati

[a] Rows in boldface denote studies using the current version of the ILS with native English speakers
[b] Portuguese translation of the ILS used
[c] Data collected with Version 1 of the ILS. (All other studies used Version 2.)

Figure 3.7: Literature Reported Learning-Style Preferences (Adapted from Felder and Spurlin 2005)

Felder and Spurlin (2005) [79] and Graf *et al.* (2007) [95]. The distribution across the FSILS spectrum was represented in Table 3.2

Each dimension was assessed to determine if the sample represented a normal distribution. In each dimension case the sample indicated a normal distribution as shown in Figure 3.9.

As shown in Figure 3.9 the overall population sample data gathered through the FSILS reflect normal population distribution across each dimension scale. It is noted that the Visual/Verbal dimension scale is skewed toward the Visual end of the scale. The Active / Reflective scale is also slightly skewed toward the Active side of that dimension scale.

	Act-Ref			Sens-Int			Vis-Vrb			Seq-Glo		
	Mod-Str Act	Mild	Mod-Str Ref	Mod-Str Sens	Mild	Mod-Str Int	Mod-Str Vis	Mild	Mod-Str Vrb	Mod-Str Seq	Mild	Mod-Str Glo
A1	27%	58%	15%	38%	52%	11%	69%	28%	3%	34%	52%	15%
A2	32%	50%	18%	38%	50%	12%	64%	32%	5%	21%	63%	16%
A3	30%	55%	15%	36%	49%	15%	62%	35%	3%	24%	62%	14%
B1	–	60%	–	–	52%	–	–	36%	–	–	58%	–
B2	–	55%	–	–	47%	–	–	36%	–	–	62%	–
B3	–	61%	–	–	52%	–	–	45%	–	–	64%	–
C	24%	61%	15%	43%	46%	11%	61%	34%	5%	31%	58%	11%
D	31%	54%	15%	48%	38%	14%	38%	45%	17%	20%	69%	11%
E	25%	69%	6%	49%	46%	5%	46%	48%	6%	29%	64%	7%
F	19%	65%	16%	33%	51%	16%	10%	61%	29%	27%	57%	15%

A1—Ryerson University, Engineering Students, 2000 cohort: $N=87$
A2—Ryerson University, Engineering Students, 2001 cohort: $N=119$
A3—Ryerson University, Engineering Students, 2002 cohort: $N=132$
B1—San Jose State University, Materials Engineering Students, $N=261$
B2—San Jose State University, Mechanical Engineering Students, $N=196$
B3—San Jose State University, Freshman Engineering Students, $N=693$
C—San Jose State University, Engineering Students, $N=183$
D—Arizona State University, Graduate Students in Social Work
E—Brazilian science students, $N=214$
F—Brazilian humanities students, $N=235$

Figure 3.8: Strengths of Preference (Adapted from Felder and Spurlin 2005 [79])

The sample is supportive of the distribution reported by Felder and Spurlin (2005) [79] and Graf *et al.* (2007) [95].

3.4 Critique of Learning-Styles

The increased use of learning-styles for teaching and learning has led to the questioning by many researchers of their existence, validity, reliability and benefits.

Coffield *et al.* (2004) [46] published a critique of learning-styles which criticised most of the main instruments used to identify an individual's learning-style. The learning-style instruments included in the review were reduced to a complete examination of 13 influential models. Coffield *et al.* examined the theoretical origins of, and the instrument used to assess types of learning-style, defined by each of the chosen models. They examined the results from external studies alongside independent empirical evidence of the relationship between the 'learning-style' identified by the instrument and students' actual learning.

Coffield *et al.* (2004) [46] state that *"the research field of learning-styles needs independent, critical, longitudinal and large-scale studies with experimental and control groups to test the claims for pedagogy made by the test developers"*. Coffield *et al's* review is focused on the measuring instruments of the learning-style models as opposed to the models themselves and most of the criticism is directed at the limitations of

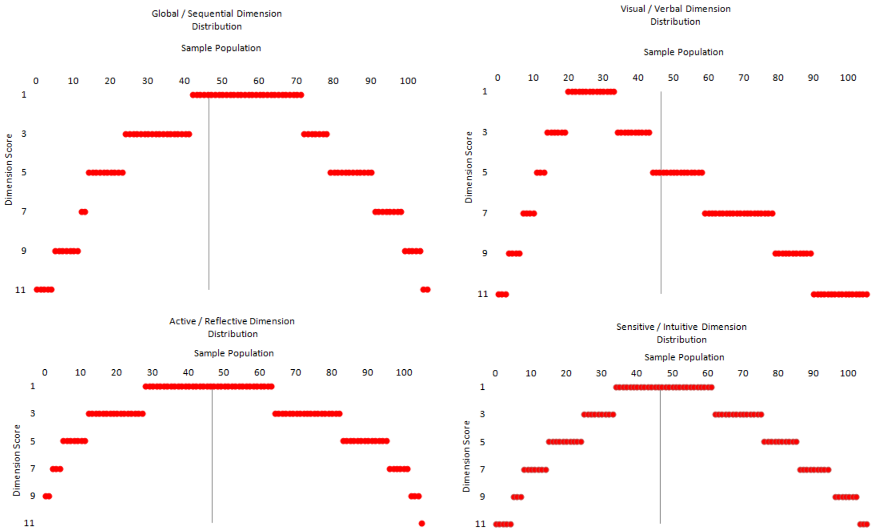

Figure 3.9: Distribution Patterns Overall Sample Population for Combined Studies

traditional face-to-face instruction, due to the routine need for teachers to change their teaching-style to meet the needs of different learning-styles within the classroom setting. eLearning systems have the potential to alleviate this burden through the *"built in potential of offering individualised learning paths to students with little overhead for the teacher"* (Popescue 2009) [191].

Coffield *et al's* findings indicate that, of the most popular learning-style theories, none had, at that time, been adequately validated. Coffield *et al.* conclude that the value of matching teaching and learning-styles is *"highly questionable"*. Rayner (2007) [198] states that Coffield *et al's* review is arguably flawed, *"it is predicated on a methodology drawn from evidence-based theory articulated by the Evidence for Policy and Practice Information Centre at London University. The researchers adopt and then dispense with rigorous criteria established as part of this methodology, citing the complexity and failings of the learning-styles field"*. However, it must be noted that Coffield *et al's* review does not dismiss learning-styles overall and acknowledges the benefits of learning-styles (Popescue 2009) [191] including *"self-awareness and metacognition, a lexicon of learning for dialogue, a catalyst for the individual, organisational or even systematic change"* (Coffield *et al.* 2004) [46].

The Matching Hypothesis refers to the match between the instructor's teaching style and the student's learning-style. Queries have arisen as to whether students benefit when teachers take the student's preferred learning-style into consideration for the

Table 3.2: Learning-Style Preference Distribution from Sample Population Data Gathered in Preparation of Thesis

Act Mod/ Stg	Bal	Ref Mod/ Stg	Sen Mod/ Stg	Bal	Int Mod/ Stg	Vis Mod/ Stg	Bal	Ver Mod/ Stg	Glo Mod/ Stg	Bal	Seq Mod/ Stg
21% 20	66% 62	13% 12	31% 29	51% 48	18% 17	60% 56	32% 30	8% 8	28% 26	54% 51	18% 17

preparation of lesson content (the Matching Hypothesis) and whether such consideration leads to an improvement in concentration, memory and better scores (Alaka 2010 [15]). The Matching Hypothesis has also met with mixed reviews. Research conducted by Smith *et al.* (2002) [215] indicates that for every study rejecting the Matching Hypothesis, there is a study to support it.

Graf (2008) [94] states that the Matching Hypothesis *"aims at a short-term goal, namely to make learning as easy as possible at the time students are learning. Looking at long-term goals, educational theorists such as Messick (1976), Kolb (1984)and Gresha (1984) suggest that learners should also train their non-preferred skills and preferences"*. Graf (2008) [94] notes that Gresha [99] argues mis-matching material and style creates learning that is interesting and challenging learning for students. Kolb argues that mis-matching provides for personal growth and creativity, but also points out that the Gregoric model (2002) demands stability and therefore the mis-match approach can hinder student learning. Felder (1993) [73] argues that permanent mis-matching, if unintentional, can be a disadvantage to some students. Graf (2008) [94] concludes that intentional mis-match is relevant dependent on the employed learning-style model and the individual learners needs. It should be applied in a controlled manner dependant on conditions such as a specific learning goal where students receive individualised material and tuition.

Pashler *et al.* (2009) [185] reviewed the literature to establish if learning-style research exists based on specific criteria which Pashler *et al.* state need to be satisfied should such learning-style research be deemed scientifically valid. Pashler *et al.* highlight these criteria as follows:

1. "On the basis of some measure or measures of learning-styles, learners must be divided into two or more groups (e.g. putative visual learners and auditory learners)".
2. *"Subjects within each learning-style group must be randomly assigned to one of at least two different learning methods (e.g. visual versus auditory presentation of*

some material)".

3. *"All subjects must be given the same test of achievement".*

4. *"The results need to show that the learning method that optimises test performance for one learning-style group is different than the learning method that optimises the test performance of a second learning-style group".*

Pashler *et al.* state that *"the learning style hypothesis receives support if and only if an experiment reveals what is commonly known as a crossover interaction between learning-style and method when learning-style is plotted on the horizontal axis".* Sample acceptable and unacceptable findings as illustrated by Pashler *et al.* are provided in Figures 3.10 and 3.11.

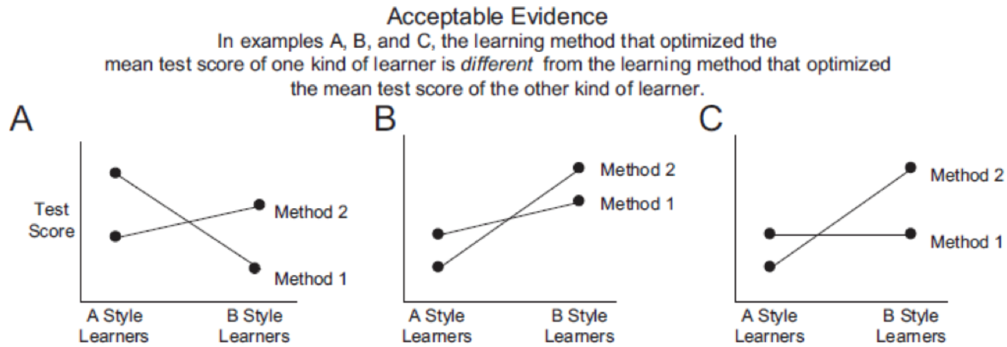

Figure 3.10: Acceptable Evidence for the Learning-Style Hypothesis (Adapted from Pashler *et al.* 2009) [185]

Here, Pashler *et al.* classify subjects as having learning-style A or B. Subjects are randomly assigned to learning method 1 or 2. Every subject takes the same test. Pashler *et al.* accepts the learning-styles hypothesis if the learning method that optimised the mean test score of one group differs from the optimising learning method of the second group, and thus, a crossover interaction is achieved, see graph A, B, and C (Figure 3.10). Conversely, in graph D - I (Figure 3.11) we see that the same learning method is optimal for the mean test score of both groups. Consequently, no crossover interaction is evident.

Pashler concludes that there is insignificant evidence that learning-styles exist. Pashler (2009) [185] cites Constantinidou and Baker, (2002) [49] and Massa and Mayer, (2006) [154] to suggest that *"several studies that used the appropriate type of research design found results that contradict the most widely held version of the learning-styles*

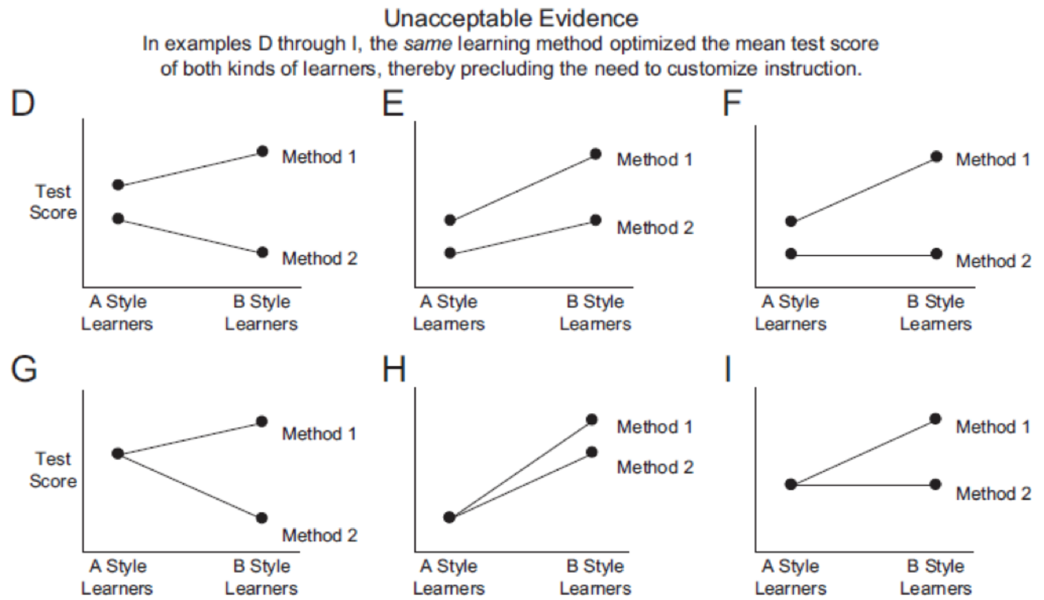

Figure 3.11: Unacceptable Evidence for the Learning-Style Hypothesis (Adapted from Pashler *et al.* 2009) [185]

hypothesis, namely, what we have referred to as the Meshing Hypothesis. Pashler states that the contrast between the enormous popularity of the learning-styles approach within education and the lack of credible evidence for its utility is, in our opinion, striking and disturbing. If classification of students' learning-styles has practical utility, it remains to be demonstrated". The research conducted by Pashler *et al.* is based on the Meshing Hypothesis (*"the claim that presentation should mesh with the learner's own proclivities"* (Pashler *et al.* 2009) [185] which can only be considered in relation to learning-style models that use type theory, it cannot be specifically and conclusively tied to the FSLSM as it can be argued that the FSLSM is not based-on type theory.

No specific references exist in the literature attributing the FSLSM model to type theory. Felder & Silverman's original paper (1988) based on learning and teaching-styles in engineering education does suggest that the model, based on five dimensions, Active / Reflective, Sensitive/Intuitive, Visual/ Verbal, Global / Sequential and Inductive / Deductive, is based-on 2^5 learning-styles (32), and these could be construed to be types. They subsequently dropped the Inductive / Deductive dimension, and consequently it can then, be assumed that the model now allows for 2^4 styles of learner (16) (Felder & Silverman 2002) [77].

Types are referred to in the original Felder & Silverman paper. For example, Felder states in relation to Sensitive / Intuitive learners that *"characteristics are tendencies* *of the two 'types' not invariable behaviour patterns* he states also that *both 'types' are capable of becoming fine engineers"* (Felder & Silverman 1988) [77]. De Vita (2001)[56] states that *"the FSLSM categorizes students' preferences in terms of type and mode of information perception, approaches for the organisation and processing of information and the rate to which students progress toward understanding"* while the associated FSILS develops the preference profile of a student on four of the learning-style dimensions. It could be argued therefore, based on the original Felder & Silverman paper (1988), that there exists a discrepancy between the FSLSM and the FSILS, in that the FSILS, in assessing preferences on the four scales of the FSLSM would provide for a higher number of possible combinations when considering the high, moderate and balanced style levels. It is however mainly thought that *"Felder's learning model categorizes an individual's preferred learning-styles along a sliding scale of four dimensions"* (Howard *et al.* 1996) [114]. Felder (2010) [75] states that *"learner styles are not mutually exclusive categories but preferences that may be mild, moderate or strong"*.

Graf (2008) [94] states that in the FSLSM, *"learners are characterized by values on four dimensions. These dimensions are based on major dimensions in the field of learning-styles and can be viewed independently from each other"*. Graf also states *"while these dimensions are not new in the field of learning-styles, the way in which they describe a learning-style of a student can be seen as new. While most learning-style models, which include two or more dimensions, derive statistically prevalent learner types from these dimensions, such as the models by Myers-Briggs (Briggs Myers, 1962), Gregorc (1982a), Kolb (1984), and Honey and Mumford (1982), Felder & Silverman describe the learning-styles by using scales from +11 to -11 for each dimension"*. It is noted that Graf refers to Felder & Silverman (1988) as opposed to Felder & Solomon. Graf (2008) states, *"the learning-style of each learner is characterized by four values between +11 and -11, one for each dimension. These scales facilitate describing the learning-style preferences in more detail, whereas building learner types does not allow distinguishing between the strength of the preference"*.

Additionally, Graf (2008) [94] states that *"the usage of scales allows expressing balanced preferences, indicating that a learner does not have a specific preference for one of the two poles of a dimension"* while also indicating that Felder and Silverman consider the resulting preferences as tendencies.

Coffield *et al.* (2004) [46], in their review of learning-styles, place the FSLSM under the heading of *"Learning-Styles are Flexibly Stable Learning Preferences"* whilst they place the MBTI under the title *"Learning-Styles are One Component of a Relatively Stable Personality Type"* (See Figure 3.1). The flexibility factor of the FSLSM removes it from the 'Type' category. Felder has indicated, in relation to the Sensitive / Intuitive dimension, that characteristics are tendencies (Felder & Silverman 1988). Similarly to the findings of the review conducted by Coffield *et al.* (2004) [46] , Hall and Moseley (2005) [107] place the FSLSM dimensions as *"fluid characteristics in individuals as opposed to their placement of MBTI as fixed characteristics of in individuals"*.

Felder (2010) [75] states that *"learner styles are not mutually exclusive categories but preferences that may be mild, moderate or strong"*. Felder (2010) also states that *"contrary to the claims of learning-style debunkers, however, sensing and intuitive learners do tend to respond differently to certain teaching approaches as do students with opposite preferences on all other learning-style dimensions"*.

Consequently it can be concluded that the FSLSM (and the associated measurement instrument, the FSILS) does not reflect a theory of type, where a student presents as one type or another, but is a theory of preference, where a student can present at different levels on a scale of preference and can be present across a range of dimensions simultaneously.

Pashler *et al's* [185] review does not totally discount learning-styles. It is noted that the learning-style questionnaire gives repeatable results and that the instruments are measuring something rather than producing random figures. This is generally verified for example by the validity of the FSILS. It is found by Pashler *et al.* that there is no correlation between a user's learning-style and performance based on material tailored to that learning-style. In relation to the FSLSM, evidence shows that a learner's learning-outcome is improved where material presented to a learner is tailored to suit their learning-style, Popescu (2009) [191] cites a number of studies where learning-style based adaptive eLearning systems report improvement in student learning-outcomes and satisfaction.

Felder (2010) [75] states the validity of the Meshing Hypothesis has no bearing at all on the appropriateness of taking learning-styles into account when designing instruction. The point is rather to achieve balance between teaching style and learning-style and to ensure that each style preference is addressed.

In reference to Pashler *et al's* [185] review, it can be said that the Meshing Hypothesis is particularly appropriate for use in relation to 'type' where users would present as one type or the other. Therefore it can be seen as not being appropriate for use in relation to 'style' in relation to the FSLSM due to the scale element employed in the model as users preference can be placed at any stage of the scale, being either strong, moderate or balanced. It must also be noted that Pashler *et al.* do not specifically refer to the FSLSM or FSILS.

3.5 Conclusion

This chapter has introduced the different learning-style and personality models that are currently used within the field of eLearning for the development of adaptive learning systems. The chapter explained the FSLSM dimensions in detail. The relationship between the FSLSM and other such models are highlighted. The FSILS is explained and its validity as a measurement instrument for measuring student placement on the FSLSM dimensions is examined according to the literature with particular focus on the distribution of learners across the dimensions. The effects of gender are considered. A detailed critique of the FSLSM is provided.

Chapter 4 will highlight the differences between eLearning and mLearning. The chapter will put forward a model of mLearning to highlight the fusions taking place within these mLearning systems. The level of system adaptively within both eLearning and mLearning will be examined with a focus on how adaptive systems can be improved for future mLearning systems based on user learning-style.

Part III

Modeling Mobile Learning

Chapter 4

Modeling Mobile Learning

4.1 Distinguishing mLearning from eLearning

The definition of mLearning includes *eLearning in your pocket to eLearning through mobile computational devices* (Quinn 2000) [196]. Lehner *et al.* (2002) [144] define mobile education as *"any service or facility that supplies a learner with general electronic information and educational content that aids in the acquisition of knowledge regardless of location and time"*. A requirement in the provision of such educational content to users is the ability to adapt disseminated content for display on different device types to meet user needs. Adaptive technology in relation to mLearning allows the device to adjust delivered or displayed content to match a particular user's device category and/or their personal needs. Adaptive technology is now playing an important role in the design considerations for development of systems within every category of mLearning (see section *4.4.5 Adaptivity in Mobile Learning*).

With the definitions of mLearning still under debate, research is focused toward mLearning as an extension of eLearning (as shown in Figure 4.1) and as a facilitator to dLearning (Distance Learning). This can mainly be seen as an attempt to set mLearning as *"somewhere on eLearning's spectrum of portability"* (Traxler 2009) [230], or as a new modality for eLearning. eLearning is still a developing field in its own right, with theories still under development as researchers attempt to distinguish it from traditional learning. Indeed, eLearning itself has seen an explosion in the development of applications while the development of theories has been slow. mLearning appears at this early stage to be taking the same track.

Currently, mobile learning can be defined as an extension to eLearning with strong ties to distance learning as it connects learners with educational resources. There is currently a focus within eLearning on learning through handheld/mobile devices. This is reflected in both research and practice-based systems. This focus is particularly evident in the trend toward blended learning and mixed modes of technology-enhanced learning. In recent years, concepts such as bring-your-own-device (BYOD) have entered the eLearning space, further emphasising the learning through mobile devices concept. Similar to eLearning, mLearning covers a wide set of applications and processes, including web-based learning, virtual classrooms, and digital collaboration. It includes the delivery of content via Internet, audio and video, games and other interactive Medias, however, unlike eLearning; the key feature of mLearning is its location independent and ubiquitous nature. mLearning also offers an increased level of conversation-based learning than eLearning. Currently mLearning can be used in both transitional (e.g. on-the-go/situated) learning and static (e.g. classroom-based) settings. It can be synchronous or asynchronous and applications can be learner-centric (one learner) or collaborative (two or more users) and can be used in online and offline settings. The continuous and significant changes in the context (tablets as one direction or the BYOD trend) will shape the future of mLearning. The continued growth and penetration of wireless devices for example, tablet PCs and smartphones will lead to a reduction in the use of traditional fixed location desktop devices. This will lead to an extension of mLearning toward the growth stage of the eLearning lifecycle in the near future while eLearning, in the traditional fixed location sense, will move to the decline stage.

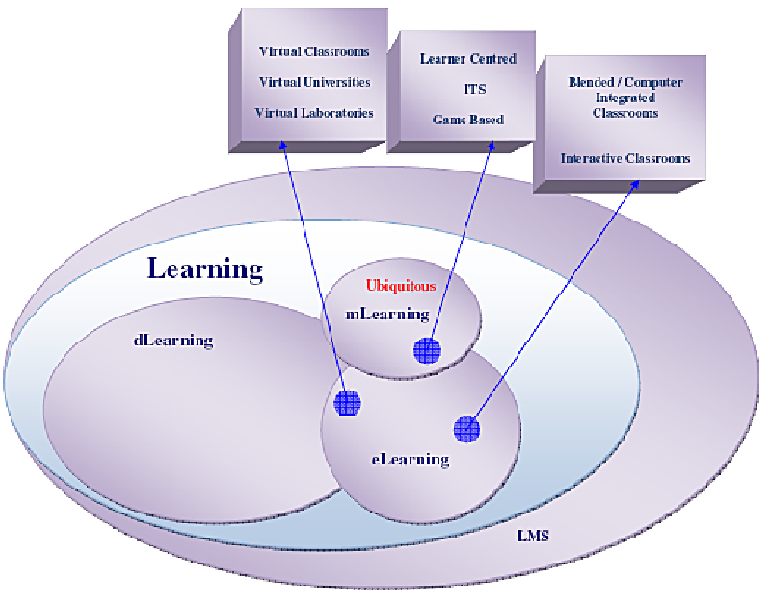

Figure 4.1: Positioning mLearning in relation to eLearning and dLearning

There are underlying differences between eLearning and mLearning at many levels. At the pedagogical level, the main differences relate to mobility. The mobile learner is not confined to the location of a terminal in a classroom or computer lab. Mobile devices, when used for learning, offer increased conversation-based learning. At communication level instantaneous connections take place between students, and/or students and teachers. This form of communication is flexible and instantaneous, offering significant benefits over passive and scheduled communication as offered through eLearning. Therefore, mLearning is much more than simply eLearning through mobile devices: mLearning will characteristically aim at specific kinds of knowledge depending on location, situation, device and learner. *"Mobile eLearning will become increasingly different from conventional eLearning and will create a new learning environment, an environment where learners can access content, teachers, and other learners anywhere and anytime"* (Mikic *et al.* 2007) [170].

Further evidence of the extension of eLearning is seen with Interactive Digital Lecture Halls and classrooms. Electronic whiteboards and mobile terminals have emerged through systems such as eClass (Abowd *et al.* 1999) [14] and the Computer Integrated Classroom (Hoppe *et al.* 2000; Tewissen *et al.* 2001) [113] [226]). In these cases, the only connection with eLearning is their ability to give access to remote learners, whom in traditional settings would not be able to attend due to limiting factors such as physical disability. This access also echoes the field of dLearning. The California Distance Learning Project (CDLP) defines distance learning (dLearning) as follows; *"Distance Learning (DL) is an instructional delivery system that connects learners with educational resources. DL provides educational access to learners not enrolled in educational institutions and can augment the learning opportunities of current students. The implementation of DL is a process that uses available resources and will evolve to incorporate emerging technologies"*.

The eSchoolbag project, piloted in Taipei, attempts to create an *ad hoc* or virtual classroom for the provision of ubiquitous learning through modern techniques. *"A wireless platform is developed for teachers and students to establish a classroom dynamically irrespective of location and time bounds"* creating new learning models focused on activity-based learning (Chang & Sheu 2002) [44]. The classroom can be created anytime, anywhere according to the requirements of the students and the teachers. Remote systems like the eSchoolbag project remind us again of the fact that eLearning has close connections with the field of dLearning.

The University of Hagen, founded with the distance learner in mind, uses mobile technology for the dissemination of its courses. There is an emphasis on the use of didactic profiling of students, to improve its existing programmes of study through mobile phones. The aim is to provide enriched learning through real time and location independency. This can be achieved by taking into account the increased need for assistance within the more demanding learning environments faced by mobile learners. They recognise that more research is needed for the deployment of appropriate learning objects for the learner's individual situation or location (Becking *et al.* 2004) [25].

The Leonardo Da Vinci project *"From eLearning to mLearning"*, funded by the European Union (EU) and run in cooperation with Ericsson Ireland, looked in particular at the advent of mobile devices for the future of eLearning when focused on the provision of dLearning. They concluded that mobile devices offered great potential for dLearning. The NKI Distance Education Institute is among the largest distance education institutions in Norway and has been involved with three main Leonardo Da Vinci projects. The institution was one of the first such institutions to offer online education in 1987 through its Learning Management System (LMS) the Electronic Combined Education (EKKO). NKI initially tested two mLearning projects, the Tutor in Distance Education and Online Teaching and Learning. Both systems evaluated students through the use of PDAs and mobile phones. The work on these systems led to an improved didactic efficiency achieved through increased quality in accessing course content and communication (Rekkedal & Dye, 2007) [199].

4.2 Categorising Mobile Learning Systems

There are many categories of learning systems that have found a place within the development of mLearning systems. Most of these catagories pre-exist within eLearning however, mobile versions of such have emerged as the wireless device has become more prolific within education. Some of these are described below.

4.2.1 The Mobile LMS

LMS software applications *"automate the administration of training events. The LMS registers users, tracks courses in a catalogue, and records data from learners; it also provides reports to management "*(eLearning Acronyms 2006) [3].

Most eLearning content today is delivered via centralised LMS applications that do very little to encourage the learner to communicate with peers and share knowledge. This is due to their mainly administrative role in education (Chatti *et al.* 2006) [43].

The advent of LMS through mobile or handheld devices has been seen mostly in University settings. The first system to emerge was Handheld Andrew in 1999 at the

Carnegie Mellon University, Pittsburgh (as an extension of its existing eLearning system Wireless Andrew). This system foreshadowed the use of electronic mail, calendar management and event notification to create a new level of integration, communication and knowledge sharing across the campus (Hills 1999) [110].

In the years after that initial implementation, other universities also saw the opportunity to take up the challenge. The University of Regensburg's successful WELCOME system (Wireless eLearning and Communication System, Lehner *et al.* (2002) [144] operates a virtual campus, offering students the opportunity to schedule classes and gain access to administrative information through their wireless device, usually, in this case, their mobile phone or PDA. Administrative support for students is at the core of this type of mLearning system; therefore mobile LMS are strongly service-based for efficiency in the organisation of education through the timely dissemination of content and information to students.

4.2.2 Situated Learning

Situated learning occurs as a function of activity, context and culture (Lave 1991) [141]. mLearning systems generally attempt to provide context-relative information based on the learner's particular location. Context-relative information can enhance the user's learning experience. The use of GPS (Global Positioning Systems) and sensors such as RFID (Radio Frequency IDentification) technology for this purpose enables learners and tourists to interact with their environment during the learning process.

Many orientation systems have been developed. The EXPLORE system (Costabile *et al.* 2008) [50] gives support through mobile devices to middle school students on field trip visits to an Italian archaeological park, extending learning techniques offered by an existing paper-based excursion game, in an attempt to make the learning experience more effective and efficient.

Ting *et al.* (2008) [227] combine RFID and Bluetooth technologies to provide a knowledge hunting system for group-based learning at museums. This AI (Artificial Intelligence) learning system presents a treasure-hunt style game, giving information and tasks to groups of learners based on their position. True interaction in a living world through a treasure-hunt game *"can get learners excited about the environment and allow them to learn beyond fact-based knowledge and skill development"* (Ting *et al.* 2008) [227]. Wu *et al.* (2010) [247] also offer a treasure-hunt style game for learning historical and cultural facts for field-trips to the five-harbour district of Taiwan. These systems are mainly based on the theory of activity-based learning and constructivism.

4.2.3 Learner-Centred Systems

Learner-centred systems focus on the learner and are evident in mLearning applications. These systems have, in many cases, been used in the area of inclusion for the socially disadvantaged learner. Literacy initiatives have become the most prominent systems developed in this area. For example, the LSDA (Learning and Skills Development Agency) project (Keegan 2005) [131] addresses the problems of socially deprived young adults, looking at the use of mobile technologies for independent learning to improve the literacy skills of these individuals. The study sought an increased participation in learning activities and learning achievement by improving skills and opportunities. It predicted an increased preference for mobile phones over personal computers for learning purposes as the technology advanced (Attewell 2005) [**?**]. However, systems have also been developed for school students, for example to assist them in the improvement of mathematical skills (Kalloo *et al.* 2010) [125].

Podcasting has also been successfully used as means to provide learner-centric systems. The provision of downloadable multimedia files to students as revision aids, resulted in more effective revision than instances where students revised from textbooks. This was perhaps because the files related directly to the contents of their lecture (Evans 2008; Cebeci & Tekdal 2006 [71] [39]. Learner-centric applications are prominent in the area of lifelong learning. Sharples (2000) [211] states that *"the basic premise of lifelong learning is that it is not feasible to equip learners at school, college or university with all the knowledge and skills they need to prosper throughout their lifetimes, therefore people will need continually to enhance their knowledge and skills in order to address immediate problems and to continue in the process of continuous vocational and professional development"*. Sharples (2000) [211] offers the HandLeR system, stating that it provides *mathemagenic* (conductive to learning) *conversation* between learners and a mentor, and acts as the learner's companion as they acquire the knowledge and skills needed to allow them to adapt to an ever and rapidly changing world.

4.2.4 Mobile Intelligent Tutoring Systems

Intelligent Tutoring System (ITS), or Knowledge Based Tutors (KBT) are computer-based instructional systems. They differ from aforementioned systems in that they hold separate knowledge-bases for instructional content, and teaching strategies. They dynamically adapt instruction to suit the learner's level of knowledge on a topic or subject area (Karlgren 2008) [127]. These allow learners to access individualised tutoring whenever they wish (Bull *et al.* 2004) [34]. The Adaptive Geometry game as offered by Ketamo (2002) [134] provides a limited ITS for kindergarten children for the learning of geometric shapes through polygon recognition using handheld computers. Results from system testing show that lower-skilled pupils can attain the skill level of the middle-skilled group of colleagues faster when using the system when compared to students using traditional methods.

Bull *et al.* (2004) [34] introduce numerous mobile ITS applications, for diverse subjects including English, programming, mathematics, and SQL administration. TenseITS for example, a system for learning the English language, attempts to adapt the student's interaction in accordance with the learner's level of concentration, potential distraction and their available time. In the case of the C-POLMILE ITS, the learner can also edit their model in line with their PC model. Students can compare their models to understand how they compare with their peers. Learner models are simplistic and are inferred from answers to multiple choice questions which attempt to identify the learner's knowledge state.

Circuela *et al.* (2010) [45] introduce an intelligent tutor that interacts with educational eBooks. This system allows users to customise their self-assessment tasks through the use of Near Field Communication (NFC) tags for ubiquitous modern language learning.

4.2.5 Collaborative Learning

Collaborative learning is defined as the efforts of students, or of teachers and students, working jointly in group activity to achieve a specific educational outcome. The goal of collaborative learning is to assist in the teaching of a specific educational objective to students working in groups (Zurita, *et al.* 2003) [251]. Within the sphere of mLearning, this type of system has mainly been seen as an extension of the traditional face-to-face (didactic) classroom to improve both teacher-student, and student-student communication within the classroom. Rochelle (2003) [203] points to early evaluations of this type of system used with mobile devices that saw both teachers and students alike responding well to handheld devices in the classroom. Classroom response systems, such as the Classtalk classroom communication system, participatory simulations that simulate a community sharing environmental information amongst members, and collaborative data gathering systems for group field trip data collection are now available for mobile devices. Weiser (1998) [242] suggests that it is appropriate to use ubiquitous computing in the classroom. mLearning has facilitated ubiquitous computing through wireless technologies. This has enabled mobility in the classroom supporting collaborative work.

Wang *et al.* (2003) [240] offer the WiTEC system as an extension of existing systems such as eClass, to create a wireless technology enhanced classroom. Successfully tested and established in a sixth grade Taipei school, the system *"empowers the teacher and students to apply technologies to a variety of traditional and innovative learning and teaching activities seamlessly"* (Wang *et al.* 2003) [240]. Further research is needed to evaluate the effect of these types of systems on the overall learning processes.

The attempt to employ mobile devices in the conventional classroom environment provides a new and blended teaching technique to facilitate the inclusion of a new generation of Digital Natives who require interactivity with modern technology for engagement and motivation (Prensky 2005) [194]. The viability of the mobile phone for the purpose of collaborative face-to-face learning is confirmed by Echeverria *et al.* (2011) [66] who examined their use in respect of teaching physics in a collaborative activity-based classroom environment.

Within the spectrum of mLearning, collaborative learning is an area of particular interest and success. While collaborative learning is used in many subject areas, the literature shows that this area to date has mainly focused on the subject of mathematics, usually within a classroom setting, but also within the lecture hall, mainly as a support to existing didactic learning. To achieve the maximum benefit from collaboration within the classroom, Zurita *et al.* (2003) [251] describe a successful collaborative activity in the classroom as *"requiring effective coordination, synchronisation of devices, face to face (one-to-one / one-to-many) communication, negotiation (between user devices), interactivity (the ability to interact with an application or the system environment) and participant mobility conditions, that is the participant's ability to be mobile"*. These requirements can be best met through mobile technology.

Through the provision of one-to-one and one-to-many computing, mobile devices provide flexibility in that they allow students and teachers to engage in highly collaborative activities anytime anywhere (Solloway *et al.* 2001; Tinker & Krajcik 2001) [217] [228].

4.2.6 The Fusion of Systems

As development of mLearning systems increases, it is becoming evident from the literature that some system categories, often separate in eLearning, are fusing, in that there are mergers among system categories as new applications emerge.

Collaborative learning cannot be confined to in-classroom learning as it can also play a successful and important role within other system categories. It can be a significant factor within situated learning systems, for example, where students work together to achieve a specific outcome in a museum field trip or during orientation at university.

The ITS offered by the Adaptive Geometry Game (Ketamo 2002 [134]) could be seen as an extension of eLearning in that its only novelty lies in the aspect of mobility and touch screen interaction. The C-POLMILE ITS provided by Bull *et al.* (2004) [34] offers collaboration, therefore creating a collaborative element in mobile ITS systems.

Looking at the area of learner centred systems, Black & Hawkes (2006) [27] examine the design of systems for user-centred collaboration focused on reading comprehension in elementary schools. The system provides for advancing the reading grade level of those students who are having difficulty. Students can learn and collaborate both within the classroom and outside. Tampere University in Finland runs a similar project, using PDAs for lifelong mathematical learning, the first stage focused on children. This is achieved though game play, where a game is presented to allow students to communicate with one another to help each other out, while the device records and measures the student's knowledge level for presentation purposes (Collazzo *et al.* 2003) [47]. Therefore, there is a strong linkage between collaboration and game play in a learner-centred system.

On a commercial level, Dr. Kawashima's Brain Training for the Nintendo DS could also be placed within this category. Although the focus is not on academic learning, the games attempt to 'train' the individual brain to reduce the brain's age, as measured by the application based on the learner's ability and skill. The system provides puzzle activities that purport to help stimulate the human brain, providing a workout that is needed for continued brain health. These systems have been commercially successful with the global 'older adult' population (Tokyo 2006) [229].

This is also evident in situated learning. The MobiLearn project (Attewell & Saville-Smith 2003) [20], provides an orientation game based on a university setting. The system enables students, through situated learning, to become quickly familiar with their learning environment for best use of onsite resources. Using GPS (Global Positioning System) and WLAN (Wireless Local Area Network), synchronous collaboration is created within the group to find particular areas or important people on campus, whilst spontaneous events encourage students to participate in, or sign up for lectures and services. The *"technology enables immersion into a mixed reality environment and more motivating learning experience"* (Goth *et al.* 2005) [92].

Ting *et al's* Knowledge Hunting System (2008) [227] employs an aspect of game-based learning. Learning is improved through interactive learning environments where learning occurs through *"seeing, touching and discovering the world"*, creating a form of immersion in the game. In the area of RFID-based situated learning systems (for example, Kim *et al.* 2007) [135] anytime, anyplace individualised learning is provided based on the learner's situation. Their system looks in particular at how learners obtain and access customised learning information suitable for the learner as an individual. Based on constructivism, learning becomes effective through the provision of knowledge in a meaningful context.

Immersive learning refers to educational experiences which are highly interactive. In Immersive learning environments, the learner engages with the content to facilitate the learning process. Generally this type of learning includes learning games, simulations and virtual learning worlds. This type of learning is seen mostly within the area of army training and other simulations, for example, simulated flight training. Immersive learning is very much an element of eLearning. As the field of mLearning has developed, game-based learning applications have been mostly apparent in situated learning. To date, situated learning has not been evident as part of eLearning due to its reliance on mobility. With few exceptions game based learning has been included in situated museum or orientation type applications used by universities. *"Immersion is the subjective impression that one is participating in a comprehensive, realistic experience ... studies have shown that immersion in a digital environment can enhance education in at least three ways; by allowing multiple perspectives, situated learning, and transfer"* (Dede 2009) [58].

As there is a move toward greater use of situated mLearning applications, it is evident from the literature that a migration is taking place from eLearning's immersive learning worlds toward situated, game-based learning.

4.3 Modeling Systems within eLearning and mLearning

The current state of mLearning is shown in Figure 4.2, which highlights overlaps that exist within the many applications and systems developed within the field to date. The figure aims to measure the current field on two scales, Richness of content information (Evans & Wurster 2000) [72] and Mobility against Functionality and Ubiquity.

Richness of content refers to content that is extensive, customised, detailed, current and interactive. Ubiquity refers to the ability to access content anytime, everywhere through any device. Mobility refers to the ability to move within locations or between locations. Functionality refers to the capability of systems/devices, their processing power, storage capabilities etc.

While not purporting to be definitive, an effort is made here to provide a classification of the types of mLearning systems piloted and employed to date, as reviewed in the literature.

As indicated in Figure 4.2, while mLearning shows greater ubiquity and location independence as it moves toward mobility and away from wired eLearning, there is a trade off in the richness of content material and functionality of systems which are now more restricted due to the processing power, capabilities, memory storage and screen-size restrictions of smaller devices.

The figure shows mLearning as an extension of eLearning, indicating that the development of systems is less established in mLearning in its state of infancy. On this basis, a smaller loop is used for mLearning systems to indicate that mLearning is less established than eLearning. To highlight this, the clustering of learning system categories are placed more on the eLearning side, while bordering on the mLearning side of the figure.

Indeed most mLearning systems on the market today are a representation of preexisting eLearning systems, for example ClassTalk. The clustering is indicative of the fusion of systems occurring between eLearning and mLearning (see section *4.2.6 The Fusion of Systems*).

Figure 4.2 also indicates the position of the LMS within the category of learning itself, but located outside both mLearning and eLearning in consideration of the administrative role of the LMS and highlighting its lack of educational function.

As indicated earlier, immersive learning is very much in the extreme of eLearning. This is mirrored by the position of situated learning in the extreme of mLearning; this is also indicated in the figure. These system categories are very much an indicative part of their respective learning type and their separation in this manner is aimed at highlighting the replacement of one category with the other in their respective fields. Immersive game-based eLearning is very much being replaced by situated mLearning.

The model also looks at adaptive mLearning systems and where they have been used (see section *4.4.5 Adaptivity in Mobile Learning*). Currently, situated learning and ITS

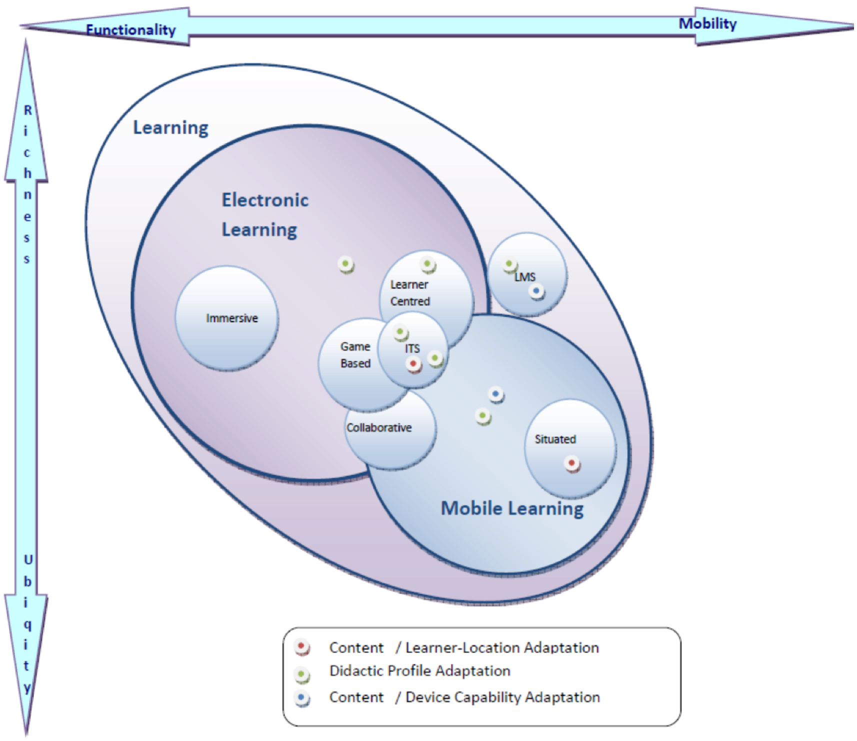

Figure 4.2: The Current State of mLearning

have been the main areas that have used adaptation based on didactic profiling, content adaptation based on device capability, and location-aware adaptation.

4.4 Adaptive systems in eLearning

Research in the field of eLearning is quickly moving toward adaptive features enabling more personalised and successful learning outcomes for students. Identification of an individual's style of learning and personality traits has, in recent years, become an essential component in the development of learner models for the creation of such adaptive eLearning environments. Indeed, the analysis of cognitive features is one of the techniques most widely-used to provide adaptivity in eLearning environments. Classification of a student is usually conducted through the use of learning-style and personality questionnaires. Adaptive systems aim to adjust the learning process by offering the individual learner specific learning objects based-on their fit on a number of learning-style model scales. The learning objects are specific to how the learner processes and receives information. The analysis of learning-style in the development of a system is the first step in the provision of personalised tuition to support improved learning outcomes at an individual level. There are many learning-style and personality analysis models available for this purpose. The main models used for eLearning systems include the MBTI (Pittenger, 1983) [189] and the Big Five Model (Busato *et al.*, 1999) [35]. The FSLSM (Felder & Silverman, 1988) [77] is a widely employed model for inferring learner characteristics. These models are examined in more detail in chapter 3.

While existing systems within eLearning already use adaptive features based on learning-style, most systems rely on the prior completion of questionnaires as a means of assessing students. The results obtained from these questionnaire sessions are then applied manually to systems to adapt the learning content to suit the individual user. Most systems using this type of adaptation are ITS applications in the area of educational hypermedia.

4.4.1 Systems where the Learner-Style model is Defined by the Teacher

In systems where the teacher determines which learner-style model is used, adaptation is based on questionnaire results. Some of these are described below.

The IDEAL (Intelligent Distributed Environment for Active Learning) System (Shang *et al.* 2001 [210]), provides adaptivity through ordering, through the inclusion and selection of learning material based on learning-style. The system allows for teacher-based determination of the learning-style model. Adaptivity is provided based on the results of a pre-assessment questionnaire relevant to the chosen learning-style model.

The AHA! (Adaptive Hypermedia for All) System (De Bra & Calvi, 1998; Stash *et al.* 2004) [57] [220] is similar to the IDEAL system. AHA! lets authors determine which learning-style model they want to use as a pre-assessment tool in the implementation of their course. To achieve this an authoring tool (De Bra *et al.* 2002) and a generic adaptation language for learning-styles called LAG-XLS (Stash *et al.* 2004) were developed. The system is manually initialised, based on a student's pre-assessment using the questionnaire for the teacher's chosen learning-style model and updated via determined instructional meta-strategies. Adaptation occurs in relation to the selection of learning objects for presentation, the ordering of these items and the creation of different navigation paths for the user.

4.4.2 Systems Developed for use with Specific Learner-Style Models

Examples of systems where a specific learner-style model is used are described below.

The iWeaver System (Wolf 2003) [245], based on presentation preferences and psychological preferences outlined by the Dunn & Dunn learning-style model (Dunn & Dunn, 1974) [65], orders and displays data links to allow for the different presentation modes and learning tools based on a user's result on the Building Excellence Inventory used to assess a user based on this learning-style model.

INSPIRE (Intelligent System for Personalised Instruction in a Remote Environment) (Papanikolaou *et al.* 2004 [183]) allows learners to manually select and update the order and method of content presentation based on their learning goals, knowledge level, progress, and learning-style. This is achieved using the Honey & Mumford learning-style questionnaire (Honey & Mumford, 1992) [111].

4.4.3 Systems based on the FSLSM

Examples of systems that specifically use the FSLSM are described below.

The CS383 system (Howard *et al.* 1999) [114] provides adaptivity based on the ordering of multimedia learning objects based on three dimensions of the FSLSM. The system relies on the use of the FSILS questionnaire to provide adaptation.

MASPLAG (Pena *et al.* 2004) [188] is a multi-agent system developed to enrich the USD (*Unitats de Suport a la Docncia or Teaching Support Units*) (Fabregat, Marzo, & Pena, 2000 as cited by Pena *et al.* 2004) [188] ITS, an adaptable platform which provides users the ability to adapt course content to their needs with a focus on the FSLSM. Adaptivity in this system is based on choosing media objects, instructional strategies and navigation tools to suit both the learning-styles and the state of knowledge of the student. Again the system relies on pre-assessment through the FSILS questionnaire. Case-based reasoning processes are also employed.

LSAS (Learning Style Adaptive System) (Bajraktarevic *et al.* 2003) [22] uses the Global/Sequential dimension of FSLSM. The system hides or displays links and learning content / objects based on the learner's pre-test results from the FSILS questionnaire.

TANGOW (Task-based Adaptive Learner Guidance On the Web) (Carro *et al.* 2001) [38] is designed for building web-based courses on the basis of ordering teaching tasks and elements within these tasks based on rules. This system focuses specifically on two dimensions of the FSLSM, the Sensitive /Intuitive dimension and the Global/Sequential dimension. The system relies on pre-assessment through the FSILS questionnaire. The system observes the learner's actions within the course environment and revises information presented where learners' actions are contrary to their predetermined learning-style preference as stored in the system.

4.4.4 Automatic Detection of Learning-styles for eLearning Systems

On examination of adaptive systems within eLearning it is noted that some systems include elements of automatic or intelligent adaptivity. For example, in the AHA! system adaptivity is event-driven based on determined instructional meta-strategies including tracing the user's preference for certain types of information. The TANGOW system provides adaptive features based on the revision of information in the student model through the monitoring of student actions. While not specific to learning-styles, the AMASE system (Wade *et al.* 2012) [238] provides a complex framework for personalised learning on the web. This work is based on expert and novice users and their interaction preferences and competence levels.

Automatic adaptive elements have become evident in systems such as MANIC (Multimedia Asynchronous Networked Individualised Courseware) (Stern *et al.* 1997) [221]. This system provides adaptivity based on a Bayes classifier through population data, which allows the obscuring or presenting of additional content for lecture-based material in terms of both slides and audio material. The system allows for dynamic slide construction based on a students' level of understanding and their learning preferences. The system uses different aspects from various learning-style models, including the FSLSM.

Despite these efforts, data gathering for the development of adaptive learner models has to-date been conducted mainly through the use of online-questionnaires in web-based learning systems. Research in eLearning suggests that user interaction with learning systems could also provide a valuable method of data gathering for the development of adaptive eLearning systems.

In recent years, studies have been conducted to determine an individual's learning-style through users' direct interaction with systems. For example, Spada *et al.* (2008) [218] found a high degree of correlation between an individual's mouse movement patterns and their learning-style (determined in advance using learning-style questionnaires). They were able to confidently predict scores on the Global/Sequential dimension of the FSLSM based on measurements of user mouse acceleration. User behaviour patterns have been explored by Graf and Kinshuk (2008) [94] as a means to predict scores on the Global/Sequential dimension of the FSLSM in the Moodle LMS. Their work examines the use of parameters such as scrolling or time spent per page to predict scores on the Global/Sequential dimension of the FSLSM. They are also developing a mobile version of the LMS system based on similar principles (Graf *et al.* 2008); Kinshuk *et al.* 2009) [94] [137]. Work has also been conducted using Bayesian Networks (Garcia *et al.* 2005; Carmona *et al.* 2008) [85] [37], Case-Based-Reasoning (Pena *et al.* 2004) [188], Decision Trees (DT) for ITS (Cha *et al.* 2006) [40], and Feed Forward Neural Networks (FFNN) (Villeverde *et al.* 2006) [236]. However, due to the use of complex modeling methods used it is difficult to analyse the relationship between data gathered by the system (through user-interaction) and the outcomes of the systems.

Spada's Research

As indicated in chapter 1, research conducted by Spada *et al.* (2008) [218] has investigated the possibility of determining an individual's learning-style directly from their interaction with a system. This offers a simpler approach to the work conducted by for example, Garcia *et al.* (2005) and Cha *et al.* (2006) [85] [40]. This research found a high degree of correlation between the way in which an individual uses a mouse and their learning-style (as determined using questionnaires). Spada *et al.* were able to predict scores on the Global/Sequential dimension of the FSLSM with a high level of confidence based on measurements of mouse acceleration. Their research presents a new approach to predict Global/Sequential learning-styles that solely make use of mouse movement patterns in desktop environments.

Through student interaction with an educational website, data was recorded based on changes in mouse coordinates as the user moved the input device. Students completed the FSILS Questionnaire included in Spada *et al's* website. The findings of their research indicate a strong correlation between maximum vertical speed of mouse movement and Global/Sequential dimension score. The correlation coefficient was found to be $r=-0.8$, indicating that students with lower maximum vertical speed tend to be more Sequential, while students with higher maximum vertical speed tend to be more Global. The results show 61% of the scores obtained by the participating students as positive (more Sequential than Global), while 39% are negative (more Global than Sequential). The study results had a high accuracy level of 94.4%, indicating that it is possible to reliably predict whether students' learning-styles are Global or Sequential in this manner.

4.4.5 Adaptivity in Mobile Learning

As a shift in focus emerges toward the development of mLearning systems, learning models are also being employed to support adaptation in mLearning. Learning objects can also be presented to meet specific measures set out by a particular system.

Examples of adaptivity within all mLearning system categories are few. Adaptive technology (for mLearning) in most cases is focused on both the dissemination of contextual information dependant on the device category used and/or the profile of the learner. Research into this area of adaptivity in mLearning is the subject of continuing research at the University of Hagen (Becking *et al.* 2004) [25]. The aim of this research is the supply of sufficient learning material to a learner's mobile device based on both their didactic needs and any constraints they face based on their surrounding environment.

Adaptivity based on the didactic profile of the user has been the focus of initiatives looking at the individual learning-style of mLearning system users. However, while pilot systems adjust the learning content (objects) displayed to the user based on their personal learning profile, in most cases there is a requirement for the prior use of questionnaires to model the learner. Few exceptions to this practice are evident within mLearning research. Efforts have been made to provide automatic learner modeling including work conducted by Kinshuk *et al.* (2009) for mobile LMS. Work has been conducted by both Meawad & Stubbs (2008) [157] and Nguyen & Pham (2011) [157] [180] for didactic profiling using Bayesian Networks.

With the advent of handheld wireless technology and the small screen size associated with these devices, coupled with the compatibility issues associated with differing manufacturers, device-dependent dissemination of material has become an area of attention. The mobile device and its communicative capabilities have seen attempts at the extension of existing eLearning systems, in many cases through the reuse of existing material. However, this is difficult to achieve due to lack of device standardisation.

Some researchers have focused on wireless technology in an attempt to sustain and reshape eLearning through the provision of mobility, offering eLearning through modified applications for deployment via the wireless device. In many cases this causes a loss of content and degradation in the quality of the material due to the physical limitations of the device when compared to its wired counterpart.

This loss and degradation of content is emphasised through studies in adaptive architectures for mobile devices. Alcantara de Oliveira and Almeida Amazonas (2008) [16] propose a learning environment architecture that adapts learning objects displayed on mobile devices based-on the characteristics of the device itself. The transfer of content to differing system architectures resulted in a degradation of quality to content dependant on the chosen device.

Bull *et al.* (2004) [34], look in particular at the Mobile ITS with a focus on adaption and interaction to meet the specific needs of the individual. A major concern within the area of adaptation surrounds the learner's location and the influence of location over the learning process. This concern is also seen within the work of Becking *et al.* (2004) [25]. The learner's surroundings also come into play within the bounds of situated learning. There may be a need to deliver contextual information to the student based on their specific location. Nagella & Govindarajulu (2008) [179] have focused on the use of Bayesian Networks for this purpose.

4.4.6 Moving toward Intelligent Adaptation in mLearning

While other methods have been employed in adaptive user profiling within eLearning, Bayesian Networks have also been used for didactic profiling in mLearning systems. Meawad & Stubbs (2008) [157] have used Bayesian Networks for device and didactic profiling, employing the FSLSM in mLearning systems and Bayesian Networks have also been proposed for the purpose by Dan & XinMeng (2006) [53].

Spada *et al's* approach offers a more definite solution to the detection of learning-styles through users' direct interaction with systems via mouse acceleration. While the approach used by Spada *et al.* offers great potential for eLearning, it was not intended for employment on systems which do not use a mouse, such as mobile devices. There is a need to extend work in adaptive eLearning system development for future use in mLearning applications and environments. The ability to create automatic adaptive systems based on learning-style in mLearning through the incorporation of biometric technology, such as accelerometers, would provide an intelligent and adaptive system.

4.5 Privacy and Ethics in Adaptive Learning Systems

Throughout the work conducted in the preparation of this thesis, consideration has been given to both privacy and ethics. In the development of any system that gathers user data and in turn categorises the user based on such data, privacy and ethics must be considered.

There are two main components within the area of privacy and ethical consideration for conducting user studies with human subjects. These are consent and trust.

Consent is part of a respectful relationship with people. When consenting, a user permits, approves, or agrees, the user complies or yields. Once consent is given, a person has the entitlement to change their minds and withdraw their consent at any given time.

Informed consent refers to an individual's consent based on their understanding of the nature, extent duration and significance of their involvement with the research [19].

Trust is reliant on social, legal and ethical rules. In essence, trust is integral in the management of privacy as the level of personal data a user will expose is dependent on the level of trust between them and the system owner. That is trust is influenced by the perceived level of privacy offered by the system (Greer 2009) [97]. Luhmann (2000)[150] describes trust as *"a choice to expose one's self to a risk toward one's counterpart, in expectation that the counterpart will not disappoint such expectatio"*.

In the development of any system that gathers user data and in turn categorises the user based on such data, privacy and ethics must be considered. In his PARA model, Mason (1986) [153] defines four main ethical issues of consideration for the Information Age (see Figure 4.4). Traxler and Bridges (2005) [231] highlight informed consent and consequently participant withdrawal as a core ethical consideration for research and evaluation in the field of pure mobile learning, which is defined by Traxler and Bridges as learning delivered solely by mobile technologies. Throughout the work conducted in preparation of this thesis, consideration has been given to both privacy and ethical issues.

Privacy	*What information about one's self or one's associations must a person reveal to others, under what conditions and with what safeguards? What things can people keep to themselves and not be forced to reveal to others?*
Accuracy	*Who is responsible for the authenticity, fidelity and accuracy of information? Who is to be held accountable for errors in information and how is the injured party to be made whole?*
Property	*Who owns information? What are the just and fair prices for its exchange? Who owns the channels, especially the airways through which information is transmitted? How should access to this scarce resource be allocated?*
Accessibility	*What information does a person or an organisation have the right or a privilege to obtain, under what conditions and with what safeguards?*

Figure 4.3: PARA Model adapted from Mason 1986 [153]

Borcea *et al.* (2006) [29] state that, as time progresses, computer-based learning systems must gather more detail about individual users in order to improve assistance and that this fact can lead to privacy problems since data collected can be misused.

This element of privacy is very relevant to adaptive learning systems. Generally in adaptive systems, users have little or no control over their data. An adaptive learning system needs to access user behaviour information to facilitate the provision of suitable learning content where information collected by the system is used to create a profile for the user. This can be of particular concern where the system is gathering subconscious interaction, behaviour and biometric data. Users can be fearful that this data will be stored and re-used for other purposes. Where information is used to categorise a user based on learner style, users fear that this categorisation could negatively affect their learning outcomes due to biased information of mis-categorisation by the system. Users may become discouraged and in particular feel that they are being restricted by the system. These issues could potentially affect user acceptance of intelligent adaptive learning systems, therefore they need to be addressed by system developers at system development stage.

"Digital Identities and profiles are essential for personalisation but any kind of misuse causes violation of privacy, fraud etc "(Mont *et al.* 2003 [175]). In order to overcome threats and problems associated with such systems, users need to be able to control access to personal information by third parties. Identity management must be maintained by the user. Identity is the personal data used to model a user's profile within the system environment. This can include user name and information, behavioural patterns and therefore biometric information. Privacy is directly related to identity (Demchak and Fenstermacher, 2004 [59]), therefore identity management must be facilitated within any adaptive system. This can be facilitated through interaction options including anonymity, pseudonymity or open identity.

Anonymity is the only true way to maintain a user's data integrity and reputation however, as a data maintenance method it is restrictive on any adaptive system as it prohibits the process of personalisation. Pseudonymity is used to associate a pseudonym with user actions. This allows for adaptation and personalisation in the system while simultaneously allowing the user to remain anonymous. Open identity occurs where users allow full access to their information to obtain the best benefit from using the system. Learners need to have the ability to control the development of their own reputation within the system. This can be achieved through the implementation of identity management facilities within an adaptive system that allows the user to control the level of information recorded by the system. This gives the user control over the information collected and stored by the system. The ability to work in an unbiased environment and thus control the transition of information from one learning session / environment / group to the other is also an important factor for the user.

4.6 The Future of mLearning

It is difficult at the infancy stage of any developing field to predict its state at maturity. In line with Mikic *et al.* (2007) [170], it is predictable that mLearning will start to take its own place in the field of learning (Figure 4.5), distinct from eLearning. As there are improvements in technology, for example, an increase in the processing power and capabilities of 4G mobile devices, the incorporation of added memory capability, devices such as the iPhone/iPad with larger screen sizes and the inclusion of touch screen and accelerometer devices, will facilitate increased opportunities for development of the field. The future of mLearning will depend greatly on both the ubiquitous nature of mobile devices and the facility of content adaptation to suit the individual needs of each user across the full spectrum of system categories. As technology improves there will be less focus on adaptation to specific device categories and particular device models. The emphasis will be on adaptive dissemination of knowledge and therefore content suitable to a learner's didactic profile, location, context and situation for anytime, anyplace learning will become the main focus in the development of mLearning systems.

As learning systems merge, difficulty will arise in adapting systems to deliver relevant content automatically across the field as a whole, regardless of the category of system employed. When combined with ubiquity, it is the achievement of this ability to adapt that will see mLearning diverge away from eLearning (Figure 4.5).

The model measures the future state of mLearning on two scales, 'Lab based' and 'Ubiqity' against 'Functionality', lab-based reflecting a separate field of eLearning and ubiquity, a separate field of mLearning.

The trade-off between richness of content, functionality, and mobility will be reduced due to advances in mobile technology and adaptivity in systems. These will become consistent across both fields. Therefore, richness is no longer a necessary scale measure.

Richness is no longer relevant as learner object display is gaining parity with that of eLearning through extended memory facilities and improvement in display and processing capability of devices boosted by the potential to provide personalised systems.

Both mLearning and eLearning will maintain similar learning system categories. This is indicated in Figure 4.5 through the inclusion of similar learning system catagories in both the eLearning and mLearning catagories. Each field will show a version based on their respective advantages. Mobility is a key factor in the development of natural interactions and therefore the mobile device is particularly appropriate as a supporting

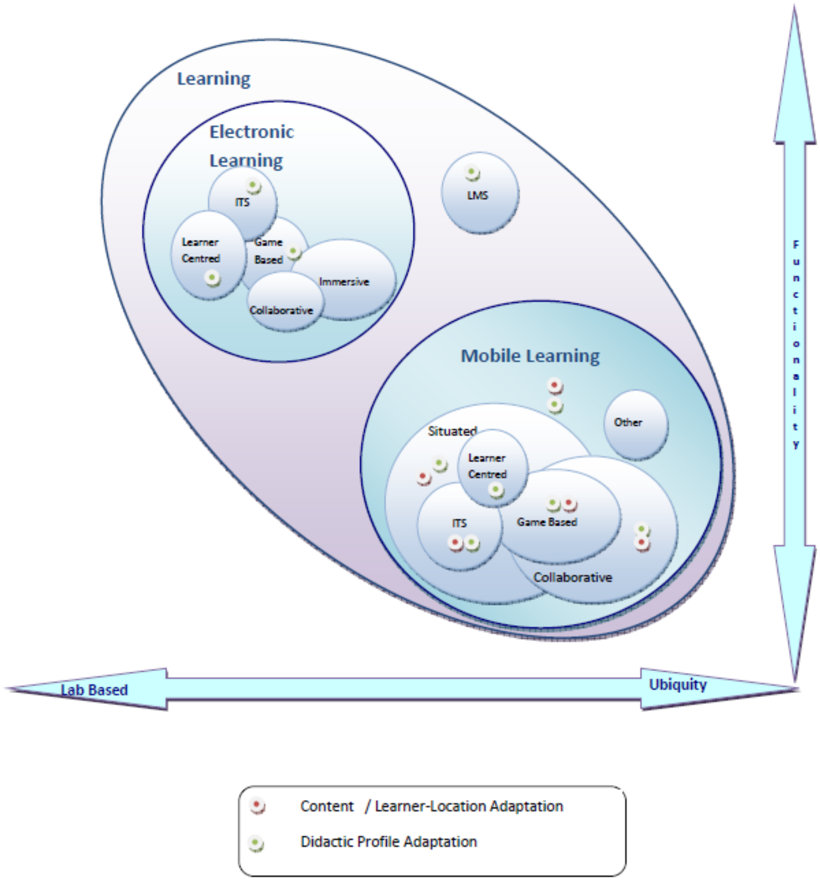

Figure 4.4: mLearning in the Future

technology for field trips and orienteering activity types. Situated, collaborative and learner-centred systems will therefore become the mainstay of mLearning, creating a new form of immersion in a ubiquitous environment for conversational and activity based learning to suit individual learners in collaborative environments.

4.7 Constructive Contributions

A content management model ‘MAPLE’ (Mobile Adaptive Personalised Learning Environment) as published in Tools for Mobile Multimedia Programming and Development, Tjondronegoro (2013) [168] was designed and developed for application to eLearning environments. Unlike some of the adaptive systems outlined in section 4.4 including MASPLAG [188], LSAS [22] and TANGOW [38], MAPLE facilitates the intelligent and automatic detection of user learning-style based on biometric interaction pattern data. The model is suitable for use with any electronic or mobile learning environment. The model can be implemented for any platform and any device category including, for example, Apple's IOS, Google's Android OS and web-based applications.

4.7.1 MAPLE - Facilitating Intelligent Learning Systems

The MAPLE model structure comprises a number of stages as indicated in the model (Figure. 4.3).

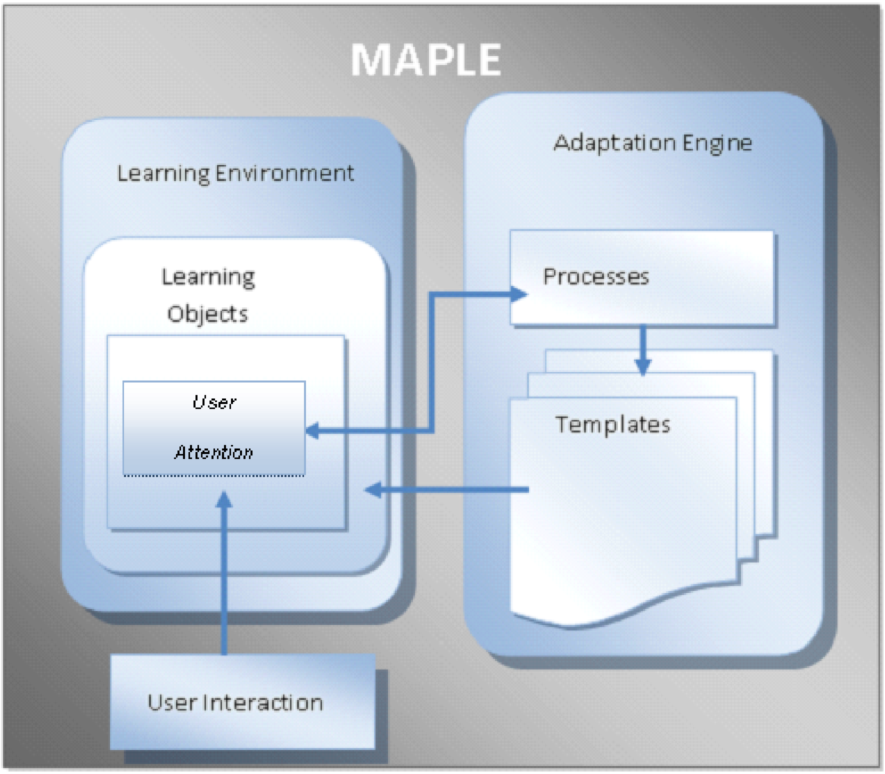

Figure 4.5: MAPLE Content Management Model [168]

The model comprises three main components, the adaptation engine, and the learning environment and user interaction facilities. Each component has associated rules which are applied at each stage of the model's implementation as follows;

The Adaptation Engine

The adaptation engine is the backend and intelligent aspect of the model. It holds learning object templates designed to match the required display to learners depending on the adaptation engine's assessment of their learning-style on completion of the adaptation processes. These processes are based on the data obtained from the user's interaction with a system through the learning environment associated with it.

Stored Templates

The stored templates comprise learning objects specific to the learning topic and course requirements. The templates include a range of learning content from which the system selects material for individual learners in accordance with their learning-style, for example, visual learning objects can be included for display to Visual learners. The visual content can comprise pictures, graphs, flowcharts, timelines, video and demonstrations. Verbal learning objects are included suitable for display to verbal learners including for example text and auditory (verbal) explanations. This content meets the requirements for content presentation outlined in Felder & Silverman's (1988) teaching-styles as prescribed by the FSLSM. Display content can be combined: for example, for the Visual / Verbal dimension the templates could include a balance of visual and verbal content displayed where a student is deemed (by a system employing the MAPLE model) to be balanced on the dimension in question.

Processes

The processes gather and interpret user interaction data obtained from the 'Learning Environment', including the amount of attention paid by users as to content as revealed through their interaction with the learning objects displayed to them. For example, the total user interaction time on particular learning objects (Visual / Verbal learners) could be used by the processes to detect the learning-style of the user on the Visual / Verbal dimension of the FSLSM (Popescu 2008 & Cha *et al.* 2006) [190][40]. A user's maximum vertical speed when viewing displayed content could be applied to detect Global / Sequential learners (Spada *et al.* 2008) [218]. The outcome of the processes determines the template to be displayed to the user as part of the overall learning environment.

The Learning Environment

The learning environment comprises the user interaction aspects and the front end of any system based on the MAPLE model. The learning environment displays learning-object-based content to users. The system initially displays an assessment screen and a subsequent display of adapted content to suit the needs of the specific learner based on the outcome of the adaptation engine's processes.

User interaction & User Attention

User interaction is facilitated via biometric technologies. These can include, but are not restricted to, the accelerometer and / or eye-tracking technologies. User attention reflects the overall attention and focus of a learner on a specific learning object within the displayed content.

Chapters 5 & 6 of this thesis expand work presented at EDMedia 2009 [160], EduLearn 2009 [161], IHCI 2009 [159], ICME 2011 [162], iGBL 2011 / 2012 [166] [164], and iHCI 2011[165] based on automatic detection of user profiles. This work has focused specifically on the automatic detection of individual learning-styles through the use of accelerometer and eye tracking technology, based on the FSLSM. This work facilitates the potential development of seamless and non-intrusive adaptive learner models for the delivery of learner objects specific to individual learner needs across system categories.

4.8 Conclusion

mLearning is clearing a pathway for a revolution in education that will see the modern learner empowered to participate in inclusive learning through anonymous and collaborative means via their mobile device. Studies have suggested that the use of handheld devices in education can lead to increased benefits from learning through one-to-one and one-to-many social interactions. It is also shown that groups who use handheld devices for their learning activities learn more than those with no technological support (Zurita *et al.* 2003) [251]. The advent of wireless technology and small handheld devices removes the lack of mobility which has been a major stumbling block in the development of successful collaborative learning outside the classroom environment. As systems merge in mobile environments they will migrate away from immersive eLearning toward immersive, situated, game-based mLearning. The future of mLearning is one that is separate from eLearning and therefore, a field in its own right. Although a model of the current state of mLearning is presented, further research into adaptive systems and mLearning's placement in relation to the separate field of eLearning is required before it is possible to move mLearning towards its growth stage.

This chapter has highlighted the differences between eLearning and mLearning. Building on work published in Mobile Learning; Pilot Projects and Initiatives (Guy 2010) [167], this chapter has put forward a model of mLearning to highlight the fusions taking place within these mLearning systems. The level of system adaptivity within both eLearning and mLearning has been examined with a focus on how adaptive systems can be improved for future mLearning systems based on user learning-style. For this purpose a separate content management model called MAPLE has been described. Based on the work of Spada *et al.* (2008) [218], chapters 5 & 6 will examine the potential use of biometric-based interaction devices for learning-style detection purposes in mLearning environments.

Part IV

Biometric Devices - User Studies

Chapter 5

Detecting Learning-Styles Through Accelerometer Devices

Building on work presented at work presented at EdMedia 2009 [160], EdTech 2009 [161] and Irish HCI (2011) [165] and work published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163], IJGBL (2012) [167] and *Tools for Mobile Multimedia Programming and Development*, Tjondronegoro (2013) [168], this chapter introduces accelerometer technology, outlining its use within eLearning to date. The term accelerometer is defined. Two studies conducted to assess the potential use of accelerometer technology for the detection of user learning-styles are outlined and results presented. The potential use of accelerometer technology with mobile devices for mobile learning is considered.

5.1 Accelerometers

An accelerometer is a tri-axis sensor device that measures an object's non-gravitational acceleration and speed of motion and vibration caused by this movement. An electrical output is produced proportional to the rate of acceleration when the device is moved. An accelerometer can be employed to measure vibration, rotation, shock and tilting. *"The simplest device to measure acceleration is the spring mass system"* (Meehan & Moloney 2010) [158]. The iPhone, for example, uses a MEMS (Micro-Electro-Mechanical Systems) accelerometer which *"uses three elements: a silicon mass, a set of silicon springs, and an electrical current. The silicon springs measure the position of the silicon mass using the electrical current. Rotating iPhone causes a fluctuation in the electrical current passing through the silicon springs. The accelerometer registers these fluctuations and tells iPhone to adjust the display accordingly"* (Apple 2006 [6]).

5.2 Background

Accelerometers have mainly been used in the field of engineering to date. For example, they have been used in the field of geology to measure seismic activity, they are also used within the transport industry for the activation of vehicular air-bags, and in the area of medical devices where they are used for the measurement of vibration and the rotation of machines. Companies like Nike and Polar have embraced the health and fitness potential of these devices, producing sports watches for runners that include 'footpods' containing accelerometers to help determine the speed and distance achieved by a runner while wearing the unit. In the last number of years, the accelerometer has become a feature within the commercial gaming industry where the device has been included in gaming consoles such as the 'Nintendo Wii'. The accelerometer is also used for desktop computing. Devices such as the Logitech 'AirMouse' are now commercially available.

		Usage	**Implementation Method**
Research-Based Uses			
	Device Interaction	Text Entry & Browsing	Tilt Velocity / Speed
		Scrolling, Zooming & Scaling	Tilt Speed-Dependant
Commercial-Based Uses			
	Geology	Measure Seismic Activity	Vibration Measurement
	Gaming	Game-Play Interaction (Mobile devices i.e. iPhone)	Tilt Interaction
		Game-Play (Consoles)	Tilt Interaction
	Health	Medical Machine Rotation	Vibration
		Sport Watches	Vibration
		Foot pods	Vibration
	Transport	Vehicular Airbag Activation	Shock Measurement

Figure 5.1: Research/Commercial-based Accelerometer Use and Method of Use Implementation.

The accelerometer has emerged as a significant device for gaming within the area of mobile technology. Included in Apple's iPhone, the device has now become a standard feature in most high-end mobile handheld devices, including many Symbian 60 and 80 series and Android-based mobile phone devices. The accelerometer is also a standard feature in tablet devices, including Apple's iPad.

The use of accelerometers in mobile technology has lead to a research-based interest in their potential use for text entry and browsing (Sung-Yung *et al.* 2007) [223] scrolling, zooming and scaling (Eslambolchilar *et al.* 2004) [70], and the enhancement of game play interaction (GamePlayTalk 06) [11] (Figure 5.1).

5.3 Detecting Global / Sequential Learners through Accelerometer Technology

Spada *et al's* (2008) [218] work (see chapter 4) raised a research question regarding the potential of learning-style detection in mLearning environments. Consequently the potential of the accelerometer device to detect learners' style based on the Global / Sequential dimension of the FSLSM was considered. The use of accelerometers in this manner would facilitate the extension of Spada *et al's* (2008) work [218] for use in mobile environments.

The use of accelerometers in this manner reduces the probabilistic elements associated with the use of complex methods such as Bayesian Networks (Garcia *et al.* 2005) [85] and Feed Forward Neural Networks (Villeverde *et al.* 2006) [236]. The gathering of data directly from user interaction allows for a more exact and non-intrusive adaptive system for users, where system outcomes are tracked directly to specific user actions.

5.3.1 Study Outline

A study was conducted to assess the potential of the accelerometer for the automatic detection of learning-styles based on a student's interaction with an eLearning application. The study outline and results were presented at EdMedia 2009 [160], EdTech 2009 [161] and published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163], IJGBL (2012) [167] and *Tools for Mobile Multimedia Programming and Development*, Tjondronegoro (2013) [168].

An application is developed comprising a web-based learning screen and a data acquisition model. The data acquisition model logs accelerometer coordinates and time duration for each user to an external file. The study is conducted to test the following hypothesis:

- Global learners (as defined in terms of the FSLSM) will exhibit faster vertical speed (speed on the *y-axis*) using an accelerometer input device than Sequential learners, while Sequential learners will exhibit slower vertical speed using an accelerometer than their Global counterparts.

5.3.2 Nintendo WiiMote

The Nintendo Wiimote (Figure 5.2), is the primary controller for Nintendo's Wii console. A main feature of the WiiMote is its motion sensing capability, which allows the user to interact with and manipulate items on screen via gesture recognition and pointing. This is achieved via the incorporated accelerometer and optical sensor technology. The WiiMote senses light from the console's Sensor Bar (model number RVL-014), The Sensor Bar is 20 cm (7.9 in) long and features ten infrared LEDs, five at each end of the bar [13].

Figure 5.2: Nintendo WiiMote [13]

5.3.3 User Interface

Simulated via a desktop computer and a Nintendo WiiMote (to represent the accelerometer) an educational Java-based application is developed. The application comprised aspects of a computer science course in web development (see Figure 5.3). The application is developed using the NetBeans IDE, and the Bluecove 2.0 library (Bluecove 2008) [10] to facilitate the Bluetooth interaction capability for the use of the WiiMote. The WiinRemote_v2006.12.25b application (Wiili) [7] is also used in conjunction with a GlovePie (Kenner 2006) [2] script to control the WiiMote interaction. The WiiMote sync connection was created using a Bluetooth adaptor combined with IVT BlueSoleil (IVT Corporation) [1] software (Figure 5.4).

The application provides a balance between images and text. A multiple choice question page is also displayed to the user at the end of the session. As the students interacts with the application, selection points highlight each learning object on screen as selected. Each student is provided with a login to ensure that records correctly match the user.

On the login page, users are presented with a small screen containing a textbox into which the user login is entered. The user then needs to select the 'Enter' command from the menu bar to proceed to the first learning page of the application. Page one of the application presents the user with learning objects in the form of text areas which

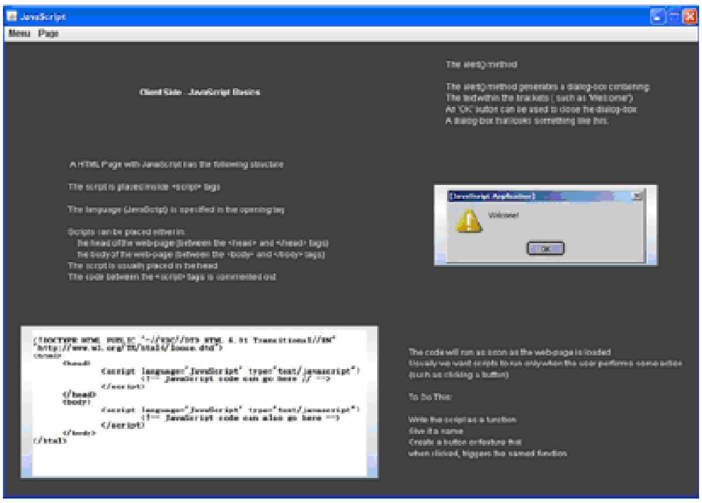

Figure 5.3: Global / Sequential Accelerometer User Study Learner Screen

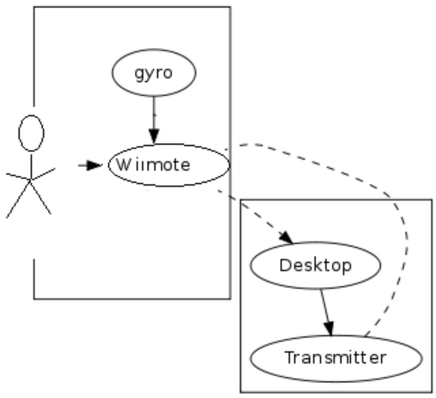

Figure 5.4: Nintendo WiiMote / PC Interaction Schematic Diagram

provided information to the user (Figure 5.3). Images are also displayed on the page. To move to the next page the user has the option of selecting the 'Enter' or 'Forward' command from a drop down menu on the menu bar.

To operate the system, the user logs in and selects the enter command from the menu bar. When page one is loaded by the application, the user interacts with the page content, using the WiiMote to move to where they are reading / viewing the screen. The user could move forward and backward through the pages by selecting commands from the menu bar.

The user interface presents the user with a simple to use and informative environment. Data is presented to the user via both text and images. The background screen is darkly coloured with white foreground font, the aim being to present clearly defined text areas. No scrollbars are used in the design of the system and learning objects are well spaced on the page.

5.3.4 Data Acquisition File

To ensure that an accurate result is achieved it is necessary to record interaction data from the WiiMote. Data is stored for each user in relation to their user login. The system is set up to record data as page coordinates relative to the position of the cursor on screen as the user interacts with the system. The user's speed moving from one coordinate to the next is recorded as well as the time taken between contact points and between screens. Stops, starts or large jump movements in association with learning objects on screen are also recorded, in particular where a learning object is skiped or remains un-highlighted. The number of visits to each page and learning object is also recorded (Figure. 5.5).

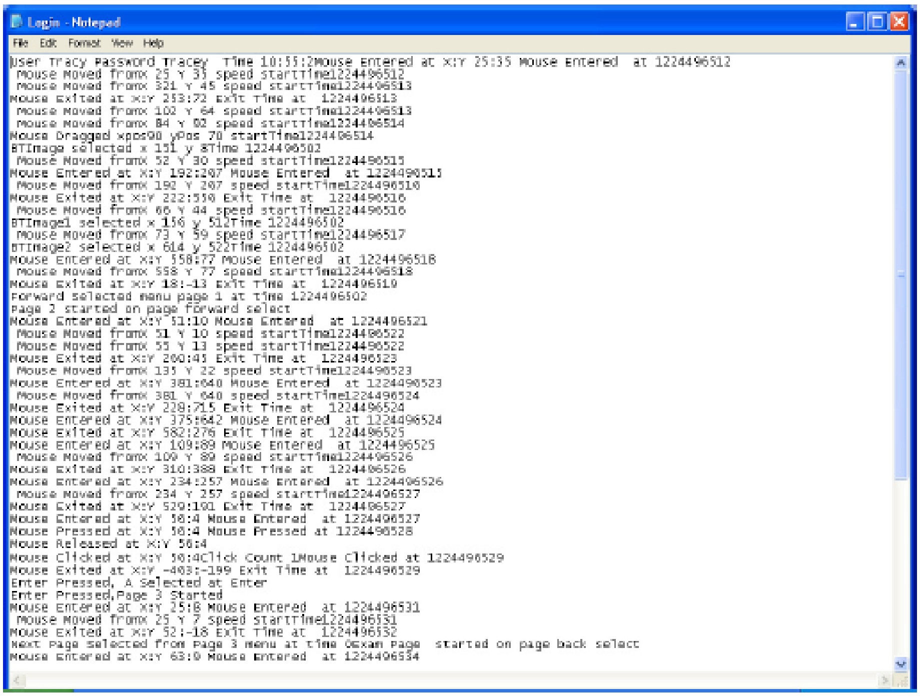

Figure 5.5: Global / Sequential Accelerometer User Study Data Aquisition Screen

In the case of the user's interaction with the quiz page, the system recorded correct / incorrect multiple choice responses. Changes that were made to multiple choice selections before submitting were also recorded.

5.3.5 Participant Selection

A balanced sample is used for the study. A total of 20 subjects took part in the study, comprising ten Global learners and ten Sequential learners. The participants' learning-style (Global or Sequential) acts as the independent variables for the test. These variables are measured against each other once the tests are completed to establish the distinctions between them.

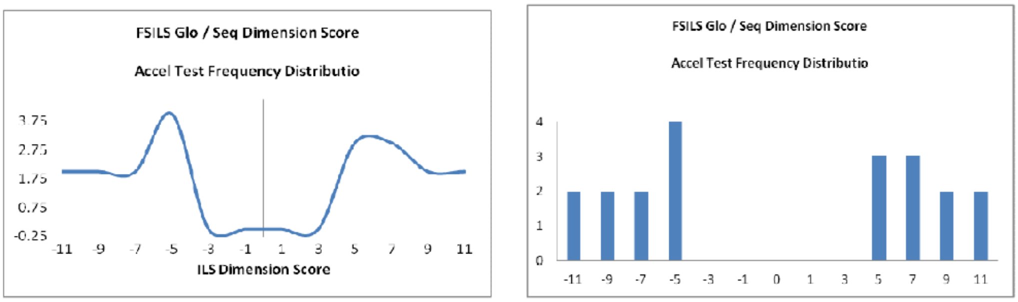

Figure 5.6: Global / Sequential Accelerometer User Study Frequency Distribution a) Line Graph, b) Bar Graph

The subjects, are all students, researchers, etc., between the ages of 16 and 65 years. In order to identify Global and Sequential learners, subjects are first asked to complete a paper-based FSILS questionnaire. This information is then processed online by the test coordinator. The screening of subjects continues until ten learners of each type had been identified (ten Global learners and ten Sequential learners) and each confirms their willingness to take part in the test.

The participants comprise both staff and students (ranging from Leaving Certificate to PhD level). Participants are chosen from the Department Computer Science, the School of Education, the Department Microbiology at UCC, from the Department of Computing, Maths and Physics at Waterford Institute of Technology, and the school of Business at Cork Institute of Technology. Leaving Certificate students from local secondary schools also participated in the study. On this basis and based on the result of the individual FSILS questionnaire, there is no potential for a bias in the study result.

All participants indicate that they have experience using mobile devices. All participants gave informed consent to each aspect of the study.

Participants chosen to progress to the interaction stage of the study (through completion of the FSILS questionnaire) are from both sides of the Global / Sequential

Table 5.1: Global / Sequential Accelerometer Study Participant Frequency Distribution

Dimension	Dimension Score	Frequency
Global	11	2
	9	2
	7	3
	5	3
	3	0
	1	0
	0	0
Sequential	-1	0
	-3	0
	-5	4
	-7	2
	-9	2
	-11	2
	Total	*20*

dimension scale. Both moderate and high scores are included. (Table 5.1). The participants represent a bimodal frequency distribution as illustrated in Figure 5.6.

To complete the study, both groups are asked to complete the same task. The system collects the users' interaction data as they move through the screens provided. This data is gathered via the data acquisition file.

5.3.6 Methodology

Subjects are asked to undertake a desktop-based eLearning task. Subjects interact with the system using the Nintendo WiiMote. Subjects are instructed in how to use the system, after which they received no help or prompting from the test coordinator.

During the task, subjects are presented with one screen of learning information on a topic in the form of text and images, followed by a multiple-choice question relating to that topic. Navigation from one screen to the next is achieved through selection from the application menu.

Interaction time with the application is approx. ten minutes per user. However, no actual time limit is imposed on the user.

The learning-style of individual subjects (Global/Sequential), determined using the FSILS questionnaire, act as the independent variable for the test. The dependant variables are the:

- X axis speed
- Y axis speed

These are automatically recorded by the application through the data acquisition file.

5.3.7 Evaluation

The results obtained from user interaction with the eLearning application via the accelerometer are based on full learning obtainment assessed through the use of Multiple Choice Questions provided to the user through the user task screen. The results show a high correlation coefficient of r = 0.81564. Consequently it can be said that a strong relationship exists between the vertical speed of a user when using the accelerometer device and their score on the Global / Sequential dimension of the FSILS questionnaire. The results are indicated in the scatter graph provided in Figure 5.7.

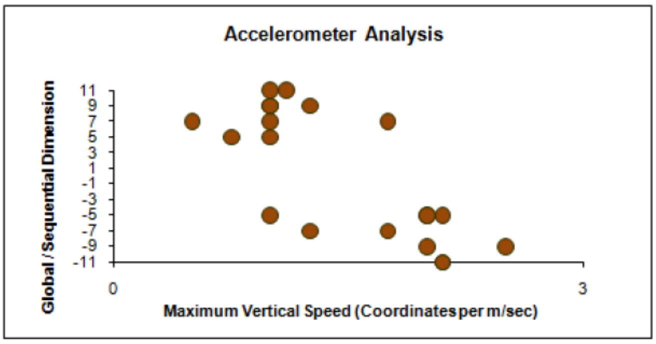

Figure 5.7: Global / Sequential Accelerometer User Study Dimension Score vs. Correlation Coefficient Max Vertical Speed (coordinates per msec)

The correlation coefficients achieved in respect of the prediction indicate that students with higher vertical speeds tend to be more Global in their learning-style than those with lower speeds.

5.3.8 Study Conclusion

The high correlation coefficient that exists between the user's score on the FSILS Global / Sequential dimension and the user's vertical speed using the WiiMote shows that accelerometer-based interaction patterns can be used as a means of determining individual user's learning-styles. Thus, based on the results achieved in the study, the hypothesis can be accepted. Therefore, in answering the research questions (chapter 1), we can conclude that accelerometer-based interaction pattern data can be used to determine a user learning-style on the Global/Sequential dimension of the FSLSM. As testing was independently conducted for all elements no further testing is required.

5.4 Detecting Visual / Verbal Learners through Accelerometer Technology

There is potential to extend the work described above to include the Visual / Verbal dimension of the FSLSM, based on elements of the work conducted by Popescu (2008) [190] and Cha *et al.* (2006) [40]. Studies conducted by Popescu (2008) [190] and Cha *et al.* (2006) [40] gathered data based on a learner's behaviour within eLearning environments. This data was subsequently analysed using Decisions and Hidden Markov Model approaches. Decision Trees are used to produce the rules of the classification which are visible for pattern recognition and classification (Margaret 2003 as cited by Popescu 2008)[152]. Hidden Markov Models are statistical methods that use probability measures to model sequential data represented by sequence of observations (Lawrence 1990 as cited by Popescu 2008) [143]. Both Popescu (2008) [190] and Cha *et al.* (2006) [40] have assessed Visual and Verbal learners based on time spent on visual and verbal learning objects. It is this element of their work which is extended. The aim of the study described here is to reduce the probablistic elements associated with the use of these complex methods. The gathering of data directly from user interaction would allow for a more exact and non-intrusive adaptive system for users.

5.4.1 Study Outline

A study was conducted to assess the potential of the accelerometer for the automatic detection of learning-styles based on a student's interaction with an eLearning application. The study outline and results were presented at EdMedia 2009 [160], EdTech 2009 [161] and Irish HCI (2011) [165] and published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163], IJGBL (2012) [167] and *Tools for Mobile Multimedia Programming and Development*, Tjondronegoro (2013) [168].

An application is developed that uses a web-based learning screen and a data acquisition model to log accelerometer coordinates and time duration for each user to an external file.

It is expected that Visual learners would spend a longer overall time on visual learning objects and Verbal learners would spend a longer overall time on textual content.

The study is conducted to test the following hypotheses:

- Visual learners (as defined in terms of the FSLSM) will exhibit longer time on visual learning content (images/graphics) than Verbal learners.
- Verbal learners (as defined in terms of the FSLSM will exhibit longer time on textual learning content than their Visual counterparts.

5.4.2 Logitech Air Mouse

Logitech's Air Mouse incorporates a IME-3000 3-axis accelerometer with IDG dual-axis family of gyroscopes (Figure 5.8). This produces a 6-axis motion detection facility [12].

Figure 5.8: Logitech Air Mouse [12]

5.4.3 User Interface

Simulated via a desktop computer and employing Logitech's Air Mouse (to represent the accelerometer function) an educational web-based application is developed, comprising elements of a computer science course in web development (see Figure 5.9). The application is developed using HTML and JavaScript. The content offers a balance of images and text. No scrollbars are used in the application to ensure simple access to information. Each student is provided with a login to ensure that records correctly match the user.

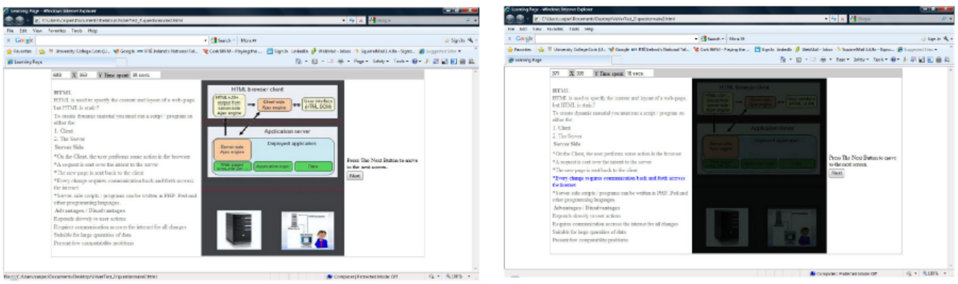

Figure 5.9: Visual / Verbal Accelerometer User Study User Learner Screen

On commencement of using the system, the user logs in with his/her name and email address. The 'Next' button is then clicked to take them to the learning screen. When the learning screen is loaded by the application all content is visible on screen (see Figure 5.9).

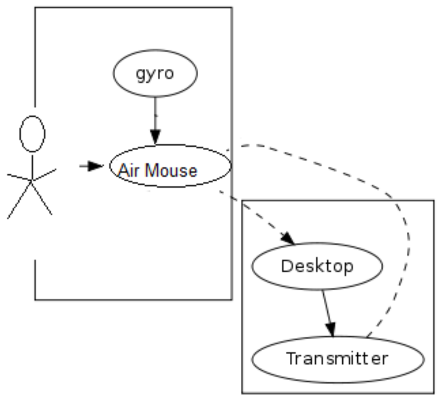

Figure 5.10: Logitech Air Mouse/PC Interaction Schematic Diagram

The user interacts with the page by viewing and reading the content using the Air Mouse to point to where they are reading / viewing the screen. As the user moves the Air Mouse over the image content, the textual content is shaded from view. When the user moves the cursor from the image content, the area of text (heading or sentence) under the cursor is highlighted whilst all the other areas of the screen remain shaded (see Figure 5.9).

When the user is finished viewing the content, the 'Next' button is clicked and the user is presented with a number of multiple-choice questions. This is the end of the application session.

5.4.4 Participant Selection

A total of 18 subjects took part in the pilot study, comprising nine Visual learners and nine Verbal learners.

The subjects are all students, researchers, etc., between the ages of 16 and 65 years. In order to identify Visual and Verbal learners, potential subjects are first asked to complete a paper-based version of the online FSILS questionnaire. On completion, the questionnaire is processed online by the test coordinator. The screening of subjects continued until nine of each learner type have been identified, that is nine Visual learners and nine Verbal learners, and each had confirmed their willingness to take part in the

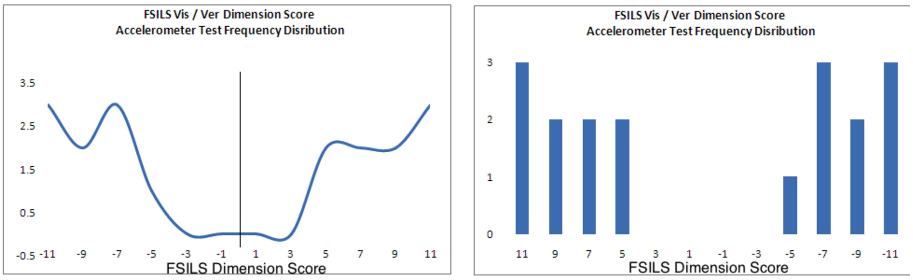

Figure 5.11: Visual / Verbal Accelerometer User Study Frequency Distribution a) Line Graph, b) Bar Graph

Table 5.2: Visual / Verbal Accelerometer Study Participant Frequency Distribution

Dimension	Dimension Score	Frequency
Visual	11	3
	9	2
	7	2
	5	2
	3	0
	1	0
	0	0
Verbal	-1	0
	-3	0
	-5	1
	-7	3
	-9	2
	-11	3
	Total	*18*

test. All participants were experienced in the use of mobile devices. All participants gave informed consent to each aspect of the study.

The participants comprise both staff and students (ranging from Leaving Certificate to PhD level). Participants are chosen from the Department Computer Science, the School of Education, the Department Microbiology at UCC, from the Department of Computing, Maths and Physics at Waterford Institute of Technology, and the school of Business at Cork Institute of Technology. Leaving Certificate students from local secondary schools also participated in the study. On this basis and based on the result of the individual FSILS questionnaire, there is no potential for a bias in the study result.

Participants chosen to progress to the interaction stage of the user study present on both sides of the Visual/Verbal dimension of the FSLSM (Table 5.2). Again, both moderate and high scores are included at the interaction stage. Participants represent a bimodal frequency distribution as graphed in Figure 5.11.

5.4.5 Methodology

Subjects are asked to undertake a PC-based eLearning task. Subjects interacte with the system using the Logitech Air Mouse.

Subjects are instructed in how to use the system. On completion of instruction, no further help or prompting is provided by the test coordinator. No user failed to complete the test. During the task, subjects are presented with one page of learning information on a topic in the form of text and images. When a user has the cursor on the text content, the image content is automatically shaded and vice versa. This is to ensure that the subject is actually viewing the text or image content as per the placement of the cursor on the screen. This screen is followed by a multiple-choice question relating to that topic. Navigation from one screen to the next is achieved through clicking a 'Next' button.

No time limit is imposed on the user to interact with the application; the normal interaction time is approximately 10 minutes per user.

The learning-style of individual subjects (Visual or Verbal), as determined using the FSILS questionnaire, acts as the independent variable for the test. The dependant variables are the:

- duration on text points
- duration on image points

These are automatically recorded by the application through the data acquisition file.

5.4.6 Data Acquisition File

The application is designed to record data as coordinates relative to the position of the cursor on screen as the user interacts with the system. This data is automatically written to an external text file by the application.

The data recorded includes the total time (in milliseconds) spent on both image and textual learning objects. This information is used for the study to highlight where each user views / reads learning object content. Much of this information can also be used

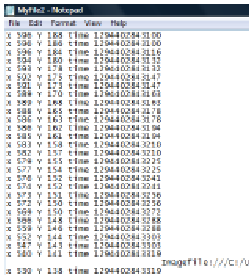

Figure 5.12: Visual / Verbal Accelerometer User Study Data Acquisition Screen

for further analysis at a later stage. In relation to the multiple choice question page, the system records both correct and incorrect multiple choice responses on submission.

5.4.7 Evaluation & Conclusions

The correlation coefficients achieved (as set out below) indicate that it is possible to detect Visual / Verbal learners through their interaction with accelerometer devices.

5.4.8 Correlation

In order to assess the results of the study it was necessary to establish a correlation co-efficient based on the user's score on the Visual / Verbal dimension of the FSILS and each of the following conditions:

- total time on text using the accelerometer.
- total time on images using the accelerometer.

The results obtained from user interaction with the eLearning application via the accelerometer are based on full learning obtainment assessed through the use of Multiple Choice Questions provided to the user through the user task screen. The results show a strong correlation coefficient of r= 0.78519 in respect of participants' total time duration on images and their score on the Visual / Verbal dimension of the FSILS. This is indicated in the scatter graph shown in Figure 5.13.

A inverse correlation of r=-0.81204 was achieved in respect of the second condition, time duration on textual content using the accelerometer vs. participant score on the FSILS, as shown in Figure 5.14.

5.4.9 Study Conclusion

The correlation coefficients achieved in respect of the two conditions clearly indicate that students spending a longer overall time on visual content are more Visual in

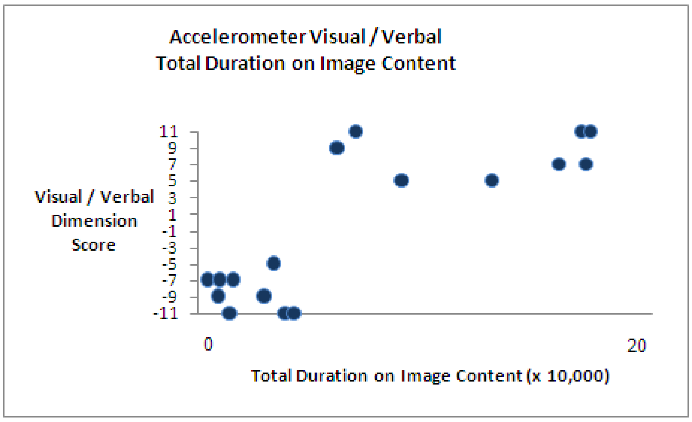

Figure 5.13: Visual / Verbal Accelerometer User Study Correlation -FSILS Dimension Score vs Total Time on Images

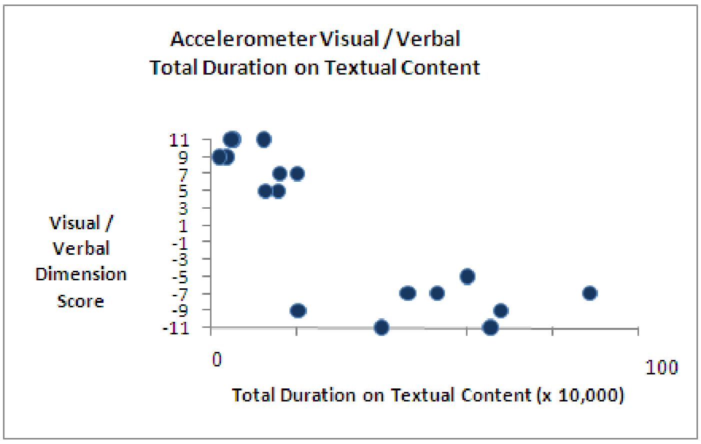

Figure 5.14: Visual / Verbal Accelerometer User Study Correlation -FSILS Dimension Score vs Total Time on Text

their learning-style, whereas learners spending a longer overall time on textual content are more Verbal in their learning-style, when measured against the FSILS. Based on the results, both hypotheses can be accepted. Therefore, in answering the research questions (chapter 1), we can conclude that accelerometer-based interaction pattern data can be used to determine a user's learning-style on the Visual / Verbal dimension of the FSLSM. As testing was independently conducted for all elements, no further testing is required.

5.5 Prototyping Adaptive mLearning Environments through MAPLE

The research described above has shown that accelerometer devices can be used to measure behavioural biometric patterns in relation to a users' interaction with a system. This information, in turn can subsequently be used to detect a user's learning-style, both on the Global / Sequential and the Visual / Verbal dimension of the FSLSM. Based on this research, a prototype application was developed through the MAPLE model (described in chapter 4) to provide an adaptive mLearning system. The system can detect a user's learning-style on the Global / Sequential and the Visual / Verbal dimension of the FSLSM and provide the user with appropriate learning content based on this detection. The application makes use of the mobile device's built in accelerometer sensor to facilitate the main user interaction function. This particular application is designed to provide an adaptive mLearning system to detect a user's learning-style on the Global/Sequential and the Visual / Verbal dimension of the FSLSM based on the user's accelerometer-based interaction. On assessment of the user's learning-style the system subsequently adapts learning-object-based content displayed to the user. The prototype mLearning system is designed to run on the Apple iPhone and iPod, however the MAPLE model can be applied to any mobile platform and/or mLearning environment.

5.5.1 Creating the Prototype Learning Environment

A view-based iPhone learning system application comprising aspects of a course in web development (JavaScript) was developed in Objective C using XCode and Interface Builder via the IOS4 SDK. When the learning environment is initialised the system presents a splash screen to welcome the user (Figure. 5.15).

To commence interaction the user is required to touch the 'Next' button. The button changes the view (or screen display) to the initial user interaction screen of the learning environment. Within the learning environment, users are presented with a set of learning objects held within an initial learning-style assessment screen (Figure. 5.16). The screen is divided into two parts creating a balance of graphical and textual learning content. Each screen section is contained within a boundary-box. A cursor image is also visible on the screen. The cursor is located at the top left-hand corner of the screen on start-up.

Figure 5.15: MAPLE-based Learning Application - Splash Screens, a) Welcome Screen, b) End Screen.

User Interaction and Adaptation Processes for Prototype Implementation

The cursor image is also contained within a boundary-box. The boundary boxes for each learning object area and the cursor are created programmatically using a boundary-box function. The cursor image boundary-box is defined by its parameters which are set with accelerometer-relative variables. This enables the re-calculation of the boundary-box coordinates depending on the current location of the cursor on screen. The location of this image (and thus its boundary) is controlled and animated via the user's accelerometer interaction.

The learning objects are each defined by an individual instance of a boundary-box function, one for textual content, and a second for visual content. However, as learning object content is stationary, the coordinates of the boundary-box are fixed to specific locations on the screen. The accelerometer interaction is used to animate the cursor image to its new position when the device is active. This facilitates the user interaction component of the MAPLE system model. As the user interacts with the system the cursor image is moved on screen by the user to the specific learning object on which they have placed their attention. A boundary-box-intersection function is applied via a condition statement to monitor when the cursor image intersects the boundary of either the textual or the graphical content.

Each boundary-box is assigned an individual timer variable that is given an initial value of *0*. When an intersection occurs between a specific learning object boundary-box (text or visual) and the cursor boundary-box, the timer is incremented. When the

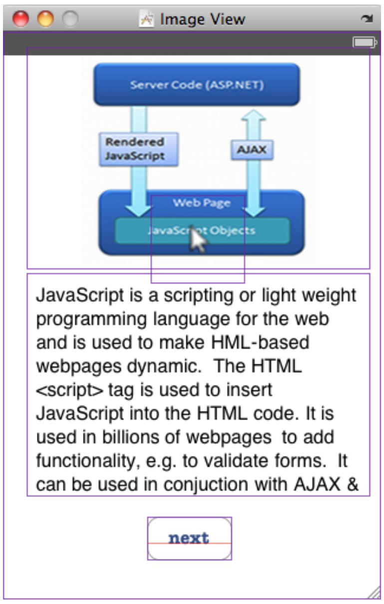

Figure 5.16: MAPLE-based Learning Application - Learner Assessment Screen.

cursor image moves away from the intersection area, the process ends and the value of the timer variable is stored until either a further intersection process occurs, for example, the user invokes the action of the 'Next' button. This allows the system to determine the user's total overall focused attention for each category of learning object. The level of user attention on each learning object is measured in milliseconds. This facilitates the learning-style detection based on the Visual/Verbal dimension of the FSILS through time-based user attention on content.

The cursor image boundary-box is also assigned a speed variable to assess the user's speed on the *y-axis* as they interact with the screen content. The speed variable is also assigned an initial value of *0*. As the user interacts with the screen content the speed variable measures the total time taken by the user to move vertically down the screen. When the user invokes the action of the 'Next' button the system determines the user's total vertical speed. The level of vertical speed is also measured in milliseconds. This facilitates the learning-style detection based on the Global/Sequential dimension of the FSILS through speed-based user attention on content focused on the *y-axis*.

Facilitating the Adaptation of Content

Once the learner completes their interaction with the assessment screen (by invoking the action of the 'Next' button in the case of the prototype system), measurement data is processed by the adaption engine. The learning object timer values are compared with each other respectively and the vertical speed variable is measured against a pre-defined

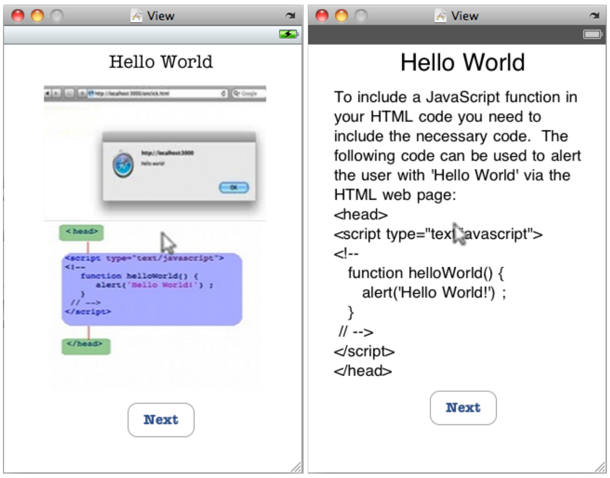

Figure 5.17: MAPLE-based Learning Application Visual / Verbal Template Screens - (a) Visual, (b) Verbal.

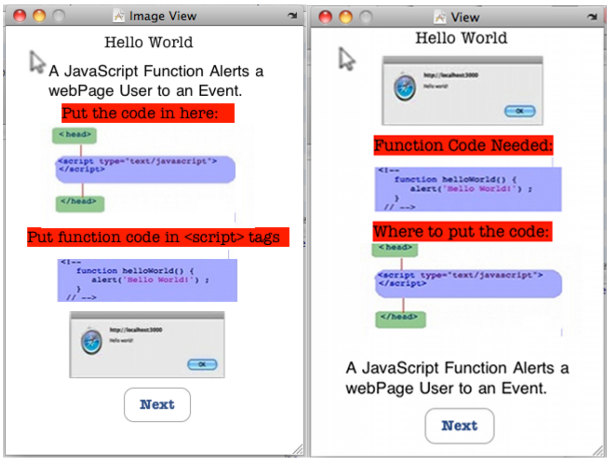

Figure 5.18: MAPLE-based Learning Application Global/Sequential Template Screens - (a) Sequential, (b) Global.

threshold. Subsequently the system decides the learning-style of the system user based on the Visual/Verbal and the Global/Sequential dimensions of the FSLSM respectively. For the purposes of developing the prototype, focus was placed on the Visual/Verbal and Global/Sequential dimension extremes, that is, whether a learner highly is Visual, highly Verbal, highly Global or highly Sequential. However, while this is the case to facilitate the development of the prototype, a full-scale learning environment could take into consideration the other dimension score measures. For example, a full-scale system could take into consideration a learner's moderate or balanced preference for one style on a dimension.

In the case of the prototype, if the visual learning object's timer value is higher than that of the verbal learning object's timer value, the system deems the user to be a Visual learner, and vice versa. Depending on whether the user's total vertical speed value is higher or lower than the predefined threshold, the learner is deemed to be Global (lower than the threshold) or Sequential (higher than the threshold). The Learning screen templates for each category of learner are held within the adaptation engine. Based on process outcomes, a new screen is issued to the learning environment by the system adaptation engine based on the system's assessment of the user's learning-style. The screens are developed in consideration of the FSLSM teaching-style requirements outlined in the FSLSM (Felder & Silverman, 1988) [77]. The second learning screen is subsequently displayed to the user (Figures 5.16 & 5.17).

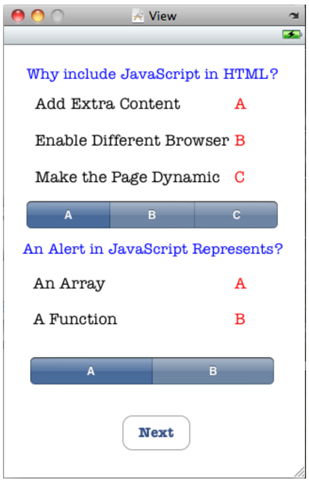

Figure 5.19: MAPLE-based Learning Application - User Test Screen.

The user's learning-style is logged to the console running from XCode when the application is run via a connection to the development environment. The learner screen templates are shown in Figure 5.20.

Inclusion of Extra Features

Once the user invokes the 'Next' button on completion of the template screen, the user is issued with a multiple choice test screen (held as a template, Figure 5.19). The user is presented with possible answers to a question. A segmented control widget is used to log the user's answer to the question. For the purpose of the prototype, the answer selected by the user is logged by the system. Such extra information could be used to extend the didactic profile of the user.

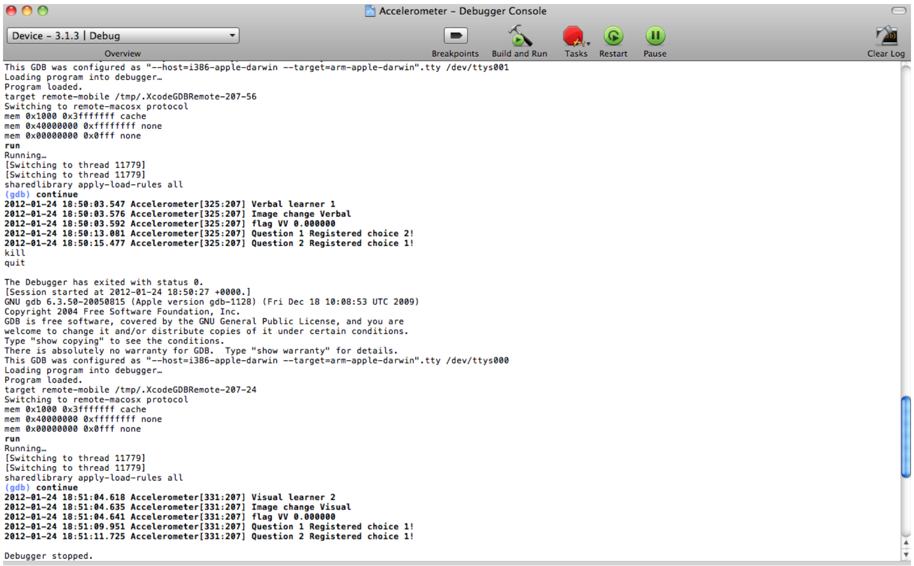

Figure 5.20: MAPLE-based Learning Application Console Log Visual/Verbal Learners.

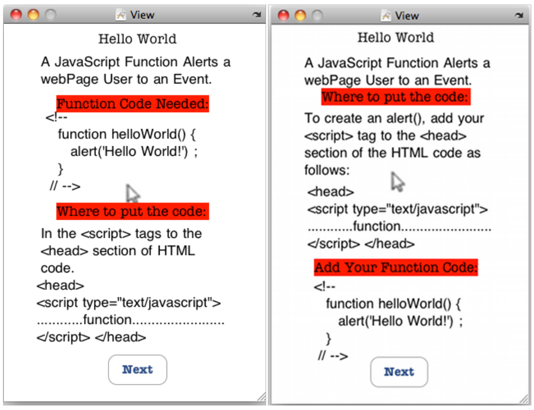

Figure 5.21: MAPLE-based Learning Application Sample Template Screens, a) Global/Verbal, b) Sequential/Verbal.

While touch-based buttons are used for the purpose of navigation in the prototype system, this could be facilitated through the use of biometric commands, such as accelerometer-based gestures, voice control and/or gaze control in the development of future systems.

In the development of the prototype system the main focus was on the Visual/Verbal and the Global/Sequential dimension of the FSLSM. Each dimension was considered independently of the other. However, MAPLE could also be applied to assess the student on both scales simultaneously. This would require extra template screens. The template screens would need to consider Global/Visual, Global/Verbal, Sequential/Visual and Sequential/Verbal learners. On this basis, sample templates are illustrated

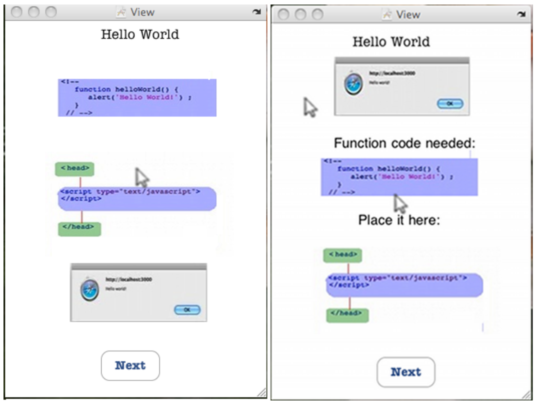

Figure 5.22: MAPLE-based Learning Application Sample Template Screens, a) Sequential/Visual, b) Global/Visual.

in Figures 5.21 & 5.22. Consideration could also be given to the mode of interaction, for example, MAPLE could be applied for use with eye-tracking technology. MAPLE could also potentially be employed in eLearning environments for data gathering based on mouse movement patterns. All interaction elements associated with MAPLE have been tested independently (as outlined in chapters 5 & 6) therefore, no further testing is required.

5.6 Conclusion

Building on the work presented at EdMedia 2009 [160], EdTech 2009 [161] and Irish HCI 2011 [165] and on work published in Mobile Learning: Pilot Projects and Initiatives (Guy 2010) [163], IJGBL 2012 [167] and *Tools for Mobile Multimedia Programming and Development*, Tjondronegoro (2013) [168], this chapter has introduced accelerometer technology. The term accelerometer has been defined. Two studies conducted to assess the potential use of accelerometer technology for the detection of user learning-styles have been described, the results of which have also been presented. In respect of the results of both studies, all hypotheses can be accepted. That is, it can be concluded that accelerometer technology can be used to detect a user's learning-style within an eLearning environment based on both the Global/Sequential and the Visual/Verbal dimension of the FSLSM.

While the results of the studies outlined are generic to all learning applications, as accelerometer devices are now included as standard in high-end mobile devices, they can also be included for the same purpose in mLearning applications. On this basis a prototype mLearning system application, comprising aspects of a course in web development, is presented. The application was developed in respect of the MAPLE

UI model (chapter 4) and in line with the research described earlier in ths chapter. The prototype application was developed for Apple's IOS and runs on the Apple iPod Touch, however, the application could equally have been developed for use in any mobile environment via any mobile platform. The application is designed to detect a user's learning-style based on the Visual / Verbal and Global / Sequential dimensions of the FSLSM. The learning system subsequently adapts the content displayed to the user based on its assessment of their learning-style on either dimension.

Chapter 6 will examine the potential to extend the work described here to include eye-tracking devices. While eye-tracking technology remains mainly lab-based, the chapter will also examine the potential use of eye-tracking devices in mLearning environments. on this basis the chapter will describe how the prototype, presented in this chapter (chapter 5), could be adapted to make use of eye-tracking technology.

Chapter 6

Detecting Learning-Styles Through Eye-Tracking Technology

"Eye-tracking works by reflecting invisible infra red light onto an eye, recording the reflection of the pattern with a sensor system" (Tobii) [9].

Building on work presented at Irish HCI (2009) [159] and ICME (2011) [162], and work published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163] and IJGBL (2012) [167], this chapter introduces eye-tracking technology, outlining its use within eLearning to date. The term eye-tracking is defined. Two studies conducted to assess the potential use of eye-tracking technology for the detection of user learning-styles in eLearning environments are outlined, and results presented. The potential use of eye-tracking technology with mobile devices for mLearning is considered.

6.1 Eye-Tracking

The use of eye-tracking dates back over a century. Eye-tracking first emerged directly as a result of Javal's gaze motion research which commenced in 1879 [122]. Javal noticed that reading does not involve a smooth sweeping of the eyes over text, but involves fixations and saccades. A pause over an area of interest is termed a fixation whilst a rapid movement between points of fixation is termed a saccade (Salvucci & Goldburg 2000) [206]. These features *"can be used to infer moment-by-moment cognitive processing of a text by a reader"* (Just & Carpenter 1980) [124] as cited by Richardson & Spivey (2004) [200]. There are many examples of formal modeling of temporal and spatial aspects of eye movement, for example, the EMMA model (Salvucci & Goldburg 2000) [206].

6.2 Background

Eye-tracking technology is widely used in many disciplines, including special-needs education (Barry *et al.* 2008) [24] [23] and commerce, where it is employed as a tool for market research (Chandon *et al.* 2007) [41]. In recent years, computational studies based on Human Computer Interaction (HCI) (Ivory & Hearst 2001) [117] and visual cognition have been conducted (Zhai 2003) [249] .

Work has also been conducted to assess the overall possibilities opened-up by eye-tracking for instruction, particularly through the use of animations. Gulliver (2003) [100] investigated the impact of differing multimedia presentation frame rates for user Quality of Service (QoS). De Koning *et al.* (2010) [55] investigated the effects of spotlight cueing for the direction of visual attention to relevant parts of biological animations. Similar work was conducted by Boucheix & Lowe (2010) [30] to employ spreading colour cues in complex animations relating to the operation of musical sound systems. Presentation speed and sequencing speed (zooming in and out) of material was investigated by Meyer *et al.* (2010) [169]. Meyer *et al.* suggest that speeds can be used as an effective way of directing learner attention in animated learning environments. Charness *et al.* (2010) [42] found that increasing knowledge leads to individuals fixating faster on task-relevant material. This is particularly evident between novices and experts (Van Gog *et al.* 2010) [233], and with individuals over time as a result of practice (Haider & French 1999; Canham & Hegarty 2010) [106] [36]. Jarodzka *et al's* (2010) [121] findings are in line with this research, indicating that experts attend more to relevant stimuli in more heterogeneous task approaches by applying knowledge-based shortcuts.

Despite this, there are few examples of research using eye-tracking technology in the field of elearning. Eye-tracking can reveal significant differences between individuals. Differences in eye movement can be detected between successful and unsuccessful elementary school children right through to undergraduates, graduate students and professors. Consequently, tracking the eye movements of readers can enable the capture of user data for practical applications in educational psychology (Richardson & Spivey 2004) [200].

Porta (2008) [192] exploited eye-tracking technology in a tutoring system environment (for engineering students) to gather user behaviour data. The data was used to assess how users conducted learning activities based on their emotional state. This data enabled Porta to adapt content to suit the user based on the screens they accessed and their emotional state.

Gutl *et al.* (2004) [103], through the use of the AdeLE system, have explored the use of eye-tracking technology for the development of adaptive eLearning systems. In Gutl *et al's* system, eye-tracking data such as saccade velocity, blink rate and the degree of eyelid openness are employed to determine a user's tiredness level and to complement other information gained by the system through behaviour patterns. User interaction based on eye movement offers us a potential means of data gathering and learning-style assessment in eLearning and now potentially in mLearning systems.

Gutl *et al.* (2004) [103] showed that analysis of a learner's gaze behaviour could allow the optimisation of material to meet a learner's needs. Gutl suggests that by exploiting data gathered through eye-tracking technology *"a finer grained learner profile can be tracked by the system and applied e.g. for personalisation of learning content and navigation"*. This personalisation of learning content can be based on, for example, a learner's cognitive or learning style.

By continuously tracking the user's eye movement, the eye-tracking data should provide more insights into the user's decisions and sequence of actions as the learning material is viewed. A gaze path and associated fixation data indicate where the user's attention is focused and how the user reacts to a stimulus or a task to be completed (Jacob & Karn 2003) [118]. This form of data gathering, gleaned from the user's reaction to a given interface, could be a better indicator of cognitive activity and learning-style than more traditional means of data gathering based on mouse or keyboard events. The use of eye-tracking technology for data gathering could potentially provide a non-intrusive system for automatic user analysis in eLearning applications including mLearning applications deployed on future devices.

6.3 Detecting Global / Sequential Learners through Eye-Tracking Technology

Building on work using accelerometer devices to detect Global / Sequential learning-styles (outlined in chapter 5) and extending work presented at Irish HCI (2009) [159] and work published in both Mobile Learning; *Pilot Projects and Initiatives*, Guy (2010) [163] and IJGBL (2012) [167], the potential to collect data in a non-intrusive manner through eye-tracking technology in eLearning environments was assessed.

Two hypotheses were proposed as follows:

- Sequential learners will exhibit a slower vertical speed of eye movement between fixation points than their Global counterparts.

- Sequential learners will show a longer focus time than their Global counterparts.

Figure 6.1: Tobii Eye-Tracker T60 [9]

6.3.1 Study Outline

A study was conducted to assess the potential of eye-tracking technology for gathering user data to allow the detection of Global / Sequential learners in eLearning environments. The study outline, method and results were presented at presented at Irish HCI (2009) [159] and published in IJGBL (2012) [167].

It is predicted that user eye movement data will provide sufficient data to assess a learner's style on the Visual / Verbal dimension of the FSLSM. To gather this data, the measurement of users' eye movements on screen is based on the duration of fixation on hot spots and gaze patterns as recorded by the eye-tracking system.

Each user undertakes the test independently, unprompted by the tester. This ensures that each user operates the application on an equal level. The test is controlled through the inclusion of the user task screen (see section *6.3.3 User Interface*). Each user's interaction with the learning screens, as detected by the Tobii monitor, is recorded by the system. The test focuses particularly on fixation on textual and visual Areas of Interest (AOIs). The user's gaze pattern between fixation points is also measured.

6.3.2 Tobii Eye-Tracking System

The Tobii eye-tracking system has a PC-like screen (Figure 6.1). It is a non-intrusive and non-restrictive system for the user. The system provides analysis software for experimental design (including gaze paths and heat maps), calibration, eye-tracking, data gathering, analysis and statistics. The system uses near Infra-red LEDs to reflect the pupil movement of the user. The system stores and calibrates each user's vision data. The system can adjust to suit users with glasses.

6.3.3 User Interface

The material presented offered a balance of text-based and visual-based learning object information. The user is required to focus on, and/or read specific areas of the screen. No scrollbars are included. This ensures that the interaction with the screen is completely visual. Except for moving to the next screen, no mouse or other device interaction is permitted for interactive purposes with the individual screens. This ensures that the user is looking at the learning material only and not the cursor associated with mouse movement. Two screens are included in the test, a learning screen and a user task screen. The screens are sized at 600*800 pixels.

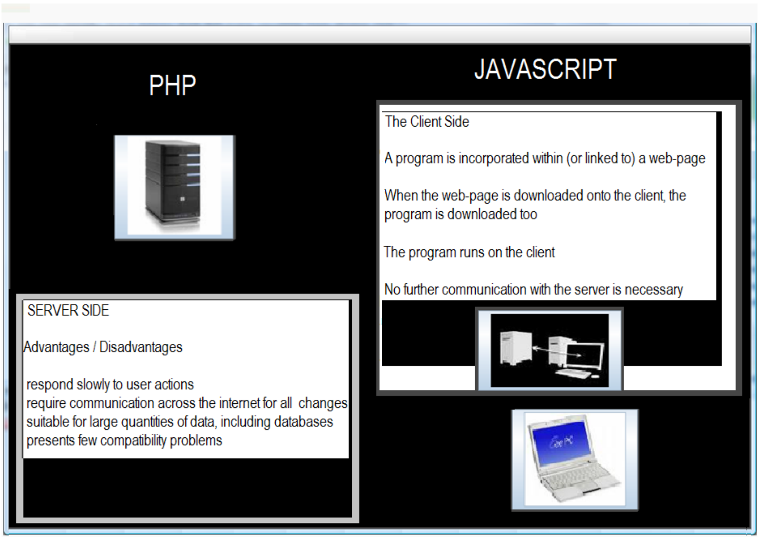

Figure 6.2: Global / Sequential ET Study Learner Screen

Again, the user task screen offers a balance between text-based and visual-based information that required the user to visualise specific areas of the screen. No scrollbars are used, again the purpose being to ensure that the interaction with the screen is completely visual.

6.3.4 Participant Selection

A balanced sample is used for the study. A total of ten subjects are selected to take part in the initial study, comprising five Global learners and five Sequential learners. The learning-style of the participants act as the independent variables for the test. These variables are measured against each other once the tests were completed to establish the distinctions between them.

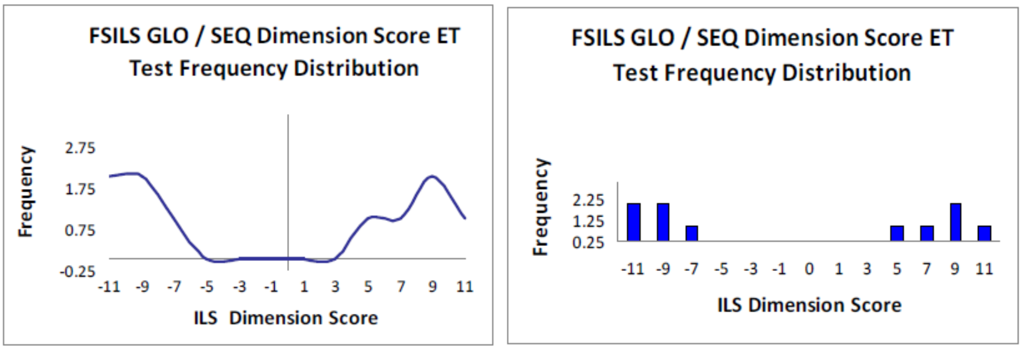

Figure 6.3: Global / Sequential ET Study Frequency Distribution, a) Line Graph, b) Bar Graph)

The subjects include students, researchers, and others, drawn from the department of computer science. The participants' ages range from 16 to 65 years. Potential subjects are first invited to complete a paper-based version of the FSILS questionnaire to identify Global and Sequential learners. The completed questionnaires are then processed online by the test coordinator. The participants comprised both staff and students (ranging from Leaving Certificate to PhD level). Participants are chosen from the Department Computer Science, the School of Education, the Department Microbiology at UCC, from the Department of Computing, Maths and Physics at Waterford Institute of Technology, and the school of Business at Cork Institute of Technology. Leaving Certificate students from local secondary schools also participated in the study. On this basis and based on the result of the individual FSILS questionnaire, there is no potential for a bias in the study result.

The screening of subjects continues until five (50%) Global learners and five (50%) Sequential learners are identified and confirm their willingness to take part in the test. All participants gave informed consent to each aspect of the study.

Participants chosen to progress to the interaction stage of the study are from both sides of the FSLSM Global / Sequential dimension scale. Both moderate and high scores are included (Table 6.1). The participants represent a bimodal frequency distribution as graphed in Figure 6.3.

To complete the study, both groups are asked to complete the same task. The system tested the users as they read / viewed looking the screens provided. The mouse is used to move between screens. Measurements are made using the participants' eye

Table 6.1: Global / Sequential ET Study Participant Frequency Distribution

Dimension	Dimension Score	Frequency
Global	11	1
	9	2
	7	1
	5	1
	3	0
	1	0
	0	0
Sequential	-1	0
	-3	0
	-5	0
	-7	1
	-9	2
	-11	2
	Total	*10*

movements as the screen was viewed, based on the users' gaze duration and focus / fixation points (hot spots) on all AOIs. These act as dependant variables in the study.

6.3.5 Methodology

Participants are asked to undertake a PC-based eLearning task. The participants interact with the system using the Tobii Eye Tracker.

Subjects are first instructed in how to use the system, but received no further help or prompting from the test coordinator once the initial instruction is completed. Before beginning the test, each user logs in to the system and the system carries out the calibration process for each individual. All users successfully completed the test.

During the task, subjects are presented with one page of learning information on a topic in the form of text and images (see Figure 6.2), followed by a multiple-choice question relating to that topic.

6.3.6 Evaluation and Conclusions

To evaluate the results of the study, gaze patterns, heat maps and fixation count are employed. Correlation coefficients are established between participant focus duration on individual AOIs and their score on the FSILS dimension.

AOIs and Fixation Count

As permitted by the Tobii system, AOIs are selected for each screen presented to the user during the test (Figure 6.4). This permits a more detailed analysis in the establishment of specific screen areas fixated on by the user when viewing the screen. This establishes the duration of fixation on each AOI. Each AOI represents a specific learning object.

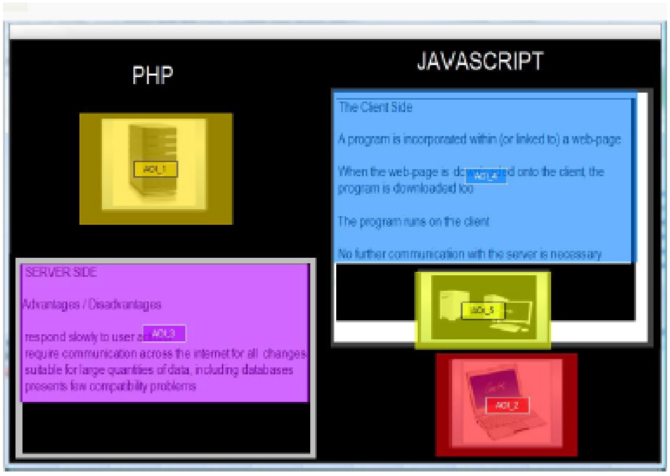

Figure 6.4: Global / Sequential ET Study Learner Screen Areas of Interest (AOI)

The results from the learner screen AOIs show a higher fixation duration percentage for the Sequential participants.

Gaze Plots & Heat Maps

The gaze patterns and heat maps for each category of participant were automatically recorded and generated by the Tobii system during the test and are illustrated in Figures 6.5 & 6.7. The gaze pattern shows the visual route taken by the user when viewing the screen content. The gaze points are shown as numbered disks which increase in size based on the time spent on each gaze area. The gaze route is indicated by connecting lines. Each fixation disk is numbered based on its occurrence.

It is clear from the gaze patterns illustrated for each category of learner that Sequential learners follow the learning objects in an incremental fashion, completing the first side of the page from top to bottom before moving across to the second side of the page where the participant again takes incremental steps along the content until reaching the image at the bottom of the page (see Figure 6.5).

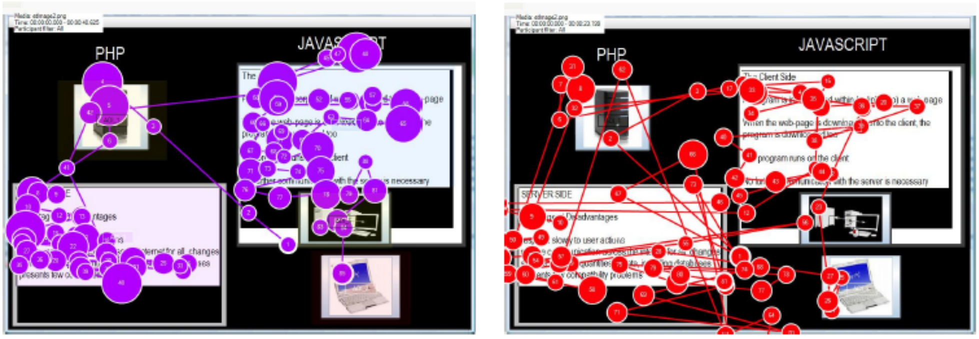

Figure 6.5: Global / Sequential ET Study a) Sequential Learner Gaze Map, b) Global Learner Gaze Map

The opposite can be seen from the second illustration (Figure 6.5) when examining the gaze pattern of a typical Global learner who has scanned the page in no particular fashion, moving backwards and forwards, up and down, both horizontally and vertically across the screen. The participant has viewed the screen in quite a haphazard pattern, in some cases gazing outside the screen area. This is compliant to the characteristics associated with a Global learner.

The gaze patterns indicate that there is a significant difference between the two categories of learner in this particular dimension. The manner in which the participants viewed and read from the page as part of the learning experience typically differs greatly from one category to the other and when looked at in sequence in relation to this dimension of the FSILS model, it is clear to the viewer that one participant is Sequential whereas the other is Global.

The Tobii system also provides a facility to view the heat map created by a user as they interact with the system. The heat map also indicates where the user viewed the screen based on fixation points. The duration of focus on the screen by the participant is indicated by different colours. Green indicates the shortest duration moving to red which indicates fixation. The heat maps for each learner category that completed the early evaluation are illustrated in Figure 6.8.

The heat maps also show a significant difference between the participants. As can be seen in Figure 6.8, the heat map from this typical Sequential learner's visualisation of the learning screen shows that there was a greater level of fixation on both sides of the screen than that of the Global learner (Figure 6.7). Little fixation has occurred outside the learning objects themselves.

	Definition	Further Detail
Fixation	A pause over an area of interest	
Saccades	A rapid movement between points of fixation	
Heat Map	This indicates where the user viewed the screen based on fixation points	
	The duration of focus on the screen by the participant is indicated by different colours	Green indicates the shortest duration Red indicates total fixation
Gaze Pattern	This shows the visual route taken by the user when viewing the screen content	
	Gaze points are shown as numbered disks which increase in size based on the time spent on each gaze area.	The gaze route is indicated by connecting lines. Each fixation disk is numbered based on its occurrence
Area of Interest	Specified screen content area perceived to be of particular interest to the viewer	
Hot Spots	Fixation Area displayed as part of the Heat Map	

Figure 6.6: Eye-Tracking Result Componant Details

Whilst the user has viewed the images as well as the text, it is interesting that fixation occurs at a higher level on the textual areas as this learner also scored as a moderate (level 5) Verbal learner on the Visual / Verbal dimension of the FSILS questionnaire.

The Global learner had fewer hotspots (areas of high fixation duration) when using the system than the Sequential participant. There is evidence of longer fixation (again indicated by red) on the textual areas of the screen. The user also shows small areas of lower fixation durations (yellow and green) spread across the screen, again indicating a haphazard fixation pattern.

The user has fixated on areas of the screen where there are no learning objects. Unlike the Sequential learner, however, the user has focused on images at a higher level. This learner was assessed as balanced (level 1) on the Visual / Verbal dimension of the FSILS questionnaire.

Correlation

To assess eye-tracking in relation to learning-style detection it was necessary to calculate a correlation coefficient in the case of each prediction. The results obtained from user

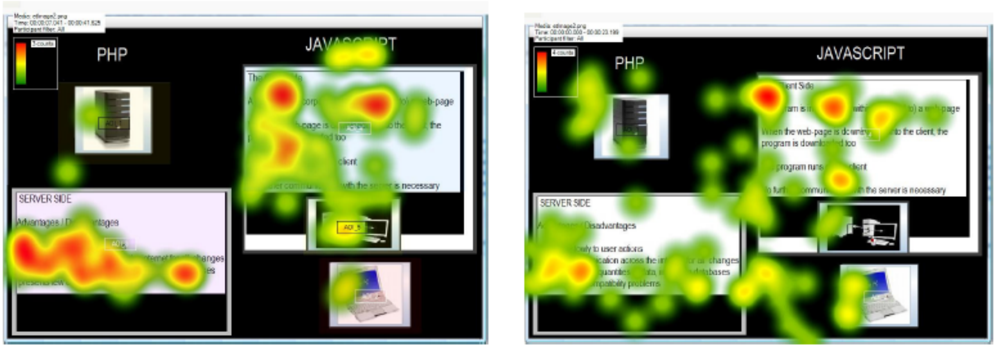

Figure 6.7: Global / Sequential ET Study a) Sequential Learner Heat Map, b) Global Learner Heat Map

interaction with the eLearning application via the the eye-tracker are based on full learning obtainment assessed through the use of Multiple Choice Questions provided to the user through the user task screen.

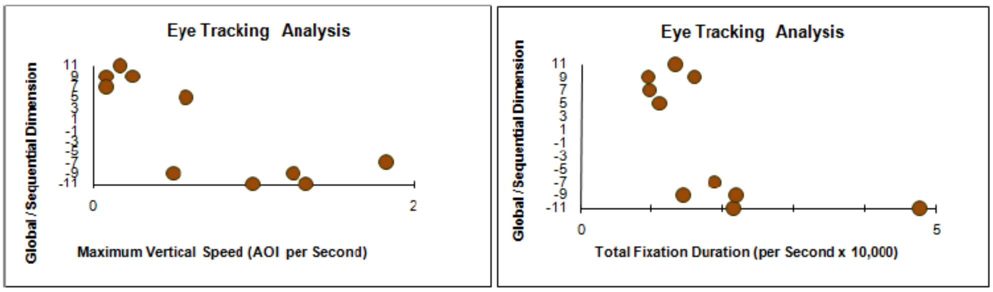

Figure 6.8: Global / Sequential ET Study a) Max Vertical Speed, b) Total Fixation Duration

For the first prediction (that Sequential learners would show a slower vertical speed of eye movement between fixation points than that of their Global counterparts) a correlation coefficient was calculated between the Global / Sequential dimension score of each participant and their maximum vertical speed between AOIs. A correlation coefficient of r=-0.95615 was established based on the information gathered from our sample. This implies that there is an inverse correlation between the variables. It indicates that students with a lower maximum vertical speed tend to be more Sequential while students with a higher maximum vertical speed tend to be more Global. This is shown in the scatter graph in Figure 6.9.

For the second prediction a correlation coefficient of r=-0.6386. was established. Again there is an inverse correlation between the variables. This indicates that students with longer focus/ fixation durations are more Sequential than their Global counterparts. This is shown in the second scatter graph, Figure 6.9.

6.3.7 Study Conclusion

The results of the study indicate that it is possible to use eye-tracking technology as a means of extracting user data for learning-style analysis in learning environments based on the Global/Sequential dimension of the FSLSM. Based on evaluation and results both hypotheses can be accepted. Therefore, in answering the research questions outlined in chapter 1, we can conclude that eye-tracking-based interaction pattern data can be used to determine a user's learning-style on the Global/Sequential dimension of the FSLSM. As all elements were tested independently no further testing is required.

6.4 Detecting Visual / Verbal Learners through Eye-Tracking Technology

Gutl *et al.* (2004) [103] state that *"if someone prefers text and ignores pictures the amount of pictures presented could be reduced and vice versa"*. Based on the results from the studies outlined to detect students on the Global / Sequential dimension of the FSLSM, there is potential to explore the Visual / Verbal dimensions of the FSLSM. As discussed in chapter 5, there are potential difficulties in using accelerometers to study the Visual / Verbal dimension. As the study relies on the user's movement of a cursor from text to images, efforts were made in the accelerometer study to address the potential difficulties in ensuring that the subject actually moves the cursor to the location that they are viewing (see chapter 5). In the case of eye-tracking it is possible to gain visual feedback from the system to measure the level of focus/fixation at particular screen locations. Building on work presented at ICME (2011) [162] and published in IJGBL (2012) [167], eye-tracking technology was investigated to establish its suitability for the measurement of a user's learning-style on the Visual/Verbal dimension of the FSLSM. This has included the examination of user gaze path and fixation points to ensure that participants are looking at either images or text. This extends elements of the work of both Popescu (2008) [190] and Cha *et al.* (2006) [40] as stated in chapter 5. Both Popescu (2008) [190] and Cha *et al.* (2006) [40] have assessed Visual and Verbal learners through user behaviour based on time spent on visual and verbal learning objects for the provision of personalised content in eLearning environments. It is this element of their work which is extended.

On this basis two hypotheses are proposed as follows:

- Visual learners, as defined by the FSLSM, will exhibit longer total time (fixation) duration on visual learning content (images / graphics) than their Verbal counterparts.
- Verbal learners (as defined by the FSLSM) will exhibit longer total time (fixation) duration on textual learning content than their Visual counterparts.

6.4.1 Study Outline

A study was conducted to assess the potential of eye-tracking technology for gathering user data to allow the detection of Visual / Verbal learners in eLearning environments. The study outline, method and results were presented at presented at ICME (2011) [162], and published in *Mobile Learning; Pilot Projects and Initiatives*, Guy (2010) [163] and IJGBL (2012) [167].

As is the case with the study conducted to assess Global / Sequential learners it wis believed that user eye movement data would potentially provide sufficient data to also efficiently measure a learner's style based on the Visual / Verbal dimension of the FSLSM. To gather this data, the measurement of users' eye movements on screen is based on the duration of fixation on hot-points and gaze patterns as recorded by the eye-tracking system.

Again, as with the earlier study using eye-tracking, each user undertakes the test independently, unprompted by the tester. This ensures that each user operated the application on an equal level. The test is controlled through the inclusion of the user task screen. Each user's interaction with the learning screens, as detected by the Tobii monitor, is recorded by the system. The test focused particularly on the fixation duration on textual and visual AOIs. The user's gaze pattern between fixation points is also measured.

6.4.2 User Interface

For this study a simple eLearning application is developed for presentation via the Tobii eye-tracker. The learning material is contained on two pages and comprised text and static images (Figure 6.10).

No scrollbars are included. The purpose of this is to ensure that the interaction with the screen is purely of a visual nature, the only exception to this being that the user is required to click a mouse button to move to the next screen. Other than this, no mouse

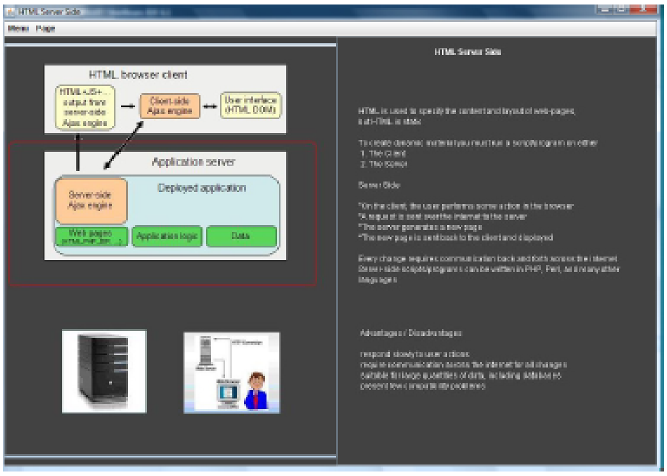

Figure 6.9: Visual / Verbal ET Study Learner Screen

or keyboard interaction was permitted for the purpose of interacting with the system. This ensures that the user is looking at the screen content rather than following the cursor associated with mouse interaction.

Each screen is clearly divided into two distinct sections. One half of the screen offered visual-based information whilst the second half of the screen offered textual information. Therefore each screen provides a balance of excusive text-based and visual-based information that required the user to focus on or read from specific areas of the screen. The screens are sized at 800*600 pixels. These are presented to the user for interaction purposes. A similar screen is included to provide the user with a multiple choice task; again the screen is balanced in its textual / visual content in that one question included a graphic, while the other question is text-based.

6.4.3 Participant Selection

A balanced sample is used for the study. A total of ten subjects are selected to take part in the initial study, comprising five Visual learners and five Verbal learners. On this basis, the participant's learning-styles acts as the independent variables for the test. These variables are measured against each other once the tests were completed to establish the distinctions between them. The selected subjects include students, researchers, and others, selected from the department of computer science. The participants' ages range between 16 and 65 years. Potential subjects complete the FSILS questionnaire to identify Visual and Verbal learners. The information is gathered through paper-based questionnaires which are then processed online by the test coordinator. The participants comprise both staff and students (ranging from Leaving Certificate to PhD level).

Participants are chosen from the Department Computer Science, the School of Education, the Department Microbiology at UCC, from the Department of Computing, Maths and Physics at Waterford Institute of Technology, and the school of Business at Cork Institute of Technology. Leaving Certificate students from local secondary schools also participated in the study. On this basis and based on the result of the individual FSILS questionnaire, there is no potential for a bias in the study result.

To complete the study both groups are asked to complete the same task. The system is used to test the users who are required to view the screens provided. The mouse is used to move between screens. Measurements are made using the participants' eye movements as they view the screen based on the users' gaze duration and focus / fixation points (hot spots) on both textual AOI and visual AOIs. These act as dependant variables in the study.

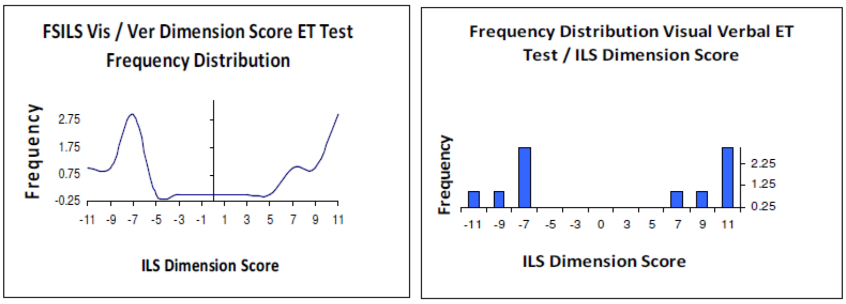

Figure 6.10: Visual / Verbal ET Study Frequency Distribution, a) Line Graph, b) Bar Graph

The screening of subjects continues until five (50%) Visual learners and five (50%) Verbal learners are identified and confirm their willingness to take part in the test. All participants gave informed consent to each aspect of the study.

Participants chosen to progress to the interaction stage of the study are from both sides of the FSLSM Visual / Verbal dimension scale. Both moderate and high scores are included (Table 6.2). Again, as is the case in the study based on the Global / Sequential dimension, the participants in this study represent a bimodal frequency distribution as graphed in Figure (6.11).

Both groups are asked to complete the same task. The system tests the users by measuring their eye movements as they view the screens provided.

Table 6.2: Visual / Verbal ET Study Participant Frequency Distribution

Dimension	Dimension Score	Frequency
Visual	11	3
	9	1
	7	1
	5	0
	3	0
	1	0
	0	0
Verbal	-1	0
	-3	0
	-5	0
	-7	3
	-9	1
	-11	1
	Total	*10*

The mouse is used to move between screens. Measurements are made using the participants' eye movements as they view the screen, based on the users' gaze duration and focus / fixation points (hot spots) on both textual AOIs and visual AOIs. These act as dependent variables in the study.

6.4.4 Methodology

Participants are asked to undertake a PC-based eLearning task. The participants interact with the system using the Tobii eye-tracker.

Subjects are first instructed in how to use the system, but receive no further help or prompting from the test coordinator once the initial instruction is completed. Before beginning the test, each user logs in to the system and the system is calibrated for each individual. All users successfully completed the test.

During the task, subjects are presented with one page of learning information on a topic in the form of text and images. This is followed by a set of multiple-choice questions relating to that topic, the purpose being to ensure that a learning experience had occurred.

6.4.5 Evaluation & Conclusions

Gaze patterns, heat maps and fixation count are employed to evaluate the results of the study. Correlation coefficients are established between participant focus duration on individual AOIs and the participant's score on the Visual / Verbal dimension of the FSILS questionnaire.

AOIs & Fixation Count

As permitted by the Tobii system, AOIs are selected for each screen presented to the user during the test. This permits a more accurate identification of the specific screen areas fixated on by the user when viewing the screen. This establishes the duration of fixation on each AOI. Each AOI is specific to a learning object. For example, one AOI is placed over a textual learning object whilst another AOI is placed over a graphic (see Figure 6.12).

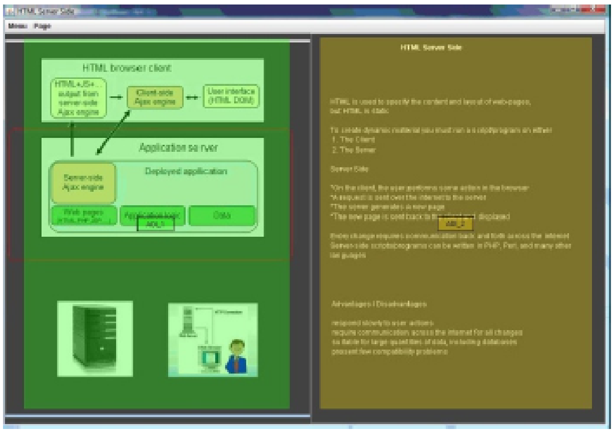

Figure 6.11: Visual / Verbal ET Study Learner Screen Areas of Interest (AOI)

The results from the Visual learners, (when looking at the fixation chart produced by the Tobii system), show that Visual participants had higher fixation counts on the visual content (AOI_1). A smaller fixation count is obvious on AOI_2, the textual content (see Figure 6.13).

The fixation counts for the Verbal learners are also illustrated in Figure 6.13. It is clear from the chart that the Verbal participants had a larger focus count when viewing AOI_2 which contained the textual content.

Interestingly, it is also evident from the chart that one Verbal participant had quite a small and almost equal fixation count of approximately five on both AOI_1 and AOI_2.

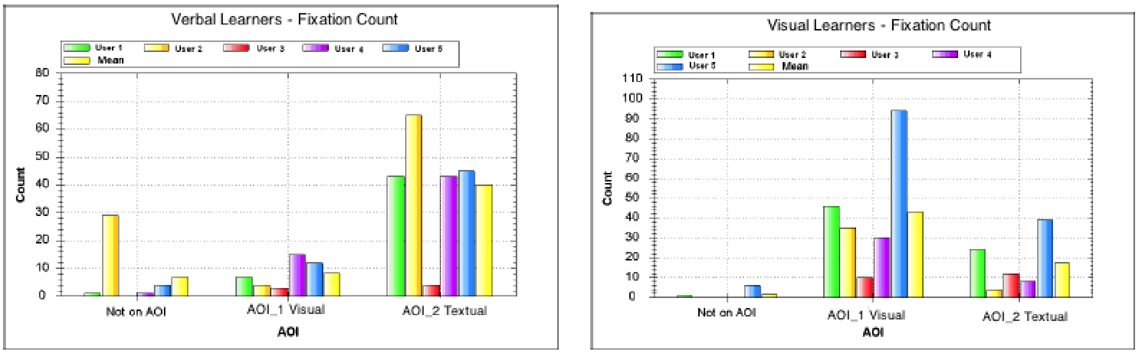

Figure 6.12: Visual / Verbal ET Study AOI Fixation Plot a) Verbal Learners, b) Visual Learners

Gaze Plots & Heat Maps

The heat maps and gaze paths (automatically recorded and generated) in relation to the participants' visualisation of both textual and visual areas of interest were examined. The gaze pattern or visual route taken by a user indicates which parts of the screen the learner viewed and the extent to which he / she had looked at text and / or graphics. Heat maps show where within the learning screen a user has concentrated the most. Both gaze patterns and heat maps for Visual and Verbal participants were recorded by the Tobii system during the test (see Figures 6.14 & 6.15).

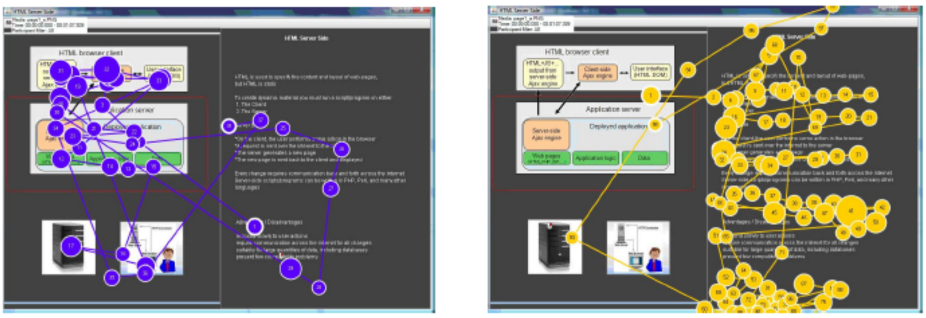

Figure 6.13: Visual / Verbal ET Study Sample Learner Gaze Paths a) Visual Learner, b) Verbal Learner

As in study one (Global / Sequential dimension), gaze patterns indicate the visual route taken by the user's eye as they move across the screen. A numbered fixation disk of varying size is used by the Tobii system to show the total time spent on each gaze area by the user, with each fixation disk being numbered in the order of its occurrence. The user's visual (gaze) route is indicated by connecting lines.

The heat map for each user also shows where the participant viewed the screen in relation to fixation points, while the duration of focus on the screen is indicated by different colours. The smallest duration is shown by the colour green whilst red shows fixation.

The gaze patterns and heat maps indicate that there is a significant difference between Visual and Verbal learners. The manner in which the participants viewed and read from the page AOIs as part of the learning experience differs greatly from one category to the other. When looked at in relation to this Visual / Verbal dimension of the FSILS model, it is clear to the viewer that one participant is a Visual learner and the other participant is a Verbal learner.

The gaze patterns illustrated in Figure 6.14 for a typical Visual learner clearly indicate that they spent a longer time focused on the visual learning objects in AOI_1. Few fixation disks are present on AOI_2, which contains the textual learning object content. The fixation disks present are scattered across the text, indicating that the participant only glanced at the particular sections of text. In most cases these fixation disks are smaller in size than those present on the graphical content.

As illustrated in Figure 6.14, the opposite is evident in the gaze plot of the sample Verbal learner. This learner has higher focus duration on AOI_2 (the textual content). Only 4 fixation disks are present on the graphical content of AOI_1, which are widely scattered across the images, again indicating that the user simply glanced at the content of AOI_1. Indeed, it is clear when examining Figure 6.13 that the Vsual learners viewed the graphical side of the screen while the Verbal learners viewed the textual side of the screen.

Again, this is reflected when viewing the participants' heat maps (Figure 6.15) for each learner category (Visual & Verbal). Just as with the gaze plots, a significant difference between the Visual and Verbal learners is evident from the heat maps. Taking two randomly selected participant heat maps, one from each category, it is clear that the Visual learner (Figure 6.15) had a higher fixation level on the graphical side of the screen (AOI_1). The Verbal learner (Figure 6.15) exhibited the opposite, that is, the Verbal learner had a higher fixation level on the textual side of the screen (AOI_2).

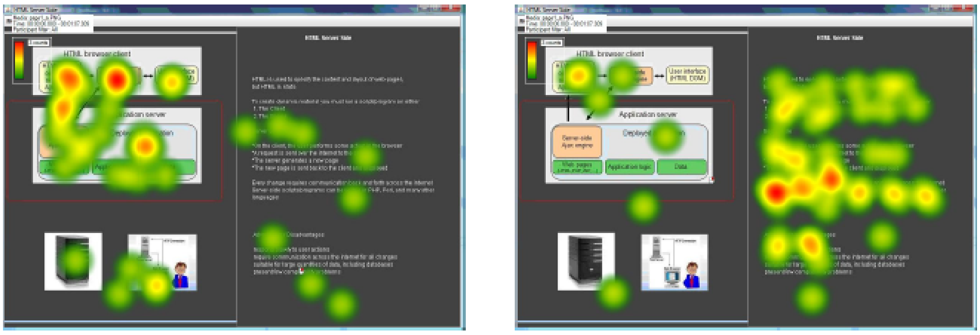

Figure 6.14: Visual / Verbal ET Study Sample Learner Heat Maps a) Visual Learner, b) Verbal Learner

Little visualisation has occurred outside the learning objects. Where this did occur it was more evident on the textual side of the screen (AOI_2) for the Visual learner and on the graphical side of the screen (AOI_1) for the Verbal learner.

Correlation

It was also necessary to calculate a correlation coefficient in the case of each prediction to allow the assessment of eye-tracking in relation to Visual / Verbal learning-style detection. It was expected that Visual learners would spend longer overall fixation duration on visual learning objects and Verbal learners would spend longer overall time duration on the text. Therefore, a correlation co-efficient was established based on the users' score on the Visual / Verbal learning-style dimension and each of the following:

- total fixation time on areas of image/graphic interest as accessed through data gathered using the eye gaze tracking
- total fixation time on areas of textual interest as accessed through data gathered using the eye gaze tracking.

The results obtained from user interaction with the eLearning application via the eye-tracking are based on full learning obtainment assessed through the use of Multiple Choice Questions provided to the user through the user task screen. The results clearly indicate a strong correlation coefficient of $r = 0.723$ between total fixation duration on AOI_1 (visual content) and each participants' score on the Visual / Verbal dimension of the FSILS questionnaire. This is illustrated as a scatter graph in Figure 6.16.

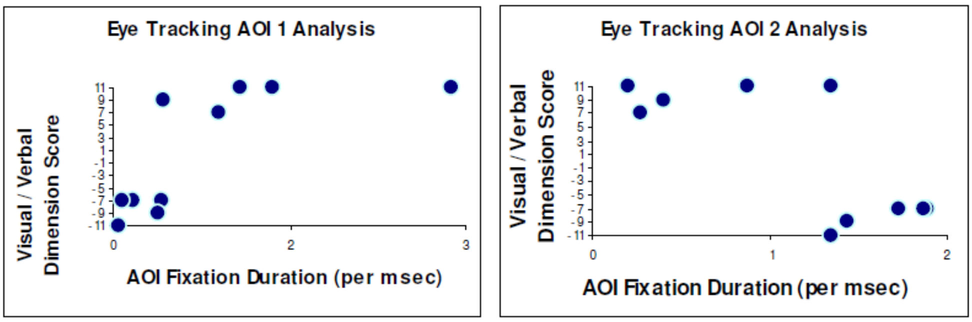

Figure 6.15: Total Fixation Duration per msec, a) AOI_1 vs. Visual / Verbal Dimension Score, b) AOI_2 vs. Visual / Verbal Dimension Score

A strong inverse correlation of r = -0.77504 was established where student overall duration on AOI_2 (textual content), was measured against their score on the Visual / Verbal dimension of the FSILS questionnaire. Again, this is illustrated in Figure 6.16 as a scatter-graph.

The results clearly indicate that students with longer overall focus duration on visual content tend to be more Visual in their learning-style while learners with longer overall focus duration on textual content, tend to be more Verbal in their learning-style.

6.4.6 Study Conclusion

The study results indicate that eye-tracking can be used to extract user data in learning environments based on elements of learning-style when focused on the Visual / Verbal dimension of the FSLSM. Visual learners, as defined by the FSLSM, do exhibit longer total time (fixation) duration on visual learning content (images / graphics) than their Verbal counterparts. Verbal learners also exhibit longer total time (fixation) duration on textual learning content than their Visual counterparts. Consequently, based on the results of the study, both hypotheses can be accepted. Therefore, in answering the research questions outlined in chapter 1, we can conclude that eye-tracking-based interaction pattern data can be used to determine a user learning-style on the Visual / Verbal dimension of the FSLSM. As testing was independently conducted for all elements, no further testing is required.

6.5 Eye-Tracking for Mobile Devices

Whilst this work was conducted using the Tobii eye tracker with a focus on an eLearning environment, it would also suit a mobile environment. As eye-tracking technology for use with mobile devices emerges, user interaction based on eye movement offers the potential to gather learning-style data for user assessment in mLearning systems.

Eye-tracking technology is getting smaller and less cumbersome, and thus becoming increasingly compatible with mobile and handheld devices. To date, most eye-tracking systems for use with mobile devices have relied on the use of standing devices and head mounted cameras, attached to a baseball cap or spectacles.

Examples include the FaceLab eye-tracker and ASL's MobileEye [8]. Desktop trackers can also be used with mobile devices. For example, the FaceLab eye-tracker has been used in cooperation with the Apple iPhone (as illustrated in Figure 6.17) to track a user's interaction with simple mobile device applications, while Tobii eye-trackers have also been used to track user interaction with Mobile devices.

Figure 6.16: Eye-Tracking on Mobile Devices a) FaceLab [4], b) Tobii [9]

As eye-trackers become smaller and less cumbersome, they could potentially offer a new method of device interaction for users, for hands free device interaction or for use by those with disabilities. Recently 'Gaze Gesturing' has emerged as a means of controlling device interaction. Drewes, De Luca & Schmidt (2007) [64] investigated how gaze-interaction could be used to control applications on handheld devices. They concluded that eye gaze interaction in mobile phones is *"attractive to users"*. With advancements in mobile technology, it is possible that built-in mobile eye-tracker technology will become available. Other alternatives could also emerge. Nokia currently have a project underway looking at 'Gaze Tracking Eye Ware Technology' which could significantly reduce the need for intrusive head mounted technologies. 'Tobii Glasses' offer the next generation of mobile eye-tracker [9]. Recent work conducted by Miluzzo *et al.* (2010) [173] uses forward facing mobile device cameras for eye-tracking purposes removing the need for external and intrusive devices.

6.5.1 Extending the Prototype to include Eye-Tracking

While eye-tracking remains mostly lab based, the mobile-based technologies highlighted above (see *section* Eye-Tracking for Mobile Devices) could be used to facilitate the use of eye-tracking techniques with mLearning environments. On this basis the prototype mLearning environment described in chapter 5 can be extended to include eye-tracking as a user interaction tool. The prototype can be created in the same way as described in chapter 5 and is identical in most aspects except cursor-based interaction is replaced or complemented by eye-gaze interaction. The purpose of the prototype is to highlight/demonstrate that such applications can be adapted for use in conjunction with eye-tracking technologies.

In the eye-tracking-based prototype the user commences interaction in the same way, that is they are required to either touch the 'Next' button or, they can also select the button by fixating on the area with their eyes (based on gaze-gesturing, Drewes, De Luca & Schmidt (2007) [64]). The button changes the view (or screen display) to the initial user interaction screen of the learning environment. Within the learning environment users are presented with the set of learning objects held within the initial learning-style assessment screen (Figure. 5.11). The screen is divided into two parts creating a balance of graphical and textual learning content. Each screen section is contained within a boundary-box. The cursor image is no longer necessary where interaction is solely based on eye-based interaction as the gaze pattern will indicate the user's interaction with the learning objects. However, the cursor can be used simultaneously with gaze for interaction purposes to allow increased accuracy by the system in detecting the user's learning-style.

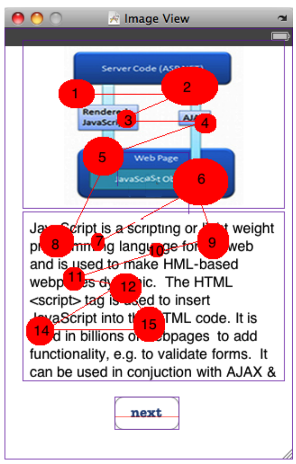

Figure 6.17: MAPLE-based Prototype - Sample Eye-Tracking Interaction on Learner Assessment Screen.

Facilitating Content Adaptation through Eye-based Interaction

To facilitate the adaptation process from interaction data the learning objects are each defined by an individual instance of a boundary box function, one for textual content, and a second for visual content. Again, as learning object content is stationary, the coordinates of the boundary-box are fixed to specific locations on the screen. As the user interacts with the system their eye-gaze moves to the specific learning object on which they have placed their attention (Figure 6.17). A function is applied via a condition statement to monitor when the eye-gaze intersects the boundary of either the textual or the graphical content. Where the cursor is also used simultaneously as an interaction tool it should be implemented as described in chapter 5.

Similar to the accelerometer-based prototype, a boundary-box is assigned an individual timer variable that is given an initial value of *0*. When an intersection occurs between a specific learning object boundary-box (text or visual) and the cursor boundary-box, the timer is incremented. When the eye-gaze moves away from the intersection area, the process ends and the value of the timer variable is stored until either a further intersection process occurs for example, the user invokes the action of the 'Next' button. This allows the system to determine the user's total overall attention duration for each category of learning object. The level of user attention on each learning object can be measured in milliseconds.

A speed variable can also be assigned to eye-gaze to facilitate the system in assessing the user's speed on the *y-axis* as they interact with the screen content. The speed variable is also assigned an initial value of *0*. As the user interacts with the screen content the speed variable measures the total time taken by the user to move vertically down the screen with their eyes. When the the user invokes the action of the 'Next' button the system determines the user's total vertical speed. The level of vertical speed can also be measured in milliseconds.

Facilitating the Adaptation of Content

Once the learner completes their interaction with the assessment screen (by invoking the action of the 'Next' button in the case of the prototype system), measurement data is processed by the adaption engine in the same manner as the accelerometer-based system. The learning object timer values are compared with each other respectively and the vertcal speed variable is measured against a pre-defined threshold. Subsequently the system decides the learning-style of the system user based on the Visual/Verbal and the Global/Sequential dimensions of the FSLSM respectively. Where the accelerometer is used simultaneously with eye-tracking, the system will combine the data from both interaction methods to enhance its decision making process and subsequently increase its accuracy. Again, as is the case with the accelerometer-based prototype (chapter 5), the subsequent learning screens can then be displayed to the user on this basis.

Expanding the Prototype for Extra Features

As with the accelerometer-based prototype described in chapter 5, a full-scale system could take into consideration a learner's moderate or balanced preference for one style on a dimension. Extra features could also be included as described in chapter 5 *section* Inclusion of Extra Features.

All interaction elements associated with MAPLE have been tested independently (as outlined in chapters 5 & 6) therefore, no further testing is required.

6.6 Conclusion

Building on work presented at Irish HCI 2009 [159] and ICME 2011 [162] and work published in *Mobile Learning; Pilot Projects and Initiatives*, Guy 2010 [163], this chapter has introduced eye-tracking technology and outlined its current usages within the field of eLearning to date. The term eye-tracking has been defined. Two studies conducted to assess the potential use of eye-tracking technology for the detection of user learning-styles have been outlined, the results of which have also been presented. The prototype mLearning application described in chapter 5 was expanded based on the results of the research outlined in this section of the thesis, to consider the use of eye-tracking technology with mobile devices.

Part V

Conclusions and Future Work

Chapter 7

Thesis Conclusions

As outlined in chapter 1, the aim of adaptive systems is the adjustment of the learning process to suit an individual learner. This can be achieved by taking account of their personal learning-style. Learning-style (see chapter 3) represents the student's fit within the specific scales of learning-style and/or personality models. Where presentation of content is targeted toward the learning-style of a individual, there is an increase in motivation and thus an improved learning outcome. Within research to-date, there has been a heavy reliance on the use of manual questionnaire-based instruments to model the learner's didactic profile.

Efforts have been made in current research to overcome the use of questionnaires through automatic user modeling based on user interaction behaviour with a system. As highlighted in chapter 4, work conducted by Spada *et al.* (2008) [218] investigated the possibility of determining an individual's learning-style directly from their interaction with a web-based learning system. Their research found a high degree of correlation between the way in which an individual uses a mouse and their learning-style based on the Global/Sequential dimension of the FSLSM (as determined using the FSILS questionnaires). Their research presented a new approach to predict Global/Sequential learning-styles that makes sole use of mouse movement patterns in a website, offering great potential for eLearning environments.

However, while progressive, these methods cannot be employed in mobile systems as such devices do not have a mouse facility. This thesis has investigated the potential use of behaviour-based biometric technologies, including the accelerometer device, now a standard feature in most high-end modern mobile phones, and eye-trackers (now coming on stream for use with mobile devices) as an alternative method to enable the use of methods described by Spada *et al.* (2008) [218] in eLearning and potentially in mLearning environments.

7.1 Contribution and Results

This thesis makes a number of research contributions to the field of adaptive learning systems. A number of research questions (chapter 1) have been answered as follows:

- To what extent will mLearning play a part in eLearning in the future?
- To what extent are adaptive features represented in mLearning?
- Is it possible to detect learning-style through the user interaction patterns in mLearning environments?
- Can biometric technologies, such as accelerometers and eye-trackers, be used to detect learning-style in mLearning environments?

In answering the research questions, the literature has been reviewed to assess the extent to which mLearning will play a part in eLearning in the future. Based on this review, a theoretical model has been presented (chapter 4). The model distinguishes between eLearning and mLearning to evaluate both the current and future placement of mLearning systems in relation to eLearning systems. The thesis concludes that mLearning has significance in the future of education and will emerge as a separate entity to eLearning based on its portability.

Tailoring content to suit individual learners is essential to increase motivation when learning and for improved learning outcomes. Adaptive learning systems can be used to facilitate this requirement. The literature has been reviewed to assess the extent to which adaptive features are represented in both eLearning and mLearning environments. The level of adaptive features represented in the literature is indicated in the theoretical model. The adaptation features currently present in eLearning and mLearning are based on content/learner location adaptation, content/device capability adaptation and didactic profile-based adaptation. Where adaptation features are available based on didactic profile, assessment of learning-styles is mostly conducted manually via questionnaires. Where automatic profiling is available, learning-styles are assessed via complex probabilistic models including Bayesian Networks. When using such models, the relationship between the data gathered and the outcome (e.g. didactic profile) remains unclear due to the complex nature of the system's data network.

To assess the potential detection of learning-styles directly through user-interaction patterns in mLearning environments, behaviour-based biometric technologies, particularly accelerometer devices and eye-tracking technology, have been used as a basis of a number of studies to explore their potential use in relation to:

- The automatic detection of Global/Sequential and Visual/Verbal Learners (as outlined in the FSLSM) based on interaction with systems through accelerometer devices.
- The automatic detection of Global/Sequential and Visual/Verbal Learners (as outlined in the FSLSM) based on interaction with systems through eye tracking technology.

Overall, results have indicated that behaviour-based biometric technologies, including both accelerometer and eye-tracking devices, facilitate the gathering of user data for didactic profiling based on user interaction patterns. The inclusion of such devices can enable the provision of adaptive systems to students based on the FSLSM in mLearning environments. This offers a simpler form of data gathering, thus removing the probabilistic element associated with complex network models allowing system-based decisions to be tracked to specific user interaction variables.

Results from studies described in chapter 5 indicate that the accelerometer offers a non-intrusive and effective method of gathering data based on individual learning-styles with respect to the FSLSM. As a result of this research, a prototype mLearning application based on the MAPLE model (chapter 4) was developed to harness the accelerometer device (included in Apple's iPhone) to provide an efficient data gathering system. The prototype system detects user learning-styles on both the Global/Sequential and the Visual/Verbal dimensions of the FSLSM. The prototype is based on the user's on-screen cursor-based interaction via the inbuilt device accelerometer. The prototype provides adapted learning content to users based on this interaction.

The results of studies described in chapter 6 indicate that the eye-tracker also offers a non-intrusive and effective method of gathering data based on individual learning-styles with respect to the FSLSM. Eye-trackers could offer hands free device interaction and / or an inclusive alternative for those with disabilities. This could be achieved for example using 'Gaze Gesturing' interaction in mobile phones which is attractive to users for controlling applications on handheld devices (Drewes, De Luca and Schmidt 2007 [64]). As discussed in chapter 6, advances in technology now facilitate the use of eye-tracking technology with mobile devices. On this basis, the prototype application described in chapter 5 can be expanded to facilitate the use of eye-tracking data for adaptation purposes. A description of how this could be achieved is given in chapter 6.

This thesis has investigated the potential use of behaviour-based biometric technologies, for example the accelerometer device, now a standard feature in most high-end modern mobile phones, and eye-trackers (now coming on stream for use with mobile devices) as an alternative method to enable the use of methods described by Spada *et al.* (2008) [218] in mLearning environments.

It can be concluded that all of the research questions listed have been answered. The results from the research facilitate the automatic detection and subsequent adaptation of mLearning systems based on interaction patterns. On this basis, a prototype has been developed based on the MAPLE content management model. The prototype can be made available for assessment/use in classroom/learning environments. The prototype application can be used with students to improve their educational motivation and thus outcomes as the presentation of content is specifically aimed at the user's learning-style.

7.2 Consideration for Future Work

There is potential to further the research described in this thesis to include the remaining learning-style dimensions of the FSLSM, the Active/Reflective and the Sensitive/Intuitive dimension. As is stated in chapter 3, there are similarities and overlaps between the FSLSM and other learning-style and personality models, therefore there is also potential to explore the use of other models for adaptive system development. Once further work has been completed to examine the potential to extend the system to include the Active/Reflective and the Sensitive/Intuitive dimensions, the MAPLE model (chapter 5 & 6) could be upgraded to include these dimensions. Data gathering for this purpose could be conducted via accelerometer, as is the case in the MAPLE prototype described in chapter 5, however, other devices including eye-tracking devices (chapter 6) and other behaviour-based biometric technologies could also be considered. Future work could be based on the MAPLE framework.

As eye-trackers become available for use with high end mobile devices, and consequently, become mobile, there is also potential to extend this work to use handheld devices with inbuilt eye-trackers. For example, as outlined in chapter 6 research in the literature indicates the potential use of forward facing cameras to facilitate eye-tracking for smart mobile devices including the Apple iPhone (Milluzzo *et al.* 2010 [173]). Consequently, there is potential therefore to use eye-trackers with mobile devices to gather user data to allow the detection of learning-styles providing an opportunity to gather user interaction data from their gaze and visualization patterns. Based on the results given in chapter 6, this advancement in technology could potentially allow for data gathering via eye tracking on both the Global/Sequential and Visual/Verbal dimension of the FSLSM, this could be employed in the MAPLE prototype as described in chapter 6.

Potential also exists to further extend this research to look at the potential of behaviour-based biometric technology in the development of adaptive mobile game-based learning (GBL) systems [167] [166] [164]. This could be of particular importance in respect of mobile GBL. Data gathering could be conducted through a users accelerometer movement patterns as he/she progresses (through Avatar movement) through the virtual or GBL environment, of particular relevance for situated learning. Data gathering from gaze and visualization patterns could also be related to avatar movement and environmental observation for GBL environments. The introduction of Collaborative Systems and the inclusion of Role Play activities based on an individual's learning-style is also an area of consideration for future applications of this research.

An opportunity also exists to extend this work to include 3D enabled mobile devices such as the LG Optimus 3D, to allow for data gathering in 3D immersive virtual environments. This would be of particular relevance in GBL environments, particularly where augmented reality is a factor for situated learning.

As technology advances research based on Around Device Interaction (ADI) (Kratz *et al.* 2009 [139]; Ketabdar *et al.* 2010 [133]) has emerged in the literature. This type of interaction technique could potentially be significant for GBL and, like the accelerometer, could potentially facilitate data gathering for learning-style analysis purposes. The development of adaptive systems in this manner could also be beneficial for use by people with physical disabilities.

There are many methods for gathering behaviour-based biometric information through the interaction of system users including physiological measures such as heart rate, skin conductance and speech (Mostow *et al.* 2011 [176]) however these methods can be intrusive for users. NeuroSky offer a commercially available headset that uses single-channel electroencephalogram (EEG) signal technology to measure biometricinformation based on voltage signals that occur between an electrode that rests on the forehead and electrodes in contact with the ear. Research from the literature indicates that this technology has been used to exploit EEG input for use in a reading tutor to reliably discriminate between students reading hard and easy sentences. An opportunity exists to assess the potential of the 'NeuroSky' headset for data gathering for learning-style analysis purposes based on the FSLSM for the provision of adaptive learning systems in mLearning environments.

As learning-styles reflect how a person perceives and processes data that is presented to them, there is also potential to extend this work using behaviour-based biometric technologies for use with other adaptive interfaces and systems, within eLearning, mLearning and other fields for example marketing considerations within mobile commerce systems.

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Part VI

Appendices

Appendix A

The FSILS Learning-Style Questionnaire

The Felder Solomon Index of Learner Styles Questionnaire

This is a paper version of the FSILS Questionnaire available at: http://www.engr.ncsu.edu/learningstyles/ilsweb.html

Question 1: I understand something better after I

- (a) try it out.
- (b) think it through.

Question 2: I would rather be considered

- (a) realistic.
- (b) innovative.

Question 3: When I think about what I did yesterday, I am most likely to get

- (a) a picture.
- (b) words.

Question 4: I tend to

- (a) understand details of a subject but may be fuzzy about its overall structure.
- (b) understand the overall structure but may be fuzzy about details.

Question 5: When I am learning something new, it helps me to

- (a) talk about it.

- (b) think about it.

Question 6: If I were a teacher, I would rather teach a course

- (a) that deals with facts and real life situations.
- (b) that deals with ideas and theories.

Question 7: I prefer to get new information in

- (a) pictures, diagrams, graphs, or maps.
- (b) written directions or verbal information.

Question 8: Once I understand

- (a) all the parts, I understand the whole thing.
- (b) the whole thing, I see how the parts fit.

Question 9: In a study group working on difficult material, I am more likely to

- (a) jump in and contribute ideas.
- (b) sit back and listen.

Question 10: I find it easier

- (a) to learn facts.
- (b) to learn concepts.

Question 11: In a book with lots of pictures and charts, I am likely to

- (a) look over the pictures and charts carefully.
- (b) focus on the written text.

Question 12: When I solve math problems

- (a) I usually work my way to the solutions one step at a time.
- (b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

Question 13: In classes I have taken

- (a) I have usually gotten to know many of the students.

- (b) I have rarely gotten to know many of the students.

Question 14: In reading nonfiction, I prefer

- (a) something that teaches me new facts or tells me how to do something.
- (b) something that gives me new ideas to think about.

Question 15: I like teachers

- (a) who put a lot of diagrams on the board.
- (b) who spend a lot of time explaining.

Question 16: When I'm analyzing a story or a novel

- (a) I think of the incidents and try to put them together to figure out the themes.
- (b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

Question 17: When I start a homework problem, I am more likely to

- (a) start working on the solution immediately.
- (b) try to fully understand the problem first.

Question 18: I prefer the idea of

- (a) certainty.
- (b) theory.

Question 19: I remember best

- (a) what I see.
- (b) what I hear.

Question 20: It is more important to me that an instructor

- (a) lay out the material in clear sequential steps.
- (b) give me an overall picture and relate the material to other subjects.

Question 21: I prefer to study

- (a) in a study group.

- (b) alone.

Question 22: I am more likely to be considered

- (a) careful about the details of my work.
- (b) creative about how to do my work.

Question 23: When I get directions to a new place, I prefer

- (a) a map.
- (b) written instructions.

Question 24: I learn

- (a) at a fairly regular pace. If I study hard, I'll "get it."
- (b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

Question 25: I would rather first

- (a) try things out.
- (b) think about how I'm going to do it.

Question 26: When I am reading for enjoyment, I like writers to

- (a) clearly say what they mean.
- (b) say things in creative, interesting ways.

Question 27: When I see a diagram or sketch in class, I am most likely to remember

- (a) the picture.
- (b) what the instructor said about it.

Question 28: When considering a body of information, I am more likely to

- (a) focus on details and miss the big picture.
- (b) try to understand the big picture before getting into the details.

Question 29: I more easily remember

- (a) something I have done.

- (b) something I have thought a lot about.

Question 30: When I have to perform a task, I prefer to

- (a) master one way of doing it.
- (b) come up with new ways of doing it.

Question 31: When someone is showing me data, I prefer

- (a) charts or graphs.
- (b) text summarizing the results.

Question 32: When writing a paper, I am more likely to

- (a) work on (think about or write) the beginning of the paper and progress forward.
- (b) work on (think about or write) different parts of the paper and then order them.

Question 33: When I have to work on a group project, I first want to

- (a) have "group brainstorming" where everyone contributes ideas.
- (b) brainstorm individually and then come together as a group to compare ideas.

Question 34: I consider it higher praise to call someone

- (a) sensible.
- (b) imaginative.

Question 35: When I meet people at a party, I am more likely to remember

- (a) what they looked like.
- (b) what they said about themselves.

Question 36: When I am learning a new subject, I prefer to

- (a) stay focused on that subject, learning as much about it as I can.
- (b) try to make connections between that subject and related subjects.

Question 37: I am more likely to be considered

- (a) outgoing.
- (b) reserved.

Question 38: I prefer courses that emphasize

- (a) concrete material (facts, data).
- (b) abstract material (concepts, theories).

Question 39: For entertainment, I would rather

- (a) watch television.
- (b) read a book.

Question 40: Some teachers start their lectures with an outline of what they will cover. Such outlines are

- (a) somewhat helpful to me.
- (b) very helpful to me.

Question 41: The idea of doing homework in groups, with one grade for the entire group,

- (a) appeals to me.
- (b) does not appeal to me.

Question 42: When I am doing long calculations,

- (a) I tend to repeat all my steps and check my work carefully.
- (b) I find checking my work tiresome and have to force myself to do it.

Question 43: I tend to picture places I have been

- (a) easily and fairly accurately.
- (b) with difficulty and without much detail.

Question 44: When solving problems in a group, I would be more likely to

- (a) think of the steps in the solution process.
- (b) think of possible consequences or applications of the solution in a wide range of areas.

Appendix B

Accelerometer-Based User Study Results

B.1 Global/Sequential Accelerometer Study Results

Dimension Score	Vertical Speed MSec
9	1.10
5	1.00
9	1.25
9	1.45
11	1.15
7	1.05
7	0.75
11	1.15
7	1.45
5	1.15
-7	1.55
-11	2.55
-5	1.15
-5	2.15

-9	2.10
-9	2.25
-11	2.00
-5	2.25
-7	1.95
5	2.25
Correlation	-0.81564

B.2 Visual/Verbal Accelerometer Study Results A

Dimension Score	Total Image Time
9	24415
11	27908
5	35910
9	24587
5	51729
11	67520
7	63555
11	69123
7	68281
-7	1856
-11	5709
-9	11731
-7	6334
-5	13416
-9	3713

-7	3948
-11	15460
-11	17035
Correlation	0.78519

B.3 Visual/Verbal Accelerometer Study Results B

Dimension Score	Total Text Time
9	4010
11	5678
5	161192
9	2247
5	13194
11	5117
7	20615
11	12839
7	16396
-7	88935
-11	40264
-9	20801
-7	53367
-5	60294
-9	68046
-7	46348
-11	65692
-11	113631

Correlation -0.81204

Appendix C

Eye-Tracking User Studies

C.1 Global/Sequential Eye-Tracking Study Results A

Dimension Score	Vertical Speed MSec
9	0.25
9	0.08
5	0.58
11	0.17
7	0.08
-11	1.33
-11	1.00
-9	1.25
-7	1.83
-9	0.50
Correlation	-0.95615

C.2 Global/Sequential Eye-Tracking Study Results B

Dimension Score	Focus Duration MSec
9	1.59

9	0.94
5	1.11
11	1.33
7	0.96
-11	4.76
-11	2.15
-9	2.19
-7	1.88
-9	1.44
Correlation	-0.6386

C.3 Visual/Verbal Eye-Tracking Study Results A

Dimension Score	Total Image Time
11	13549
7	8951
9	4340
11	10743
11	25287
-7	1624
-7	822
-11	425
-7	4108
-9	3775
Correlation	0.72333

C.4 Visual/Verbal Eye-Tracking Study Results B

Dimension Score	Total Text Time
11	8726
7	2687
9	4064
11	2037
11	13483
-7	17308
-7	18850
-11	14517
-7	18726
-9	14421
Correlation	-0.77504

Appendix D

Privacy and Ethics

D.1 Privacy and Ethics in conducting research in relation to this Thesis

While conducting studies in preparation of this thesis, consideration was given to both privacy and ethical issues with particular emphasis on the following areas;

Informed consent and Participant withdrawal At all stages of the research conducted for the preparation of this thesis, the informed consent of participants was sought prior to testing. On selection, participants were informed of the nature of the study, the requirements of the study and the nature of the analysis applied to data collected during their participation. Students were requested to provide only their first name. Contact details were also requested for participants, however, were not prerequisite to participation. Students could withdraw from the study at any time. On this basis, participation in a study was deemed to represent informed consent.

Retention of Information While participant information was retained post user study for referral purposes in preparing this thesis, the information is maintained in relation to the users first name only and is not and will not be used in any other capacity. No personal information or study data relating to any individual has been transferred to any third party nor will any such data be transferred to any other party at a future date. All information therefore remains the property of the participant whom can request a copy of their information at any time while the data is maintained based on their first name information.

Digital identities, Anonymity and the control of reputation Participant information is used solely for the purpose of the study in which they took part. No participant is requested to reuse the system. Information is not maintained by any of the test systems. All participants used the systems anonymously, that is no records of their identification (Name / Contact details) were maintained by the system. Therefore, the use of the system will not affect the reputation of the user.

Consequently, it is concluded that every effort was made while conducting studies in preparation of this thesis, to maintain the privacy of participants and ensure that all areas of ethical concern were considered.

Appendix E

Source Code

E.1 Source Code - Prototype

AccelerometerAppDelegate.h

```
//  AccelerometerAppDelegate.h

#import <UIKit/UIKit.h>

@class AccelerometerViewController;

@interface AccelerometerAppDelegate :
NSObject <UIApplicationDelegate> {
    UIWindow *window;
    AccelerometerViewController *viewController;

//int flag;
}

@property (nonatomic, retain) IBOutlet UIWindow *window;
@property (nonatomic, retain) IBOutlet AccelerometerViewController *viewController;

@end
```

AccelerometerAppDelegate.m

```
//  AccelerometerAppDelegate.m

#import "AccelerometerAppDelegate.h"
#import "AccelerometerViewController.h"

@implementation AccelerometerAppDelegate

@synthesize window;
@synthesize viewController;

- (void)applicationDidFinishLaunching:(UIApplication *)application {

    // Override point for customization after app launch
    [window addSubview:viewController.view];
    [window makeKeyAndVisible];
}
- (void)dealloc {
    [viewController release];
    [window release];
    [super dealloc];
}


@end
```

AccelerometerViewController.h

```
//  AccelerometerViewController.h

#import <UIKit/UIKit.h>

@interface AccelerometerViewController : UIViewController

<UIAccelerometerDelegate>{

IBOutlet UIImageView *imageView;
```

```
NSTimer *timer;

//Add x,y textfields
IBOutlet    UITextField* AccelX;
IBOutlet    UITextField* AccelY;
IBOutlet    UITextField* SecondTime;

CGPoint delta;
CGPoint translation;
float ballRadius;
float seconds;
double CurrentTime;

//write to file
NSOutputStream *asyncOutputStream;
NSData *outputData;
NSRange outputRange;
}

@property (nonatomic, retain) UIImageView *imageView;

-(void)accelerometer:(UIAccelerometer *)accelerometer
   didAccelerate:(UIAcceleration *)acceleration;
//declare action for button
-(IBAction) displayView: (id) sender;

@end
```

AccelerometerViewController.m

```
//  AccelerometerViewController.m

#import "AccelerometerViewController.h"

#import "SecondAccelerometerView.h"

@implementation AccelerometerViewController
SecondAccelerometerVIew *secondAccelerometerView;
```

```
//AccelerometerAppDelegate
*accelerometerappDelegate = [[UIApplication sharedApplication]
delegate];

@synthesize imageView;
//@synthesize Time;
//@synthesize AccelX;
//@synthesize AccelY;

//@synthesize SecondTime;

-(void) viewDidLoad{
// AccelerometerAppDelegate *appDelegate =
       [[UIApplication sharedApplication] delegate];

[super viewDidLoad];

}

/*
-(IBAction)startAccelerometerClicked:(id)sender {
[[UIAccelerometer sharedAccelerometer] setUpdateInterval:0.20] ;
    [[UIAccelerometer sharedAccelerometer] setDelegate:self];

}
 // this code could potentially be used to reduce the
 //length of the textfield but as it
 //locally declares the variable for the textfield
 //it needs to be adjusted to work
 -(BOOL)textField:(UITextField *)AccelX shouldChangeCharactersInRange:
    (NSRange)range replacementString:(NSString *)string {
 //limit the size :
 int limit = 3;
 return !([AccelX.text length]>limit && [string length] > range.length);
 }

-(IBAction)stopAccelerometerClicked:(id)sender {
```

```
    [[UIAccelerometer sharedAccelerometer] setDelegate:nil];
}
*/
/*
-(void) accelerometer: (UIAccelerometer *)acel
didAccelerate: (UIAcceleration *)acceleration {

//NSLog(@"x: %g", acceleration.x);
//NSLog(@"y: %g", acceleration.y);
       //NSLog(@"z: %g", acceleration.z);

if (acceleration.x>0)delta.x = 2; else delta.x = -2;
if (acceleration.y>0)delta.y = -2; else delta.y = 2;

[UIView beginAnimations:@"translate" context:nil];
imageView.transform =
       CGAffineTransformMakeTranslation(translation.x, translation.y);
translation.x = translation.x + delta.x;
translation.y = translation.y + delta.y;
[UIView commitAnimations];

if (imageView.center.x + translation.x >320 - ballRadius ||
              imageView.center.x +translation.x < ballRadius) {
translation.x -= delta.x;
}
if (imageView.center.y +translation.y >460 - ballRadius ||
              imageView.center.y + translation.y < ballRadius) {
translation.y -= delta.y;
}

//the following code needs to be removed to allow updating of textfields
//[AccelX.text release];
    //[AccelY.text release];

//The following code allows you to update the accelerometer
           x and y to the textfield
       //AccelX.text = [NSString stringWithFormat:@" X: %f", acceleration.x];
       //AccelY.text = [NSString stringWithFormat:@" Y: %f", acceleration.y];
```

```
//update the current position (x and Y) of the image to the  textfield
seconds++;

SecondTime.text = [NSString stringWithFormat:@" MS: %f", seconds];

CGPoint origin = imageView.frame.origin;

AccelX.text = [NSString stringWithFormat:@" X: %f", origin.x];
AccelY.text = [NSString stringWithFormat:@" Y: %f", origin.y];
//SecondTime.text = [NSString stringWithFormat:@" T: %f", seconds];
//NSLog(@"Current position: (%f, %f)", origin.x, origin.y);
}
*/

 //action for button
-(IBAction) displayView: (id) sender {

//display screen 2
secondAccelerometerView = [[SecondAccelerometerVIew alloc]
   initWithNibName:@"SecondView"
   bundle:nil];

[self.view addSubview:secondAccelerometerView.view];

//active=YES;
}
/*
// The designated initializer. Override to perform setup that is
//required before the view is loaded.
- (id)initWithNibName:(NSString *)nibNameOrNil
     bundle:(NSBundle *)nibBundleOrNil {
    if (self = [super initWithNibName:nibNameOrNil bundle:nibBundleOrNil]) {
        // Custom initialization
    }
    return self;
}
*/
```

```
/*
// Implement loadView to create a view hierarchy programmatically,
//without using a nib.
- (void)loadView {
}
*/
/*
// Implement viewDidLoad to do additional setup after loading the view,
//typically from a nib.
- (void)viewDidLoad {
    [super viewDidLoad];
}
*/
/*
// Override to allow orientations other than the default portrait orientation.
- (BOOL)shouldAutorotateToInterfaceOrientation:(UIInterfaceOrientation)
    interfaceOrientation {
    // Return YES for supported orientations
    return (interfaceOrientation == UIInterfaceOrientationPortrait);
}
*/
- (void)didReceiveMemoryWarning {
// Releases the view if it doesn't have a superview.
    [super didReceiveMemoryWarning];

// Release any cached data, images, etc that aren't in use.
}

- (void)viewDidUnload {
// Release any retained subviews of the main view.
// e.g. self.myOutlet = nil;
//self.AccelX = nil;
       // self.AccelY = nil;
//self.Time = nil;
//self.SecondTime = nil;
}

- (void)dealloc {
```

```
//[Time release];
[imageView release];
[secondAccelerometerView release];
//[Time dealloc];
    [super dealloc];
}

@end
```

SecondAccelerometerVIew.h

```
//
//  SecondAccelerometerVIew.h
//  Accelerometer


#import <UIKit/UIKit.h>

@interface SecondAccelerometerVIew : UIViewController
<UIAccelerometerDelegate> {

IBOutlet UIImageView *imageView;

IBOutlet    UITextField* Time;
IBOutlet    UITextField* Time2;

CGPoint delta;
CGPoint translation;
CGRect imagespace;
CGRect textspace;
CGRect textspace1;
float ballRadius;
float seconds;
float textSeconds;
float seconds2;
float xTime;
float yTime;
float xTimeEnd;
float yTimeEnd;
```

```
float textEventTime;
int imageTime;
float flag;
float flag1;

BOOL active;
BOOL change;
BOOL change1;
}

-(void)accelerometer:(UIAccelerometer *)accelerometer
   didAccelerate:(UIAcceleration *)acceleration;

//action for the display button
-(IBAction) displayView: (id) sender;

@property (retain) IBOutlet UITextField *Time;
@property (retain) IBOutlet UITextField *Time2;

@end
```

SecondAccelerometerVIew.m

```
//  SecondAccelerometerVIew.m
//  Accelerometer

#import "AccelerometerViewController.h"
#import "AccelerometerAppDelegate.h"
#import "SecondAccelerometerVIew.h"
#import "ThirdAccelerometerView.h"
#import "FourthAccelerometerView.h"


@implementation SecondAccelerometerVIew

@synthesize Time;
@synthesize Time2;
```

```
ThirdAccelerometerView *thirdAcclerometerView;
SecondAccelerometerVIew *secondAccelerometerView;
FourthAccelerometerView *fourthAccelerometerView;

//action for button
-(IBAction) displayView: (id) sender{

active=YES;

textspace1 = CGRectMake(286,2,255,149);
textspace = CGRectMake(311,159,291,243);

if (seconds2 < seconds) {change=YES;
fourthAccelerometerView = [[FourthAccelerometerView alloc]
   initWithNibName:@"FourthView"
   bundle:nil];
[self.view addSubview:fourthAccelerometerView.view];

NSLog(@"Verbal learner 1 ", yTime);
//flag = 1;
//NSLog(@"Image change Verbal ");
change = YES;

}

if (seconds < seconds2){ change=NO;
thirdAcclerometerView = [[ThirdAccelerometerView alloc]
 initWithNibName:@"ThirdView"
 bundle:nil
 ];
[self.view addSubview:thirdAcclerometerView.view];

NSLog(@"Visual learner 2", yTime);
//flag = 2;
NSLog(@"Image change Visual ");
change=NO;
```

```
}

NSLog(@"flag VV %f", flag);
//NSLog(@"flag GS %f", flag1);

}

-(void) accelerometer: (UIAccelerometer *)acel
didAccelerate: (UIAcceleration *)acceleration {

active=YES;

if (active = YES) {

if (acceleration.x>0)delta.x = 1;
if (acceleration.x<0)delta.x =-1;
if (acceleration.x==0)delta.x=0;

if (acceleration.y>0)delta.y = -0.5;
if (acceleration.y<0)delta.y = 0.5;
if (acceleration.y==0)delta.y=0;

[UIView beginAnimations:@"translate" context:nil];
imageView.transform =
              CGAffineTransformMakeTranslation(translation.x, translation.y);
translation.x = translation.x + delta.x;
translation.y = translation.y + delta.y;

[UIView commitAnimations];

if (imageView.center.x + translation.x >320 - ballRadius ||
              imageView.center.x +translation.x < ballRadius) {
translation.x -= delta.x; //xTime++;
}
if (imageView.center.y +translation.y >460 - ballRadius ||
               imageView.center.y + translation.y < ballRadius) {
translation.y -= delta.y; //yTime++;
}
```

```
if (acceleration.y<0) {yTime++;}
if (acceleration.x>0) {xTime++;}

imagespace = CGRectMake(imageView.center.x+translation.x,
              imageView.center.y+translation.y, 100, 100);
textspace1 = CGRectMake(0,2+10,255+30,149+80);
textspace = CGRectMake(0,280,291+20,223);


if (CGRectIntersectsRect(imagespace, textspace)){
seconds++;
}
else if(CGRectIntersectsRect(imagespace,textspace1)){
seconds2++;
}
else{NSLog(@"***NO COLLISION*** ");}
}
if (active=NO) {
NSLog(@"***not active*** %f ");
}
}


- (void)didReceiveMemoryWarning {
// Releases the view if it doesn't have a superview.
    [super didReceiveMemoryWarning];
}

- (void)viewDidUnload {
// Release any retained subviews of the main view.
self.Time = nil;
self.Time2 = nil;
}

-(void) viewDidLoad {

UIAccelerometer *accel = [UIAccelerometer sharedAccelerometer];
accel.delegate = self;
```

```
accel.updateInterval = 1.0f/60.0f;

ballRadius = imageView.frame.size.width / 2;
delta = CGPointMake(12.0,4.0);
translation = CGPointMake(0.0,0.0);

seconds = 1.0;
seconds2 = 1.0;
xTime = 0.0;
yTime = 0.0;

}

- (void)dealloc {

[super dealloc];

}

@end
```

ThirdAccelerometerView.h

```
//  ThirdAccelerometerView.h

#import <UIKit/UIKit.h>

@interface ThirdAccelerometerView : UIViewController
 <UIAccelerometerDelegate> {
IBOutlet UIImageView *imageView;

IBOutlet    UITextField* xtime;
IBOutlet    UITextField* ytime;

CGPoint delta;
CGPoint translation;
float ballRadius;
```

```
float seconds;
}

-(void)accelerometer:(UIAccelerometer *)accelerometer
   didAccelerate:(UIAcceleration *)acceleration;

-(IBAction) displayView: (id) sender;

@property (retain) IBOutlet UITextField *xtime;
@property (retain) IBOutlet UITextField *ytime;

@end
```

ThirdAccelerometerView.m

```
//  ThirdAccelerometerView.m

#import "AccelerometerViewController.h"
#import "AccelerometerAppDelegate.h"
#import "ThirdAccelerometerView.h"
#import "SecondAccelerometerVIew.h"
#import "FourthAccelerometerView.h"
#import "Thanks.h"

@implementation ThirdAccelerometerView

Thanks *thanks;
@synthesize ytime;
@synthesize xtime;

//action for button
-(IBAction) displayView: (id) sender{

thanks = [[Thanks alloc]
 initWithNibName:@"Thanks"
 bundle:nil];
[self.view addSubview:thanks.view];
```

```
}

/*
// The designated initializer.
//Override if you create the controller programmatically
//and want to perform customization that is not appropriate
//for viewDidLoad.
- (id)initWithNibName:(NSString *)nibNameOrNil bundle:(NSBundle *)
    nibBundleOrNil {
    if (self = [super initWithNibName:nibNameOrNil bundle:nibBundleOrNil]) {
        // Custom initialization
    }
    return self;
}

// Implement loadView to create a view hierarchy programmatically,
//without using a nib.
- (void)loadView {
}

// Implement viewDidLoad to do additional
//setup after loading the view, typically from a nib.
- (void)viewDidLoad {
    [super viewDidLoad];
}

// Override to allow orientations other than the default portrait orientation.
- (BOOL)shouldAutorotateToInterfaceOrientation:
(UIInterfaceOrientation)interfaceOrientation {
    // Return YES for supported orientations
    return (interfaceOrientation == UIInterfaceOrientationPortrait);
}
*/
-(void) accelerometer: (UIAccelerometer *)acel
didAccelerate: (UIAcceleration *)acceleration {


if (acceleration.x>0)delta.x = 0.5;
```

```
if (acceleration.x<0)delta.x =-0.5;
if (acceleration.x==0)delta.x=0;


if (acceleration.y>0)delta.y = -0.5;
if (acceleration.y<0)delta.y = 0.5;
if (acceleration.y==0)delta.y=0;


[UIView beginAnimations:@"translate" context:nil];
imageView.transform =
       CGAffineTransformMakeTranslation(translation.x, translation.y);
translation.x = translation.x + delta.x;
translation.y = translation.y + delta.y;
[UIView commitAnimations];

if (imageView.center.x + translation.x >320 - ballRadius ||
       imageView.center.x +translation.x < ballRadius) {
translation.x -= delta.x;
}
if (imageView.center.y +translation.y >460 - ballRadius ||
       imageView.center.y + translation.y < ballRadius) {
translation.y -= delta.y;
}

seconds++;


}
-(void) viewDidLoad {

UIAccelerometer *accel = [UIAccelerometer sharedAccelerometer];
accel.delegate = self;
accel.updateInterval = 1.0f/60.0f;

ballRadius = imageView.frame.size.width / 2;
delta = CGPointMake(12.0,4.0);
translation = CGPointMake(0.0,0.0);
```

```
seconds = 1.0;
}
- (void)didReceiveMemoryWarning {
    [super didReceiveMemoryWarning];
}

- (void)viewDidUnload {
self.xtime = nil;
self.ytime = nil;
}

- (void)dealloc {
[xtime release];
[ytime release];
    [super dealloc];
}


@end
```

FourthAccelerometerView.h

```
//  FourthAccelerometerView.h

#import <UIKit/UIKit.h>

@interface FourthAccelerometerView : UIViewController <UIAccelerometerDelegate>{

IBOutlet UIImageView *imageView;

CGPoint delta;
CGPoint translation;
float ballRadius;
float seconds;
}

-(void)accelerometer:(UIAccelerometer *)accelerometer
```

```
   didAccelerate:(UIAcceleration *)acceleration;

-(IBAction) displayView: (id) sender;

-(IBAction) displayView: (id) sender;
@end
```

FourthAccelerometerView.m

```
//  FourthAccelerometerView.m

#import "FourthAccelerometerView.h"
#import "ThirdAccelerometerView.h"
#import "Thanks.h"

@implementation FourthAccelerometerView

Thanks *thanks;

-(void) accelerometer: (UIAccelerometer *)acel
didAccelerate: (UIAcceleration *)acceleration {

if (acceleration.x>0)delta.x = 0.5;
if (acceleration.x<0)delta.x =-0.5;
if (acceleration.x==0)delta.x=0;

if (acceleration.y>0)delta.y = -0.5;
if (acceleration.y<0)delta.y = 0.5;
if (acceleration.y==0)delta.y=0;

[UIView beginAnimations:@"translate" context:nil];
imageView.transform =
       CGAffineTransformMakeTranslation(translation.x, translation.y);
translation.x = translation.x + delta.x;
translation.y = translation.y + delta.y;
[UIView commitAnimations];
if (imageView.center.x + translation.x >320 - ballRadius ||
        imageView.center.x +translation.x < ballRadius) {
```

```
translation.x -= delta.x;
}
if (imageView.center.y +translation.y >460 - ballRadius ||
       imageView.center.y + translation.y < ballRadius) {
translation.y -= delta.y;
}
seconds++;
}
-(void) viewDidLoad {

UIAccelerometer *accel = [UIAccelerometer sharedAccelerometer];
accel.delegate = self;
accel.updateInterval = 1.0f/60.0f;
ballRadius = imageView.frame.size.width / 2;
delta = CGPointMake(12.0,4.0);
translation = CGPointMake(0.0,0.0);
seconds = 1.0;
}

//action for button
-(IBAction) displayView: (id) sender{

thanks = [[Thanks alloc]
  initWithNibName:@"Thanks"
  bundle:nil];
[self.view addSubview:thanks.view];
}

- (void)didReceiveMemoryWarning {
    [super didReceiveMemoryWarning];
}
- (void)viewDidUnload {
}
- (void)dealloc {
    [super dealloc];
}
@end
```

Thanks.h

```
//  Thanks.h

#import <UIKit/UIKit.h>

@interface Thanks : UIViewController {
}

IBOutlet UISegmentedControl *choice1;
IBOutlet UISegmentedControl *choice2;

@property    (nonatomic, retain) UISegmentedControl *choice1;
@property    (nonatomic, retain) UISegmentedControl *choice2;

-(IBAction) segmentActionToLabelOne:(id)sender;
-(IBAction) segmentActionToLabelTwo:(id)sender;
-(IBAction) displayView:(id) sender;

@end
```

Thanks.m

```
//  Thanks.m

#import "Thanks.h"
#import "FourthAccelerometerView.h"
#import "ThirdAccelerometerView.h"
#import "EndScreen.h"

@implementation Thanks

ThirdAccelerometerView *thirdAccelerometerView;
FourthAccelerometerView *fourthAccelerometerView;
EndScreen *endScreen;

@synthesize choice1;
@synthesize choice2;
```

```
-(IBAction)segmentActionToLabelOne:(id)sender{
UISegmentedControl *segmentedChoice1 =
      (UISegmentedControl *)sender;
NSLog(@"Question 1 Registered choice %d!",
       segmentedChoice1.selectedSegmentIndex);
}

-(IBAction)segmentActionToLabelTwo:(id)sender{
UISegmentedControl *segmentedChoice2 =
      (UISegmentedControl *)sender;
NSLog(@"Question 2 Registered choice %d!",
       segmentedChoice2.selectedSegmentIndex);

}
-(BOOL) textFieldShouldReturn: (UITextField *)Answer1 {
[Answer1 resignFirstResponder];
return YES;
}
-(IBAction) displayView: (id) sender{
endScreen  = [[EndScreen alloc]
  initWithNibName:@"End"
  bundle:nil];
 [self.view addSubview:endScreen.view];
}
- (void)didReceiveMemoryWarning {
    [super didReceiveMemoryWarning];
}
- (void)viewDidUnload {

}
- (void)dealloc {
[choice1 release];
[choice2 release];
    [super dealloc];
}
@end
```

EndScreen.h

```
//  EndScreen.h

#import <UIKit/UIKit.h>

@interface EndScreen : UIViewController {
IBOutlet    UITextField* Answer1;
IBOutlet    UITextField* Answer2;
}

@end
```

EndScreen.m

```
//  EndScreen.m

#import "EndScreen.h"
#import "Thanks.h"

@implementation EndScreen

Thanks *thanks;

- (void)didReceiveMemoryWarning {
    [super didReceiveMemoryWarning];
}
- (void)viewDidUnload {
}
- (void)dealloc {
    [super dealloc];
}
@end
```

E.2 Source Code - Visual and Verbal Accelerometer User Study

Login Page

```
<HTML>
<HEAD>
<script type='text/javascript'>


function WriteToFile() {

try {
var fso, s;
fso = new ActiveXObject("Scripting.FileSystemObject");
s = fso.OpenTextFile("VisVerTest_2/MyFile2.txt" , 8, 1, -2);

for (var i=0; i < document.MyFile.name.length; i++)
{

}

s.writeline(" name");
s.writeline(" "+document.MyFile.name.value + ", ");
s.writeline(" email");
s.writeline(" "+document.MyFile.email.value + ", ");
//s.Close();
}
catch(err){
var strErr = 'Error:';
strErr += '\nNumber:' + err.number;
strErr += '\nDescription:' + err.description;
document.write(strErr);
}
}

function validateform()
```

```
{
valid = true;

if ( document.MyFile.name.value == "" )
{
alert ( "Please complete the 'Name' field." );
var mytext = document.getElementById("name1");
mytext.focus();

valid = false;
}


return valid;
}
function echeck(str) {

var at="@"
var dot="."
var lat=str.indexOf(at)
var lstr=str.length
var ldot=str.indexOf(dot)
if (str.indexOf(at)==-1){
alert("Invalid E-mail ID")
return false
}

if (str.indexOf(at)==-1 || str.indexOf(at)==0 ||
str.indexOf(at)==lstr){
alert("Invalid E-mail ID")
return false
}

if (str.indexOf(dot)==-1 || str.indexOf(dot)==0 ||
str.indexOf(dot)==lstr){
alert("Invalid E-mail ID")
return false
}
```

```
if (str.indexOf(at,(lat+1))!=-1){
alert("Invalid E-mail ID")
return false
}

if (str.substring(lat-1,lat)==dot ||
str.substring(lat+1,lat+2)==dot){
alert("Invalid E-mail ID")
return false
}

if (str.indexOf(dot,(lat+2))==-1){
alert("Invalid E-mail ID")
return false
}

if (str.indexOf(" ")!=-1){
alert("Invalid E-mail ID")
return false
}

return true
}

function checkemail(){
var emailID=document.MyFile.email

if ((emailID.value==null)||(emailID.value=="")){
alert("Please Enter your Email address")
emailID.focus()
return false
}
if (echeck(email.value)==false){
email.value=""
email.focus()
return false
}
```

```
return true;
}
</script>
<TITLE>
Learning Styles Questionnaire
</TITLE>
</HEAD>

<BODY BGCOLOR=#ffffff>
<CENTER>
<TABLE CELLPADDING=2 CELLSPACING=0 BORDER=0 BGCOLOR=#ff0000 WIDTH=90%>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ff0000 WIDTH=100%>
<TABLE CELLPADDING=5 CELLSPACING=0 BORDER=0 BGCOLOR=#ffffff
WIDTH=100%>
<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ff0000>
<FONT FACE="Helvetica" COLOR=#ffffff>

</FONT>
</TD>
</TR>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ffffff>
 <P>
<H1>

</TD>
</TR>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ffffff>
<HR WIDTH=90%>
</TD>
</TR>
<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ffffff>
<BLOCKQUOTE>
<FORM ACTION="myFile" METHOD="post" name="MyFile"
```

```
onsubmit="return validateform()">

<B>
Directions
</B><P>
Please provide your name. Press the 'Next' button to move to the
next screen.
<p> Thank You.

<DL>
<DT>
<DD><B>Name</B>
<DD><INPUT TYPE=text id=name1 NAME=name SIZE=40 id="tf1"><P>
<DT>
<DD><B>Email Address</B>
<DD><INPUT TYPE=text NAME=email SIZE=40 id="tf2"><P>
<DD><INPUT TYPE=button VALUE=Next onClick="
WriteToFile(this.form),
parent.location='questionnaire2.html' " >

<INPUT TYPE=reset VALUE=Reset>

</DL>
</FORM>
</TD>
</TR>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ffffff>
<HR WIDTH=90%>
</TD>
</TR>
<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ffffff>
</TD>
</TR>
</TABLE>
</TD>
</TR>
```

```
</TABLE>
</CENTER>

</BODY>
</HTML>
```

Assessment Screen

```
<HTML>
<HEAD>
<script type='text/javascript'>

var start;
var getX;
var getY;
var fso, s;
try {

fso = new ActiveXObject("Scripting.FileSystemObject");
s = fso.OpenTextFile("VisVerTest_2/MyFile2.txt" , 8, 1, -2);

s.writeline(" Learner Screen");

// s.Close();
}
catch(err){
var strErr = 'Error:';
strErr += '\nNumber:' + err.number;
strErr += '\nDescription:' + err.description;
document.write(strErr);
}

// Detect if the browser is IE or not.
// If it is not IE, we assume that the browser is NS.
var IE = document.all?true:false

// If NS -- that is, !IE -- then set up for mouse capture
if (!IE) document.captureEvents(Event.MOUSEMOVE)
```

```
// Set-up to use getMouseXY function onMouseMove
document.onmousemove = getMouseXY;

// Temporary variables to hold mouse x-y pos.s
var tempX = 0
var tempY = 0
startday = new Date();
//endday = new Date();
var getX;
var getY;

clockStart = startday.getTime();

function initStopwatch(){
var myTime = new Date();
var timeNow = myTime.getTime();
var timeDiff = timeNow - clockStart;
this.diffSecs = timeDiff/1000;
return(this.diffSecs);
}
function getSecs(){
var mySecs = initStopwatch();
var mySecs1 = ""+mySecs;
var miliSecs = new Date().getTime();
mySecs1= mySecs1.substring(0,mySecs1.indexOf(".")) + " secs.";
//endday = mySecs1.substring(0,mySecs1.indexOf("."));
endday = miliSecs;
start = mySecs1.substring(0,mySecs1.indexOf("."));
document.forms[0].timespent.value = mySecs1;
window.setTimeout('getSecs()',1000);
}
// Main function to retrieve mouse x-y pos.s

function getMouseXY(e) {
if (IE) { // grab the x-y pos.s if browser is IE
tempX = event.clientX + document.body.scrollLeft
tempY = event.clientY + document.body.scrollTop
```

```
} else { // grab the x-y pos.s if browser is NS
tempX = e.pageX
tempY = e.pageY
}
// catch possible negative values in NS4
if (tempX < 0){tempX = 0}
if (tempY < 0){tempY = 0}
// show the position values in the form named Show
// in the text fields named MouseX and MouseY
getSecs();
document.Show.MouseX.value = tempX
document.Show.MouseY.value = tempY
s.writeline("x "+tempX+" Y "+tempY+" time "+endday); //miliSecs here
maybe?

return true
}

function getEndTime(){
//endday = getSecs().mySecs1.substring(0,mySecs1.indexOf(".")) + "
secs.";

//alert(endday);
//s.writeline(" Learning Page 2 at "+endday);
//if(document.getElementById)
//{img =document.getElementById(id);s.writeline("learning Object"+img);}
}
function getStartTime(){

//s.writeline(" Enter Learning Object at "+start);
//alert(start);}
}
//get rollover to change images

function roll(img_name1, img_src1, img_name2, img_src1)
{
document[img_name1].src = img_src1; s.writeline("
Image"+document[img_name1].src);
```

```
//document[img_name2].src = img_src1; s.writeline("
"+document[img_name1].src);
}

</script>
<link rel="stylesheet" type="text/css" href="main.css" />
<TITLE>
Learning Page
</TITLE>
</HEAD>

<BODY BGCOLOR=#ffffff onLoad=" window.setTimeout('getSecs()',1)">
<CENTER>
<TABLE CELLPADDING=2 CELLSPACING=0 BORDER=0 BGCOLOR=#ff0000 WIDTH=80%>
<TR>

<TD ALIGN=center VALIGN=middle BGCOLOR=#cccccc WIDTH=100%>

<TABLE CELLPADDING=2 CELLSPACING=0 BORDER=0 BGCOLOR=#ffffff
WIDTH=100%>
<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ffffff>

<div id = "text" onMouseOver="this.style.color = 'grey'; s.writeline('
Text');">

<b onMouseOver="this.style.color = 'blue';
s.writeline(' Heading HTML');"
onMouseOut="this.style.color = 'grey';">HTML</b>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' HTML is used for');"
onMouseOut="this.style.color = 'grey';">
HTML is used to specify the content and layout of a web-page, but HTML
is static? </p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' To create Dynamic Material');"
```

```
onMouseOut="this.style.color = 'grey';">
To create dynamic material you must run a script / program on either
the:</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Client');
" onMouseOut="this.style.color = 'grey';">
1. Client</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Server');
" onMouseOut="this.style.color = 'grey';">
2. The Server</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' ServerSide heading');
" onMouseOut="this.style.color = 'grey';">
<b>Server Side</b>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Serverside point 1');
" onMouseOut="this.style.color = 'grey';">

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Serverside point 2');
" onMouseOut="this.style.color = 'grey';">
*On the Client, the user performs some action in the browser</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Serverside point 3');
" onMouseOut="this.style.color = 'grey';">
*A request is sent over the internt to the server</p>

<p onMouseOver="this.style.color = 'blue';s.writeline(' Serverside point 4');
" onMouseOut="this.style.color = 'grey';">
*The new page is sent back to the client</p>

<p onMouseOver="this.style.color = 'blue';s.writeline(' Serverside point 5');
```

```
" onMouseOut="this.style.color = 'grey';">
*Every change requires communication back and forth accross the internet</p>

<p onMouseOver="this.style.color = 'blue';"
onMouseOut="this.style.color = 'grey';">
*Server-side scripts /
programs can be written in PHP. Perl and other programming languages.</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' Heading Advantages and Disadvans title');"
onMouseOut="this.style.color = 'grey';">
<b>Advantages / Disadvantages</b></p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' AD1');"
onMouseOut="this.style.color = 'grey';">
Reponds slowely to user actions</p>

<p onMouseOver="this.style.color = 'blue';s.writeline(' AD2');"
onMouseOut="this.style.color = 'grey';">
Requires communication accross the internet for all changes</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' AD3');"
onMouseOut="this.style.color = 'grey';">
Suitable for large quantities of data</p>

<p onMouseOver="this.style.color = 'blue';
s.writeline(' AD4');"
onMouseOut="this.style.color = 'grey';">
Present few compatability problems</p>

</TD>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ffffff>
<a href="questionnaire2.html"
onmouseover="roll('sub1', 'cs2.jpg', 'sub1', 'cs.jpg')"
onmouseout="roll('sub1', 'cs.jpg', 'sub1', 'cs2.jpg')">
```

```
<image src="cs2.jpg" name="sub1" width=383 height=495
alt="" border="0" align = "center"></a>
<TD>
<P>Press The Next Button to move to the next screen.</p>

<INPUT TYPE=Button VALUE=Next
onClick="parent.location='questionnaire3.html'"> </TD>

<form name="Show">
<input type="text" name=MouseX value="0" size="4"> X
<input type="text" name=MouseY value="0" size="4"> Y
<form name="time">Time spent: <input size=9 name=timespent>
</form>
</form>
</BODY>
</HTML>
```

Test Page

```
<HTML>
<HEAD>
<script type='text/javascript'>

var start;

var fso, s;
try {

fso = new ActiveXObject("Scripting.FileSystemObject");
s = fso.OpenTextFile("VisVerTest_2/MyFile2.txt" , 8, 1, -2);

s.writeline(" Test Screen");

// s.Close();
}
catch(err){
var strErr = 'Error:';
strErr += '\nNumber:' + err.number;
```

```
strErr += '\nDescription:' + err.description;
document.write(strErr);
}

function GetSelectedItem() {

chosen = ""
chosen1 = ""
chosen2 = ""
chosen3 = ""

len = document.f1.q1.length
len1 = document.f1.q2.length
len2 = document.f1.q3.length
len3 = document.f1.q4.length

for (i = 0; i <len; i++) {
if (document.f1.q1[i].checked) {
chosen = document.f1.q1[i].value
}
}
for (i = 0; i <len1; i++) {
if (document.f1.q2[i].checked) {
chosen1 = document.f1.q2[i].value
}
}
for (i = 0; i <len2; i++) {
if (document.f1.q3[i].checked) {
chosen2 = document.f1.q3[i].value
}
}
for (i = 0; i <len3; i++) {
if (document.f1.q4[i].checked) {
chosen3 = document.f1.q4[i].value
}
}

if (chosen == "") {
```

```
alert("No Location Chosen")
}
else {
//alert(chosen)
//alert(chosen1)
//alert(chosen2)
//alert("Thank You Please Click on the 'Next' Button")
s.writeline(" answers "+chosen+" : "+chosen1+" : "+chosen2+" :
"+chosen3)
}
}

</script>
<TITLE>
Test Page
</TITLE>
</HEAD>

<BODY BGCOLOR=#ffffff >
<CENTER>
<TABLE CELLPADDING=2 CELLSPACING=0 BORDER=0 BGCOLOR=#ff0000 WIDTH=90%>
<TR>

<TD ALIGN=center VALIGN=middle BGCOLOR=#ff0000 WIDTH=100%>

<TABLE CELLPADDING=5 CELLSPACING=0 BORDER=0 BGCOLOR=#ffffff
WIDTH=100%>
<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ff0000>

<FONT FACE="Helvetica" COLOR=#ffffff>

</FONT>
</TD>
</TR>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ffffff>
<H1>Please answer the following quetions</H1>
```

```
 <P>
<H1>

</TD>
</TR>
<TR>
<TD ALIGN=center VALIGN=middle BGCOLOR=#ffffff>
<HR WIDTH=90%>
</TD>
</TR>

<TR>
<TD ALIGN=left VALIGN=middle BGCOLOR=#ffffff>

<OL>
<form name="f1">

<LI>The DOM and CSS are used for scripting on the ..<BR>

<INPUT TYPE=radio NAME=q1 id=rb1 VALUE=Client checked>  
<B>(a)</B>
Client ?<BR>

<INPUT TYPE=radio NAME=q1 id=rb2 VALUE=Server>   <B>(b)</B>
Server ?<P>

<LI>The Server responds quickly to user data..<BR>

<INPUT TYPE=radio NAME=q2 id=rb3 VALUE=True checked >  <B>(a)</B>
True<BR>

<INPUT TYPE=radio NAME=q2 id=rb4 VALUE=False>   <B>(b)</B>
False<P>

<LI>PHP is used for scripting on the ..<BR>

<INPUT TYPE=radio NAME=q3 id=rb5 VALUE=Server checked >
  <B>(a)</B>
```

```
Server side ?<BR>

<INPUT TYPE=radio NAME=q3 id=rb6 VALUE=Client>   <B>(b)</B>
Client side ?<P>

<LI>HTML is dynamic ..<BR>

<INPUT TYPE=radio NAME=q4 id=rb7 VALUE=True checked>  
<B>(a)</B>
True<BR>

<INPUT TYPE=radio NAME=q4 id=rb8 VALUE=False>   <B>(b)</B>
False.<P>
</OL>

<INPUT TYPE=Button VALUE=Next onClick=" GetSelectedItem(),
parent.location='questionnaire5.html'">
</form>

</BODY>
</HTML>
```

E.3 Source Code - Global and Sequential Accelerometer User Study

ThankYou.java

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.Component;
import javax.swing.ImageIcon;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;
import java.awt.image.*;


public class ThankYou extends JFrame{

BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
BevelBorder bevel2 = new BevelBorder (BevelBorder.RAISED);
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;

Component component;
//Global Declaration of Menus
JLabel l = new JLabel(" HTML \n" +

"Server Side");
JLabel l2= new JLabel(" ");
```

```
JLabel question = new JLabel(" Multiple Choice Question ");

JTextArea ta,ta1,ta2,ta3,ta4,ta5,ta6,ta7,ta8;
JScrollPane sp;
String text=new String("What is the Answer" );

ImageIcon images = new ImageIcon("images/flower.jpg");
BufferedImage img;
FileWriter fstream;

int startX, startY;
int x,y = 0;
long startTime, endTime;
int pageCount1=1;
JMenuBar mBar = new JMenuBar();
JMenuItem enter = new JMenuItem ("Enter");
JMenuItem exit = new JMenuItem ("Exit");

JMenu menu = new JMenu ("Menu");
JMenu nw = new JMenu("Page");
JPanel p1 = new JPanel();
GridBagConstraints c = new GridBagConstraints();

//generates the interface and registers ActionListener mouse listener
ActionHandlerClass actionHandlerClass = new ActionHandlerClass();
KeyHandlerEvent keyHandlerClass = new KeyHandlerEvent();
MouseMovementClass mouseMovementClass = new MouseMovementClass();

//create a new instance of file utilities and the next page

FileUtilities app=new FileUtilities();
ReadInFile rif =new ReadInFile();

//start the constructor method
public ThankYou()
{
super("Thank You!!");
```

```
setSize(240,320);
setResizable(false);

GridBagConstraints gbc = new GridBagConstraints();
p1.setLayout(new GridBagLayout());
p1.setBackground(Color.DARK_GRAY);p1.setForeground(Color.white);

gbc.weighty = 2.0;
gbc.weightx = 2.0;
gbc.gridx = 1;
gbc.gridy = 1;

ta1 = new JTextArea(" Thank You \n\n\n" +
" For Your Help!! ");
ta1.setEditable(false);ta1.setBackground(Color.DARK_GRAY);
ta1.setForeground(Color.white);

gbc.gridx = 0;
gbc.gridy = 1;

p1.add(ta1, gbc);
ta1.addMouseListener(mouseMovementClass);
ta1.addMouseMotionListener(mouseMovementClass);
p1.addMouseMotionListener(mouseMovementClass);
p1.addMouseListener(mouseMovementClass);
p1.addKeyListener(keyHandlerClass);
p1.setRequestFocusEnabled(false);

menu.add(exit); exit.addActionListener(actionHandlerClass);
mBar.add(menu);
setJMenuBar(mBar);

getContentPane().add(p1);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );
}

public static void main(String[] args) {
ThankYou thanks= new ThankYou();
```

```
thanks.show();
}

class ActionHandlerClass implements ActionListener{

long startTime = System.currentTimeMillis()/1000 ;
int posX, posY;
public void actionPerformed (ActionEvent e){

if (e.getSource()==exit)
{
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Exit Selected,
System Exited");

System.exit(0);
}}}}
```

ReadInFile.java

```
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.BorderLayout;
import java.awt.Component;
import javax.swing.JFrame;
import javax.swing.JPanel;


public class ReadInFile extends JFrame {

BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
```

```
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;

Component component;
JTextArea ta;

FileWriter fstream;

JScrollPane sp;
JPanel p1 = new JPanel();
MouseMovementClass mouseMovementClass = new MouseMovementClass();
KeyHandlerEvent keyHandlerClass = new KeyHandlerEvent();

FileUtilities app=new FileUtilities();

public ReadInFile()
{
super("Read In File");

setSize(800,800);
setResizable(true);
p1.setLayout(new BorderLayout(1, 1));
String str= app.readFromFile("E:/AccelerometerUserTest1/Login.txt","EOF");
sp = new JScrollPane(ta);
ta = new JTextArea(str);
ta.add(sp);
p1.add(ta);
getContentPane().add(p1, BorderLayout.CENTER);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );

}

public static void main(String[] args) {
ReadInFile rif = new ReadInFile();
rif.show();
}}
```

Page1.java

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.Component;
import javax.swing.ImageIcon;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;
import java.awt.image.*;
import java.awt.DefaultKeyboardFocusManager;


public class Page1 extends JFrame implements FocusListener{

BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
BevelBorder bevel2 = new BevelBorder (BevelBorder.RAISED);
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;
DefaultKeyboardFocusManager myFocusmgr
= new DefaultKeyboardFocusManager();

Component component;
//Global Declaration of Menus
JLabel l = new JLabel(" HTML \n" +"Server Side");
JLabel l2= new JLabel(" ");
JLabel question = new JLabel(" Multiple Choice Question ");
JTextArea ta,ta1,ta2,ta3,ta4,ta5,ta6,ta7,ta8;
```

```
JScrollPane sp;
String text=new String("What is the Answer" );

ImageIcon images = new ImageIcon("images/flower.jpg");
BufferedImage img;
FileWriter fstream;
JButton btImage1 = new JButton("", new ImageIcon ("images/cs.jpg"));
JButton textButton = new JButton();
int startX, startY;int x,y = 0;
long startTime, endTime;
int pageCount1=1;

JMenuBar mBar = new JMenuBar();
JMenuItem enter = new JMenuItem ("Enter");
JMenuItem exit = new JMenuItem ("Exit");
JMenuItem size = new JMenuItem ("Size 1");
JMenuItem size1 = new JMenuItem ("Size 2");
JMenuItem back = new JMenuItem ("Back");
JMenuItem next = new JMenuItem ("Forward");
JMenu menu = new JMenu ("Menu");
JMenu reSize = new JMenu ("Resize");
JMenu nw = new JMenu("Page");

JPanel p1 = new JPanel();
JPanel p2 = new JPanel();
JPanel p3 = new JPanel();

ButtonGroup g = new ButtonGroup();

JRadioButton rb1 = new JRadioButton("A", true),
rb2 = new JRadioButton("B", false), rb3 = new JRadioButton(
"C", false);

Calendar now = Calendar.getInstance();
int h = now.get(Calendar.HOUR_OF_DAY);
int m = now.get(Calendar.MINUTE);
int s = now.get(Calendar.SECOND);
String time=("" + h + ":" + m + ":" + s);
```

```
GridBagConstraints c = new GridBagConstraints();

//generates the interface and registers ActionListener mouse listener
ActionHandlerClass actionHandlerClass = new ActionHandlerClass();

//create a new instance of file utilities and the next page

FileUtilities app=new FileUtilities();
Page2 page2 = new Page2();

//start the constructor method
public Page1()
{
super("HTML");

setSize(240,320);
setResizable(false);
images = new ImageIcon("flower.png");
startTime = System.currentTimeMillis()/1000 ;
GridBagConstraints gbc = new GridBagConstraints();
p1.setLayout(new GridBagLayout());
p1.setBackground(Color.DARK_GRAY);p1.setForeground(Color.white);

gbc.weighty = 1.0;
gbc.weightx = 1.0;

gbc.gridx = 0;
gbc.gridy = 2;
p1.add(btImage1, gbc);

gbc.gridx = 0;
gbc.gridy = 0;
l.setBackground(Color.darkGray); l.setForeground(Color.WHITE);

gbc.gridx = 0;
gbc.gridy = 1;
```

```
ta = new JTextArea("HTML is used to specify the content and\n" +
"layout of web-pages," +
" but HTML is static \n\n" +
"To create dynamic material \n " +
"you must run a script / program\n " +
"on either \n 1. The Client \n" +
" 2. The Server \n" );

ta.setEditable(false);
ta.setBackground(Color.DARK_GRAY);
ta.setForeground(Color.white);
textButton.setBackground(Color.DARK_GRAY);
textButton.add(ta);
p1.add(textButton, gbc);

ta1 = new JTextArea(" Advantages / Disadvantages \n\n" +
" respond slowly to user actions\n" +
" require communication across the internet for all changes\n" +
" suitable for large quantities of data, including databases\n" +
" present few compatibility problems");

ta1.setEditable(false);ta1.setBackground(Color.DARK_GRAY);
ta1.setForeground(Color.white);

gbc.gridx = 0;
gbc.gridy = 2;

rb1.addActionListener(actionHandlerClass);
rb2.addActionListener(actionHandlerClass);
rb3.addActionListener(actionHandlerClass);
g.add(rb1);
g.add(rb2);
g.add(rb3);

btImage1.addActionListener(actionHandlerClass);
btImage1.addFocusListener(this);

textButton.addActionListener(actionHandlerClass);
```

```
textButton.addFocusListener(this);

ta.addFocusListener(this);

menu.add(enter); enter.addActionListener(actionHandlerClass);
menu.add(exit); exit.addActionListener(actionHandlerClass);

menu.add(next);next.addActionListener(actionHandlerClass);
reSize.add(size); size.addActionListener(actionHandlerClass);
reSize.add(size1); size1.addActionListener(actionHandlerClass);
nw.add(next);
mBar.add(menu);
mBar.add(nw);
setJMenuBar(mBar);
getContentPane().add(p1);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );
}
public static void main(String[] args) {
Page1 page1 = new Page1();
page1.show();
page1.pack();
page1.setVisible(true);
page1.changeFocusOwner(page1.myFocusmgr);
page1.printDefaultSettings(page1.myFocusmgr);
}
class ActionHandlerClass implements ActionListener{

long startTime = System.currentTimeMillis()/1000 ;;
int posX, posY;
public void actionPerformed (ActionEvent e){

if (e.getSource()==exit)
{
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Exit Selected,
System Exited");
System.exit(0);
}
if (e.getSource()==size){
```

```
setSize(400,400);
}
if (e.getSource()==size1){
setSize(176,208);
}

if(e.getSource()==next){
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 2 visited
"+pageCount1+" at "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Forward Selected
menu page 1 at time "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 2 started
on page forward select"+startTime);
page2.show();
dispose();
}
if(e.getSource()== textButton){
posX=textButton.getX();
posY=textButton.getY();
//JOptionPane.showMessageDialog(null, "A JavaScript Alert"," ", 1);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","main text
selected page 1 at x "+posX+" y "+posY+"Time "+startTime);
}
if (e.getSource()==btImage1){
posX=btImage1.getX();
posY=btImage1.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Client/Server
image selected at x "+posX+" y "+posY+"Time "+startTime);
}
if(e.getSource()==enter){
page2.show();
dispose();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Enter
Pressed,Page 2 Started");
}}}

public void keyTyped(KeyEvent arg0) {
throw new UnsupportedOperationException("Not supported yet.");
```

```
}

public void keyPressed(KeyEvent arg0) {
throw new UnsupportedOperationException("Not supported yet.");
}

public void keyReleased(KeyEvent arg0) {
throw new UnsupportedOperationException("Not supported yet.");
}

public void focusGained(FocusEvent e) {
System.out.println("area gained "+e.getOppositeComponent()+" Focus gained");
if(textButton==e.getSource()){textButton.setBackground(Color.white);
btImage1.setBackground(Color.darkGray);System.out.println("textbutton
focus gained");
int x=textButton.getX();
int y = textButton.getY();
int z = textButton.getWidth();
int w = textButton.getHeight();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt"," textButton
selected at "+x+":"+y+" at time "+startTime );
app.appendToFile("E:/AccelerometerUserTest1/Login.txt"," textButton
width / heightt "+z+":"+w +" at time "+startTime );
}
else
if(btImage1==e.getSource()){btImage1.setBackground(Color.white);
textButton.setBackground(Color.darkGray);System.out.println("textbutton
focus gained");
int x=btImage1.getX();
int y = btImage1.getY();

app.appendToFile("E:/AccelerometerUserTest1/Login.txt"," ImageButton
selected at "+x+":"+y+" at time "+startTime );
}}

public void focusLost(FocusEvent e) {

System.out.println("LAST COMPONENT LOST FOCUS: Focus lost");
```

```
System.out.println("The opposite component "
+ "in this focus traversal is "
+ e.getOppositeComponent()+".");
}

public void printDefaultSettings(DefaultKeyboardFocusManager fm) {
/* print the four default traversal keys */
System.out.println("Default keys "
+ "for the DefaultFocusManager class:");
System.out.println(" FORWARD_TRAVERSAL_KEYS: "
+ fm.getDefaultFocusTraversalKeys(
KeyboardFocusManager.FORWARD_TRAVERSAL_KEYS));
System.out.println(" BACKWARD_TRAVERSAL_KEYS: "
+ fm.getDefaultFocusTraversalKeys(
KeyboardFocusManager.BACKWARD_TRAVERSAL_KEYS));
System.out.println(" UP_CYCLE_TRAVERSAL_KEYS: "
+ fm.getDefaultFocusTraversalKeys(
KeyboardFocusManager.UP_CYCLE_TRAVERSAL_KEYS));
System.out.println(" DOWN_CYCLE_TRAVERSAL_KEYS: "
+ fm.getDefaultFocusTraversalKeys(
KeyboardFocusManager.DOWN_CYCLE_TRAVERSAL_KEYS));
}
public void changeFocusOwner(DefaultKeyboardFocusManager fm) {
/* programmatically change the focus owner */
System.out.println("The current focus owner is "
+ fm.getFocusOwner());
System.out.println("The current focus cycle root is: "
+ fm.getCurrentFocusCycleRoot());
System.out.println("forwarding focus to the next component...");
fm.focusNextComponent();
System.out.println("Now, the focus owner is "
+ fm.getFocusOwner());
System.out.println("going up one focus cycle...");
fm.upFocusCycle();
System.out.println("Now, the focus owner is "
+ fm.getFocusOwner());
System.out.println("going down one focus cycle...");
fm.downFocusCycle();
```

```
System.out.println("Now, the focus owner is "
+ fm.getFocusOwner());
System.out.println("clearing the global focus owner ...");
fm.clearGlobalFocusOwner();
System.out.println("Now, the focus owner is "
+ fm.getFocusOwner());

}}
```

MouseMovementClass.java

```
import java.awt.event.*;
import java.awt.event.MouseEvent;
import java.awt.event.MouseMotionListener;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import java.awt.Graphics2D.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.Component.*;

class MouseMovementClass implements MouseMotionListener, MouseListener
{
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;
FileWriter fstream;
int startX, startY;
int x,y = 0;
int seconds =0;

long startTime, endTime;
FileUtilities app=new FileUtilities();
public void mouseMoved(MouseEvent ma) {

startTime = System.currentTimeMillis()/1000 ;
```

```
int posX=ma.getX();
int posY=ma.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt"," Mouse Moved
fromX "+posX+" Y "+posY+ " speed"+" startTime"+startTime);
}}

public void mouseDragged(MouseEvent mb) {
startTime = System.currentTimeMillis()/1000 ;

int dragposX=mb.getX();
int dragposY=mb.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Dragged
xpos"+ dragposX+ " yPos "+dragposY+" startTime"+startTime);
}
public void mousePressed(MouseEvent mc){

startTime = System.currentTimeMillis()/1000 ;
x=mc.getX(); y=mc.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Pressed at
X:Y "+x+":"+y+" Mouse Pressed at "+startTime);
}

public void mouseExited(MouseEvent md){
startTime = System.currentTimeMillis()/1000 ;
x=md.getX(); y=md.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Exited at
X:Y "+x+":"+y+" Exit Time at "+startTime);
}

public void mouseEntered(MouseEvent me) {

startTime = System.currentTimeMillis()/1000 ;
x=me.getX(); y=me.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Entered at
X:Y "+x+":"+y+" Mouse Entered at "+startTime);
// System.out.println("Mouse Entered at X:Y "+x+":"+y+" Mouse Entered
at "+startTime);
```

```
}

public void mouseClicked(MouseEvent mf) {

startTime = System.currentTimeMillis()/1000 ;

x=mf.getX();
y=mf.getY();

int count =mf.getClickCount();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Clicked at
X:Y "+x+":"+y+"Click Count "+count+"Mouse Clicked at "+startTime);
}

public void mouseReleased(MouseEvent mg) {

startTime = System.currentTimeMillis()/1000 ;
x=mg.getX();
y=mg.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Mouse Released
at X:Y "+x+":"+y);
}}
```

main.java

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
```

```
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;


public class Main extends JFrame{

BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;


FileWriter fstream;
//Global Declaration of Menus
JLabel l = new JLabel(" Name ");
//JLabel l2 = new JLabel(" Password ");
JTextField tf = new JTextField(10);
JPasswordField tf2 = new JPasswordField(10);
Calendar now = Calendar.getInstance();
int h = now.get(Calendar.HOUR_OF_DAY);
int m = now.get(Calendar.MINUTE);
int s = now.get(Calendar.SECOND);
String time=("" + h + ":" + m + ":" + s);

String user;
String pass;
char[] input;
int flag = 0;
long startTime, endTime;
int count = 0;

JMenuBar mBar = new JMenuBar();
JMenuItem enter = new JMenuItem ("Enter");
JMenuItem exit = new JMenuItem ("Exit");
JMenuItem size = new JMenuItem ("Size 1");
JMenuItem size1 = new JMenuItem ("Size 2");
JMenu menu = new JMenu ("Menu");
JMenu reSize = new JMenu ("Resize");
```

```
JPanel p1 = new JPanel();

Component component;

GridBagConstraints gbc = new GridBagConstraints();


//generates the interface and registers ActionListener
ActionHandlerClass actionHandlerClass = new ActionHandlerClass();
KeyHandlerEvent keyHandlerClass = new KeyHandlerEvent();

Page1 page = new Page1();
//create the constructor method
public Main(String str)
{
super(str);

setSize(240,320);
setResizable(false);

p1.setLayout(new GridBagLayout());
p1.setBackground(Color.DARK_GRAY);p1.setForeground(Color.white);

tf.setBackground(Color.DARK_GRAY);tf.setForeground(Color.white);
tf.setEditable(true);
//tf.setCaretPosition(0);
l.setBackground(Color.DARK_GRAY);l.setForeground(Color.white);

gbc.weighty = 1.0;
gbc.weightx = 1.0;
gbc.gridx = 1;
gbc.gridy = 1;

p1.add(l,gbc);
gbc.gridx = 1;
gbc.gridy = 2;
p1.add(tf,gbc);
```

```
//add action / mouse listeners to the panels

menu.add(exit); exit.addActionListener(actionHandlerClass);
menu.add(enter); enter.addActionListener(actionHandlerClass);
reSize.add(size); size.addActionListener(actionHandlerClass);
reSize.add(size1); size1.addActionListener(actionHandlerClass);
mBar.add(menu);
//$ mBar.add(reSize);
setJMenuBar(mBar);
//set up content pane and set default close operator
getContentPane().add(p1);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );

}
public static void main(String[] args) {

Main main = new Main("LOGIN");

main.show();
}

//create action handler
class ActionHandlerClass implements ActionListener{
public void actionPerformed (ActionEvent e){
if (e.getSource()==exit)
{ //exit application when exit selected from menu bar
System.out.println("Exit is pressed");

System.exit(0);

}
if (e.getSource()==enter)
{ //exit application when exit selected from menu bar
// System.out.println("enter is pressed");
dispose();
page.show();
flag=1;
```

```
String user = new String ();
user = tf.getText();

System.out.println(user);

// Create file
//write username & password to external file
try{
fstream = new FileWriter("Login.txt");

out = new BufferedWriter(fstream);
user = tf.getText();

out.write("User "+user+" Time "+time);
out.close();
}catch (Exception ef){//Catch exception if any
System.err.println("Error: " + ef.getMessage());
}

tf.setText("");
}



}}
//check that password length == 3 characters
static boolean isPasswordCorrect(char[] input) {
boolean isCorrect = true;
char[] correctPassword = { 't', 'm', '6'};

if (input.length != correctPassword.length) {
isCorrect = false;
System.out.println("pass "+isCorrect);
} else if (input.length == correctPassword.length) {
isCorrect = true;
System.out.println("pass "+isCorrect);
}
return isCorrect;
```

```
}}
```

Login.java

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;


public class Login extends JFrame{

//set up components and variables etc
BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;

FileWriter fstream;

JLabel l = new JLabel(" Name ");
JTextField tf = new JTextField(10);
JPasswordField tf2 = new JPasswordField(10);
Calendar now = Calendar.getInstance();
int h = now.get(Calendar.HOUR_OF_DAY);
int m = now.get(Calendar.MINUTE);
```

```
int s = now.get(Calendar.SECOND);
String time=("" + h + ":" + m + ":" + s);

String user;
String pass;
char[] input;
int flag = 0;
long startTime, endTime;
int count = 0;

JMenuBar mBar = new JMenuBar();
JMenuItem enter = new JMenuItem ("Enter");
JMenuItem exit = new JMenuItem ("Exit");
JMenuItem size = new JMenuItem ("Size 1");
JMenuItem size1 = new JMenuItem ("Size 2");
JMenu menu = new JMenu ("Menu");
JMenu reSize = new JMenu ("Resize");

JPanel p1 = new JPanel();

Component component;

GridBagConstraints gbc = new GridBagConstraints();

//generates the interface and registers ActionListener
ActionHandlerClass actionHandlerClass = new ActionHandlerClass();
KeyHandlerEvent keyHandlerClass = new KeyHandlerEvent();

Page1 page = new Page1();
//create the constructor method
public Login(String str)
{
super(str);

setSize(240,320);
setResizable(false);

p1.setLayout(new GridBagLayout());
```

```
p1.setBackground(Color.DARK_GRAY);p1.setForeground(Color.white);

tf.setBackground(Color.DARK_GRAY);tf.setForeground(Color.white);
tf.setEditable(true);
//tf.setCaretPosition(0);
l.setBackground(Color.DARK_GRAY);l.setForeground(Color.white);

gbc.weighty = 1.0;
gbc.weightx = 1.0;
gbc.gridx = 1;
gbc.gridy = 1;

p1.add(l,gbc);
gbc.gridx = 1;
gbc.gridy = 2;
p1.add(tf,gbc);

menu.add(exit); exit.addActionListener(actionHandlerClass);
menu.add(enter); enter.addActionListener(actionHandlerClass);
reSize.add(size); size.addActionListener(actionHandlerClass);
reSize.add(size1); size1.addActionListener(actionHandlerClass);
mBar.add(menu);

setJMenuBar(mBar);

getContentPane().add(p1);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );

}
public static void main(String[] args) {

Login login = new Login("LOGIN");

login.show();
}
//create action handler
class ActionHandlerClass implements ActionListener{
public void actionPerformed (ActionEvent e){
```

```
if (e.getSource()==exit)
{ //exit application when exit selected from menu bar
System.out.println("Exit is pressed");

System.exit(0);

}
if (e.getSource()==enter)
{ //exit application when exit selected from menu bar
// System.out.println("enter is pressed");
dispose();
page.show();

flag=1;

String user = new String ();
user = tf.getText();

System.out.println(user);
// Create file

try{
fstream = new FileWriter("Login.txt");

out = new BufferedWriter(fstream);
user = tf.getText();

out.write("User "+user+" Time "+time);
out.close();
}catch (Exception ef){//Catch exception if any
System.err.println("Error: " + ef.getMessage());
}

tf.setText("");
}}}
```

```
//check that password length == 3 characters
static boolean isPasswordCorrect(char[] input) {
boolean isCorrect = true;
char[] correctPassword = { 't', 'm', '6'};

if (input.length != correctPassword.length) {
isCorrect = false;
System.out.println("pass "+isCorrect);
} else if (input.length == correctPassword.length) {
isCorrect = true;
System.out.println("pass "+isCorrect);
}
return isCorrect;
}}
```

KeyEventHandler.java

```
import java.awt.DefaultKeyboardFocusManager;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;

public class KeyHandlerEvent implements KeyListener, FocusListener{
DefaultKeyboardFocusManager myFocusmgr
= new DefaultKeyboardFocusManager();
static final String newline = "\n";
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;

String keyString, modString, tmpString, actionString, locationString;
FileWriter fstream;
int startX, startY;
```

```
int x,y = 0;
int seconds =0;
int left, right, up, down;

long startTime, endTime;
FileUtilities app=new FileUtilities();

public void keyTyped(KeyEvent e) {
displayInfo(e, "KEY TYPED: ");
}

/** Handle the key pressed event from the text field. */
public void keyPressed(KeyEvent e) {
displayInfo(e, "KEY PRESSED: ");
}

/** Handle the key released event from the text field. */
public void keyReleased(KeyEvent e) {
displayInfo(e, "KEY RELEASED: ");
}

/** Handle the button click. */
public void actionPerformed(ActionEvent e) {

//Clear the text components.


left=1;
right=1;
up=1;
down=1;

}

protected void displayInfo(KeyEvent e, String s){

startTime = System.currentTimeMillis()/1000 ;
```

```
int id = e.getID();
if (id == KeyEvent.KEY_TYPED) {
char c = e.getKeyChar();
keyString = "key character = '" + c + "'";
} else {
int keyCode = e.getKeyCode();
keyString = "key code = " + keyCode
+ " ("
+ KeyEvent.getKeyText(keyCode)
+ ")";
}
int modifiers = e.getModifiersEx();
modString = "modifiers = " + modifiers;
tmpString = KeyEvent.getModifiersExText(modifiers);
if (tmpString.length() > 0) {
modString += " (" + tmpString + ")";
} else {
modString += " (no modifiers)";
}
actionString = "action key? ";
if (e.isActionKey()) {
actionString += "YES";
} else {
actionString += "NO";
}

int keyCode = e.getKeyCode();

if(keyCode==37){left++; right--; System.out.println("Left "+left);
Page1 page1 = new Page1();
if(e.getSource()==page1.textButton)page1.textButton.setBorderPainted(false);

}
else if(keyCode==39){right++; left--;System.out.println("Right "+right);}
else if(keyCode==38){up++; down--;System.out.println("Up "+up);}
else if(keyCode==40){down++; up--;System.out.println("Down "+down);}

app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Key Pressed "+
```

```
s + "\n" + " " +
keyString + "\n"+ " " + modString + "\n"
+ " " + actionString + "\n" +
" " + locationString + "\n");
}

public void focusGained(FocusEvent e) {
System.out.println("area gained "+e.getOppositeComponent()+" Focus gained");
}

public void focusLost(FocusEvent e) {

System.out.println("myTextField: Focus lost");
System.out.println("The opposite component "
+ "in this focus traversal is "
+ e.getOppositeComponent()+".");

}}
```

FileUtility.java

```
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import java.awt.Graphics2D.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.Component.*;

public class FileUtilities {

public static void main(String args[])
{
FileUtilities app=new FileUtilities();
}
```

```
public void writeToFile(String fileName,String text)
{
FileOutputStream out; // declare a file output object
PrintStream p; // declare a print stream object

try
{
// Create a new file output stream
out = new FileOutputStream(fileName);

// Connect print stream to the output stream
p = new PrintStream( out );

p.println (text);

p.close();
}
catch (Exception e)
{
System.err.println ("Error writing to file");
}}

public void replaceInFile(String fileName,String text,String
replacementText)
{
String fileContents =readFromFile(fileName,"EOF");
int startOfLineIndex = fileContents.indexOf(text);
int endOflineIndex = fileContents.indexOf("\n",startOfLineIndex);
int length = fileContents.length();

String newFileContents=fileContents.substring(0,startOfLineIndex)
+replacementText+fileContents.substring(endOflineIndex-1,length);
writeToFile(fileName,newFileContents);
}
public void appendToFile(String fileName,String text)
{
String fileContents =readFromFile(fileName,"EOF");
```

```
fileContents=fileContents+"\n"+text+"\n";


writeToFile(fileName,fileContents);
}
public String readFromFile(String fileName,String search)
{ String fileContents="";
boolean done = false;
byte b[] = new byte[1024];
int num_bytes = 0;

FileInputStream fin = null;
try {
fin = new FileInputStream(fileName);
}

catch (FileNotFoundException e) {
System.out.println("Could not open input file " + fileName);
System.exit(0);
}
catch(IOException e) {
System.out.println("Error while opening input file" + fileName);
System.exit(0);
}
catch (Exception e) {
System.out.println("Unexpected exception: " + e);
System.exit(0);
}

try {
num_bytes = fin.read(b);
}
catch(IOException e) {
System.out.println("Finished Reading: " + e);
done = true;
}
catch (Exception e) {
System.out.println("Unexpected exception: " + e);
```

```
System.exit(0);
}

while(!done) {
String testSerString = new String(b,0,num_bytes);

fileContents=fileContents+testSerString;
try {
num_bytes = fin.read(b);
}
catch(IOException e) {
System.out.println("Finished Reading: " + e);
done = true;
}
catch (Exception e) {
System.out.println("Unexpected exception: " + e);
System.exit(0);
}
if (num_bytes == -1) done = true;
} // end while

if(search.equals("EOF"))
{
return fileContents;
}
int i,j;

i=fileContents.indexOf(search,0);
if(i !=-1)
{
j=fileContents.indexOf('\n',i);
fileContents=fileContents.substring(i,j);
}
else
{
fileContents="";
}
return fileContents;
```

```
}

public String rot13( String unemcrypted)
{
String unemcryptedString=unemcrypted;
String emcryptedString="";
unemcryptedString=unemcryptedString.toLowerCase();
int length= unemcryptedString.length();

String c;
int j;

for(int i=0;i<length;i++)
{

c=unemcryptedString.substring(i,i+1);
j=c.hashCode();
j=j-96;


switch (j) {
case 1: emcryptedString=emcryptedString+"n"; break;
case 2: emcryptedString=emcryptedString+"o"; break;
case 3: emcryptedString=emcryptedString+"p"; break;
case 4: emcryptedString=emcryptedString+"q"; break;
case 5: emcryptedString=emcryptedString+"r"; break;
case 6: emcryptedString=emcryptedString+"s"; break;
case 7: emcryptedString=emcryptedString+"t"; break;
case 8: emcryptedString=emcryptedString+"u"; break;
case 9: emcryptedString=emcryptedString+"v"; break;
case 10: emcryptedString=emcryptedString+"w"; break;
case 11: emcryptedString=emcryptedString+"x"; break;
case 12: emcryptedString=emcryptedString+"y"; break;
case 13: emcryptedString=emcryptedString+"z"; break;
case 14: emcryptedString=emcryptedString+"a"; break;
case 15: emcryptedString=emcryptedString+"b"; break;
case 16: emcryptedString=emcryptedString+"c"; break;
case 17: emcryptedString=emcryptedString+"d"; break;
```

```
case 18: emcryptedString=emcryptedString+"e"; break;
case 19: emcryptedString=emcryptedString+"f"; break;
case 20: emcryptedString=emcryptedString+"g"; break;
case 21: emcryptedString=emcryptedString+"h"; break;
case 22: emcryptedString=emcryptedString+"i"; break;
case 23: emcryptedString=emcryptedString+"j"; break;
case 24: emcryptedString=emcryptedString+"k"; break;
case 25: emcryptedString=emcryptedString+"l"; break;
case 26: emcryptedString=emcryptedString+"m"; break;
}

}
return emcryptedString;
}

public String removeWhiteSpace(String astring)
{
astring=astring.trim();
int g= astring.indexOf('\u0020',0);
int i=astring.length();
int h =astring.lastIndexOf('\u0020',i-1);

String noSpaceString="";
if( g != -1)
{
noSpaceString=astring.substring(0,g);
}
if( h != -1)
{
noSpaceString=noSpaceString+astring.substring(h+1,i);
}
if (g==-1 && h ==-1)
{
noSpaceString=astring;
}
return noSpaceString;
}}
```

```
import java.util.*;
import java.awt.*;
import java.awt.event.*;
import java.awt.event.MouseListener.*;
import java.awt.image.BufferedImage.*;
import java.awt.Graphics.*;
import javax.swing.*;
import javax.swing.border.*;
import javax.swing.Timer.*;
import javax.swing.ImageIcon.*;
import java.io.*;
import java.lang.Math.*;
import java.awt.Component;
import javax.swing.ImageIcon;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;
import java.awt.image.*;


public class Page2 extends JFrame{

BevelBorder bevel = new BevelBorder (BevelBorder.RAISED);
BevelBorder bevel2 = new BevelBorder (BevelBorder.RAISED);
BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
BufferedWriter out;

Component component;
//Global Declaration of Menus
JLabel l = new JLabel(" HTML \n" +

"Server Side");
JLabel l2= new JLabel(" ");
JLabel question = new JLabel(" Multiple Choice Question ");
```

```
JTextArea ta,ta1,ta2,ta3,ta4,ta5,ta6,ta7,ta8;
JScrollPane sp;
String text=new String("What is the Answer" );

ImageIcon images = new ImageIcon("images/flower.jpg");
BufferedImage img;
FileWriter fstream;

JButton btImage = new JButton("", new ImageIcon
("images/clientserver.jpg"));
int startX, startY;
int x,y = 0;
long startTime, endTime;
int pageCount1=1;

JMenuBar mBar = new JMenuBar();
JMenuItem enter = new JMenuItem ("Enter");
JMenuItem exit = new JMenuItem ("Exit");
JMenuItem size = new JMenuItem ("Size 1");
JMenuItem size1 = new JMenuItem ("Size 2");
JMenuItem back = new JMenuItem ("Back");
JMenuItem next = new JMenuItem ("Forward");
JMenu menu = new JMenu ("Menu");
JMenu reSize = new JMenu ("Resize");
JMenu nw = new JMenu("Page");

JPanel p1 = new JPanel();
JPanel p2 = new JPanel();
JPanel p3 = new JPanel();

ButtonGroup g = new ButtonGroup();
JButton textButton = new JButton();
JRadioButton rb1 = new JRadioButton("A", true),
rb2 = new JRadioButton("B", false), rb3 = new JRadioButton(
"C", false);

Calendar now = Calendar.getInstance();
int h = now.get(Calendar.HOUR_OF_DAY);
```

```
int m = now.get(Calendar.MINUTE);
int s = now.get(Calendar.SECOND);
String time=("" + h + ":" + m + ":" + s);
GridBagConstraints c = new GridBagConstraints();

//generates the interface and registers ActionListener mouse listener
ActionHandlerClass actionHandlerClass = new ActionHandlerClass();
KeyHandlerEvent keyHandlerClass = new KeyHandlerEvent();
MouseMovementClass mouseMovementClass = new MouseMovementClass();

//create a new instance of file utilities and the next page
FileUtilities app=new FileUtilities();
Page7 page7 = new Page7();

//start the constructor method
public Page6()
{
super("Adv / DisAdv");
setSize(240,320);
setResizable(false);

GridBagConstraints gbc = new GridBagConstraints();
p1.setLayout(new GridBagLayout());
p1.setBackground(Color.DARK_GRAY);p1.setForeground(Color.white);
gbc.weighty = 2.0;
gbc.weightx = 2.0;
gbc.gridx = 0;
gbc.gridy = 2;
p1.add(btImage, gbc);

gbc.gridx = 0;
gbc.gridy = 0;
textButton.setBackground(Color.DARK_GRAY);

ta = new JTextArea(" Advantages / Disadvantages \n\n" +
" Respond quickly to user actions\n" +
" Do not require communication across\n the internet\n" +
" Unsuitable for large data quantities\n" +
```

```
" May not be compatible across\n browsers");

ta.setEditable(false);ta.setBackground(Color.DARK_GRAY);ta.setForeground(Color.white
textButton.add(ta);

p1.add(textButton, gbc);
btImage.addActionListener(actionHandlerClass);
btImage.addKeyListener(keyHandlerClass);
btImage.addMouseMotionListener(mouseMovementClass);

textButton.addKeyListener(keyHandlerClass);
textButton.addActionListener(actionHandlerClass);
textButton.addMouseMotionListener(mouseMovementClass);
textButton.addMouseListener(mouseMovementClass);

rb1.addMouseListener(mouseMovementClass);
rb2.addMouseListener(mouseMovementClass);
rb3.addMouseListener(mouseMovementClass);
rb1.addMouseMotionListener(mouseMovementClass);
rb2.addMouseMotionListener(mouseMovementClass);
rb3.addMouseMotionListener(mouseMovementClass);

question.addMouseListener(mouseMovementClass);
question.addMouseMotionListener(mouseMovementClass);

ta.addMouseListener(mouseMovementClass);
ta.addMouseMotionListener(mouseMovementClass);

p1.addMouseMotionListener(mouseMovementClass);
p1.addMouseListener(mouseMovementClass);
p1.addKeyListener(keyHandlerClass);
p1.setRequestFocusEnabled(false);

menu.add(enter); enter.addActionListener(actionHandlerClass);
menu.add(exit); exit.addActionListener(actionHandlerClass);
menu.add(back);back.addActionListener(actionHandlerClass);
menu.add(next);next.addActionListener(actionHandlerClass);
reSize.add(size); size.addActionListener(actionHandlerClass);
```

```
reSize.add(size1); size1.addActionListener(actionHandlerClass);
nw.add(next);
nw.add(back);
mBar.add(menu);
mBar.add(nw);

setJMenuBar(mBar);
getContentPane().add(p1);
setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE );
}

public static void main(String[] args) {

Page2 page2 = new Page2();
page2.show();
}

class ActionHandlerClass implements ActionListener{

long startTime = System.currentTimeMillis()/1000 ;
int posX, posY;
public void actionPerformed (ActionEvent e){

if (e.getSource()==exit)
{
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Exit Selected,
System Exited");

System.exit(0);
}
if (e.getSource()==size){
setSize(400,400);
}
if (e.getSource()==size1){
setSize(176,208);
}

if(e.getSource()==next){
```

```
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 3 visited
at "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Forward Selected
menu page 2 at time "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 3 started
on page forward select"+startTime);
page3.show();
dispose();
}
if(e.getSource()== textButton){
posX=textButton.getX();
posY=textButton.getY();
//JOptionPane.showMessageDialog(null, "A JavaScript Alert"," ", 1);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","main text
selected page 6 at x "+posX+" y "+posY+"Time "+startTime);
}
if(e.getSource()==back){

app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 1 visited
at "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Back Selected
menu page2 at time "+startTime);
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Page 1 started
on page forward select"+startTime);
Page1 page1 = new Page1();
page1.show();
dispose();
}
if (e.getSource()==btImage){
posX=btImage.getX();
posY=btImage.getY();
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Server image
selected at x "+posX+" y "+posY+"Time "+startTime);
}

if(e.getSource()==enter){
page7.show();
dispose();
```

```
app.appendToFile("E:/AccelerometerUserTest1/Login.txt","Enter
Pressed,Page 3 Started");
}}}}
```

Appendix F

List of Publications

The following publications were authored in regard to this thesis:

F.1 Journal Articles

1. **T. Mehigan**, I. Pitt, **Detecting Learning Style through Biometric Technology for Mobile GBL**, IGI Global - International Journal of Game Based Learning (IJGBL), 2 (2), 55-74.

F.2 Conference Papers

1. **T. Mehigan**, I. Pitt, **Assessing Eye-Tracking Technology for Learning-Style detection in Adaptive Game-Based Learning**, iGBL 2012, Irish Symposium on Game Based Learning, June 7th, 2012, Waterford Institute of Technology, Ireland.

2. **T. Mehigan**, I. Pitt, **Learning on the Move: Harnessing Accelerometer Devices to Detect Learner Styles for Mobile Learning**, IHCI, Irish Human Computer Interaction Conference, 2011, September 8 to 9, 2011, Cork Institute of Technology, Ireland.

3. **T. Mehigan**, M. Barry, A. Kehoe, I. Pitt,**Using Eye Tracking Technology to Identify Visual and Verbal Learners**, ICME 2011, IEEE International Conference on Multimedia & Expo, July 11 to 15, 2011, Barcelona, Spain.

4. **T. Mehigan**, I. Pitt, **Learner Style Inference for Game Based Learning Systems**, iGBL 2011, Irish Symposium on Game Based Learning, May 19th, 2010, Waterford Institute of Technology, Ireland.

5. F. Neff, **T. Mehigan**, I. Pitt, **Accelerometer & Spatial Audio Technology: Making Touch Screen Mobile Devices Accessible**, ICCHP 2010, 12th International Conference on Computers Helping People with Special Needs, July 14 16, 2010, Vienna University of Technology, Austria.

6. **T. Mehigan**, M.Barry, I.Pitt, **Individual Learner Styles Inference Using Eye Tracking Technology**, I-HCI 09, 3rd conference of the Irish HCI Community, Dublin, Ireland, 17-18 September, 2009, pp 63 - 69.

7. **T. Mehigan**, I.Pitt, **Assessment of the Accelerometer as a means to Infer Individual User Learning Styles for Inclusive Mobile Learning Systems**, EDULEARN09 International Conference on Education and New Learning Technologies, Barcelona, Spain, 6-8 July, 2009, pp 3856 - 3865.

8. **T. Mehigan**, A. Kehoe, I. Pitt, **Accelerometer Input as an Alternative to Direct Manipulation Input for the Assessment of Individual User Learning Styles**, ED-Media 2009 World Conference on Educational Multimedia, Hypermedia & Telecommunications, Honolulu, Hawaii, 22-26 June 2009, pp 864-871.

F.3 Book Chapters

1. **T. Mehigan** ,I. Pitt **Intelligent Mobile Learning Systems for Learners with Style**, In Tools for Mobile Multimedia Programming and Development, Tjondronegoro, D. (Ed), IGI-Global. (Due for publication 2013).

2. **T. Mehigan** ,I. Pitt **Individual Learner Style Inference for the Development of Adaptive Mobile Learner Systems** Chapter 11, In Mobile Learning - Pilot Projects and Initiatives, Guy, R. (Ed), (2010), Santa Rosa, California: Informing Science Press, (pp 167-183).

3. **T. Mehigan**,I. Pitt **Toward a Ubiquitous Future: Modeling Existing Mobile Learning System Research** Chapter 17, In Mobile Learning - Pilot Projects and Initiatives, Guy, R. (Ed), (2010), Santa Rosa, California: Informing Science Press, (pp 273-299).

4. R. Guy, C. Chaka, N. Ngesi, **T. Mehigan**, I. Pitt, M. Simbulan, P. Williams **Mobile Learning Reviewed** Chapter 5, In Mobile Learning - Pilot Projects and Initiatives Guy, R. (Ed), (2010), Santa Rosa, California: Informing Science Press, (pp 57-74).

5. D. Doolan, **T. Mehigan**, S. Tabirca, I. Pitt **Cross Platform M-Learning for the Classroom of Tomorrow**, In T.-T. Goh (Ed.) Multiplatform E-Learning Systems and Technologies:Mobile Devices for Ubiquitous ICT-Based Education. London: IGI Global, pp 112-127

F.4 Posters

1. **T. Mehigan**, **Measuring Learner Styles through User Device Interaction forAdaptive eLearning Systems**, Poster / Abstract, IRCSET Symposium 2009, "Innovation fuelling the Smart Society", RDS, Dublin, Ireland, September 25 2009.

F.5 Doctoral Consortium Abstract

1. **T. Mehigan**, **Harnessing Accelerometer Technology for Inclusive Mobile Learning**,Doctoral Consortium, MOBILEHCI09, the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services, Bonn, Germany, September 15-18 2009.