A Mobile Context-Aware Learning Schedule Framework with Java learning objects

by

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List of Tables and Figures

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G) Yau, J. & Joy, M. (2008) A Self-Regulated Learning Approach: A Mobile Context-aware and Adaptive Learning Schedule (mCALS) Tool. *International Journal of Interactive Mobile Technologies*, vol. 2, no. 3, pp. 52-57.

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ABSTRACT

The focus of this thesis is the study of mobile learning, specifically learning in different locations and under various contextual situations, from the perspective of university students. I initially derived and designed a theoretical *mobile context-aware learning schedule (mCALS) framework* from an extensive literature review. Its objective is to recommend appropriate learning materials to students based on their current locations and circumstances. The framework uses a learning schedule (i.e. electronic-based diary) to inform the location and available time a student has for learning/studying at a particular location. Thereafter, a number of factors are taken into consideration for the recommendation of appropriate learning materials. These are the student's learning styles, knowledge level, concentration level, frequency of interruption at that location and their available time for learning/studying.

In order to determine the potential deployment of the framework as a mobile learning application by intended users, I carried out three types of feasibility studies. First, a pedagogical study was conducted using interviews to explore together with students (a) what their learning requirements were when studying in a mobile environment, (b) whether the framework could potentially be used effectively to support their studies and, (c) using this user-centred understanding, refined user requirements of the framework. Second, a diary study was conducted where I collected data and analysed the usability feasibility of the framework by (a) determining whether students could plan their daily schedule ahead and keep to it, (b) ascertaining which learning contexts were important and, (c) establishing which learning materials were appropriate under which situations. Two validation studies were conducted. The first one was an online experiment utilising Java learning objects. Participants of this study were suggested appropriate learning objects to study with, based on their amount of

available time, current motivation level for learning and their proficiency level of Java. The second validation study was an investigation into high-quality Java learning objects available in the public domain. Finally, a technical design of the framework was carried out to determine whether the framework at present could realistically be implemented using current mobile technologies.

The data analyses of the feasibility studies show that (a) a learning schedule approach is successful to an extent in obtaining location and available time information to indicate accurate values of these contexts, (b) different learners may require different personalisation strategies when selecting appropriate learning materials for them in mobile environments, and (c) the mCALS framework is particularly well-suited for self-regulated students. I also proposed a set of suggestion rules which can be used to recommend appropriate Java learning materials to students in different contexts. The validation studies show that 1) the proposed suggestion rules are effective in recommending appropriate materials to learners in their situation, in order to enhance their learning experiences, and 2) there are a sufficiently large number of high-quality LOs available in the public domain that can be incorporated for use within my framework. Finally, the development of mCALS has been considered from three perspectives – *pedagogical*, *usability* and *technical*. These perspectives consist of critical components that should be considered when developing and evaluating mobile learning software applications. The results demonstrated that the mCALS framework can potentially be used by students in different locations and situations, and appropriate learning materials can be selected to them, in order to enhance their learning experiences.

Chapter 1

Introduction

1.1 Background

The mobile learning (hereafter abbreviated as m-learning) research field first emerged around a decade ago. One of the earliest definitions of m-learning was "e-learning through mobile computational devices" (Quinn, 2000) where electronic learning materials were simply transferred onto mobile devices for learning purposes. Many other researchers also viewed m-learning as an extension of e-learning (Sharples, 2006). The types of mobile devices concerned with m-learning included PDAs, handheld computers, smart-phones, mobile phones and occasionally (smaller) laptop computers. In other words, m-learning was fundamentally the utilization of mobile devices equipped with learning materials (either stored offline or accessed online) for learning/studying. The portability of these devices allowed learning opportunities to be created anytime, anywhere and removed the restrictions for learners to learn/study in fixed locations (such as classrooms, computer laboratories and libraries). These two aspects formed the initial motivational grounds for m-learning and subsequently a large wealth of information was constructed which could be accessible by learners anytime, anywhere.

As research progressed, considerations from three different perspectives – *technological, usability* and *pedagogical* - were incorporated into the design and development of m-learning materials and applications. *Technological* considerations included the physical layout of learning materials and how they should fit to the different sizes of screens of mobile devices. *Usability* considerations included the interaction between the user and device (also known as human computer interaction (HCI)) and how the user interfaces of software applications on mobile devices should be designed. *Pedagogical* considerations included the educational value of the learning content and how materials should be designed to enhance the learning experiences for students. Consequently, m-learning research could stem from the following different research disciplines - Computer Science, Education, Psychology, Electronic or Information Systems Engineering, Human Computer Interaction (HCI) and Mobile HCI.

Much current ongoing m-learning research from a mixture of these disciplines has been presented at a number of annual international m-learning conferences, including mLearn, WMUTE (Wireless and Ubiquitous Technologies in Education), IADIS Mobile Learning, and IMCL (International Conference on Mobile and Collaborative Learning). International journals have also been dedicated to the publication of m-learning research such as IJIM (International Journal of Interactive Mobile Technologies), IJMBL (International Journal of Mobile and Blended Learning) and RPTEL Special Issue of Context-aware and Ubiquitous Mobile Learning Systems. Moreover, an *International Association for Mobile Learning* (IAML) (mlearning.noe-kaleidoscope.org) has been set up '*to promote excellence in research, development and application of mobile and contextual learning*' as well as for sharing information about current projects, emerging technologies and teaching resources. Research activities, practices and issues/problems of m-learning at an international level are shared across this research community. This illustrates an increasing global presence of m-learning as well as the fact that research problems within this area are currently being investigated by a large group of people.

An overview of past and current m-learning projects revealed that they had been undertaken by researchers and developers across different parts of the world in the past decade, in the educational as well as commercial sectors. These include many European countries (such as England, Germany, Finland, Spain, Italy), Asian countries (such as Taiwan, Japan, Hong Kong, Malaysia, Singapore), African countries (such as Tanzania, Uganda, South Africa), as well as America, New Zealand and Australia. The growth of research on m-learning has not been restricted within specific areas in the world, rather it seems to be widely scattered across the globe.

The commercial projects were typically oriented towards employees, trainees and/or learners in the business sector. In the educational sectors, projects were targeted towards conventional students either for *formal learning* in educational institutions (such as schools or universities) or for *informal learning* (such as in museums or sightseeing around cities) or, increasingly, for *distance learning* students. Additionally, mobile technologies had great potential in enabling various types of learning which could take place including *situated learning, collaborative learning, lifelong learning*, *independent learning, flexible learning* and *self-regulated learning*. In understanding this thesis, it is helpful to know the definitions of these different types of learning, and the differences between them. Definitions of these different types of learning are given below. In this thesis, I am specifically interested in self-regulated learning, lifelong learning, independent learning and flexible learning. A literature review of self-regulated learning is further provided in 2.7.2, and I describe my work more specifically in relation to self-regulated learning in 4.2.

- *Formal learning* is planned, structured and undertaken by students when they are officially enrolled in an educational institution such as a school or university (Eraut, 2000).

- *Informal learning* is the spontaneous and unstructured learning which goes beyond the school, and is the most prevalent kind of adult learning (Coombs, 1985).
- *Distance learning* is the learning performed by a learner who is not physically present at the institution, but rather is learning remotely via electronic media, technology or printed media (Graham *et al*., 2000).
- *Situated learning* is learning that takes place in the same physical space and/or context in which the learning or activity is applied. Mobile technologies have the potential to a) support real situated learning to take place where feasible, and b) imitate the physical space and/or context to allow situated learning to be simulated if, for example, real situated learning is infeasible (Naismith *et al*., 2004).
- *Collaborative learning* involves joint intellectual effort by students who are working together to achieve understanding and/or completion of a learning task (Smith and McGregor, 1992).
- *Lifelong learning* includes all areas of learning – kindergarten, school, further and higher education, informal learning at home, work or community, training courses in industry, vocational and non-vocational adult courses in colleges and universities (Vavoula, 2004).
- *Independent learning*, which is also known as self-regulated learning, is defined as students "*being motivated to take responsibility for their learning*" (Meyer *et al*., 2008).
- *Flexible learning* is centred on the student and their learning and accommodates their preferences for different learning environments and

opportunities as well as time and place of study and pace at which the learning takes place (Brown, 1999; Luckin *et al*., 2005)

- *Self-regulated learning* is centred on the deployment of motivational strategies such as self-talk, elaborative planning, processing and monitoring in order to increase one's willingness and/or motivation to learn/study (Code *et al*., 2006).

I am interested in the context-based and context-aware m-learning research areas; background on these is provided in 2.5 and 2.6 respectively. In particular, I am interested in developing an m-learning framework which can eventually be implemented to be used as a support tool for university students to support their formal studies. The purpose of this tool is, however, not a replacement for formal education. Learners may use the tool as informally as they wish, for the learning purposes they require. This framework is not intended to be used in distance, situated or collaborative learning situations. Rather, its ultimate aims are targeted at supporting lifelong, independent, flexible and/or self-regulated learners.

As described, mobile technologies can be used to facilitate students, to enable them to carry out different types of learning. Many other researchers have also developed different types of m-learning applications. I have categorised these different types of m-learning applications into three groups, as follows.

1. *Content-specific applications* such as for learning a particular language (such as English, Chinese or Japanese) or a particular topic (such as maths, science, butterflies or a city) have been developed for students to learn, improve and extend their knowledge relating to these topics. References to these applications by other authors are provided in 2.6.
2. *M-learning applications* may be aimed primarily at helping students plan or organise their workload, allowing learning materials such as lecture notes to

be retrieved from the devices, such as a mobile learning organiser (Corlett *et al*., 2004) or a personal learning organiser (Ryu and Parsons, 2008). The research in my framework aims to build on these supportive m-learning applications and these relating applications are further described in 2.7.1.

3. Mobile technologies can be used to create a learning infrastructure and to provide rich multimedia learning materials, for example in Africa where neither computers nor an infrastructure for the Internet are affordable or available respectively (Traxler, 2005). Similarly, Attewell and Savill-Smith, (2004) established a project to assist young adults who were deprived of education because they had left formal schooling at a young age. The focus involved retrieving text-messages on their mobile phones in order to improve their literacy and numeracy rates.

My work aims to provide Java learning materials to students as the learning content in my m-learning framework and as a supportive application, i.e. to help students organize their workload.

M-learning has its limitations; these are described in 1.3. These include a) *technological* constraints such as the small screen sizes of devices; b) *usability* constraints such as interruptions in the physical environment affecting students' abilities to concentrate; and c) *pedagogical* constraints such as whether students' learning requirements are met. The advancement of technologies has helped to solve some of the technological constraints whereas ongoing research and development of m-learning software applications has led to more sophisticated m-learning systems, which meet more precisely students' usability and pedagogical requirements.

I have made a classification of previous and existing m-learning applications into four generations – *'non-adaptive'*, *'learning-preferences'-based adaptive,* *‘learning-contexts’-based adaptive* and *‘learning contexts’-aware adaptive*, which are discussed in 2.2, 2.3, 2.5 and 2.6 respectively.

Applications from the first ‘non-adaptive’ generation were not personalised to the individual learner in any way. Subsequently, two important pedagogical as well as usability requirements were realised and emerged as necessary attributes of a well-designed pedagogical m-learning application. The first requirement was the concept of developing applications which allowed the learning content to be personalised to students based on their individual learning preferences (such as LS, strategies, knowledge level). This relates to the second succeeding generation – *‘learning-preferences’-based adaptive*.

The second requirement was the concept of developing applications which were constructed to highlight the learning contexts relating to and/or surrounding the learner. This allows the learning content or task to be personalised to the student according to their learning contexts. These applications can be categorised into both the third and fourth generations - *‘learning-contexts’-based adaptive* and *‘learning-contexts’-aware adaptive*. The difference between the applications of these two generations is that the user’s learning contexts from the former generation are typically input by the users, whereas the user’s learning contexts from the latter generation are retrieved from the application, using context-aware or sensor technologies. Note that learning contexts may also comprise learning preferences. Learning contexts are described in 2.4.2.

The focus of my thesis is on constructing a pedagogical m-learning suggestion mechanism framework for recommending possible appropriate learning materials for students based on their learning contexts. Scenarios of which appropriate learning materials can be recommended to students based on their learning contexts are described in 4.1. In the remainder of this first chapter, views of different perspectives and definitions of m-learning are given in 1.2, and limitations of m-learning and using mobile devices for learning are discussed in 1.3. The structure of the thesis and the research questions are presented in 1.4.

1.2 A definition of mobile learning

Various views and perspectives of m-learning have been interpreted by different researchers and developers. A broad encompassing definition of m-learning is the "*ability to learn independently of place and time, facilitated by a range of mobile devices*" by Ufi/learndirect and Kineo (2007), who further described five characteristics of m-learning – *ubiquitous, bite-sized, on demand, typically blended,* and *collaborative*.

- *Ubiquitous* denotes the availability of m-learning content via mobile devices to be accessed anytime anywhere. M-learning services have an increasing ubiquitous presence due to the growth of mobile network services. The ubiquitous characteristic falls into the technological perspective of m-learning.
- M-learning applications are intended to be accessed in environments which may be full of potential interruptions. The content should therefore be *bite-sized* to accommodate possible challenges to concentration due to interruptions. These possible challenges are tackled in the usability perspective of m-learning.
- The portability of mobile devices with enhanced battery life suggests the 'always on' nature of m-learning content and providing immediate access for

the learner whenever necessary (*on demand*). The portability characteristic falls into the technological perspective.

- It is uncommon for an m-learning device to be the primary platform or main source of delivery or learning content for a learner. M-learning services are typically used in addition to other course materials and act as part of a blended approach to learning. *Blended learning* is defined as the accomplishment of a combination of different modes of delivery, models of learning and teaching styles (Heinze and Proctor, 2004). The typically blended characteristic falls into the pedagogical perspective of m-learning. A context-aware blended m-learning environment was described in Boticki *et al*. (2009).
- M-learning can take advantage of the communication ability of mobile devices to enable *collaboration* between peers. The collaborative characteristic also falls into the pedagogical perspective.

Traxler (2009) also grouped similar categories of m-learning as above. These categories include a) technology-driven mobile learning, b) miniature but portable e-learning, c) connected classroom learning, d) informal, personalized, situated mobile learning, e) mobile training/performance support, and f) remote/rural/development mobile learning.

Specifically, the typical views of the definitions of m-learning can be categorised into one of the three following perspectives:

- *Technological* also known as *techno-centric* (mobile devices being the focus).
- *Usability* (learners being the focus).
- *Pedagogical* (learners being the focus).

From a *technological* perspective, Velasco *et al*. (2007) defined m-learning as a "learning methodology which involves the use of small mobile devices, such as mobile phones or PDAs, that is to say, any handheld device with wireless connection. Mobile learning solutions allow people to access the information technologies whenever and wherever they need, facilitating the possibility of implementing innovative ways of teaching and learning". This range of wireless connections includes - "Wi-Fi, Bluetooth, multi-hop wireless LAN and the global wireless technologies such as GPS, GSM, GPRS, 3G and satellite systems" (O'Malley *et al.*, 2005). Similarly, Traxler (2005) defined it as "any educational provision where the sole or dominant technologies are handheld or palmtop devices". Common between these definitions is that m-learning was viewed with technology at its centre, rather than the user or learner. These definitions also implied that m-learning was a function of the momentarily available and dynamically changing technology at a specific point in time (Laouris and Eteokleous, 2005a).

In the *usability* and *pedagogical* perspectives, there was a shift of focus from the mobile device to the learner. From the usability perspective, the interaction between the mobile devices and the human users formed the focus; this is known as Human Computer Interaction (HCI) or Mobile HCI. This included formatting m-learning materials to fit appropriately onto the screens of mobile devices to enable users to deploy the materials in the intended manner.

From the *pedagogical* perspective, m-learning was defined as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of learning opportunities offered by mobile technologies" (O'Malley *et al*., 2005). The first part of this definition implies that any type of learning that took place with or without mobile devices could be classed as m-learning, where fixed locations may have included computer laboratories, libraries and lecture theatres and so on. In this sense, m-learning was not necessarily an exclusive property of mobile technology, rather it was the mobility of the learner, who during their everyday life moved from one situation to another, being in different locations with different social groups, using different portable and non-portable technologies and learning different topics. Under these circumstances, the following examples would also constitute m-learning:

- Language students studying/improving their language skills whilst at home or abroad,
- Students reading paper-based lecture notes on the bus to the university, and
- Nurses or doctors accessing/updating their medical knowledge on hospital grounds using medical books.

This same view was shared by Becking *et al*. (2004) who defined m-learning as a learning process in which a learner had the time and was willing to learn either alone or in a group, with or without mobile devices.

For the purpose of the thesis, I have defined m-learning as

"*The learning/studying of learning/studying materials, in various locations, with or without the use of mobile devices. These locations can primarily, but not necessarily, be dedicated for learning/studying activities.*"

1.3 Advantages and limitations of mobile learning

The advantages of using mobile devices for learning/studying include *functionality, portability, connectivity, space-saving, and cost*. Much of the functionality of desktop or laptop computers, and the learning materials which are stored thereon, can be delivered on portable mobile devices. This can eliminate the need for users to carry large numbers of textbooks or other large or heavy learning materials in other formats.

Mobile devices can have internet connectivity and email access, allowing usage of academic or commercial software and deployment of other accessories such as video recording, camera, dictionary, thesaurus, calculator and diary tool functions. Electronic books can also be accessed. Less desk space is required due to the small physical size of mobile devices and the cost of most mobile devices is less than that of desktop or laptop computers. As anticipated by Lockitt (2005), technologies are continuously advancing, which results in higher quality of mobile devices including larger screen sizes and longer battery life.

The limitations of using mobile devices for learning/studying can be classified into three inter-related categories – *technological, usability* and *pedagogical*. The *technological* limitations of mobile devices include the small screen sizes and keyboards of these devices which consequently make it more difficult to view content, to input information, and to navigate around. Although improvements in mobile devices are continuously and consistently being made relating to these technological limitations, some users may still prefer the bigger screen sizes and keyboards of traditional desktop and laptop computers. Mobile devices may not contain all of the functionality of desktop or laptop computers and may also be harder to upgrade and expand. The robustness of these devices is also questionable in that they may be more susceptible to physical breakage and/or computing failure (Lockitt, 2005).

The *usability* limitations of using mobile devices for learning/studying relate to the possible restrictions in the use of mobile devices for viewing content and interacting with others in order to learn/study effectively. These include possible interruptions by people, noise distractions and other factors. Mobile devices can be used anytime, anywhere and the interruptions/distractions that may occur outside of fixed locations (where desktop and laptop computers are used) can be potentially higher. These interruptions/distractions should be factored in when designing m-learning materials for students to learn/study with at different locations. Other limitations may include not having sufficient working space when learning/studying whilst using public transport and not feeling comfortable.

The *pedagogical* limitations of using mobile devices to learn/study mainly comprise the distractions, which can take the learner's attention and/or focus away from the actual learning materials on mobile devices. These include not being able to meet the learning needs and requirements of mobile learners.

1.4 Structure of the thesis and the research questions

This thesis tackles the design of a potential pedagogical m-learning framework and the development of a proactive (i.e. automatically without input required from users) approach for retrieving users' learning contexts without the use of context-aware sensor technologies. The user's learning contexts are taken into consideration, as well as the learner's current situation and/or location. The suggestion mechanism framework makes recommendations for possible appropriate learning/studying materials for students, enabling them to perform under their current circumstances and location.

The purpose of this proactive approach is to reduce the number of interactions that users may be required to enter into the mobile device to inform about their current situation, whilst 'on the move'. The target users of this framework are university students. In particular, I wish to examine an appropriate set of suggestion rules for the Java programming language subject to be incorporated into this framework. This is so that students can have appropriate Java materials suggested to them based on their current learning contexts. The aim is to potentially enhance their learning experiences and increase their learning effectiveness, whilst learning Java 'on the move'. I envisage that careful consideration of which Java materials are appropriate for which situations, and recommending only those appropriate materials to learners for particular situations, can be beneficial for students in terms of their learning/studying. This argument is supported by Martin and Carro (2009), Cui and Bull (2005), and Becking *et al*. (2004) among others.

I decided to incorporate Java LOs from existing online repositories for use within my framework because there are a large number of existing high-quality reusable LOs available. I also conducted an exercise to locate available high-quality Java LOs, which can be feasibly incorporated into my framework (see chapter 8).

To help me examine these issues, I constructed a theoretical framework from an extensive literature review. Subsequently, I conducted two feasibility studies, an interview and diary study, relating to the framework to analyse their real potential, in terms of two perspectives – *pedagogical* and *usability*. Then I conducted two framework validation studies, a Java LOs experiment and an exercise to locate available high-quality LOs. Finally, I conducted a *technological* feasibility study in order to determine whether this framework can be potentially developed and implemented with the required components.

My research was conducted from an interdisciplinary approach, combining computer science and education. The aim was to bring together the three important design fundamentals (pedagogical, usability and technological) to form a well-designed pedagogical m-learning framework. The pedagogical and usability studies have helped us to determine a) the significant learning contexts that should be deployed within our framework, and b) a set of suggestion rules for recommending appropriate Java learning materials for different situations. The first validation study helped to gain user feedback on my framework about the appropriateness of the recommended Java learning materials for different situations as well as other resulting enhanced learning experiences or benefits and so on. The second validation study has helped me to visualise the potential number of Java LOs that can be deployed within the framework in order for a larger set of materials to be made available to learners. The refined requirements established via these studies are a contribution to the technological design and potential implementation of my framework, as presented in chapter 9.

The thesis was not focused on the technological use of mobile devices or an implementation of a mobile software application, but rather the pedagogical and usability design issues of a technologically-feasible m-learning framework. The two validation studies have helped to prove the realistic deployment thereof.

Chapter two presents a review of the literature on m-learning and describes it from the perspective of four succeeding generations – '*non-adaptive', 'learning-preferences'-based adaptive, 'learning contexts'-based adaptive and 'learning-contexts'-aware adaptive.* I distinguish and highlight the differences between these generations and provide related applications within these generations to illustrate the respective characteristics. The initiation of a '*context*' concept is explored and subsequently a '*learning context*' is derived for describing contexts with pedagogical attributes. I identify and analyse challenges associated with learning contexts including difficulties in retrieving them. Current context-aware m-learning research primarily focuses on the technological and usability perspectives; there is a lack of studies which focus on the pedagogical aspect. I have further classified the applications of the latter *'learning-contexts'-aware adaptive* generation into three different types of learning applications - *context-aware location independent learning* applications, *context-aware location dependent learning* applications and *context-aware situated learning* applications. The chapter concludes with a range of methodologies and approaches which can be adopted for the evaluation of m-learning applications. Each of these approaches focuses on the evaluation of one of the three following aspects - *pedagogical, usability* and *technological*. Furthermore, difficulties and challenges of evaluating m-learning applications are described.

Chapter three explains the research methodology I adopted to tackle the design of a proactive context-aware m-learning framework which acts as a suggestion mechanism to recommend appropriate materials to students in different situations. Central to the thesis is the derivation of a theoretical framework based on an extensive literature review and research findings – called *mCALS* (mobile context-aware learning schedule) framework. The design of this framework comprises the use of the student's learning schedule (i.e. electronic diary) integrated in the mobile device to retrieve their location and available time contexts. The process of the framework derivation forms the first section of this chapter and is the first phase of the research methodology. To examine the potential feasibility of the framework, the methodology adopted includes *a pedagogical, usability, technological* and *two validation studies*. Our chosen research methodologies are influenced by the difficulties and challenges in evaluating m-learning, as described in 2.8. The rationales for conducting these studies are described in the subsequent sections of this chapter. The *pedagogical* study uses an interview methodology to ascertain from the qualitative perspective and the *usability* study consists of a diary study to determine from the quantitative perspective the following three aspects - 1) The potential deployment of a learning schedule for retrieving learning contexts; 2) The significance of the proposed learning contexts to be deployed within a context-aware suggestion mechanism; 3) A set of suggestion rules to recommend appropriate Java learning materials to learners studying in different circumstances. Subsequently, the procedures in which I conducted the two validation studies are described in detail. Finally, the *technological* study consists of a technical framework design to illustrate an implementation of whether it is technically feasible at the present time. The final requirements of the framework are elicited from the data analyses of the pedagogical and usability studies to form the final technical framework design. The validity and reliability of these research methodologies, together with the data collection and analysis methods are explained in the relevant sections of this chapter.

Chapter four illustrates the derivation of the theoretical mCALS framework. The intended functions of this framework are demonstrated with a set of scenarios concerning four different Java-learning students. The proposed contributions resulting from this framework are discussed in the context of related works. Five research questions are addressed in this chapter, from a theoretical perspective.

4A: Can a proactive approach for the retrieval of learning contexts without the use of sensor technologies be incorporated into a suggestion mechanism?

4B: Which learning contexts are significant in the recommendation of appropriate learning materials?

4C: Which types of learning materials are appropriate for recommendation to students under different circumstances?

4D: What are the design modules of the framework?

4E: What are the user requirements of the framework?

Chapter five presents the data analysis relating to the potential adoption of a learning schedule for retrieving learning contexts. This data analysis is derived from both the interview and diary studies. Three main research questions are addressed in this chapter, from the qualitative and quantitative perspectives respectively.

*5A: How feasible is the adoption of a learning schedule for retrieving learning contexts from a **qualitative** perspective?*

*5B: How feasible is the adoption of a learning schedule for retrieving learning contexts from a **quantitative** perspective?*

- *Can users plan their schedule ahead, conform to it and keep it up-to-date?*
- *Can the location and available time be accurately retrieved from the learner's diary?*

5C: How do participants view the use of mobile devices as a learning tool?

Chapter six presents the data analysis relating to a) the significance of the proposed learning contexts (in chapter 4) to be used within a context-aware suggestion mechanism, and b) the possible recommendations of appropriate learning materials for different circumstances, i.e. a set of suggestion rules. The data obtained from the interview and diary studies is analysed and presented from the qualitative and quantitative perspectives respectively. We also describe the refined user requirements of the framework, based on these results. Four research questions are addressed in this chapter. Significance is in terms of how much the learning is affected.

*6A: How significant are the proposed learning contexts, which are to be used within a context-aware suggestion mechanism, from a **qualitative** perspective?*

*6B: How significant are the proposed learning contexts, which are to be used within a context-aware suggestion mechanism, from a **quantitative** perspective?*

6C: Can a set of suggestion rules be derived for recommending appropriate Java learning materials to students based on their situation?

6D: What are the refined user requirements of the framework?

I conducted data triangulation of the study results of chapters five and six in order to strengthen the integrity of my results. The data triangulation is presented in 3.7.

Chapter seven presents the data analyses of the first validation study of the framework. I constructed a suggestion mechanism which students can access online from any computer machine. At the beginning of the learning session, students are asked to choose their current motivation level, their available time and their Java proficiency level. A number of LOs which are thought to be appropriate for students situated within these contexts are presented and the student may choose one to learn/study with. After the student has completed the learning object, they are asked to complete a questionnaire/feedback form to provide their opinions about their learning experiences. Two main research questions are addressed in this chapter, as follows:

7A: Is the proposed set of suggestion rules appropriate for use within my context-based suggestion mechanism framework?

- *How useful had students found the study of learning objects in the proposed contexts?*
- *Were their learning experiences of the LOs more enjoyable as a result of studying the objects in the proposed learning contexts?*
- *How appropriate were the suggestion rules for recommending Java LOs to students?*

7B: What were the reasons that students chose particular time slots to study in?

Chapter eight presents the data analyses of the second validation study of my framework. In this chapter, I investigate the possibility of integrating a larger quantity of high-quality and reusable LOs into the framework. One research question is addressed in this chapter.

8A: Which Java LOs in the public domain are high-quality and reusable and can be incorporated into the framework?

The refined framework and final requirements are illustrated in chapter nine. A software engineering design approach is adopted to demonstrate the technical feasibility of the framework using current mobile and context-aware technologies. Six research questions are addressed, from a technical perspective.

9A: Can the proactive learning contexts retrieval approach be implemented?

9B: Can the framework be strengthened?

9C: Can users' learning contexts be incorporated into the framework design?

9D: How can m-LOs be incorporated into the framework design?

9E: Can a set of suggestion rules be incorporated?

9F: What are the system architecture and configuration of the final framework?

In chapter ten, I conclude the thesis with recommendations for future work. Then my research contributions and a discussion summarising how the research questions are addressed in the thesis are presented. Finally, limitations of the research work are discussed.

1.5 Publications in relation with the thesis content

My thesis has gained the endorsement of the mobile learning research community. The list of publications in the Declaration on pages xi-xiii is evidence that my thesis work has been accepted for publication by peer review. All of the publications are co-authored with my supervisor; however, the research conducted is my own original work. This section lists where the content of these publications relates to the content of the thesis, as follows:

- Publication A in the Declaration describes the four m-learning generations composed in the literature review as presented in 2.1 to 2.6 of the thesis and the main qualitative interview study data results related to the framework, as presented in 5.1, 5.3 and 6.1.
- Publication B describes the personalized m-learning application presented in 10.1.2.
- Publication C describes the validation study for validation of the suggestion rules for Java learning materials in mCALS, as presented in chapter 7.
- Publication D describes the proposal of an m-learning preferences model, as presented in 10.1.1.
- Publications E and F describe the quantitative diary study data results related to the framework, as presented in 5.2 and 6.2 to 6.5.
- Publication G describes the mCALS framework as a self-regulated learning approach, as presented in 4.2 and parts of 4.5.

- Publication H describes the research methodology, overall challenges of evaluating the mCALS framework and the lessons learnt. These were presented in parts of chapter 3.
- Publication I describes the mCALS framework as a support for self-regulated learners, as presented in 4.2 and 5.3.
- Publications J, K and L describe the conceptual and architectural design of the mCALS framework in its preliminary stages.
- Publication M describes the relationship mappings between the Dunn & Dunn model and the contexts models, as presented in parts of 4.5.

Chapter 2

Literature Review

In this chapter, I present a detailed literature review of m-learning applications, forming the majority of this chapter, i.e. from 2.1 to 2.7. An introduction of the four different *m-learning generations*, which I have classified from a review of past and present m-learning applications, is provided in 2.1. The four generations are '*non-adaptive*', '*learning-preferences'-based adaptive*, '*learning contexts'-based adaptive* and '*learning-contexts'-aware adaptive*. These are described in 2.2, 2.3, 2.5 and 2.6 respectively. Learning contexts are used to aid the design of m-learning applications in the subsequent generations; these are described in 2.4. My mCALS framework lies between the '*learning contexts'-based adaptive* and '*learning-contexts'-aware adaptive*, dependent on whether the proactive learning schedule approach can be successfully adopted in the framework for the retrieval of users' learning contexts. Study results on this are presented in chapter 5.

Learning theories which have been incorporated into the design of m-learning applications are discussed, where appropriate. Additionally, four different types of m-learning (or non-mobile) applications are included in 2.7. These are 1) m-learning organizer applications, 2) self-regulated learning applications, 3) Java-learning applications, and 4) LOs applications. All are related to the framework in one aspect or another. Further details are provided in 2.7.

In section 2.8 of this chapter, *evaluation methods for m-learning applications* are presented. In 2.9, I provide a brief review on the psychology of the learning process. Finally, a summary of the chapter is presented in 2.10.

2.1 Introduction to the m-learning generations

This section presents a literature review relating to the design, development and application of both completed and ongoing m-learning research and studies. Much research has been conducted and is ongoing by researchers in this field to expand and advance pedagogical m-learning. A decade ago, the m-learning research paradigm was new, with some projects having succeeded whereas others failed. Numerous lessons were learnt within the m-learning community through these project experiences. At the present time, most researchers are aware that an m-learning application should comprise pedagogical components, and also that usability considerations should be addressed. Most researchers are aware of the limitations and disadvantages of using mobile devices for learning and attempt to compensate for these factors with additional pedagogical values of using mobile devices for learning/studying (Parsons *et al.*, 2006).

As a result of ongoing m-learning research, I propose a classification of four m-learning generations, which encompass the different varieties of m-learning research and applications that researchers and developers had aimed to develop and construct. The emergence of these generations was a result of the attempts to a) overcome challenges within the m-learning field and b) include additional pedagogical components within m-learning applications.

A review of the past and present m-learning applications revealed four different varieties of applications, which I have classified into '*non-adaptive*', '*learning-preferences'-based adaptive, 'learning contexts'-based adaptive* and *'learning-contexts'-aware adaptive*, hence forming the four so-called "generations" of m-learning. These are described in 2.2, 2.3, 2.5 and 2.6 respectively. In 2.4.2, the notion of a '*learning context*' is described prior to introduction of the latter two generations, which deploy learning contexts in their m-learning applications. Characteristics of these generations are described, and example applications are given. Challenges and difficulties relating to various aspects within these generations have also emerged and these are discussed in the relevant sections.

2.2 The non-adaptive m-learning generation

Some of the initial m-learning applications from this first m-learning generation were built centred on transferring existing electronic learning (e-learning) materials onto mobile devices to enable portability of these learning materials. Thereafter, it was recognised that the format that e-learning materials were in may not be compatible with the format required for materials to be viewed on a mobile device, in terms of their size, font, quality and scope (Becking *et al*., 2004); these are also technological constraints of m-learning. Whilst some materials met the minimum requirements of being m-learning materials, others did not due to, for example, not fitting onto screens appropriately, or requiring too much scrolling. The learning content in the subsequent applications within this generation was adapted more appropriately to be sufficiently deployable on mobile devices for learning.

A common characteristic of applications within this generation was that the learning content viewed by learners was generic. This is known as the '*one-size-fits-all*' approach and denotes that personalisation of learning content was not applied in any way, such as, in terms of learning preferences or learning contexts. The main focus of these applications was on

a. providing learning content in a mobile format which can be accessed irrespective of location and time,
b. facilitating portability of learning content where the use of desktop and/or laptop computers was inconvenient or impractical, and/or
c. allowing communication via portable devices to enable collaborative learning between teachers and/or peers situated in different locations.

Example applications are given below.

- To facilitate learners in carrying out exam revisions anytime, anywhere, revision materials on desktop computers were synchronised onto a PDA (Bull and Reid, 2004). This is also known as individual and/or independent learning.
- An application which can be used on a PDA was designed to act as a guided tour tool in the Tate Modern museum (Proctor and Burton, 2004).
- A language and cultural mobile application was developed for foreign students to learn the local language and to help minimise ‘culture shock’ before or when they went abroad to study (Maniar & Bennett, 2007).
- Collaborative learning was enabled between students located on a field trip and their classroom-based peers via the use of PDAs (Hine *et al.*, 2004).

Many of the implications of m-learning between individual and collaborative learning were described by Moura and Carvalho (2008).

2.3 The ‘learners-preferences’-based adaptive m-learning generation

“M-learning is causing educators to rethink how learning happens and how specific learning needs and styles are expanded and enabled with multifunctional hand-held devices” (Valentine, 2004).

The main aspect which was present within applications of this generation and absent in the previous generation was that an *adaptive learning mechanism* was contained within applications of this generation. This mechanism specifies the personalisation of learning content (for use on mobile devices) for individual learners according to their learning preferences. Learning preferences encompass all of the specific ways in which a student prefers to learn or study, including

- *LS* – students' preferred styles of learning, (discussed in 2.3.1),
- *learning strategies* – students' preferred strategies for learning, and
- *learning characteristics* – related to the personality of a learner and how these may affect the way they prefer to learn. These characteristics may include levels of motivation, background, strengths and weaknesses, interests, ambitions, and sense of responsibility. For example, a conscientious learner may want more detailed learning materials than a non-conscientious learner.

The aims of these applications were to a) move towards delivering personalised and user-centred learning content to learners and b) enhance the learning quality and experiences that may be given to users by matching the content to students' learning preferences (Laouris & Etekleous, 2005b). It was argued that additional pedagogical benefits result for learners a) by presenting learners with learning materials which are consistent with the learners' preferences or characteristics and/or b) when the material structure and content suited the students' LS. These benefits include more effective understanding of learning concepts and simpler acquisition or absorption of learning content (Riding, 1996). For example, active students may learn and/or achieve more when attempting hands-on exercises than if reading lecture notes passively.

The concept of *adaptive learning* is important within e-learning or web-based education. This is because much generic learning content has been developed and might not cater to the needs of individual learners. It is argued that a pedagogically-effective application should consist of materials which can be used by different students with various kinds of LS. Different adaptive learning courses can also be constructed to provide additional help to students with visual or physical handicaps, for example (Muir, 2001). In particular, distance learning students may benefit most from a personalised application (or learning materials) for the following two reasons.

1. Distance learning students are physically situated away from their educational institution and usually work independently. Intelligent customisation of learning materials may result in these students a) acquiring a higher level of understanding of their course, b) becoming more motivated to learn/study, and c) achieving better learning experiences and/or quality.
2. The participants in a distance learning course may constitute a more diverse range of enrolled students. For example, there may be large differences in age, educational background, family commitments and responsibilities, proficiency levels, learning needs and requirements. A generic learning course may not be sufficient in meeting the learning goals of the different participants. Therefore, an adaptive learning course is essential in this regard (Meisalo *et al*., 2002).

The personalisation of e-learning materials (or similarly m-learning materials) requires less effort than the personalisation of traditional learning materials such as textbooks and lecture notes. This is because once the fundamental content or materials have been electronically developed similar content can be built thereon to be directed at students with different learning preferences (Muir, 2001). Similarly, adaptive m-learning is important because of a) the technological limitations of mobile devices, and b) possible interruptions and/or distractions in different locations where mobile devices are used for learning/studying may possibly result in lower levels of concentration. Related works include an adaptive m-learning application which adapts learning content according to the students' LS (Park, 2005).

In the development of a '*learning-preferences*'-based adaptive m-learning application, four typical stages are involved, as follows.

1. A learning preference to be taken into consideration for the application is determined. There are different reasons why a particular learning preference (or a particular preference/style within a LS model) may be selected for deployment. For example, the range of LS according to the Felder and Silverman LS model (Felder and Silverman, 1988) may be deployed by an application due to the flexibility of describing learners on a spectrum within four categories.
2. A variety of learning materials appropriate for users with the different learning preferences/styles, as determined in (1), are developed and/or incorporated into the m-learning application.
3. Each learner's learning preference/style is established prior to the use of the application. There are two typical ways of detecting a learner's LS - a) by asking them to complete a learning style questionnaire which will determine the LS they have (or approximately have), or b) if a learner is already aware of their LS, they can simply enter this information into the application. There are web-based systems which directly request LS information using the Index of LS questionnaire (Felder and Silverman, 1988) from learners such as in Paredes and Rodriquez (2004). Similarly, there are systems which

automatically detect the learners' LS uses, for example, Bayesian Networks (Garcia *et al*., 2005).

4. An adaptation process is performed to select appropriate learning materials to match learners with their specific type of learning preferences/styles. The sequencing of materials into the application can also be adapted and personalised to suit the users' learning preferences (Sampson *et al*., 2002).

In 2.3.1, I further explore the concept of a 'learning style' including its definitions and their classification categories. Two LS models are explored - 'Dunn and Dunn' and 'Felder and Silverman'. I have chosen to describe the 'Dunn and Dunn' model because this model comprises components formed under the three main learning style categories. An overview of different LS is presented by exploring this model. Felder and Silverman's learning style model is more frequently used within adaptive learning and m-learning applications such as in Park (2005) and Graf (2007), and therefore is also included in the discussion.

2.3.1 The concept of a 'learning style'

The concept of a '*learning style*' was initially introduced by educationalists as a "description of the attitudes and behaviours that determine our preferred way of learning" (Honey, 2001). Keefe (1979) defined a learning style as "the composite of characteristic cognitive, affective and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment". Different approaches to studying (i.e. *deep, surface* or *strategic*) are also classified as LS. A '*deep*' learner is described as one who uses analytical skills to gain a thorough understanding of a given topic. A '*surface*' learner is described as one who learns materials by memory in order to, for example, pass an exam and does not try to gain a thorough understanding. A '*strategic*' learner may use both approaches, i.e. analytical skills to learn, or learn by memory, where they feel necessary to gain a thorough understanding of a given topic and/or to pass an exam.

There are three main LS categories: 1) *Instructional and Environmental Learning Preferences,* 2) *Information Processing Learning Preferences* and 3) *Personality Related Learning Preferences* (Curry, 1987). Many learning style models are classified into the second category, for example, the Felder and Silverman model (Felder and Silverman, 1988), Gardner's Multiple Intelligences (Gardner, 1993), Kolb's Learning Style Theory (Kolb, 1984) and Myers-Briggs Type Indicator (Briggs and Myers, 1977). The Dunn and Dunn LS model (Dunn and Dunn, 1978) consists of five components which are formed under the above three categories. Table 2.1 lists the components along with their factors.

Table 2.1: The Dunn and Dunn LS model

Categories	**Components**	**Factors**
Instructional & environmental	*Environmental*	Sound/Noise Level, Temperature, Light, Seating, Layout of Room/Location
Personality related	*Emotional*	Motivation, Degree of Responsibility, Persistence and Need for Structure
Information processing	*Physiological*	Modality Preferences, i.e. for visual, auditory, kinaesthetic/tactile learning, Intake (Food and Drink), Time of Day, Mobility
Personality related	*Sociological*	Learning Groups, Help/Support from authoring figures, working alone/with peers, motivation from parent/teacher
Personality related	*Psychological*	Anxious/Depressed, Somatic Complaints, Aggressive Behaviour, Attention Problems, Thought Problems, Delinquent Behaviour (Cheats, Lies, Play Truant), Social Problems

The Felder and Silverman model (Felder and Silverman, 1988) is formed under the Information and Processing learning preferences category and distinguishes learning preferences of learners based on the following four dimensions - (1) Active/Reflective, (2) Sensing/Intuitive, (3) Visual/Verbal, and (4) Sequential/Global, as shown in Table 2.2. Each dimension can be represented as a spectrum consisting of values from 1 to 10. This model is based on tendencies implying that learners can sometimes act differently if they have a high preference for certain behaviour, within a particular dimension. For example, active learners may prefer testing and experimenting and the use of exercises and tests would be ideal for them; whereas for reflective learners, they may prefer to read materials and therefore content containing objects and examples would be appropriate (Graf and Kinshuk, 2006; Graf, 2007).

Table 2.2: The Felder and Silverman LS model

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

Note that various learning style models may describe a learner's LS in different ways. Some describe LS as fixed qualities that a learner has, for example, a learner may be an absolute visual learner and not a verbal learner.

According to Stern (2004), not many studies have concentrated on matching LS with particular technologies to enhance a student's learning experiences. M-learning has potential for providing a mechanism where each learner has their own individualised learning process. A web-based intelligent tutoring architecture developed by Kinshuk and Lin (2004) consists of a *student module, tutorial module, learning style analysis module* and *access device analysis module.* The learning style analysis module, using the Felder-Silverman learning style theory (Felder and Silverman, 1988), handles the students' LS and communicates with the student module. The access device analysis module identifies the type of device that the student is using and sends this information to the tutorial module. Based on the student module and access device type, the tutorial module generates individualised learning content for the student.

A number of adaptive web-based learning environments where students are presented with their individualised learning paths based on their preferred LS have been identified. However, at the time of writing, these have not made available or developed into a mobile learning application (Kinshuk and Lin, 2004). In recent years, research into and implementations of adaptive mobile learning have increased significantly. Example applications include Jung *et al*. (2006) and Guo *et al*. (2008).

2.4 Contexts and learning contexts

This section provides background information concerning the origination of a 'context' and subsequently a 'learning context', described in 2.4.1 and 2.4.2 respectively. In 2.4.3, I describe the deployment of learning contexts within m-learning applications. Finally in 2.4.4, the challenges relating to this deployment are explained.

2.4.1 The concept of a 'context'

It was in the field of context-aware mobile computing that the concept of a context was first delivered. Several authors' definitions of a context from various perspectives were assembled by Dey and Abowd (1999). These definitions were divided into the following.

a. Contexts relating to the user's environment concerning the user situation, which the user's computer or mobile device is aware of. These include users' attributes such as their emotional state, focus of attention, social and informational state.
b. Contexts relating to the application's environment, surroundings, settings or states, or the environment as a whole relating to aspects of the current situation.

Attributes of these contexts which are common within the two categories of definitions include location, time of day, season, temperature, identities of people and objects around the user and changes to these identities. Additionally, two classification systems of contexts were proposed. The first is by Schilit *et al*. (1994) and Chen and Kotz (2000), which contains four categories of contexts, and the second is by Schmidt *et al*. (1998), which contains two categories from the two different perspectives. The first is as follows.

1. Computing context – such as network connectivity, communication costs and bandwidth, nearby resources such as printers, displays and workstations.
2. User context – such as the user profile, location, people nearby and current social situation.
3. Physical context – such as lighting, noise levels, traffic conditions and temperature.
4. Time context – such as time of day, week, month and season of year.

The computing, user and physical contexts can be recorded across a time span to form a context history, which could be useful for certain applications. For example, if the user's calendar was known, as well as the current location and time, the application may have an accurate idea of the user's social situation (such as being in a meeting or having lunch).

The second classification system is as follows.

1. Human factors –
    - User – personal habits, mental state, etc.
    - Social environment – proximity of other people, social relations, collaboration
    - Task – goal directed activities or more general objectives
2. Physical environment – location
    - Infrastructure – interactive and computing environment
    - Conditions – level of noise, brightness, fixed vs. changeable conditions

The deployment of contexts enables applications to be developed to facilitate certain services appropriate to different values of the contexts. For example, directions to a location can be given to a user if the user's current and destination locations are known to the application. A concise summary of context has been provided by Dey and Abowd (1999), which was identified in an attempt to simplify the task of specifying contexts for a given application scenario for application developers:

> "Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves".

2.4.2 The concept of a 'learning context'

A 'learning context' is derived from a context; a learning context may also be a context and vice versa. The main difference between the two is that a learning context is used to define and describe pedagogical components which are incorporated into the design of m-learning applications to facilitate m-learning services/activities. General learning applications (such as e-learning) and services/activities can also deploy learning contexts into their applications for providing appropriate services/activities based on contexts' values. The two subsequent m-learning generations which deploy learning contexts are described in 2.5 and 2.6, respectively.

An encompassing definition of a learning context is the circumstances or conditions that surround the learning (Basaeed *et al.*, 2007). Learning contexts may include any conditions "which affect the learner's learning service discovery and access such as learner's profiles and preferences, network channels and devices the learners are using to connect to the Web etc" (Yang and Chen, 2006). Similar to contexts, learning contexts can be divided as the perspective which surrounds the user and one which surrounds the application. This view was shared by Prekop and Burnet

(2003) who divided learning contexts as *internal* (surrounds the user), and *external* (surrounds the application) dimensions, as follows.

1. The internal dimensions included
   - *human factors* such as users (emotional/physical state, personal events, beliefs, and previous experiences), and
   - *social environment* (work context, business processes, communication), and *activities* (goals, tasks).
2. The external dimensions included
   - the *physical environment* (light, sound, movement, touch, acceleration, temperature, air pressure, proximity to other objects, time),
   - *infrastructure,*
   - *location*, and
   - *technological features* (device and product design).

The following learning contexts can be classified into the internal dimension - *activeness of a student according to the time of day* (Bhaskar and Govindarajulu, 2008), *mood* and *motivation* (Ting, 2005) and *concentration level of a student* (Cui and Bull, 2005). The *frequency of interruption level at a location* (Ibid) can be classified into the external dimension.

A classification system has been proposed by Wang (2004), which consists of six categories of learning contexts. Collectively these form the '*context space'*, as shown in Table 2.3. The six dimensions are *identity, spatio-temporal, facility, activity, learner and community*. *Identity* refers to that of the unique learner such as their login. *Spatio-temporal* refers to the time and location of the learning process taking place. *Facility* describes the type of mobile device being used for the learning process, and which type of wired/wireless network is available for connectivity. *Activity* describes the learning activity taking place – such as individual or collaborative. The *Learner* dimension describes the learner characteristics such as their LS and knowledge level. The sixth dimension – the *Community* – describes the social interactions between participants, if any. This context space may help researchers and developers to conceptualise what the range of learning contexts may constitute and how they may be utilized for providing different, effective m-learning applications.

Table 2.3: Wang's six dimensions of contexts in mobile learning

Dimension	**Explanation**
Identity	Unique identifier of each learner, recognized usually via a login system, or through special devices such as smart cards.
Spatio-Temporal	This consists of *Time* and *Location*. The time can be obtained through the clock on the mobile device and the location can be provided through a locating sensor such as Global Positioning System (GPS). Knowing these two elements allows for indication of an instant or period during which some information will be required by a user. Applications which deploy this dimension include the PDA guided tour in museums such as the Nottingham Castle museum gallery (Lonsdale *et al*., 2005).
Facility	This consists of the type of mobile device, such as PDA, mobile phone, smart phone, tablet PC, laptop; and the capabilities of the devices such as the CPU power, display size, colour resolution and input method. Learning materials can be adapted to the mobile device accordingly.
Activity	Detecting and determining an appropriate set of activities for a learning process may be difficult. Ways to obtain this context include using discussion records online, or by viewing live actions occurring in classrooms, or acquired by web actions that are portfolios of the student's access log.
Learner	This consists of the intrinsic and psychological properties of a learner which are important for learning successfully, such as the learner's emotional state, focus of attention and background; however, not easy to detect.
Community	This is the social context and can be complex due to the status and interactions among members of the community. Different learning activities can be connected across time, place, school, home and expertise, and each learner's role can be dynamic among the participants.

Basaeed *et al.* (2007) have also categorised learning contexts in a similar way as in the context space of Wang (2004). Their categorisation consists of three categories - *learner*, *device* and *connectivity*. Additional learning contexts extending from Wang's (2004) context space are incorporated. This includes from the learner category *learning-related information* (such as current and previous learning sessions) and *personal preferences* (such as preferred multimedia presentation and preferred content length and depth). The preferred content length was noted as having potential importance to students where they are required to pay for their own connectivity costs. The device and connectivity categories are mirrored in the *facility* dimension in the context space of Wang (2004).

A different view of a learning context can be portrayed by describing it in terms of the learning settings in an m-learning environment. These settings are dynamic in an environment where m-learning takes place because learning contexts are subject to frequent and rapid changes, for example, when learners move between locations, encountering different peers and services/resources (Chan *et al.*, 2004). In this viewpoint, each instantiation of settings is a set of learning contexts (Wang, 2004). In a similar manner, a learning context can be viewed as a *situation* and defined as a "complex of environmental and intentional constraints in a given mobile learning setting" (Becking *et al.*, 2004). From the viewpoint of m-learning activities, five categories of activities associated with the following five learning contexts were classified (Frohberg, 2006) - *free, formalised, digital, physical* and *informal*.

1. *Free context activities* – learning contexts are not considered as relevant for these m-learning activities. More precisely, for example, the location of the learner performing an activity is irrelevant to the actual task, such as doing an

interactive quiz on a bus, beach or in a café; there is no relation or relevance between the location and the task.

2. *Formalised context activities* – these are activities which take place within an educational institution such as in a classroom, lecture hall, auditorium, seminar room or library, possibly also in virtual classrooms or lecture theatres.
3. *Digital context activities* – these are activities conducted on a computer or mobile device. Two typical attributes of these activities include that a) teachers usually have full control of the learning environment and b) the computer acts as a playground for learners where they may participate in learning by simulations. For example, the Savannah project (Facer *et al*., 2004) allows children to learn about animal survival by simulating different animals and acting out their roles.
4. *Physical context activities* – these activities contain elements of the digital context activities with the addition that these activities take place in the same physical space and/or context in which the learning or activity is applied, i.e. situated learning. For example, learning about real butterflies may be supported by the use of mobile devices giving additional information to learners regarding these objects (Chen *et al*., 2004).
5. *Informal context activities* – these activities support everyday learning, i.e. within a non-formal curriculum.

With the exception of the physical context activities which actually deploy the use of learning contexts, the remaining four categories do not make use of them. Nonetheless, they are called free context, formalised context, digital context and informal context activities. The reason that the word *context* was used for these activities is primarily due to the literal meaning of the word context, and is not related to the description of learning contexts discussed in this section.

2.4.3 Deployment of learning contexts within m-learning applications

The deployment of learning contexts within m-learning applications is not a straight-forward process. There are several considerations which need to be addressed as well as many challenges which are faced in this process. The advantages and challenges are discussed in 2.4.4. The process of deployment involves three stages – a) retrieval of learning contexts, b) determining *whether or not* an action is to be performed, and c) determining *in which approach* an action is to be performed. These are described below.

1. In order for learning contexts to be deployable within an m-learning application, a method of retrieval of learning contexts is required to be in place. There are two types of retrieval methods – *interactive* and *proactive*, also known as non-automatic and automatic. *Interactive* applications directly issue requests to the users to input information about their learning contexts. This may interfere with what the user is doing at the time of request, and it may also take additional time and effort for them to enter these values. Proactive applications automatically retrieve this information via sensor and/or location-tracking technologies such as the use of GPS technologies (Jones and Brown, 2002). The elimination of the need to input values aims to provide ease of use and convenience to users. I have classified interactive m-learning applications into the *'learning-contexts'-based adaptive* generation, which is discussed in

2.5. Proactive applications are classified into the *‘learning-contexts’-aware adaptive* generation, and discussed in 2.6.

2. Once the information is obtained from the retrieved learning contexts, the application determines whether or not an action should be performed. These actions can be either *active* or *passive,* and the learning contexts which are associated with these actions are known as active and passive contexts, respectively. An *active* context directly influences the behaviours of an application. For example, the handheld learning organiser automatically detects whether requested library books are available when the user walks past the library (Ryu *et al*., 2007). A passive context is retrieved by the system but may not necessarily provoke an action to be performed. For example, in Martin *et al*.’s (2006a) adaptation mechanism, when an activity becomes available, their alert module determines whether or not to interrupt the user. The user is only interrupted when an activity of a higher priority becomes available; otherwise the user is not interrupted at that time.

   An application is said to be context-aware if it can detect and become aware of contexts using sensor technologies and without the user having to provide this information, i.e. a proactive application. In a similar sense, an active context-aware application is one which “automatically adapts to discovered context, by changing the application’s behaviour” (Chen & Kotz, 2000) with or without the user being aware of these changes. A passive context-aware application is one which “*presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later*” (Ibid). This means that no changes to the application would take place without the acknowledgement or consent of the user.

3. Once it has been determined that an action should be performed, there are different approaches for this action to be performed. Five different methods are described - *proximate selection, automatic contextual reconfiguration, context information and commands*, *context-triggered actions* (Schilit *et al*., 1994) and *contextual event notification* (Wang, 2004). One or more of the following methods can be deployed to facilitate certain activities/services in an m-learning application, dependent on the aim and purpose.
    a. Proximate selection, also known as context restriction, is a user interface technique for making it easier to emphasize or select objects located nearby. For example, an application can use this technique to automatically identify a user's nearest printer by knowing the location of the user and identifying the nearest printer.
    b. Automatic contextual reconfiguration is a technique performed when the values of certain contexts change and results in components being added, removed or altered. Referring to the previous example, if the user moves outside of the range of the nearest printer, that printer is removed from the application as being the nearest.
    c. Contextual information and commands produce different results (such as on the users' screen displays) based on the associated context states which may inform the demands, wants and/or desires of the users. For example, if a user moves to a different location (such as to the library), the browser may change the displayed directory to correspond to the user's location (for example, by providing information about the library).
    d. Context-triggered actions are simple *IF-THEN* rules used for specifying the adaptations of context-aware systems. For example, *if* the user is in a

meeting in location A, *then* alert the user of relevant meeting notes (Schilit *et al*., 1994).

e. A method known as *contextual event notification* can be used to remind a user of their important events and/or deadlines through the information retrieved from the user's calendar.

In addition to the above approaches which can be deployed to facilitate certain activities/services, once it has been determined that an action should be performed, the following different adaptation strategies can be deployed, depending on whether it is the *interaction, service, content* and/or *environment* that should be adapted (Norros *et al*., 2003).

1. An application may *adapt the interaction* between the user and device. This is primarily achieved via the user interface. For example, if the application is aware that the user is a novice, a simpler interactive user interface can be presented to the user.
2. An application may *adapt the service*, for example providing customised services by recommending the user's favourite products, auto-filling in forms for users, and providing access to services related to the user's location.
3. An application may *adapt the content* which is relevant to the user's context, activities or interests.
4. An application may *adapt the environment* by altering the physical environment that the user is situated in to better suit their desires (e.g. music, lighting).

Each of the adaptation strategies, whether to adapt the interaction, service, content or environment, require a significant amount of work to be done on the original state to achieve the adapted state. The research on my framework is focused on the *suggestion of appropriate materials* to learners based on their contexts, rather than the *adaptation of materials* to their contexts. In particular, I am interested in the use of LOs in Java as the learning materials for the framework. A review of the availability of Java LOs in the public domain confirms that a large number of high-quality, reusable and editable Java LOs exist. These can be deployed in my framework. The validation study of Java LOs, in which this topic is further explored, is presented in chapter 8.

2.4.4 Advantages and challenges of deploying learning contexts

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

1. *Improve the learning/studying situation* – context-aware m-learning applications can enable real-time situated learning to take place in real physical environments and to increase the potential learning effectiveness (Basaeed *et al*., 2007). Some learning materials are not desirable for learners to learn/study with in some locations and circumstances. By filtering these out and selecting appropriate materials, learners can enhance their learning opportunities and productivity (Cui & Bull, 2005).
2. *Bringing convenience to the learner* – the aims of context-aware m-learning applications include a) enabling users to focus more on the learning materials or situation and less on the technology (Winters and Price, 2004) and b) eliminating the need for users to provide information to the system to save them time and effort (Schilit *et al*., 1994; Kaenampornpan and O'Neill, 2004).

Timely information can be provided to learners (such as in a museum) with minimal required effort. The output of the mobile device can be adapted to suit the current situation to bring additional benefits to learners whenever necessary, for example, adjusting font-size, volume, brightness, and privacy settings (Schmidt, 2000).

There are two main challenges relating to the deployment of learning contexts within m-learning applications – *difficulties in the detection and retrieval of learning contexts* and *the dynamic nature of learning contexts*.

1. There are difficulties in both the detection and retrieval of a learner's internal and external learning contexts; these are described below.

    - Detecting a user's *internal* contexts (such as their emotions, intentions and motivation) is a complex process which may involve attaching a number of wearable sensors onto users to retrieve readings. For example, a learner's facial expressions can be detected by machine vision algorithms and the learner's focus of learning can be detected by eye gaze shift. Both require complex analysis and may cause discomfort and inconvenience to users. The results may also not be entirely accurate (Schmidt, 2000; Wang, 2004).
    - Detecting a user's *external* contexts (such as location, noise level, and temperature) is a comparatively easier process. Current technologies being deployed for detecting a user's location include GPS, Radio Frequency Identification technology (RFID) and wireless and cellular network services (Ibid). GPS data may not always be very accurate and available – the signal is lost when users enter most buildings, with the location-detection sensor attached or built-in to their mobile devices (Marmasse and

Schmandt, 2000). RFID can only be operated by having a writer attached in the deployed locations and a reader attached to a mobile device, prior to usage. There are inaccuracy issues with both wireless and cellular network services (Wang, 2004). Users may also be concerned with their privacy and may not be comfortable with using location-tracking services (Synnes *et al.*, 2003).

2. The nature of both internal and external contexts is dynamic and may continually change resulting in different values of contexts in the same period of time or within the same location (Chan *et al*., 2004). For instance, if an application selects appropriate learning materials for a student based on the current noise level, what should the application do when it detects a change in this noise level during the learning session? To overcome this problem, a mechanism must be built-in to take into account the dynamic nature of contexts and to determine a) whether changes in contexts should provoke an action, and b) whether this action should be performed, and, if so, with or without acknowledgement/consent of the user. In other words, an application must be able to distinguish those context changes which should trigger new recommendations and those which it should record silently (Schmidt, 2005).

A recommendation process has been developed and includes a decision mechanism to determine whether users should be interrupted and alerted regarding newly available activities, whilst they are working on their current tasks (Martin *et al*., 2006a).

2.5 The 'learning-contexts'-based adaptive m-learning generation

The main difference between this generation and the previous two is that applications within this generation take into account users' learning contexts for determining which learning materials or activities students should be given to perform. The values of these learning contexts are requested by the application to be inputted by the user, i.e. an interactive method of retrieving contexts.

My mCALS suggestion mechanism framework is related to the foundations of these systems in this generation. This is because, like the other applications in this generation, there is common aim to suggest appropriate learning materials to students based on their situation. However, the suggestion mechanisms in this generation are not context-aware, and I wish to construct my framework so that it has context-aware capabilities in order to increase benefits for learners, such as to minimize the need for students to provide input to the mobile device whilst 'on the move'.

However, if the learning schedule proactive approach of my framework were to be unsuccessful, then my framework would be 'learning-context'-based (i.e. this generation), rather than 'learning-contexts'-aware (i.e. the next 'learning contexts'-aware adaptive generation). 'Learning-contexts'-aware adaptive applications are described in 2.6. Note that context-based applications only require an additional feature in order to be developed as context-aware. However, authors/developers may want to develop context-based applications instead of context-aware applications due to various reasons, some of which are discussed below.

Three main applications/research works included in this generation include TenseITS (Cui and Bull, 2005), CoMoLE (Martin and Carro, 2009) and didactic profiling (Becking *et al*., 2004); these are described below along with other miscellaneous suggestion mechanism applications/frameworks.

Cui and Bull's (2005) TenseITS application

This application focuses on providing English learning materials for Chinese students to learn in their available time. Four learning contexts are taken into consideration – *location, available time, concentration level* (at the beginning of the session) and *the frequency of interruption* (at that location). The learner's user model is also considered when learning materials are selected for students. The attributes of the user model include *their knowledge level*, *misconceptions of the English language* and *difficulties in learning the language*. The attributes of the user model are constructed continuously from the user during their interactions with the application. A similar system prototype (Bomsdorf, 2005) also selects appropriate materials for students based on the four learning contexts, a slight difference being the frequency of interruption replaced by frequency of disruption.

Cui and Bull (2005) pointed out two reasons why they employed an interactive multiple choice method, rather than deploying a proactive method by means of, for example, retrieval from the student's electronic diary. The first reason was that students often did not conform to their schedule as observed by their absence from lectures, so the information retrieved from their electronic diary may not be accurate if it was used for obtaining their available time and location information at a specific point in time. The second reason was that the authors' system was designed for use within short periods of time and primarily in-between other activities which students may not have recorded in their electronic diary, even if they had kept one. Therefore, the authors noted that the location may not be detected accurately because this was not recorded. Similarly, there was no way of inferring the learner's available time.

The application operates by first requesting the user to input the values of the four learning contexts, which are to be selected from multiple choice answers, before each learning session. A set of suggestion rules are built-in to the application to determine which learning materials are appropriate to learners based on the context values and their user model. Subsequently, learning materials are recommended to users when they wish to learn/study. This set of suggestion rules is described in 4.4, where I discuss the recommendation of learning materials appropriate for different contexts.

The future work of the authors includes extending their system “to other areas of English that Chinese students find difficult, for example: the use of articles” (Ibid), as well as for Russian or Arabic speakers, as these students may also have difficulties with tenses and articles, or other languages. Their system is particularly good for “[a]ny language or aspect of language that can be tested with multiple choice questions (because input on a handheld device is difficult), and where students commonly have difficulties, could be potentially useful” (Ibid).

The TenseITS prototype has not been evaluated and the authors noted that “the feasibility of extending the system in different areas and for different target groups, needs to [also] be tested” (Ibid). I contacted the author of this work to determine whether we could discuss this research further; however, the authors declined as they are no longer continuing with this work. No further work relating to this topic has been published since Cui and Bull (2005).

Martin and Carro (2009)’s CoMoLE suggestion mechanism

The CoMoLE suggestion mechanism has been designed for recommending appropriate learning activities to learners where the recommendation process is dependent on both the user's internal and external learning contexts. The user's internal contexts include the learner's profile (such as their LS, preferences and previous actions/interactions with the application). The user's external contexts include their location, available time and mobile devices used as well as devices available to them. It also takes into account the fact that users may use different physical devices (such as PCs, laptops, mobile phones and PDAs) and thus activities are adapted appropriately to the different device types. There is an option which, if appropriate, according to the user's learning contexts, would interrupt them and alert them to the availability of an activity. The system also allows collaborative activities between users to be performed. The system could accommodate both individual and collaborative learners. If the learner is conducting collaborative learning, then their partners' internal and external contexts are taken into consideration for the selection of appropriate materials.

A number of courses have been incorporated into the CoMoLE environment:

- A 'boolean algebra' course, which was described in Martin *et al*. (2007), describes how individual and collaborative activities are adapted or suggested to users based on the users' learning contexts and preferences. The types of activities include theoretical examples, interactive examples (simulations), individual tests and collaborative activities.
- Two subjects, "data structures" and "operating systems", were described in Martin and Carro (2009). These were used by students to learn/study with and also formed their two evaluative case studies. Different types of learning activities related to these subjects were included. Students could use different

devices such as PCs, laptops or PDAs to access and perform these learning activities. Results of the case studies are discussed together with the results of our Java LOs validation study in chapter 7.

Note: Most of the suggestion mechanisms need to be (at least in part) content-specific, as they have to be teaching something. These materials can be adapted or changeable in the system. This requirement normally exists to ensure that the quality of the content is sufficient, and an expert teacher is normally required to check the quality of the content.

Becking et al. (2004)'s didactic profiling framework

This didactic profiling framework is a generic standardized mechanism which can be deployed by researchers/developers. It defines a set of contexts that should be considered for determining the types of learning materials/activities for learners in different situations. It is centred on an inference engine and contains a set of filtering rules, which are based on learner profiles and the characterization of LOs. The learning contexts used within this mechanism are classified into the following four categories - *situation*, *learner*, *LOs,* and *participation*. However, exact details of the filtering rules for their inference engine were not presented.

1. The situation category contains *frequency of interference* (during a learning session), *available time* (scheduled or estimated), *equipment at disposal* (learning tools, aids, books, other learning materials which can be used in the situation) and *restriction of action and expression* (for example, restriction to read, write, listen or speak in that situation). The first two learning contexts were deployed in Cui and Bull's (2005) application.

2. The learner category includes *level of concentration/distraction* (self-evaluated ability to keep concentration despite environmental interferences), *previous knowledge relating to topic*, and *previous knowledge relating to technology*. The first two learning contexts were also deployed in Cui and Bull's (2005) application.
3. The LOs category includes *instructional goals* (standards appropriate for the conditions of mobile learning) and *learning content*.
4. The participation (also known as collaboration with peers) category includes *individual learning session* (self-paced or supported by tutor), *partner session* (working in groups of two students), *group session* (working in groups – self-organised or by teacher, informal or formal).

I also contacted these authors regarding the evaluation of their framework/system prototype; however, no replies were received.

Other miscellaneous frameworks/systems

- A system was developed by Cheverst *et al*. (2000) for tourists visiting the City of Lancaster, England, which took into consideration environmental contexts (such as the opening times of the city's attractions and the current time of day), which were relevant for creating a tailored tour and navigating a visitor around the city. The visitor's personal context information was also stored and used for adapting the visiting materials including the visitor's current location, personal profile (interests, preferred reading language, set of attractions already visited) and learning style (whether active/passive role).
- A situation-aware framework/mechanism has been developed by Bouzeghoub *et al*. (2007) that takes into consideration time, place, user knowledge, user

activity, user environment and device capacity for adaptation of learning resources to the user.

2.6 The 'learning-contexts'-aware adaptive m-learning generation

Applications from this generation are similar to those from the previous generation (i.e. the 'learning-contexts'-based adaptive generation) with the addition that applications from this generation are *proactive*, and are known as context-aware applications. This means that learning contexts are automatically retrieved without the users having to provide them. These applications are currently dominating the m-learning research field.

Eight out of the nine recent context-aware applications discussed in this section were developed in Japan or Taiwan. Reasons for this may be due to 1) more advanced technologies in these countries, and b) a higher motivation and willingness for teachers and students to use these technologies for learning.

Both context-aware m-learning and ubiquitous m-learning applications are centred on the idea of context-awareness and are branches of computer-supported learning (Wang, 2004). A ubiquitous m-learning application is one which focuses on "embedded and invisible computers in everyday life" (Ogata & Yano, 2004a). Its goal is to have a network of devices, people and situations ubiquitously available to facilitate learning experiences (Nino *et al*., 2007). Five attributes collectively characterise ubiquitous learning - *permanency, accessibility, immediacy, interactivity* and *situating of instructional activities* (Ogata and Yano, 2004a). Similarly, Hwang (2006) defines four characteristics (as well as benefits) of a ubiquitous learning environment, as follows.

1. It is context-aware.
2. Appropriate learning materials are selected to students at the right place and at the right time based on their internal and external learning contexts.
3. Learners are enabled to learn from place to place without lost or interrupted connection or communication to materials and/or with peers, anytime, anywhere.
4. Despite dissimilarities between various mobile devices, subject contents are adapted automatically to learners as appropriately as possible.

In the remainder of this section, I present a review of related context-aware m-learning applications. These are divided into three classifications – *location independent*, *location dependent* and *situated learning* applications, described in 2.6.1, 2.6.2 and 2.6.3 respectively – and Table 2.4 shows nine context-aware m-learning applications, labelled from A-I. If a context-based m-learning application is converted into context-aware, then it would fit into the first category of application – location independent, as it can be used independent of the location, unlike the second and third types – location dependent and situated learning. Note that my framework is also to some extent related to some of these applications.

Table 2.4: Related context-aware m-learning applications

Ref	Application Name	Application Type	Authors
A	*JAMIOLAS (Japan)*	Location independent	Ogata *et al*. (2006)
B	*English Vocabulary Learning (Taiwan)*	Location independent	Chen *et al*. (2007a)
C	*CLUE (Japan)*	Location independent	Ogata *et al*. (2004b)
D	*Learning Chinese at Taipei Underground (Taiwan)*	Location dependent	Chen & Chou (2007)
E	*JAPELAS (Japan)*	Location dependent	Ogata & Yano (2004a)
F	*TANGO (Japan)*	Location dependent	Ogata & Yano (2004a)
G	*Learning Reminder (New Zealand)*	Location dependent	(Ryu & Parsons, 2008)
H	*Butterfly-watching (Taiwan)*	Situated learning	Chen *et al*. (2004)
I	*Bird-watching (Taiwan)*	Situated learning	Chen *et al*. (2002)

2.6.1 Context-aware location independent m-learning applications

There are two common characteristics shared by applications in this category.

- The learning location can affect the selection of learning materials to students; however, the learning/studying activities conducted can be irrespective of the location chosen for them to be performed in.
- The focus of learning is content-specific (such as a language or a topic) and the materials are self-contained on the mobile device.

Application A - *JAMIOLAS* (Ogata *et al*., 2006) is a Japanese language learning application which aims to help foreign learners to recognise the subtle differences of the meaning of various phrases used often in Japan. These differences are difficult to be conveyed to students via traditional means of teaching because they are based on "senses such as hearing, vision, touch, taste, smell and spirit" (Ibid). For example, two different words are used to describe the situation when it is raining heavily as opposed to raining lightly. The differences are hard to distinguish without being able to hear the two different scenarios. Therefore, the aim of this application was to simulate these situations by providing to students additional senses which they can hear, see, touch, taste and smell. Referring to the above example, a visualisation with audio of the two scenarios is shown to students and then the corresponding Japanese impression or mimicry is given to them to learn. These constructed scenarios can enhance the students' abilities and effectiveness in learning and memorising the language via the additional multimedia. This is a context-aware application because the scenarios were built according to specific impressions which relate to specific situations of how they are being used. The application must be aware of each specific scenario in order to select the right words for students to learn.

Application B - *English Vocabulary Learning* (Chen *et al*., 2007a) is an English language learning application which selects relevant vocabulary based on three internal and external learning contexts respectively. These are the *learner's location*, *leisure learning time* (i.e. the physical point in time) and *individual abilities*. The aim was to increase the learner's interests in language learning and enhance their ability and performance in using and practicing the language with others. For example, Christmas vocabulary is displayed when the date is 25 December, and food/drinks vocabulary is displayed if the learner is in a restaurant.

Application C - *CLUE* (Ogata & Yano, 2004b) is a knowledge-awareness application which enables collaborative learning. It makes use of two community contexts - *the learner* and *other learners surrounding them* – in order to facilitate the learning process. The application is particularly aimed at helping distance learners to identify which learners are situated around them and what they know about different subjects/topics. This information is graphically displayed in a knowledge awareness map to enable them to seek help from one another and to find collaborative peers to learn/study with.

2.6.2 Context-aware location dependent m-learning applications

There are two common characteristics shared by applications in this category.

- The situation of learning may not necessarily be associated with a particular location; however, application deployment is restricted to being used in specific locations. Location sensor technologies are used (such as GPS or RFID).
- The focus of learning is content-specific and the scope of materials used for engaging with may range beyond the mobile devices to include learning from environment surroundings, for example.

Application D - *Learning Chinese at Taipei Underground* (Chen & Chou, 2007) is a Chinese language learning application which was developed for use within the Taipei underground system. RFID writer tags were attached to the various points in the underground stations and a learner used a PDA equipped with a RFID reader to access Chinese language dialogues. The aim was to enable foreign students to practice their use of Chinese in everyday life in real situations. The application shows that the users' dialogues enable them to hold conversations with the local staff or people. These conversations may include seeking information about the underground system and asking for directions for different amenities (such as a cinema, hospital, ticket office). These language materials were created in Macromedia Flash and were prepared by an expert language teacher.

Application E - *JAPELAS* (Ogata & Yano, 2004a) is a Japanese language learning application which was developed to teach foreign students different Japanese expressions used when talking to people a) of a different, higher or lower rank and b) in situations of different formality (distinguished by being in different types of meeting rooms). RFID writer tags were attached to different meeting rooms (in a particular building) to indicate the formality of that room. A learner, using a PDA equipped with a RFID reader, plays a role of a certain rank and together with the formality of the room, results in only appropriate expressions for that room and ranking being given to them on their PDA to practise with their peers. This is a simulated scenario for students to practice with each other the different Japanese expressions used in everyday life when talking to different people in different formalities.

Application F - *TANGO* (Ogata & Yano, 2004a) is an English language learning application which was originally designed for use within the authors' classroom in Japan. Physical objects (such as a remote control, table or chair) had been attached with RFID writer tags. A student uses a PDA equipped with a RFID reader reads the writer tags attached to the objects. The noun of that object is then displayed on the learner's device. The aim of this application was to enhance students' ability to learn and remember foreign words, whilst being able to simultaneously visualise the objects.

Application G - *Learning Reminder* (Ryu & Parsons, 2008) is an application which was used for supportive services, rather than for conducting actual learning/studying activities. The application has two main functions. First, it helps students to find their way to different locations on campus (such as lecture halls, library and seminar rooms). A GPS receiver in the device is used to track the locations of students and subsequently for finding directions to navigate them to their desired destinations. Second, when learners walk past particular points of interest on campus, relevant information may be given to them. For example, a book which has become available may be notified to the student as they walk past the library.

2.6.3 Context-aware situated learning m-learning applications

There are two common characteristics of applications in this category.

- These m-learning applications are designed to be used within physical environments to enable students to learn particular real-life concepts, topics or situations which are physically situated in these environments. This is known as *situated learning*; which can result in an enhancement and reinforcement of the student's learning process and/or their knowledge, and can often make the learning process much more interesting and enjoyable (Naismith *et al*., 2004).
- As mentioned, the focus of learning is usually on the real-life concepts and situations in the physical environment. The application is viewed as a support to give additional information to learners relating to these concepts and situations.

Application H – *Butterfly watching* (Chen *et al*., 2004) was designed to give students additional information on the real butterflies that they were watching in the butterfly farm. The application was designed so that when a student took a photograph of a butterfly with the built-in camera in their PDA, this photograph could be transmitted to the local server via wireless means. A technique was then applied to search for the most closely matched butterfly, based on the photo. Real-time information was sent back to the learner's device to provide them with information about these butterflies.

Application I - *Bird-watching* (Chen *et al*., 2002) functions in a similar way and was developed by the same authors.

Many of the '*learning-contexts'-based* and *'learning-contexts'-aware* m-learning applications have concentrated on providing appropriate content-specific learning materials to students based on their learning contexts. The term *content-specific* was used to refer to the content relating to a specific topic or language such as the following.

- The Maths subject - as developed in the work of Martin *et al*. (2006c), Zhao and Okamoto (2008).
- The English language - as developed in the works of Cui and Bull (2005), Chen *et al*. (2007a), Ogata *et al*. (2004b) and Wang (2002).
- The Japanese language – as developed in the works of Ogata and Yano (2004a) and Ogata *et al*. (2006).
- Topics relating to birds and butterflies respectively – as developed in the works of Chen *et al*. (2002) and Chen *et al*. (2004).

2.7 Other m-learning applications

In this section, I discuss other m-learning applications which are also related to my framework. These are a) m-learning organizer applications, b) self-regulated learning applications, c) Java-learning applications, and d) LOs applications.

2.7.1 Mobile learning organizers applications

In this section, I describe three m-learning organizer applications, namely a student learning organizer by Corlett *et al.* (2005), a learning reminder/organizer by Ryu and Parsons (2008), and a (context-aware) university m-learning organizer by Mirisaee and Zin (2009). My framework is related to these applications; however, with the exception that the organizer functions of these systems were not used for the purpose of capturing and retrieving users' contexts, as in my framework.

Corlett et al.'s (2005) student learning organizer

This was one of the first m-learning organizers built to support students' learning. Their initial investigation for the requirements of an m-learning organizer established that there was a demand by users for institutional support of m-learning, especially for timetabling information and providing course content This organizer included the standard pocket PC applications and incorporated specific tools for students to access course material, view their timetables, communicate via email and instant messaging and organize ideas and notes. The rationale for developing the student learning organizer was that the built-in software in mobile computing devices was not specifically designed to support students' learning activities such as attending lectures, reading course content, revising and meeting course deadlines; however, this tool is not context-aware.

The student learning organizer was evaluated over a 10-month trial that included 17 MSc students at the University of Birmingham, UK. Wireless PDAs were loaned to these participants and the university building was equipped with wireless coverage throughout. The aims of the study were to investigate – "a) the usability of the hardware and software; b) the perceived usefulness of the PDA as a learning organizer; c) the perceived impact of the tools on learning; d) reported patterns of usage; e) whether students installed and used additional tools to those provided for them at the start; and f) the students' attitudes to the PDAs and their provided tools". Reported problems from participants included the limited memory of the devices, the volatility of the device's memory, general crashes and inputting of text was cumbersome.

Ryu and Parsons' (2008) learning reminder/organizer

A learning organizer/reminder was developed for students to find their way around campus and to alert students when reserved library books had become available. The requirements for the prototype were first elicited via an interview study. Their interview data revealed that most of their new students did not know where the lecture theatres, classrooms and laboratories were, as the campus is very spread out.

In contrast, many of the senior students were aware of these locations but required more in-depth information about the personal organisation of their studies – including being aware of assessments, and being up-to-date with resources and messages from lecturers. Spatial awareness was found to be very important by junior students, but temporal contexts were more relevant to senior students, e.g. relating to the time of day in their study schedules. A key point was noted – "the success of any m-learning application relies on taking into account different contexts of use for different learner groups, who may have different expected learning experiences" (Ibid).

After the elicitation of the user requirements, an implementation of the prototype system was developed and usability testing was carried out with targeted users. The participants 'roamed' around the campus for fifteen minutes in order to experience a) finding out the location of their classrooms and b) the contextual help information. Both new and senior students found the contextual help function to be more useful than the location finder. The authors' future work includes the integration of students' current learning activities into the learning organiser; the organizer functions of these systems were not intended to capture and retrieve users' contexts

Mirisaee and Zin's (2009) context-aware university m-learning organizer

This organizer was first developed as a university mobile organizer, which was a piece of "software that acts like an assistant for students in their universities' activities. Its purpose was to help students in their indoor and outdoor activities within the university environment". However, it had not been successful as students' user requirements were not met. The authors subsequently upgraded the organizer into the context-aware university mobile organizer, which has now been implemented but not yet evaluated.

The applications/functions in the organizer that the students required include information about class schedules, changes in class schedules, ability to send and receive messages to/from their lecturers, method of informing about new events, information on faculty news, announcement of university of faculty activities, online submission of assignments, downloading of course material, online multimedia, a lecturer evaluation system, information about bus schedules, information about nearby shops, online discussion forums and an online system evaluation.

2.7.2 Self-regulated learning strategy and applications

The components of self-regulated learning theories include deployment of motivational strategies such as self-talk, elaborative planning, processing and monitoring. Code *et al*. (2006) argued that instructional designers of e-learning environments can use cognitive tools to promote motivational strategies and enhance learners' self-efficacy. Self-efficacy is related to the self-regulated theory, which is the belief that one is capable of performing certain tasks in order to attain their goals.

Self-Determination Theory (Deci *et al*., 1985) describes motivational strategies (from two perspectives – intrinsic and extrinsic) based on the various reasons or goals a learner sets to complete a certain task. *Intrinsic* motivation originates from the learner's inherent interest in the subject/tasks, whereby individuals find the completion of such tasks rewarding and satisfying. A learner is said to be *extrinsically*-motivated when they are motivated externally by another party and are performing or completing a task to satisfy the goal of this third party. The depth of the knowledge and skills gained from an intrinsically-motivated student tends to be greater than that of an extrinsically-motivated one. The act of goals-setting can be used as a constant criterion for students to measure their achievements (Code *et al*., 2006).

Common amongst models of self-regulated learning theories are goals-setting and the comparison of such goals against the effort put in by learners and their achieved performances. Both goal theory and motivation consist of the *orientation* component, which relates to the goal-setting reasons and the motivation for achieving (or failing) to achieve these goals. There are two main goal orientations – *mastery goal orientation* (also known as task/goal orientation or learning goal orientation) and *performance-goal orientation* (also known as ego orientation or ability-goal orientation). The different goal orientations can be used to identify students' various approaches in regulating their learning to complete a particular task (Ibid).

Mastery goal orientation theorizes that students do persist and elaborate on study materials at a greater length and depth, and additionally experience enhanced task enjoyment. *Performance goal orientation* theorizes that the depth of the study process of materials is less; learners experience comparatively less task enjoyment, and they may withdraw their efforts when they are confronted with failure or severe challenges. The design of learning environments can be enhanced by obtaining a deeper understanding of the relationship between individual differences in learning attitudes, motivation, goals-setting and achievement (Ibid).

Four self-regulated e-learning systems are presented below. I am currently not aware of any m-learning systems that have specifically incorporated components to facilitate self-regulated learning.

- *gStudy*, an e-learning software application developed at Simon Fraser University (Winnie *et al*., 2006), uses self-regulated learning strategies to support active knowledge construction. A Goal Setting Kit (GSK) was developed for students to set, search and mange their goals and learning objectives using embedded tests, note templates, concept maps, organizers and exercises. This application allows students to "articulate, organize, prioritize and monitor their progress toward achieving [their] personal and instructional goals" (Code *et al*., 2006).
- A personalized e-learning system, with self-regulated learning assisted mechanisms for helping learners to enhance their self-regulated learning abilities to become lifelong learners, was developed by Chen *et al*. (2007b). In

the application, the learner is first directed to fill a self-monitor form before performing any e-learning activities. Information related to their learning targets are to be completed – *learning time, number of learned courseware, effort level of learning courseware, concentrated study degree of learning courseware, and achievement index of learner ability*. During courseware learning, a function menu for quickly accessing the application functions is available. This includes *self-monitoring of performance, self-inspection, self-evaluation* and *Q & A*.

- An individualized and self-regulated e-learning multi-agent system was developed by Hwang *et al*. (2006). This converts learners' learning goals into learning strategies, which are then applied to fulfil their learning goals. A learner-centred environment is provided for learners to access different personalized learning services based on their learning strategies tailored to their individual requirements. The multi-agent system consists of three agents – *contract, learning support* and *learning management*, as well as three databases – *learner, learning materials* and *questions*.
- A self-regulated e-/m-learning system was developed by Shih *et al*. (2007). This was based on the self-regulated learning cycle (Zimmerman *et al*., 1996). Six subsystems were designed – *content accessibility, learning scheduler, self-evaluation, analysis, learning & monitor,* and *synchronization*. The system consists of four processes – *activities scheduling, learning and monitoring, learning evaluation* and *analysis*. A learner arranges suitable learning schedules for their learning, and the system maps these to the goal-setting and strategic planning process. The learner has the option to evaluate their learning achievements, using the self-evaluation subsystem. Learners are encouraged to

motivate their learning by exchanging learning schedules and records with others.

2.7.3 Java e-learning and m-learning applications

In this section, I focus specifically on applications which aim to teach students the Java programming language, both as e-learning and m-learning applications. Many of these applications are web-based and have not been made specifically available for use on mobile devices. Many are part of intelligent tutoring systems or web-based educational systems, and have adaptive features in order to adapt learning materials to students based on their knowledge level. Example Java e-learning applications include Sykes (2003) (this has been qualitatively evaluated (Sykes, 2005)), Ab Hamid and Fung (2007), Mungusukh and Cheng (2002). A review of intelligent tutoring systems for programming is given in http://perun.im.ns.ac.yu/java/

An adaptive Online Computer Aided Tool (OCTA) was previously developed at the University of Warwick (Joy *et al*., 2002; Boyatt *et al*., 2003). In order to demonstrate the tool's adaptive features, a non-adaptive introductory Java course was imported into this system (Yau and Joy, 2004). The learner's proficiency level in Java was considered as a significant attribute that should be considered when providing Java materials to students to learn/study with. This course consists of learning materials and test questions from nine basic Java topics, and I had constructed a repository to store them.

In order to assign particular Java topics to students based upon their proficiency level of Java, I needed to first determine an order of difficulty of Java topics. My supervisor and I were not aware of any previous work that had been completed on this topic at the time, so we conducted two experiments – 1) a literature review of currently deployed Java textbooks at the Warwick library, and 2) a questionnaire completed by students to indicate their perceived difficulty levels of Java topics. The results of these experiments are in Yau and Joy (2004), and the topics and their levels of difficulty (in brackets) were established as follows – assignment (1), expressions (2), output (3), input (4), if-statements (5), for-loops (6), arrays (7), methods (8), classes (9). Evaluations on the four different roadmaps constructed as part of OCTA were conducted.

2.7.4 LOs and their applications

In this section, I first discuss 1) the advantages of using LOs in applications, 2) learning object metadata standards for retrieving LOs, and 3) general learning object repositories. Then I give a few examples of LOs applications. One of the aims in my research is to demonstrate that Java LOs can be successfully incorporated into and used within my framework by students.

Advantages of LOs

LOs consist of a set of rich metadata for describing which learners these are appropriate for. Advantages of constructing learning materials as LOs were identified (Yau, 2004):

1. *Flexibility* of learning materials because LOs were initially designed to be used in multiple contexts.
2. Metadata tags facilitate *ease of updates, searches* and *content management*.

3. *Customization* – a personalized learning experience for each individual learner is easier to be constructed due to the modularity of LOs.
4. *Interoperability* – LOs are compatible for use within different applications.
5. *Facilitation of competency-based learning* – since metadata tags describe the LOs, learners are able to fill their knowledge gaps by finding appropriate objects.
6. *Increased value of content* – the value of content is increased each time LOs are used.

A number of reasons that teachers had deployed LOs include reviewing a previous concept, motivating students, providing a different way of examining a concept and introducing or exploring a new concept (Kay *et al*., 2009).

Standards such as Learning Object Metadata (LOM)

Different LOs standards, for example LOM, have been established by different standards initiatives such as the Learning Technology Standards Committee (LTSC) (IEEE LTSC, 2005) which created the *Learning Object Metadata (LOM)*, Dublin Core Metadata Initiative (dublincore.org) which created the *Dublin Core Metadata (DCM)*, the Instructional Management System Global Learning Consortium (www.imsglobal.org) which created the *IMS Learning Resource Metadata (LRM) Specification* and Advanced Distributed Learning (www.adlnet.org) which created *Sharable Content Object Reference Model (SCORM).* Common among each of these standards/specifications is the promotion of LOs to be exchangeable across any web-based learning system. SCORM was written in order to a) store and catalogue and retrieve Shared Content Objects (SCOs) within and from different web-based intelligent learning environments, and b) promote SCORM-compliant Learning Management Systems (Ibid).

Learning object repositories

LOs are usually stored in global learning object repositories; the repositories of which are usually built on a client/server architecture employing brokerage services and providing peer-to-peer access to the local repository of the LOs. For example, 1) *Codewitz* (www.codewitz.org) was an international project which created many LOs for learning programming contained in their so-called *Material Bank* repository, 2) *Merlot* (www.merlot.org) contained about 7500 LOs in disciplines including Biology, Business, Engineering, History, Mathematics, Psychology and World Languages, 3) *CAREO* (www.careo.org) contained about 3000 LOs, and 4) *Telecampus* (telecampus.edu) contained over 66,000 courses and programs available on a commercial basis (Ibid).

A learning object repository located at the LORDEC website (www.education.uoit.ca/lordec/collections.html) has been used on a regular basis by a number of teachers. Google is also often used for searching and selecting LOs from repositories (Kay *et al*., 2009).

LOs applications

A number of applications which allow the use of LOs have been developed. In particular, many of these are focused on teaching students programming including Brennan (2005), who proposed a “development of LOs designed to address the needs of novice programmers" and to supplement teaching. Their focus is on how to make programming less difficult for students to learn. They argue that students have individual preferences on how they best learn programming, and students must be able to develop a mental model of the language's constructs in order to learn the semantics of a programming language. A Java learning object ontology (Lee *et al*., 2005) was developed "for organizing LOs of Java courses in an adaptive e-learning environment". A LOs approach to teaching programming was described by Adamchik and Gunawardena (2003). Applications which allow mobile LOs to be used on mobile devices were created by Smith (2006) and Bradley *et al*. (2007). This is further discussed in chapter 9.

2.7.5 Supporting knowledge workers 'on the move'

Mobile technologies or m-learning applications can be used to support knowledge workers 'on the move'. A report written by Kristine (2005) contains many examples for supporting learners in business, m-commerce, and in the workplace. The author described four types of business applications for mobile technologies. These are 1) "custom built hardware (such as NEVE's personal GPS device to collect data about travel patterns for transport research and planning), 2) custom built software (such as the Finnish STTV/Nokia joint venture), 3) modified software for existing devices (mainly PDA and web based training products), and 4) unmodified proprietary and open source software for existing devices".

Based on interviews held with a group of businesses, respondents envisioned the next evolution of mobile technology applications for their businesses to have potential for the following:

- The needs of individual businesses are better fitted with commercially available devices due to the greater choice of hardware.
- An increased proportion of learning via blended training, delivered on mobile devices.
- A normal work environment consisting of faster and more efficient technology.
- Using games to teach problem solving and resolving issues, via simulated and interactive training.

Additionally, Kristine (2005) classified four categories of the use of mobile technologies for learning at work – referencing information, learning about the job, collaborating with co-workers, and learning about the mobile device itself. The following mobile technologies have been used as learning tools for staff – "CDs for multimedia learning, laptops for tutorials on how to use equipment and software, and DVD/CD-ROM-based training packages".

Other examples of knowledge workers 'on the move' include the use of Tablet PCs to help learners "to capture and store confidential patient information and deliver just-in-time information on clinical problems", as part of supporting remote learning in rural health education (Hartnell-Young and Jones, 2004; Kristine, 2005).

In a more recent article by Miller (2007), the worldwide mobile workforce stood at 676 million in 2004 and was expected to reach 878.2 million by 2009. A mobile worker was defined as "anyone who spends at least 10 hours per week away from his or her main workplace" (Ibid). Three subgroups of these workers have been classified, as follows:

1. Office-based mobile worker: the majority of the worker's time is spent in a company-provided office, but who also sometimes works at home or in a third place.
2. Non-office based mobile worker: "this worker is in the field, such as a salesperson, or working between buildings on a corporate campus, such as an IT professional. They are more often at someone else's office than their own" (Ibid).
3. Home-based mobile worker: "The former "telecommuter," this employee spends most of the work week in a home office, but comes into the corporate workplace for meetings or collaborative work sessions" (Ibid).

2.8 Evaluation methods for m-learning applications

There is currently a lack of an existing comprehensive framework for evaluating m-learning applications, hence resulting in many challenges in the evaluation process (Avellis *et al*., 2003; Magal-Royo, 2007; Traxler, 2009; Kukulska-Hulme, 2007). The challenges of evaluating m-learning applications include a) being able to identify the appropriate components which should be assessed during the evaluation, b) being able to define a suitable standard to ascertain whether the outcomes of the assessment are successful, and c) being able to effectively evaluate traditional learning theories which have been adopted in an m-learning application in the light of advanced mobile technologies (Sharples, 2006).

A particular software development approach which places evaluation at the centre of its development process has been the *lifecycle* system development approach. This approach combines evaluation methods from software engineering, educational evaluation and models for the evaluation of learning technology. At each key point in the lifecycle of the system design process, evaluation activities are performed, starting from the early design stage up to the final technology assessment stage. The outcomes of the evaluation activities inform the next stage of the system development process, or allow a re-iteration of an earlier stage of the lifecycle if user requirements are not met (Meek, 2006; Meek and Sharples, 2001). Vavoula *et al*., (2006) have used this approach for evaluating their MyArtSpace project.

Three different aspects are usually involved in the evaluation process, namely *pedagogical, usability* and *technological* which target the various perspectives of an evaluation of an m-learning application (Taylor *et al.*, 2002). A pedagogical evaluation assesses the user's learning experience in terms of the learning process, opportunities, and/or learning outcomes; this is described in 2.8.1. A usability evaluation assesses the application in terms of its usability aspects and utility of functions; this is described in 2.8.2. A technological evaluation assesses the technology and the user's experience relating to it; this is described in 2.8.3. Examples of m-learning applications that adopted the different evaluation perspectives are described in the subsequent sections. A particular assessment approach within a certain evaluation perspective may be conducted very differently from an approach within another perspective.

Increasingly, the importance of combining assessment approaches from the different evaluation perspectives was emphasised. This was in order to facilitate a) the rapid evolvement of both of the educational approaches and mobile technologies available for m-learning, and b) the construction of new combinations of m-learning with advanced mobile technology to form suitable up-to-date evaluation methods suitable (Vavoula *et al*., 2007). The types of adoptable evaluation methods in each of the three perspectives may overlap. However, the way in which these methods are deployed may be aimed at an entirely different perspective from one another.

2.8.1 Evaluation methods from a pedagogical perspective

An evaluation method from the *pedagogical* perspective appears differently than those from the *technological* and *usability* perspectives. The pedagogical methods typically aim to evaluate *m-learning experiences* or *m-learning outcomes*, which are created after m-learning session(s). An m-learning experience is a learning experience constructed whilst learning in a mobile (i.e. non-fixed) environment and/or learning with mobile devices. An m-learning outcome is a learning outcome which specifies what a student should have learnt after a period of m-learning study. The nature of these two elements brings challenges in the evaluation process, especially in the light of m-learning, which are described as follows.

Evaluating an m-learning experience

There are many differences between an m-learning experience and a traditional classroom learning experience because an m-learning experience may consist of a number of factors which are unpredictable (such as the location of learning, layout of space, social setting, learning objectives and outcomes, learning methods, activities and tools). For example, a learner's learning objectives may not always be known in advance, as these may be developed spontaneously 'on the move'. The lack of these objectives makes it difficult for m-learning experiences to be measured or assessed against.

Collecting data relating to m-learning experiences is challenging and may involve having to track individuals or groups who are moving across different locations; the locations may include various public and private spaces (such as library, café, transport and home). There are practical and ethical issues for both a researcher and volunteer to track and be tracked across a period of time. Even if it is feasible, the data collected may not reflect the true learning experiences that volunteers have had due to the possibility that they may have been uncomfortable whilst being tracked. Traditional methods of evaluating learning (such as the use of fixed video and audio recorders, observation and data logs) may not be used successfully with respect to m-learning experiences which occur in non-fixed environments.

An alternative method of data collection of m-learning experiences is to request volunteers to provide a self-report. However, these reports cannot be trusted as the only source of data collection because of two reasons. First, it is crucial for students to record detailed information about the different situations in which the learning has taken place so that comparisons can be made against different contexts. It was found that insufficient information is often recorded in this regard. Second, it was found that there could be differences in what learners said they had done or will do and what they actually did or will do. Therefore, additional data collection methods must be in place to add a secondary valuable perspective to the interpretation of the collected data, and so the data can be triangulated and strengthened (Waycott, 2004).

Evaluating a learning outcome

Evaluating a learning outcome is a difficult task, even in terms of traditional learning. The difficulties lie within the assessment of what the learner has learnt in the particular study session(s), which requires an understanding of their previous knowledge in order to make an accurate deduction. Making this deduction is difficult because knowledge and skills are ordinarily developed over long periods of time and are cumulative and they do not result from individual, single experiences. The typical methods used for evaluating learning outcomes include interviews, semi-structured interviews, questionnaires and diary studies, all of which allow learners to give their own retrospective accounts of learning. Thereafter, researchers use these accounts for meta-cognitive analysis. Limitations relating to these methods include the following (Vavoula *et al*., 2007).

- There may be inaccuracies relating to the recall and rationalisation of information.
- Younger learners may not possess the meta-cognitive skills necessary to reflect on their own accounts of learning experiences.
- Some learners may not have the ability to convey this information accurately.
- Learning developed after the evaluation will not usually be made known to the researcher.
- As mentioned, learning is cumulative therefore it is difficult to isolate a particular learning event for examination.

2.8.2 Evaluation methods from a usability perspective

Usability of an application has been defined as a "measurable feature that is present to a higher or lower degree and which describes how effectively a user can interact with a certain produce (system/service)" (Taylor *et al*., 2002). There are two main measurable aspects of usability; each of these contains several attributes, as follows.

- *System 'learnability' and efficiency* - how easy the system or service is to learn or use or memorise, how efficient or productive the system is, how much training time and support is required to use the system, how clear and consistent the language of the system is, how much feedback is given from the system and how much technical maintenance costs.
- *System design* – how easy is it to interpret data, how fast can data be input, how satisfied are users with the system, did any errors occur in the system, how visible is the system, is there use of physical constraints, can actions be invalidated, do users have control over the system, is it flexible, do the designs include the users' knowledge base, are there cultural constraints, does it meet existing standards (Ibid).

A usability inspection method/evaluation may consist of a number of data collection and analysis methods. The aim is to a) find usability problems in order to construct suitable utility and usability functions for the application of the design of the user interface, and b) to specify and fulfil system requirements of potential users. The focus is on the human computer interaction between the device and the end-users. This process, *user-centred system design*, usually begins with an extensive analysis of potential users, tasks and environment, where potential users are involved in the process of system design from the beginning of system development and are consulted at each incremental stage of the development and evaluations. The process is complete when the system usability criteria are satisfied (Petrelli and Not, 2005).

Common usability methods used which were mainly developed from the HCI research field include heuristic evaluation, heuristic estimation, cognitive walkthrough, pluralistic walkthrough, feature inspection, consistency inspection and standards inspection and formal usability inspection (Taylor *et al*., 2002).

2.8.3 Evaluation methods from a technological perspective

Methods/approaches used for the evaluation of m-learning applications from a technological perspective are targeted at the assessment of the mobile technologies deployed and the user's experiences relating to this deployment of technologies. Typically, in order to facilitate this type of assessment, an implementation of the application (or at least a prototype of the implemented application) needs to be available on a mobile device for users to evaluate it and provide feedback. The evaluation process typically involves a) an *evaluator* (such as a researcher and/or developer) who plans and conducts the evaluation to take place, and b) a *volunteer* (such as a student) who tests the implemented application on the different implemented functions of the mobile device for a period of time. Depending on the nature of the evaluation, the volunteer is asked to provide information about the usage of the application, before, during and/or after the hands-on experience with the device. Several ways of providing this information can take place including the following.

1. Use of data logs on the device through an automatic data collection technique which can be used to collect dialogue responses, navigation information and user choices etc.
2. Interviews are held following evaluation of the application to obtain feedback about the various aspects of the usage of the device.
3. By filling in a questionnaire during or after the evaluation in order to obtain feedback.

The technological evaluation of an application can take place in either its authentic context in which it is intended to be used, i.e. *real* evaluation, or a *simulated* evaluation which is one that takes place in a virtual or replicated context other than the original designed one. The reasons that simulated evaluations are deployed include reducing the time and cost involved in the evaluation process. Two examples are given below, describing firstly a real evaluation, and secondly, a simulated evaluation.

1. A *real* evaluation of the Mobile Helper system (Zawacki-Richter *et al*., 2006) was completed by a group of volunteers who travelled around the intended university campus of use for fifteen minutes to experience the system functions.
2. A *simulated* evaluation of the Learning Chinese at Taipei Underground system (Chen & Chou, 2007) was completed in a classroom with wireless network services. RFID write tags were attached to the walls to represent the different underground stations in Taipei. After evaluation of the devices, volunteers were asked to answer a questionnaire to provide relevant feedback about the system.

2.9 Psychology literature relating to the learning process

Three objectives were identified by Steinar (1996) for building a psychological learning process in learning the vocabulary of a foreign language: (1) the vocabulary must be learned efficiently and according to the difficulty degree of the materials. (2) The learning process must ensure that long-term retention of materials can be held. (3) The usefulness of certain words in the vocabulary must be identified and held according to their utility. Individuals may also experience dissimilarities due to their existing knowledge and personal learning habits. Adaptive vocabulary learning can enhance a student's learning process in learning a foreign language. Other processes including perception and motivation have a critical role in the course of learning (Walker, 1996), and these can also be taken into consideration in adaptive learning.

Learning can be said to be implicit when "*subjects behave as if they have learned something but they cannot report what they have learned*" (Frick & Lee, 1995). In the field of psychology, learning is usually assessed by performance via intentional or unintentional retrieval of this knowledge (Buchner & Wippich, 1998). Three main test paradigms for examining implicit learning have been summarised by Valentino (2002) – artificial grammar, sequence learning and process control. These test paradigms can be conducted to collect and analyse participants' implicit learning relating to concept knowledge, procedural knowledge and knowledge of specific instances, respectively.

2.10 Summary

The large amount of research being conducted in the m-learning field coupled with advancement in mobile technologies and capabilities have led to the innovation of four succeeding m-learning generations - *non-adaptive, 'learning-preferences'-based adaptive*, '*learning contexts*'*-based adaptive* and '*learning-contexts*'*-aware adaptive*, which I classified. The characteristics of the applications within each of these generations have been examined and related example applications were given. The concept of a learning style has been discussed, and the Dunn and Dunn and Felder and Silverman LS models were described. Prior to the description of the latter two generations, the concepts of a context and a learning context were explored in detail. I then explained the rationales for the deployment of learning contexts within m-learning applications as well as the related advantages and challenges.

A discussion of the ‘learning-contexts’-based adaptive generation was then presented together with related works, and the relation of these applications to my proposed framework was examined. The learning contexts adopted within these applications/mechanisms were explored in detail, and the differences between the latter two generations were identified and presented. Thereafter, I described the ‘learning-contexts’-aware adaptive generation and the relationship between these applications and context-aware ubiquitous learning applications. Three classifications of these applications were then described – location independent, location dependent and situated learning applications. Example applications were given, demonstrating the aims and purposes of each, the technologies being used and the differences among each of these groups of applications.

I then discussed m-learning organizer applications, self-regulated learning strategies and applications, Java e-learning and m-learning applications and LOs applications.

The next section focused on the evaluation methods for m-learning applications which were presented together with the challenges of evaluating the technologies, learning experiences and learning outcomes of the m-learning process. The evaluation methods were described in terms of three different perspectives – pedagogical, usability and technological. The approaches within each of these perspectives may be conducted very differently from one another. A technological evaluation assesses the technology and the user’s experience relating to it, whereas a usability evaluation assesses the application in terms of its usability aspects and utility of functions. A pedagogical evaluation, on the other hand, assesses the user’s learning experience in terms of the learning process, opportunities and learning outcomes.

Increasingly, the importance of combining assessment approaches from the different evaluation perspectives was emphasised.

Chapter 3

Research Methodology

The aims of the thesis are 1) to construct and demonstrate a pedagogical suggestion mechanism framework, which is intended to be implemented and deployed for use by university students on a mobile device (this was conducted as proof of concept as I did not implement the framework for use on a mobile device), and 2) to determine a successful way of retrieving users' learning contexts without using context-aware sensor technologies or requiring users to directly provide such contexts to the devices at the point of usage. Benefits include allowing users more time to concentrate on their learning/studying task at hand. The purpose of this framework is to take into account important and relevant learning contexts in order for appropriate learning materials to be recommended to students based on context values, at the time they wish to conduct learning/studying.

In order to proceed with my aims, I constructed a theoretical *Mobile Context-aware Learning Schedule (mCALS)* framework; this phase of the research formed the first of the six phases of the research methodology. The idea of using a learning schedule (i.e. the user's electronic diary) was developed and integrated into the framework, as a way of retrieving the users' locations and available time contexts without them having to provide this information at the point of usage, i.e. a proactive retrieval approach. The subsequent components of the theoretical framework are derived from an extensive literature review, which contains a collection and analysis of related research findings, and any associated problems and challenges faced by researchers.

I consider it critically important that the theoretical framework is to be evaluated from each of the three different evaluation perspectives – *pedagogical, usability* and *technological* (as discussed in 2.8), in addition to the first theoretical framework development phase. The reason is that a more complete understanding and assessment of an m-learning application can be obtained, from three overlapping perspectives, in particular, whether the application had met the user requirements of learners from the pedagogical and usability perspectives, and whether it can be supported and feasibly implemented and deployed at present using current mobile technologies. I consider this combined approach to be good practice in the development and evaluation of m-learning applications. This is supported by Sharples, (2006) and Vavoula *et al.*, (2009).

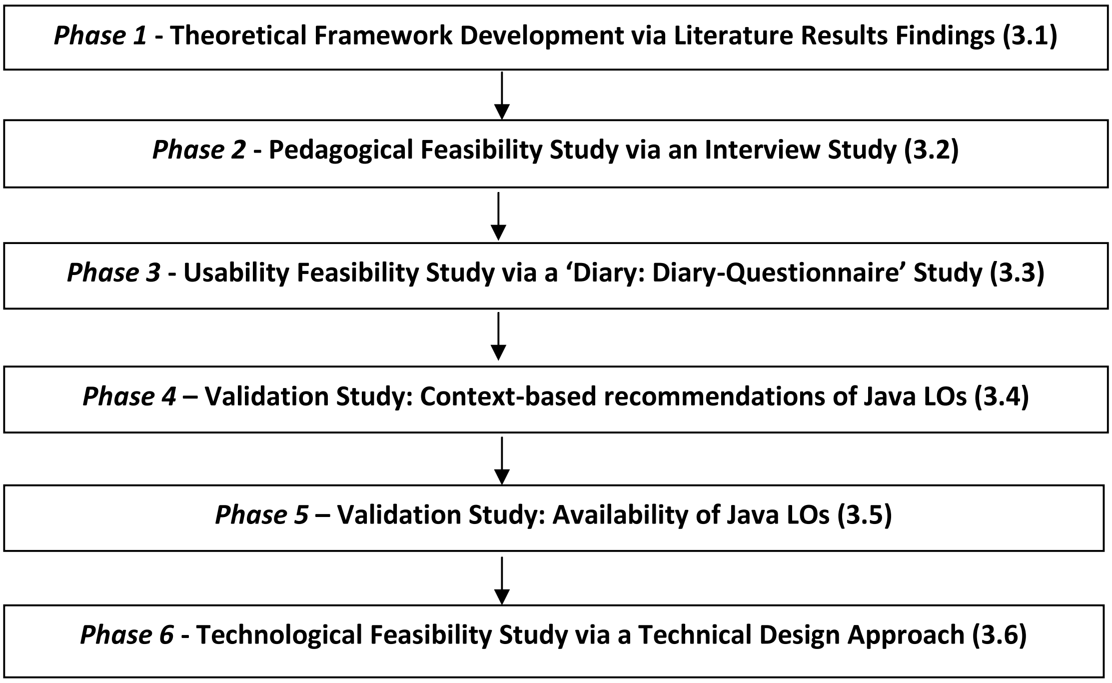
The construction of the theoretical framework formed the first phase of the research methodology. The chosen three feasibilities studies, selected from each of the three evaluation perspectives, formed the next two and the last phases of the research methodology. The second phase consisted of a pedagogical feasibility study which was an interview study, and the third phase consisted of a usability study which was a diary study. The interview study was an exploratory method for gaining the users' perspectives on their (m-) learning requirements and to determine whether the framework would fit to these requirements. The user requirements of the theoretical framework were refined based on the data analyses of the interview and diary studies. Hypotheses were formed from the interview study results and were tested in the diary study. The design of the diary study was constructed based on the findings, hypotheses and initial refined requirements gained from the interview study. The data analyses from these two studies were triangulated to form the final requirements of the framework.

The fourth and fifth phases of the research methodology were two validation studies respectively. The first study attempted to validate the Java suggestion rules obtained from the interview and diary study. This study was conducted as an online experiment that suggested appropriate Java LOs to students based on their current learning contexts. User feedback was obtained from students concerning each Java LO that they study. The second study was an investigation of the availability of high-quality Java LOs that can be feasibly incorporated into the framework.

Using the final requirements of the framework, I formed the final phase of the research methodology. This was a technological feasibility study consisting of the construction of a technical framework design. Currently available technologies were included in the design to assess at the present time a) whether the framework can be implemented, thus fulfilling all of the final user requirements, and b) whether the proposed functions of the framework can successfully be performed. The three feasibility and two validation studies collectively formed the evaluation pillars of the theoretical *mCALS* framework. Figure 3.1 depicts the six phases of the research methodology.

My research methodology has been influenced from the evaluations of the related works by Cui and Bull (2005), Becking *et al*. (2004) and Martin and Carro (2009); evaluations of these works were provided in 2.5. This is because, at the time of evaluation of my framework, a limited number of evaluations had been conducted on these related works. In the course of my research, I attempted to contact the respective authors regarding the evaluations of their frameworks/systems. Cui and Bull (2005) informed me that they had discontinued their work and were no longer planning to evaluate their system. I did not receive a response from Becking *et al*. (2004). A case study was completed by Martin and Carro (2009), which I was able to refer to for the analysis of my validation study detailed in chapter 7.

Figure 3.1: The research methodology consisting of six phases



In the remainder of this section, the six phases of the research methodology are described in 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6 respectively. The structure of these studies, validity and reliability thereof, data collection and analysis methods and limitations of the research methodology are described within the relevant sub-sections. In 3.7, I present the triangulation of the data obtained from the interview and diary studies. Finally, the summary is presented in 3.8.

3.1 A process of deriving a theoretical framework

A review into existing ‘learning-contexts’-based m-learning applications, for example, Martin *et al*. (2006c), Cui and Bull (2005) and Becking *et al*. (2004), revealed that five main components were contained within a context-based suggestion mechanism, as follows. Note that these related works were described in 2.5.

1. *A method for detecting and retrieving learning contexts* – either through user requests to input these and/or automatic retrieval by using context-aware sensor technologies. This information is then transferred to the contextual model.

2. *A user model* – consisting of information regarding the user’s profile such as their learning preferences/styles and knowledge level.

3. *A contextual model* – consisting of different retrieved context values, which represent the user’s current learning situation such as available time, location, concentration level and the frequency of interruption (at the location).

4. *An adaptation/suggestion mechanism* – for adapting and/or selecting appropriate learning materials, activities or services to learners, based on the information provided by the user and contextual models.

5. *A database of learning materials, activities or services* – for example, a learning object repository is made available for providing appropriate learning materials to students.

As mentioned, the suggestion mechanism I aim to construct is centred on a method which can be used to retrieve the users’ learning contexts proactively and without having to attach a number of sensors onto the mobile device, i.e. via electronic diaries. I hypothesize that intended users may currently already use electronic diaries for time management of their studies. Electronic diaries are typically built into modern mobile devices.

Using this proactive approach for retrieving users' locations and available time contexts can potentially eliminate a) the need for users to interactively input context values into the device whilst 'on the move' at the point of usage, and b) the need of having to attach sensors onto the device. The use of an electronic diary (or learning schedule) for retrieving learning contexts in an m-learning suggestion mechanism is a novel idea and has not yet been conducted in the context-aware m-learning research field. Two learning contexts were intended to be retrieved from the learning schedule - the *user's location* (at a particular point in time) and the *available time* (that they have until their next appointment).

I needed to make further design decisions with regard to the construction of my suggestion mechanism framework corresponding to (2), (3), (4) and (5) of the components listed above. I conducted an extensive literature review in order to establish the specific details of each of the components. These included deciding on the types of learning preferences that should be deployed in the user model, the types of learning contexts that should be deployed in the contextual model, the type of adaptive/suggestion strategies that would be appropriate for use within the framework and the form of learning materials that should be used. In particular, when I had addressed all six of the research questions successfully, the outcome would be a theoretical framework which was built on a strong literature review. The development of the theoretical framework is addressed in Chapter 4.

3.1.1 The validity and reliability of the derivation process

The development of a suggestion mechanism framework (or any other framework or system) requires a knowledge and understanding of previous and existing related work as well as an awareness of the problems and challenges faced by researchers and developers. There are two main reasons for this, as follows.

1. Successful results findings, which have been previously established, can be used in the research work to allow me to build a stronger, more up-to-date, informed and integrated underlying foundation to the framework. This applies particularly to the design and development of the theoretical framework.
2. Original research can be ascertained and development thereof can be used to make an important contribution to the research community. This, in particular, can save time and effort in not repeating already attempted and/or completed research works, and obtaining the same or similar results as other researchers/developers.

3.2 A pedagogical feasibility study via an interview study

This section is divided into five parts – *structure of the interview study, validity and reliability of the study, data collection, data analysis* and *limitations of the study*.

3.2.1 The structure of the interview study

The structured interview study was designed and organised into four coherent topics and contained collectively 30 interview questions, as well as a checklist; these are discussed below. The difference between unstructured and structured interviewing is described in 3.2.2. Appendix A shows the interview study questions presented to participants as well as the interview checklist.

Topic 1 – Diary usage for time management

Participants were asked whether they regularly used a diary for time management and would be willing and feel comfortable enough to provide me with their diaries' events for research purposes. Diary users were asked whether they included study-related and/or study-unrelated activities in their diaries, whether they used paper- or electronic-based diaries (software and device information were also obtained), to describe benefits of using a diary and to evaluate how closely they followed their planned schedules. Non-diary users were asked whether they thought they could benefit from the use of a diary for time management and to provide any reasons for not using one.

Topic 2 – Significance of the proposed learning contexts

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

Topic 3 – M-learning preferences – locations, mobile devices, learner characteristics

Participants were asked about the locations where they normally studied, liked studying in and studied better in. There were overlaps in these answers. Participants were then asked if they sometimes had to study in undesirable places and what effects that had on their learning activities being performed, which factors in a location affected their abilities to concentrate and how distractions/interruptions affected them during their studies. They were asked about the computing devices and software that they utilized for their studies, whether they would use a mobile device for engaging in learning/studying in different locations, whether they would feel it was an intrusion and/or object to the use of GPS technologies for tracking their locations and to choose from a set of pre-defined scales to best describe their learner characteristics relating to how hardworking they are, how much they enjoy their studies, how conscientious they are, how soon they complete their work and how self-disciplined, organized and routine-structured they are.

A learner characteristics scale was created and participants were asked to choose between the given values to select the one which described them best, in their opinion, as follows: (Note that these were self-assessments given by participants and may not be entirely honest).

- 1 - Very hard-working, 2 – Hard-working, 3 – Not so hard-working, 4 – Lazy
- 1 – Enjoy studies very much, 2 – Enjoy studies, 3 – Don’t enjoy studies, 4 – Hate it
- 1 – Very conscientious, 2 – Conscientious, 3 – Careful, 4 – Careless
- 1 – Complete work ASAP, 2 – Last-week, 3 – Last-day, 4 – Last-minute
- 1 – Very self-disciplined, 2 – Quite self-disciplined, 3 – Not so self-disciplined
- 1 – Very organized, 2 – Quite organized, 3 – Not organized at all
- 1 – Very routine-structured, 2 – Semi-routine-structured, 3 - Spontaneous

Interview checklist

An interview checklist was created and participants were asked to complete this at the end of the interview. They were required to indicate the significance (on a scale of 1-5 from least to most significant) of the following factors in affecting how well they learnt/studied - *noise level, temperature, lighting level, seating, room layout, type of location, motivation, responsibility felt towards their studies, their persistence in learning, how organised they are, their learning preferences, food and drink, time of day, how free/restricted they felt, whether they are working alone/peers, motivation from their teacher* and *how anxious they felt*. Volunteers were given an opportunity to ask any questions which they may have relating to the interview and our research.

3.2.2 The validity and reliability of the interview study

In this section, I first describe the advantages of collecting data via an exploratory interview study. Then I provide examples of where exploratory interview studies have taken place in similar, related research studies. Thereafter, I provide reasons of why an interview study is critical for the refinement of the framework's user requirements, and the validity and reliability of the interview study.

> "Interviews can provide rich data and give considerable insight into perception and attitudes. Misperceptions or misunderstandings about what is being asked can be recognised and dealt with at the time. The interviewee has the opportunity to express opinions important to them, clarify ideas and feel that

these are valued. The interview can be a learning process for both interviewer and interviewee" (Taylor *et al*., 2002).

An exploratory interview study is one of the most appropriate and effective ways to gain perspectives of users relating to a subject matter/topic (Ibid). Due to the nature of m-learning, which can occur in highly unpredictable places and conditions, an accurate analysis of the requirements of target users is essential. This is to ensure that precise user requirements are captured and/or refined and such that learners' m-learning needs are catered for during the design and development of an m-learning application (Grasso and Roselli, 2005; *Mirisaee* and *Zin*, 2009).

There are four types of interviewing methods – *unstructured, structured, semi-structured* and *group*. *Unstructured interviewing* is where the interviewer does not have a well-defined agenda and may put questions to the interviewees depending on the given responses. *Structured interviewing* has a specific, pre-determined agenda with a precise set of questions which are put to all of the interviewees involved. *Semi-structured interviewing* consists of elements from both unstructured and structured interviewing. These three methods usually take place on a one-to-one basis with an interviewer and an interviewee. The *group interviewing* method involves an interviewer interviewing a number of participants in a group. In this situation, responses of one participant may trigger inspirations and/or responses from another participant, possibly leading to a flowing discussion from different participants, which can provide same, similar, different views on the proposed topic (Taylor *et al*., 2002; Cohen *et al*., 2007).

A related example of where exploratory interview studies have taken place includes the personal learning organiser (Ryu *et al*., 2007). Ten university students were interviewed in order to identify the user requirements of their application. This was particularly in terms of the following:

- In which contexts students would be using the organiser.
- Which tasks students needed support with in and around campus.
- The desired design features of the organiser
- Any other functions that the organiser should contain.

Their interview results showed the precise requirements of new and senior students. New students required map information of the campus and help with navigation to locations within the campus (such as lecture theatres). Senior students required more in-depth information relating to their personal studies, such as being aware of assessments, organisation of their studies, and receiving updates of lecture notes and information. Interview studies are relatively low in cost to conduct and can be very effective in obtaining precise user requirements of different students.

Similarly, the interview study conducted by Brown and Crawshaw (1998) addressed the use of shared electronic diaries at the University of Surrey, UK. Their study involved 15 staff members who employed electronic diaries and included a selection of users, administrators and management. The study helped them to investigate the precise ways in which different hierarchies of staff and students made use of their electronic diaries, and whether shared electronic diaries would be technically feasible for implementation as well as widely deployable by the staff and students.

The pedagogical feasibility phase is critical as part of the research methodology for two reasons. First, in order to ensure that the user requirements of the theoretical framework fit to those of intended users, and second, that requirements can be refined where they are not consistent. One of the most appropriate ways of obtaining the users' perspectives of their m-learning requirements and deciding whether the framework would fit to their requirements is via structured interviewing with participants. I selected the use of structured interviewing in order to maximise the consistency of the interview with each participant, and to ensure that answers amongst participants could be compared and analysed with one another. A similar questionnaire survey research methodology was carried out by Mirisaee and Zin (2009) in order to verify students' requirements for their context-aware mobile organizer for university students.

In most interview studies, each interviewee would define the situation of study in a specific way and thus have their own bias. Hence, it is important to have a sufficient number of interviewees and to make sure that the sample of interviewees is as varied as possible. This is to increase the chances of interviewees of having a range of different biases. In view of that, the range of the interviewees that participated in the study consisted of both undergraduates and postgraduates students from different 1) years of studies, 2) courses of studies and departments and 3) universities. The interactions between the interviewer and interviewee also facilitated greater depth in the collection of data than other research methods such as the use of a questionnaire (Cohen *et al*., 2007).

3.2.3 Data collection of the interview study

This section describes the recruitment of volunteers, the pilot study and the actual interview study. Details of the interview process and data sample are presented. The target of the study was university students as these are the intended users of the framework. The recruitment process included the following four methods.

- Paper-based advertisements were posted into undergraduate students' pigeon holes within the computer science department at my university.
- Verbal announcements in computer science lectures were given to request students to volunteer. These were undergraduate lectures of years 1, 2 and 3.
- Paper-based advertisements and verbal requests elsewhere within the university were used to recruit students from other departments.
- Interviewees from another university were recruited via colleagues.

The initial intended users of the framework were computer science undergraduate students because I had wanted to use Java learning materials within the framework for students to learn/study with. This is part of my ongoing work to facilitate ways of supporting novice learners to learn Java programming. Hence, most of the interviewees were computer science undergraduate students. However, it was decided that a different and/or wider range of perspectives of the learning requirements of students should also be gained to increase the adoptability of the framework for other students. Therefore, a considerable number of students were recruited from other courses and/or departments.

A pilot study which consisted of five participants on a one-to-one basis was conducted before the real interviews. This was to ensure that they understood each interview question in the way that it was intended to be asked and that there was no ambiguity. It also provided an opportunity for me to reflect on the interview questions in light of the responses from participants. In light of the pilot study, I included a) an extra question which asked participants to describe any strategies that could help them when studying in a distracting environment and b) the checklist (as described in 3.2.1).

The pilot study was conducted over a period of two days and included four PhD students within the university computer science department and a Masters student enrolled on a European cultural policy and management program. Subsequently, 32 university students participated in the interview study, for a total of 37 participants over a period of three weeks.

The data sample consisted of one physics, one law, one history, one industrial relations, two engineering, six mathematics, seven business studies (including international business, accounting and finance, management) and 13 computer science (including digital media technology) students. Some 24 students were undergraduates and 13 were postgraduates (PhD and Masters). Students were in different years of studies and the age range was 18-34. A total of 31 students were from the University of Warwick, five were from the University of Nottingham and one student was on an exchange visit from the University of Tampere, Finland.

After I had conducted around 30 interviews, it could be observed that responses from volunteers given in the interviews started to recur. In other words, there were only a limited number of different perspectives which could be given for each interview question, and most of the later responses may already have been covered by earlier respondents. At this stage, I decided that further interviews would not assist me in revealing much further information. I was also restricted by time and resource constraints. Therefore, the interview study ended after the interview with the 37^{th} participant.

The interviews with participants were conducted by the same interviewer on a one-to-one basis. The duration of each interview was approximately 27 minutes. Each interview was recorded on a recording device and transcribed for data analysis. Participants were asked to sign a consent form to indicate that they were willing for the interview to be recorded and they were informed that they could withdraw at any time if they wished to. All data results were made anonymous prior to data analysis and were kept confidential. University ethical guidelines and procedures were followed and consent was obtained prior to the commencement of interviews.

3.2.4 Data analysis of the interview method

The pedagogical and exploratory nature of the interview questions required a qualitative data analysis method to be deployed because of the descriptive meaning and perspectives we wished to interpret from this data. It was decided that the *content data analysis* method would be used to allow categories of results findings to emerge from the interview raw data. This process included grouping together the responses from participants for each interview question to enable categories or themes to emerge from the grouped responses. When these categories or themes had emerged, the responses corresponding to the categories or themes were grouped together for further analysis. The categories were given corresponding appropriate names. This is a commonly used data analysis method for evaluating interview transcripts (Cohen *et al*., 2007).

Content analysis has been used for analysing the teaching of statistics (Mahmud and Rahim, 2002), for identifying factors to promote the innovation potential of employees (Hartner *et al*., 2003), and for analysing case study research (Kohlbacher, 2006). The aim of this methodology is to provide a set of guided steps in order to simplify and summarise the large amount of complex qualitative data gained from studies such as interviews (Ibid). The eleven steps of content analysis are summarised as 1) define the research questions to be addressed by the content analysis, 2) define the population from which units of text are to be sampled, 3) define the sample to be included, 4) define the context of the generation of the document, 5) define the units of analysis, 6) decide the codes to be used in the analysis, 7) construct the categories for analysis, 8) conduct the coding and categorizing of the data, 9) conduct the data analysis, 10) summarizing and 11) make speculative inferences (Cohen *et al*., 2007).

The research questions of the interview study (as described in 1.4) together with the process of data analysis are discussed below; the results to questions one and two are presented in Chapter 5, and the results to questions three to five are presented in Chapter 10.

1. *How effective do users find the use of a diary?*

   I obtained the responses relating to the interview topic – *diary usage for time management*. Three types of diary users emerged from the given responses.

2. *What are the user's views on having materials suggested to them based on the proposed contexts?*

   I obtained responses relating to the interview topic - *learning preferences and contexts*. Both positive and negative categories of views emerged.

3. *How do users make use of studying in different types of locations to increase their productivity?*

   I obtained responses relating to the interview topic - *studying in various locations*. Categories emerged based on the responses given for the locations students preferred to study in, and the reasons for these preferences.

4. *Which factors can distract their concentration?*

   A list of factors was obtained from the responses from the *studying in various locations* topic and the interview questionnaire/checklist. I divided these into internal and external factors relating to the user.

5. *What are the user's views on the use of mobile devices for learning?*

I obtained responses relating to the interview topic – *use of mobile devices and learner characteristics*. Three categories of m-learning views emerged. In addition, I used statistical correlation tests to determine whether there was a relationship between participants' learner characteristics and a) their m-learning views and b) how closely they followed the schedules in their diaries.

3.2.5 Limitations of the interview study

Limitations of the interview study are centred on the following three concepts.

1. The sample size of 37 participants consisting primarily of students within my university may not be a representative sample of university students in general. Students from another university and/or from another country may have provided different perspectives. Finding a representative group of students for any type of study is always a challenge. Also, students who volunteered to participate in the study may be those who are more opinionated (McAlpine *et al*., 2004). The framework is targeted primarily at university students; therefore, it may not meet the requirements of secondary school or college students.
2. A sufficient understanding and the ability to reflect and convey accurately their learning preferences, beliefs and opinions are required for the students to answer the interview questions in their intended manner. The level, maturity and ability may vary between participants. Different positive or negative learning experiences may have determined their learning preferences. Similarly, some students may not have had certain types of learning experiences and may not be aware of their preferences.

3. Interviews are prone to subjectivity and bias on the role of the interviewer. For example, the collection of learners' characteristics is subjective and students may not tell the truth about their true opinions of their characteristics to portray themselves in a better light, and different learners may see themselves differently from one another but may select the same choice(s). However, given the nature of the interview study, prior consent given by volunteers to participate and the fact that characteristics inquired about were relatively impersonal, I have no reason to believe that most of the participants' opinions were not conveyed to us truthfully. Views and opinions of participants are also subject to change. In the interview study of Brown and Cranshaw (1998) where 15 diary users participated, one of these participants commented that - "I never thought I would use an electronic diary, but I was convinced within a week and threw the paper diaries away".

3.3 A usability feasibility study via a 'diary: diary-questionnaire' study

The '*diary: diary-questionnaire*' study was adapted from the '*diary: diary-interview*' research methodology (Zimmerman and Wieder, 1977). I first explain the latter approach. The term 'diary' refers to an annotated chronological record and is typically specifically designed and structured by a researcher to fulfil a number of set objectives. These 'diaries' are filled in by volunteers for a duration of time, which is usually set by the researcher. The diaries are returned upon completion and the researcher prepares for the second part of the methodology – the *diary-interview*. The interview is constructed based on the responses of that volunteer and then conducted. Each *diary-interview* usually differs for each volunteer.

In the remainder of this section - *the structure of the 'diary: diary-questionnaire' study, validity and reliability of the study, data collection, data analysis* and *limitations of the study* are described in each of the sub-sections that follow. The data analysis of the diary study is presented in chapter 6.

3.3.1 The structure of the diary study

The '*diary: diary-questionnaire*' (hereafter, abbreviated as diary) study was constructed based on the results findings obtained from the interview study. It was a three-part pen-and-paper exercise, designed to be carried out for two days, and was generic for all volunteers including the '*diary-questionnaire*' part. Appendix B shows parts 1, 2 and 3 of the diary study, which are described below.

- Part 1 required participants to plan out both their study-related (such as lectures, self-studies) and study-unrelated (such as social meetings and lunch) events at the beginning of the day for each of the two days, in chronological order. They were asked to choose two typical days where they had a number of studying activities. Two designated '*diary schedule*' sheets – one for each day – were used by each participant to record this information. The following information was required for each event.

    a. Whether the event was studying-related (S) or studying-unrelated (N).
    b. The time (to and from) planned for the event.
    c. The geographic location (*e.g. Coventry, Warwick campus*).
    d. The type of location *(e.g. lecture room, library, home)*.
    e. The actual task or event (*e.g. writing assignment, lunch, meeting)*.
    f. Whether an event was completed after the time had elapsed.

g. Reason(s) for not having attended an event or completed a task.

- Part 2 required participants to fill out information about each of their study-related events on the designated '*diary entry*' sheets. Each participant was given 20 sheets which allowed for a maximum of 20 study-related events to be filled out during two days. They were asked to complete a '*diary entry*' sheet immediately after each event/ task had been attended or completed. The following information was required, most of which can be selected by multiple choices given on the sheets.

  a. The time started and finished, location, nature of the event, and why they performed the event in that location.

  b. Characteristics of the environment of the study location – how *noisy* and *busy* they found the environment, what the *temperature* was like, and how *frequently* they were interrupted.

  c. How *motivated* they were to carry out the task, how *urgent* the event/task was and if anything else distracted from their concentration.

  d. How well they concentrated during the event, and whether they thought they had concentrated better or worse at the beginning and end of the session.

  The six italicized factors in b) and c) are elicited from the interview data analysis, which showed that these factors were significant in affecting the concentration level of a student; the related interview data analysis is described in 5.2.

- Part 3 required participants to fill in a designated '*diary-questionnaire*' to provide the following additional information.

a. *Diary planning* – a) whether they normally used a diary, b) if not, did they experience difficulties in planning and keeping it up-to-date and c) whether they were in the planned locations and/or carrying out the planned activities.
b. *External factors* – whether noise, busyness of the environment and temperature affected their concentration.
c. *Internal factors* – whether motivation, internal distractions and doing an urgent task affected their concentration.
d. *Concentration level* – whether this was consistent during a learning session.
e. *Learning activities* – which activities they would carry out when they had a) less than 15 minutes, b) 15 – 30 minutes, c) 30 – 60 minutes and d) over an hour.

An instruction sheet containing the procedure of conducting the diary study accompanied the diary study sheets which were given to each volunteer. Additionally, the exact procedure was verbally explained to the participants. They also signed a consent form to confirm that they agreed to participate, and the same university ethnical guidelines (for the interview study) were met and followed. The data results were made anonymous prior to data analysis and were kept confidential.

3.3.2 Validity and reliability of the diary study

This section presents a discussion on a) why a usability feasibility phase was critical to the research methodology, b) related works in diary studies and c) the decision in replacing the '*diary-interview*' with the '*diary-questionnaire*'.

A usability feasibility phase was critical to the research methodology because of the nature of the framework which deployed a learning schedule. In order to be able to retrieve the location and available time contexts accurately, users must be able to plan their schedule ahead, conform to it and keep it up-to-date. The interview data analysis showed that many participants did make use of a diary and that they followed their events closely. However, there may be discrepancies between what participants said they did, and what they actually did. Therefore, this phase was important for determining a) whether a diary approach could be used as a successful way of retrieving users' location and available time contexts, by investigating the degree of accuracy that students were able to keep to their diary; b) the important learning contexts that should be considered as the basis for recommending appropriate learning materials to students; and c) the type of learning materials that are appropriate for students under different circumstances. Further results findings were required to analyse the interview data results to answers b) and c).

Additional benefits of this methodology include that real-time information relating to participants' different learning sessions, external and internal contexts, can be collected and aggregated to provide more reliable and valid indicators of this information as opposed to those being obtained from a single interview study/assessment, focus group interview or questionnaire etc. The aggregation of multiple different situations collected by a diary study has the potential a) to increase the reliability and validity of self-reported data due to the possibility of the error or noise in the data being averaged out, and b) to reduce errors which may occur in the recall of information in a retrospective manner (Delongis *et al.*, 1992).

The diary study is a reflective data collection method and is appropriate for collecting data in situations where 1) there may be potential problems with direct or continuous observation, 2) extended observation can strain available time and financial resources, 3) natural settings are required to prevent data from being influenced by artificial conditions (Ross *et al*., 1994), 4) situational characteristics during learning/studying are required to be captured (Quenter *et al*., 2009) as people may not always be able to accurately and precisely recall their experiences after some time had elapsed, 5) rich real-time data is required and 6) the events of interest are too private and geographically dispersed to conduct direct observation (Colbert, 2001). It provides an alternative to observational research methods or the use of self-reports and is a relatively low-cost and effective way of collecting a large amount of qualitative and quantitative data (Ross *et al*., 1994; Wild *et al*., 2005).

Successful diary studies have been conducted primarily in the social sciences field, where extensive use has been made of these studies. These studies have been undertaken in the areas of health (Keleher and Verrinder, 2003), care-giving, nursing, childcare, food preparation, housekeeping, care of elderly members or the handicapped (Berk & Berk, 1979; Nissel & Bonnerjea, 1982), intercultural variables by anthropologists (Ross *et al*., 1994), time spent across life span (Harvey & Singleton, 1989), and time-allocation (Ross, 1990).

Increasingly, diaries studies have been conducted in other domains such as engineering, Human-Computer Interaction (HCI) and education. Over 30 diaries studies have been conducted in HCI, two were found in the engineering domain (Wild *et al*., 2005) and a number of studies have been completed for collecting data regarding learners' experiences as well as in user-centred development such as the work of Rieman (1993). Examples of diaries studies completed in the education domain include the investigation of learners' lifelong learning episodes for the construction of their Knowledge and Organisation System (Vavoula, 2004), the investigation of language learning experiences (Leung, 2002) and the evaluation of a first year physics course using an online diary study (McAlpine *et al*., 2004).

Initially, I adopted the '*diary: diary-interview*' approach (Zimmerman and Wieder, 1977) (RQ from the usability perspective to be answered) and had conducted this with three students in the pilot study. In light of the three conducted '*diary-interviews*' that had taken place, I felt that these were unnecessary and could be replaced simply by a standardised '*diary-questionnaire*', which participants could be asked to fill in. This is because a) an extensive exploratory interview study had already taken place and I had gathered sufficient data analysis to refine user requirements of the framework, and b) a sufficient amount of quantitative data was required to support (or reject) the formed hypotheses. Replacement of the '*diary-interview*' by the '*diary-questionnaire*' had potential 1) to assist me in obtaining the quantitative data required, 2) to provide a more straight-forward and time-effective approach for both the researcher and volunteers to conduct the interview, in order to obtain the quantitative data, 3) to increase the number of participants without requiring too much additional time and financial resources and 4) to compare data subjects easily (Wild *et al*., 2005).

3.3.3 Data collection method of the diary study

This section presents details of the recruitment of volunteers, the pilot and actual diary study and the data sample. The same recruitment process was carried out as in the interview study. Additionally, I recruited 16 students from PA College in Cyprus, who were made available to me via a colleague. I accepted this recruitment for the experiment due to a) the low availability of potential volunteers willing to participate in experiments; a well-known problem in academia (Cooley *et al*. 2003), and b) the potential to increase participants from more than one country and expand the representativeness of the data sample. Also, I felt it would be of interest to compare the data analyses between the two batches of participants.

The diary study commenced with a pilot study of three students over two days. Reasons for carrying out the pilot study were the same as those for carrying out the interview study, as described in 3.2.3. Two PhD and a Masters student from our computer science department participated in the pilot study. Subsequently, 10 students from the University of Warwick, two students recruited from a language school in Germany and one student from the University of Nottingham participated in the study. The data from these 16 students were named *batch 1*. The data from the 16 students from the PA College in Cyprus were named *batch 2*. The total participants numbered 32. The data sample is valid because a range of different students were required to increase its representativeness and to produce as wide a range of data as possible from different students (Cohen *et al*., 2007).

The *batch 1* data sample includes 12 computer science (including PhD, Masters and undergraduate), one law, one engineering and two German language learning students. The *batch 2* data sample includes seven business administration students, four business computing, three accounting, and two marketing students. Participants were in different years of studies and the age range was 18-30.

Some 32 students kept a diary for two days, forming a total of 64 days of diary entries. A total of 275 events were recorded from the diary schedule sheets from all participants – 181 of these were study-related events and 94 were study-unrelated. Only 162 of the study-related events had a corresponding completed '*diary entry*' sheet – a total of 109 '*diary entry*' sheets completed by *batch 1* and a total of 53 completed by *batch 2*. A total of 19 ‘diary entry’ sheets were not filled in by some of the participants from *batch 2*. They noted that since their study events were the same (such as a revision lecture) they had felt that other context information would also be the same and had not bothered to complete additional ones. Meanwhile, 31 out of 32 participants had completed the ‘*diary-questionnaire*’. This formed a sufficient amount of quantitative data for analysis for me to use as a sufficiently large enough data set to answer the research questions. In the ‘diary: diary-interview study’ carried out by Vavoula (2004), the researched obtained 118 learning experiences from 12 student volunteers, which helped them to form the user requirements of their Knowledge and Organisation System.

3.3.4 Data analysis method of the diary study

The diary study was a collection method for primarily quantitative data as well as a small amount of qualitative data. A statistical data analysis was required to be performed on this data for interpretation. I formed a number of hypotheses from the interview study results, which required testing through statistical analyses. I have described below the methods/statistical tests used to prove (or disprove) the hypotheses in each of the research questions of the diary study; these questions are presented in 1.4.

1. *Can users plan their daily schedule ahead, conform to it and keep it up-to-date?*

   H_0: Users are able to plan their daily schedule ahead and conform to those activities that they feel are important to them.

   I observed the frequencies of events that were adhered to and examined the reasons students provided for the events which were not adhered to.

2. *Can the location and available time be retrieved from the learner's diary?*

   H_0: The location and available time can be retrieved accurately from the learner's diary for those events that they feel are important to them.

   I investigated whether there were discrepancies between the planned and actual location and start and finish times of events that were adhered to.

3. *Which learning contexts should be used for recommendation?*

   H_0: There is a *negative correlation* between the concentration level of a student and a) *the level of noise in the environment*, b) *how busy the environment is* and c) *the frequency that they are interrupted*.

   H_0: There is *a negative correlation* between the concentration level of a student and *the temperature in the environment*.

   H_0: There is a *positive correlation* between the concentration level of a student and a) *their motivation* and b) *the urgency of the task*.

   Zero-order and partial correlations as well as regression analysis were obtained from the '*diary entry*' observations to determine the relationships between the concentration level of a student and each of the variables, in order to ascertain which learning contexts are significant and should be used for recommendation.

   H_0: There is a degree of consistency among student concentration levels throughout a learning session, providing that they are motivated.

   To test this hypothesis, a t-test and analysis of variance were performed to compare students' concentration levels a) at the start and end of learning sessions, and b) at the start, throughout and end of the learning sessions, respectively.

4. *Which types of learning materials are appropriate for different situations?*

H_0: The more reflection a learning/studying activity requires, the higher the concentration level students require for the task.

Qualitative data analyses of the interview and diary studies need to be investigated collectively in order to define a set of materials appropriate for different situations.

3.3.5 Limitations of the diary study

I describe the limitations of the diary study in terms of the general advantages and disadvantages of using an implemented framework prototype to perform real technological evaluation on human users with mobile devices. Advantages include that a) the evaluation would be conducted in the same authentic manner that the eventual product would be used, and b) different and more informative results than the pen and paper exercise may be obtained.

General disadvantages and constraints include that a) large amounts of time and financial resources are required for implementation including the debugging process and a data-logging function for tracking interactions and operations carried out by users with the system, b) these are difficulties in achieving a system robust and reliable enough for participants to work alone for a few days, c) a fault occurring in other parts of the system may result in data being lost, d) PDAs do not contain permanent memory and therefore, steps must be taken to ensure that unintentional loss of data do not occur, i.e. need to ensure that the battery has enough power and is regularly charged, if required, e) having enough data storage and ensuring that data is held safely (Quenter *et al*., 2009), f) mobile devices may get lost, misplaced or damaged and g) if the system fails, volunteers may be deterred and reluctant to continue with the experiment. Similar technological problems were reported in the prototype evaluation of the Mobile Learning Organiser (Corlett *et al*., 2005).

Precise constraints (relating to the research methodology) include a) the number of mobile devices, which must be sufficient for volunteers to carry out the evaluation for two days (or the amount of time must be sufficient if only one mobile device was available), b) the requirement of potential training time if participants were not familiar with using mobile devices. Reported drawbacks of using an electronic diary for evaluation include screen display and input problems (Quenter *et al*., 2009). Due to the constraints and disadvantages of using implemented prototypes, Gillham (2005) had utilized a diary study for their cross-cultural investigation instead of a laboratory-based study.

The aim of the usability study was to a) eliminate the possible technological influences so that the potential deployment of the framework is not related to the maturity of mobile devices, or how sophisticated they are, b) eliminate the reliance on computer logs as these could be unreliable and c) focus on the learner and their learning process. The interview results findings showed that, while some participants had objected to the use of mobile devices for learning, they had not objected to learning in different locations using paper-based materials. As a result, an additional design of the framework aims to suggest appropriate paper-based materials to learners, whereas the original design is aimed at providing electronic-based Java learning materials (in the form of LOs) to learners. The diary study was designed so that data could be collected and analysed relating to both of these designs.

3.4 Case Study: Context-based recommendations of Java LOs

Some of the challenges faced in the design of further research activities to validate my framework are derived from the novelty of this field, especially in the design and evaluation of context-aware suggestion mechanisms. At the time of writing, only one publication (Martin and Carro, 2009) has been located which contained two case studies and results findings of an evaluation of a context-based suggestion mechanism.

In order to validate my mCALS framework, I designed a further research activity to answer two research questions relating to the framework. The first question is *how appropriate are the modified suggestion rules of Cui and Bull's (2005) work, which are incorporated into my framework, for suggesting Java learning objects to students based on their contexts*. The second question is *for what reasons do students choose particular time slots to study in*, in order to validate my novel concept of using a learning schedule to retrieve users' learning contexts.

This activity was an evaluation of a number of Java LOs by first year computer science (and other related courses) undergraduate students, primarily at our university. The LOs were obtained from the Codewitz LOs repository www.codewitz.org. Since these LOs are primarily of *tutorial* type, I have adapted the suggestion rules for students to study particular Java LOs. This was based on the learners' level of motivation, their knowledge/proficiency level of Java and their amount of available time. For example, when a student had a lower level of motivation, easier LOs to study were suggested, and vice versa. The proficiency level of the LO and the length of time it requires to be completed are matched with the knowledge level of the student and the amount of available time that they have.

Participants of the study were asked to complete a feedback form after they had completed each online Java learning object. The feedback form was divided into three sections. The first section provided some basic information about the LO that was studied, the location it was studied in, length of time required, the rated motivation level of the participant at the time of study, the participant's year and course of study and name of university. The second section provided information about studying the LO in those contexts, as follows:

1. How useful it was to study the LO in the set of contexts, i.e. motivation level, Java knowledge level, amount of available time;
2. Whether their learning experience of the LO was enjoyable;
3. Whether their experience was more enjoyable as a result of studying the LO in the proposed contexts;
4. Whether the LO was appropriate to be studied in those contexts;
5. How feasible, in their opinions, it would be to study the LO in any other contexts;
6. Which other learning activities, in their opinions, CAN be studied effectively and enjoyably in the same contexts;
7. Which other learning activities, in their opinions, CANNOT be studied effectively and enjoyably in the same contexts;
8. Whether they are aware of any LS that they may have;
9. Whether they know what these LS are;
10. Whether they would have benefitted from studying a LO suited to their LS.

The final section a) related to learning content – 1) how useful they found the LO to be; and 2) would they use it again; and b) related to the time slot – 1) why they chose the particular time slot to study the LO; and 2) whether the time slot was a good time for them to study in.

My online experiment can be viewed in Yau (2010). Appendices C and D show some screen shots of the online experiment, and the user feedback form for each LO respectively.

3.4.1 The validity and reliability of the Java LOs study

This experiment is valid as one of the means to validate whether the proposed learning contexts and suggestion rules are appropriate for use within my framework because it is a proof of concept regarding these two aspects that I wish to validate within the proposed framework. I have set up the online Java experiment using a selection of procedural and object-oriented topics taken from the Codewitz learning object repository including If-statements, arrays, while-loops, exceptions, methods, classes, arithmetic and object-oriented programming. The experiment was set up to allow participants to first select their available time (10, 15 or 20 minutes), followed by their current motivation level (high, medium, low), followed by their knowledge level of Java (high, medium or low). A choice of a few LOs that are appropriate for the context appears for the participant to select to learn/study. These suggestions are based on 1) formed general suggestion rules are as follows, and 2) the established proficiency levels of Java. Note that the difficult, medium and easy levels of tasks are in terms of cognition. See Appendix C for some screen shots of this experiment.

- If motivation = high and available time > 30 min then difficult tasks are selected.

- If motivation = medium and available time > 30 min then medium tasks are selected.
- If motivation = low and available time > 30 min then easy tasks are selected.
- If available time < 30 min then easy tasks are selected.

In order to assign particular Java topics to students based upon their proficiency level of Java for my case study, I needed to first determine an order of difficulty of Java topics. A fellow student and I were not aware of any previous work that had been completed on this at the time, so we conducted two experiments – 1) a literature review of currently deployed Java textbooks at our university, and 2) a questionnaire completed by students to indicate their perceived difficulty levels of Java topics. The results of these experiments are in Yau and Joy (2004), and the topics and their levels of difficulty (in brackets) were established as follows – assignment (1), expressions (2), output (3), input (4), if-statements (5), for-loops (6), arrays (7), methods (8), classes (9). For example, when participants have a lower level of motivation, easier LOs will be suggested to them to study, and vice versa. The proficiency level of the LO and the length of time it requires to be completed are matched with the knowledge level of the student and the amount of available time that they have. In summary, I had used my previous knowledge of Java and the difficulty levels of topics within this (from my masters studies – Yau (2004)), to assign some of the appropriate Java LOs to particular contexts of use.

3.4.2 Data collection of the Java LOs study

Participants were recruited via lectures and emails within our university as well as in other universities via HEA-ICS (Higher Education Academy – Information Computer Sciences). A total of 14 university students participated in our study – Warwick (6), Nottingham Trent (2), Coventry (2), Greenwich (2), Bradford (1) and Dundee (1). It was not necessary to record gender and age information. Participants were asked to complete an online feedback form after they had finished studying/learning an LO. Feedback required from participants primarily related to 1) how useful they had found the study of the LO in the contexts, 2) whether their learning experiences of using the LO was more enjoyable as a result of studying it in those contexts and 3) whether the suggestion rules were appropriate in the recommendation of LOs.

3.5 Case Study: Availability and quality of LOs in the public domain

In order to analyse how viable it is to incorporate reusable LOs into the framework, we conducted a case study. The research question I seek to obtain answers for in this exercise is "which Java LOs in the public domain are high-quality and reusable and can be incorporated into the framework?" My research methodology for this study is divided into two parts. The first part includes a web search of the following to determine all potential LOs developed by institutions in the English-speaking world, as described in 1-3. The second part includes an assessment of the quality of the LOs, using an administrative criterion, described in 4, and the Learning Object Review Instrument (LORI), described in 5.

1. A list of institutions in the English-speaking world was formed. These countries include the UK, USA, Canada, Australia, New Zealand, Hong Kong, Singapore, India, Sri Lanka, South Africa and some countries in the Middle

East such as UAE. I included these countries because the primary language of instruction is English. The institutions include all universities, polytechnic institutions and any other institutions which offer higher degrees including diplomas, bachelors and masters degrees. My aim is to investigate the potential LOs that may be used as part of these degrees for teaching university students in these institutions.

2. I searched through the institutions' websites to determine whether the institutions have a computing (or related, such as software engineering, business computing, mathematical computing, information technology, digital multimedia, web-scripting and so on) course. A total 1567 institutions were found to contain a computing department and I noted down the names of the departments in which these computing courses were offered. The different names of computing departments include Dept/College/School of Technology, Engineering, Science and Technology, Maths and Computer Science, Information Technology, Information Systems, Informatics, Computing, Computer Science, Computational Sciences, Business Studies and so on. I filtered out 2633 institutions because they did not contain any computing courses. Some 17 of these were Canadian institutions which provided instruction in French and were therefore also filtered out.
3. I then searched through each of the 1567 institutions' internal search engines using the term "learning object". Note that the Google search engine was used, where institutions did not have an internal search engine. In such cases, I searched using the terms "<name of institution>" and "learning object". A total of 895 institutions returned relevant hits, while 672 produced no relevant hits with the term "learning objects", respectively. Next, I again searched

through those 895 institutions with relevant hits using the term “learning object”. Only 14 of these institutions had a learning object repository or had developed more than one LO for instructional purposes. See 8.1 for the list of these institutions. Note that a few of these institutions were not included in this list because – 1) a login is required to view their LOs, or 2) their LOs are copyrighted, or 3) there are no metadata attached to the LOs or 4) their LOs do not actually contain learning materials. I then generated a list of LOs – distinguishing between computing, programming, object-oriented and Java; see 8.1.

4. I investigated the quality of these LOs based on administrative criteria as part of the research work with HEA-ICS. The criteria are that a LO 1) must be editable, 2) contains English-speaking material, 3) contains metadata, 4) must be used as part of a course, 5) have a sufficient level of granularity (it must be a lecture, assessment etc.), and 6) it must have free licensing such as creative commons. I decided that this criterion was too rigorous and subsequently lessened the quality requirements to incorporate a larger set of LOs which are also of high-quality. The new criterion requires that the LOs are free to view (but not necessarily for editing or re-distribution), and must not have free licensing. The generated list of LOs numbers 1112.
5. Finally, I further examined around 200 of the 1112 LOs based on the LORI (Nesbit *et al*., 2003). I selected a represented sample of 200 LOs due to time constraints. LORI is an instrument for researchers to use to assess the quality and suitability of LOs by providing a common review format for making comparisons among LOs. Reviewers can rate and comment with respect to nine items when evaluating a LO with LORI. The nine criteria are 1) content

quality, 2) learning goal alignment, 3) feedback and adaptation, 4) motivation, 5) presentation, 6) interaction usability, 7) accessibility, 8) reusability and 9) standards compliance. I used the first eight criteria for reviewing a random sample of 200 LOs. The ninth criterion was not applied because concern is not currently placed on the conformance of LOs according to the international standards and specifications such as LOM and SCORM. My focus is primarily on the pedagogical qualities of these LOs concerning the first eight categories. Table 8.1 shows the number of counts for the 200 LOs on a ratings scale of 1-5 for each of the eight criteria of LORI. Examples of how I assessed some of the LOs are illustrated in 8.3.

3.5.1 The validity and reliability of the LOs study

My investigation is valid as a snapshot of the number of LOs available in the public domain. I conducted a comprehensive search and spent a considerable amount of time on this investigation. The validity and reliability of this investigation for each of the steps carried out in 3.5 above are as follows:

1. I gathered the lists of institutions in English-speaking countries, primarily from Wikipedia. This is mostly reliable and it was not possible to search for every individual institution in a search engine on my own, due to time constraints.
2. In the searches for computing and related departments within the institutions, it is possible that I missed some institutions if the departments were classified under faculties which could not be deemed obvious or normally expected, and therefore were missed. For example, there might have been computing courses

hidden in other departments such as ‘art history with computing’, within the Department of Art. This is a potential threat, but likely a small one. Were I to want to determine exactly how great of a threat this is, I would have to find the additional data and this was not possible due to time constraints.

3. I used the term “learning object” in my searches and may have missed those LOs which did not have the phrase “learning object” in them. Due to time constraints, I could not second guess all the other possibilities/variations of what the LOs would have otherwise been named. I eliminated those references to LOs as non-LOs where they were research papers, conferences focused on LOs etc, and there could have been slight possibilities that these were in fact learning materials (i.e. LOs) but chances of this are low.
4. This step was reliable because I had checked through every LO in the generated list and carefully compared it with each of the administrative criteria. As the criteria was fairly objective (either yes or no), the outcomes of this criteria for each LO are fairly consistent.
5. The ratings within LORI standard are fairly subjective and the same LO may be given different ratings by different researchers. It was difficult to ensure the consistency of the ratings across the 200 selected LOs. Due to time constraints, I was not able to spend a large amount of time cross-checking the ratings among the different LOs. See 8.3 for more details about this.

3.6 A technological feasibility study via a technical design approach

I decided to construct a technical framework design to illustrate the technological feasibility of the framework. The aim, however, was not on assessing the effectiveness of implemented mobile technologies because technology capabilities tend to advance continuously. User requirements of my framework were refined and these were finalised using the interview and diary data analyses. These requirements were used to extract the required components for constructing the software design documentation. I conducted an extensive literature review to demonstrate the successful deployment of various mobile and context-aware technologies so that I could determine how various technological components were effectively incorporated into the design specification. The target end result of this was a specification which developers can make use of to fully implement the framework. The validity and reliability of this study is described in 3.6.1. Limitations of this study are similar to those described in 3.3.5 and are therefore omitted in this section.

3.6.1 The validity and reliability of the technical design approach

To illustrate the validity and reliability of the paper-based technical design approach, I have compared it with an alternative evaluation methodology using an implemented prototype, described in 3.3.5. An experiment using a prototype on a mobile device can be used by participants to determine whether the recommendations of learning materials are appropriate to students in different situations (these recommendations are as established in 6.5) is consistent with the opinions of the students themselves. Performing learning/studying activities on an actual mobile device may allow students to visualise learning/studying in that location and situation. Therefore, different results may be obtained relating to the types of learning materials they wish to perform. On the one hand, this experiment with the system prototype can be regarded as a pedagogical activity to determine how accurate and suitable the recommendation of learning materials for students studying in different situations. On the other hand, it can be regarded as a technological activity to determine how accurate and suitable the recommendations are for students when using mobile devices.

Throughout the various phases of my research methodology, the learner was placed at the centre of the feasibility studies. The focus was on assessing how a typical learner would use an m-learning framework/application from the pedagogical viewpoint and not vice versa. I envisioned that there may be differences in the evaluative outcomes between the deployment of evaluation methodologies from the *pedagogical* and *technological* perspectives. Currently, there are many developed context-aware m-learning applications which have been evaluated by users from the technological perspective, as described in 2.6. Similar technical feasibility studies have been conducted for developing generic mobile e-learning applications (Dochev and Hristov, 2006), for aggregating m-learning materials (Yang, 2007), for designing an acceptability analyzer in context-aware m-learning applications (Bhaskar and Govindarajulu, 2008) and for developing an ontology-based context-aware m-learning framework (Siadaty *et al.*, 2008). However, evaluations from the pedagogical perspective of many of these applications are still lacking.

3.7 Data Triangulation

I performed three sets of data triangulations to check the consistency and validity of the interview and diary studies findings. I first triangulated participants' interview responses with the questionnaire/checklist that they completed at the end of the interview. Secondly, I triangulated the interview study findings with the diary study findings. Thirdly, I triangulated each part of the diary study with the other parts of this diary study. The three sets of data triangulations are discussed below.

1. I checked the completed checklist of each participant against the responses they gave during the interview. It was found that the interview responses were consistent with the information participants had provided in the checklist. For example, during the interview, a participant may have noted that noise and temperature can affect their concentration, and they had indeed noted in the checklist that noise and temperature had a high significance in affecting their concentration level.
2. The interview and diary study findings were triangulated. For example, participants in the interview study had noted a variety of study locations, and in the diary study participants had studied in many of these different locations. The noted reasons by the interview participants of preferring to study in particular locations correspond to the reasons given by the diary study participants.
3. The three parts of the diary study were triangulated with one another. For example, the factors which participants indicated affected their concentration significantly in part 2 of the diary study were compared with the responses given in the 'diary-questionnaire' in part 3 of the study.

3.8 Summary

This chapter focused on the research methodologies deployed to achieve the aims of my research, which were 1) to construct and demonstrate a pedagogically effective suggestion mechanism framework, intended to be implementable on a mobile device and deployable by university students, and 2) to determine a successful way of retrieving users' location and available time contexts, while avoiding the use of context-aware sensor technologies as well as making users directly provide them to the device at the point of usage. The research methodology consisted of six phases. The first theoretical framework development phase was based on an extensive literature review. A suggestion mechanism should contain a method for detecting and retrieving contexts, a user and a contextual model, an adaptation mechanism and a database for storing learning materials. The idea of using a learning schedule was developed and integrated into the framework, as a way of retrieving contexts.

Three types of feasibility studies to be conducted were described – *pedagogical*, *usability* and *technological*. The pedagogical study was an interview study, the usability study was a diary study and the technological study was a technical framework design. The interview study was conducted to investigate the daily (m)-learning requirements of intended users and examined whether the framework could be successfully utilized by these users. I formed hypotheses using the results findings concerning factors which could distract learners from learning/studying in a location. These hypotheses were tested using the data obtained from the usability diary study. The validity of both of these studies was examined and described as were the limitations of these studies. I discussed the data collection and analysis methods in detail for both of these studies. The research methodology of two further validation studies was then presented.

The practicality, advantages and disadvantages of alternative evaluation methods including the deployment of an implemented prototype on a mobile device were presented. One advantage is that users would be deploying the real system on a mobile device, which may help them to better visualise the scenarios as these may cause them to feel differently and may produce different results than the paper-based diary study. Disadvantages included the large amount of time and financial resources required to complete a prototype implementation, and for it to be robust enough for volunteers to work on alone for a couple of days.

Finally, I presented the discussion of a technical system framework design, utilizing the final requirements elicited from the studies. This can be used to facilitate the construction and implementation of the suggestion mechanism framework on a mobile device.

Chapter 4

A Theoretical mCALS Framework

"A mobile learning system according to our understanding must sort out inappropriate learning material and provide the learner with exactly the material he needs, is willing to and able to deal with and which makes sense in the special learning situation" (Becking *et al*., 2004).

One of the motivations of my research in constructing a suggestion mechanism is inspired by one of Cui and Bull's (2005) arguments, which is as follows: (Note that ITS refers to Intelligent Tutoring System).

"In a full ITS, local storage of a large amount of information on the handheld device can become problematic. Therefore, it is suggested that data is stored on a desktop PC, and the learner model transferred between desktop and mobile device during synchronisation. All currently potentially appropriate or relevant materials according to the learner model, will be transferred to the handheld computer when the learner synchronises the devices, and those materials no longer relevant will be deleted" (Cui and Bull, 2005).

The construction of a suggestion mechanism framework for recommending appropriate learning materials to students based on their learning contexts was motivated by two factors. The first is that there are an increasing number of university students who choose to learn/study in different types of locations (such as in the library, café, park, at home, on the bus and train) (Cui and Bull, 2005). The rationales for students wishing to learn/study in these various locations include the following.

1. Library – students may enjoy the quietness in this environment, which they find very productive for carrying out intensive tasks such as essay or report writing.
2. Cafe – students may enjoy the company or presence of other people whilst doing some light studies such as reading.
3. Park – students may enjoy learning/studying in this environment as they find that it can help them to release some of the stress that they are experiencing.
4. At home – students may find it a) helpful to study at home because they enjoy the comfort there, and/or b) convenient as they are able to simultaneously look after their children (for example).
5. Bus – students may find that they are required to complete an urgent task on the bus en-route to a lecture
6. Train – students may find that they want to make constructive use of commuting time to and from their university each day. This applies especially to those who have limited time due to additional work and family commitments.

Examples (1), (2), (3) and (4a) illustrate the reasoning behind students *wanting to study in a particular location*. These include increased productivity and satisfaction, comfort and enjoying a more laid-back environment for learning/studying. The latter two factors may possibly lead to higher productivity levels as a result. Examples (4b), (5) and (6) illustrate the reasoning behind students *requiring to study in a particular location*. The basis for this may include that a) their time is constrained in completing an urgent task, and b) other commitments are binding them to a particular location. The conditions within different locations can affect a learner's choice of learning activities differently, and also their ability to accomplish them successfully. Students may also wish to carry out their learning/studying activities at every given opportunity and/or whenever they have available time. This may not naturally always hold true, however as argued by Kukulska-Hulme and Traxler (2005):

"Learning outside a classroom or in various locations requires nothing more than the motivation to do so wherever the opportunity arises".

The second motivating factor is that the act of learning/studying usually requires a learning infrastructure and/or actual learning/studying materials to be available to a student, otherwise learning would become difficult or impossible. An adequate learning infrastructure coupled with pedagogically-sound materials appropriate for that location may result in an increase of students' motivation for conducting learning/studying (Becking *et al*., 2004).

Martin and Carro (2009) have suggested that "[i]t is a fact that many people usually carry one or more mobile computing devices with them, including smart phones, personal digital assistants (PDAs), or laptop…[and] people usually spend a lot of time working and also travelling from one place to another (from home to work/study and vice versa, for meetings, business, and so on). Time has become a really valuable good in our society, and in many cases, organizing one's time in an optimal way is rather complicated. In such a scenario, the use of mobile devices either to get on with pending tasks or even to ask for advice about how to spend well (sic) time is pretty useful".

Martin and Carro (2009) further argued that "mobile devices and wireless technologies can be used to motivate students to learn in different contexts and active ways, for example, by proposing and allowing them to interact with online educational resources through handheld devices, suggesting them different activities according to their particular context so that they can benefit from idle time to study.

These devices can be used from anywhere to take notes, communicate with other students and teachers, as well as to perform learning tasks (either individually or collaboratively) in real time" (Ibid). They argued that it is also important to help students organize their tasks and time too.

The aim of my framework is to assign learning materials to students which they would find appropriate for the location they are situated in as well as for the amount of time they have available, and appropriate for other current learning contexts such as their knowledge level and current concentration level for learning. This is in order to maximise the productivity of students in a given situation.

The remainder of this chapter investigates how a theoretical framework can be constructed to support the appropriate recommendation of materials to students. In 4.1, I provide illustrative scenarios of the potential outcome of the intended recommendation process of the final framework. From 4.2 to 4.6, five research questions relating to the theoretical framework are presented and discussed. Finally, summary and conclusions to the chapter are presented in 4.7.

4.1 Scenarios of the potential outcome of the final framework

In order to demonstrate the potential outcome of the intended recommendation process of the final framework, I present four scenarios with four different Java-learning students. Learning materials are selected for these students based on three learning contexts – *their knowledge level* (of the proposed topic), *their available time*, and *their concentration level* (at that location). The primary target of the theoretical framework is computer science students who are required to learn an object-oriented programming language such as Java. The reasons for the consideration of these contexts to be incorporated into the framework are discussed in 4.3. The four scenarios are as follows:

1. Tom is a first year computer science student. He has previously studied computer science at A-level and has a lot of object-oriented programming experience including Java. I therefore estimate that his proficiency level of Java is approximately medium. He has 30 minutes to spare and his current concentration level is medium. An appropriate example learning activity for his current situation is to program some input and output statements, as part of the input and output topic.
2. Andy is also a first year computer science student. He has no previous programming experience whatsoever. I therefore presume that his proficiency level of Java is novice. He has 15 minutes to spare and his current concentration level is low. An appropriate example learning activity for his current situation is to read about some If-statements.
3. Sam is a second year computer science student. I therefore estimate that his proficiency level of Java is advanced. He has 15 minutes to spare and his current concentration level is low. An appropriate example learning activity for his current situation is to write or solve a While-loop.
4. Tim is also a second year computer science student and I estimate that his proficiency level of Java is advanced. He has also only 15 minutes to spare and his current concentration level is high. An appropriate example learning activity for his current situation is to write a small Classes inheritance method.

4.2 A proactive approach for the retrieval of learning contexts without the use of sensor technologies

In this section, I address the research question – “Can a proactive approach for the retrieval of learning contexts without the use of sensor technologies be incorporated into a suggestion mechanism?”

I propose to use the learner’s *learning schedule* (i.e. electronic diary on a mobile device) to retrieve their learning contexts. This is proactive and does not require the use of context-aware sensor technologies. The initial learning contexts intended to be retrieved from the learning schedule include the *location* and *available time* (that a student has at a specific point in time). These two contexts are considered because the study location of a student may affect their concentration and thus should be considered when selecting appropriate materials for students. Selecting an appropriate length of materials to learn/study according to students’ available time for study is important in the m-learning context. This is to ensure that learners have the opportunity to finish their learning task in the time available (Cui and Bull, 2005; Becking *et al*., 2004; Martin *et al*., 2006c; Bouzeghoub *et al*., 2007). The retrieval of these two learning contexts is important in an m-learning application in order to determine appropriate learning materials for students. Therefore, I wish to investigate a proactive approach without the use of context-aware technologies or requiring users to input these contexts ‘on the move’. Consequently, I developed the idea of using the learner’s learning schedule to find out their location and available time, at the time when they wish to carry out a learning/studying task.

I propose to add the following learning contexts to the framework – *concentration level of the student* and *frequency of interruption* (at a location). Cui and Bull (2005) anticipated that these contexts can be successfully inferred from the location and collectively replace the *location* context. This is because the importance of the location context is concerned with how much a student can concentrate in that location due to the possibilities of interruption. I wish to investigate whether the idea of using a learner's learning schedule to retrieve their location and available time is realistically possible. Additionally, I examined whether the location context can indeed be replaced by the concentration level of the student and frequency of interruption (at the location). Results findings relating to this are detailed in 5.5.

The addition of two learning contexts from the user model is also proposed – LS and knowledge level. The reasons for the selection and addition of learning contexts are discussed in 4.3. The LS and knowledge level contexts cannot be automatically retrieved by means of technologies, context-aware or otherwise. These need to be input by the students.

The learning schedule approach relies on students capable of a) inputting all of their daily activities (including study-related and study-unrelated) into the learning schedule on a mobile device, b) keeping all of their scheduled activities up-to-date, and c) conforming to the activities as scheduled. Providing that these three requirements are met, the learning schedule is able to accurately retrieve the location and available time of a student (until their next scheduled appointment) at a particular point in time. I propose that the following information relating to a scheduled event should initially be recorded in the learning schedule – *geographical location*, *type of location* (such as lecture theatre) (in order to ascertain the concentration level and frequency of interruption contexts), *start and finish time*, *type of event* (such as seminar) and *nature of activity* (study-related or study-unrelated).

I propose that the learning schedule approach would give further pedagogical benefits to students, in addition to the convenience of not requiring a) context-aware sensor technologies and b) input of parameters into the device 'on the move'. These pedagogical benefits stemmed from the use of a diary for students as a time management technique for their studies, especially for self-regulated students (Montalvo and Torres, 2004). In particular, it is argued that students are more likely to a) remember to attend their events and carry out their learning activities if the information regarding these is stored and could easily and regularly be referred to; b) be able to plan their study-related and study-unrelated events more effectively if information regarding their existing schedule could be viewed visually; and c) be able to self-motivate or self-regulate themselves through the act of planning their studies (Quenter *et al*., 2009). A self-regulated student can be characterized by their "active participation in learning from the meta-cognitive, motivational, and behavioural point of view" (Montalvo and Torres, 2004). The characteristics of self-regulated students coincide with the attributes of higher-performance and higher-capacity students. More precisely, a self-regulated student would be able to perform the following (Winnie *et al*., 2006; Chen *et al*., 2007; Hwang *et al*., 2006; Shih *et al*., 2007):

- Use cognitive strategies to organize, transform, elaborate and recover information.
- Direct their mental processes toward the achievement of personal goals through planning and control.
- Show positive emotions towards tasks and a high sense of academic self-efficacy, and have the ability to control these to adapt to the requirements of the task and of the specific learning situation.
- Plan and control the time and effort on tasks, and create and structure preferable learning environments such as identifying a suitable place for study and obtaining help from teachers and students when they experience difficulties.

- Use strategies to maintain their concentration, effort and motivation and avoid external and internal distractions whilst performing tasks.

Self-regulated students require both *will* and *skill* for the achievement and attainment of their learning/studying processes (Ibid). My mCALS framework aims to support the skill part for students by determining which learning materials would be appropriate for them in the current situation. I believe that by considering these circumstances, the learning/studying processes of students can be improved.

In this section, I described the proactive approach of using a learner's learning schedule to automatically identify their location and available time at the time when they wish to carry out a learning/studying task. This approach eliminates the need of context-aware sensor technologies and the requirement of students to input these context values at the time of usage i.e. 'on the move'. Advantages of this approach were discussed. My mCALS framework is built upon the m-learning organizer works of Chan *et al*. (2004), Ryu and Parsons (2008) and Mirisaee and Zin's (2009) – these works are described in 2.7. However, their organizer does not use learning contexts to recommend learning materials to users based on different contexts, and this is the area I wish to focus on to make my research contributions.

4.3 Learning contexts which are significant in the recommendation of appropriate learning materials

In this section, I address the research question – "Which learning contexts are significant in the recommendation of appropriate learning materials?"

To decide upon which learning contexts are most significant in the recommendation of appropriate learning materials, I examined the works of Cui and

Bull (2005) and Martin *et al*. (2006b), which are most related to my framework – these works were described in 2.5. I selected five learning contexts to be incorporated into the framework - *LS, knowledge level, concentration level, frequency of interruption* and *available time*. The latter four contexts were utilized in the work of Cui and Bull (2005), and the LS, knowledge level and available time contexts were utilized in the work of Martin *et al*. (2006b). The four scenarios in 4.1 illustrate the types of materials that may be appropriate for students with different levels of Java proficiency and available time, at the time of learning/studying. The reasons for the proposal of the incorporation of these five learning contexts are presented below.

LS – The importance of incorporating cognitive learning contexts into the design and development of context-aware m-learning applications has been emphasized by many authors (Prekop and Burnett, 2003; Beale and Lonsdale, 2004). This dimension of context has often been neglected in the design and development of learning applications. The dimension includes LS/preferences/strategies, knowledge level, user's goals, personality and characteristics etc. Learners may have different preferred styles of learning and psychological attributes, which were shaped by their learning experiences. These should be taken into consideration, especially during m-learning (Parsons *et al*., 2006). A more enjoyable and effective learning experience for learners can be created by matching the correct level of information according to the learner's most preferred learning style (Beale and Lonsdale, 2004). In contrast to this view, critics maintained that no difference was made in the level of the students' abilities to learn/study, whether they used materials that suited their LS or not (Coffield *et al*., 2004). However, we propose that many students can benefit from the selection of learning materials based on their LS; hence this learning context should be incorporated. Extensive research results have been obtained by Graf (2007), which established, via two evaluative studies that a relationship did exist between a learner's LS (as defined by the dimensions of the Felder and Silverman LS model, 1988) and their working memory capacity. It was found that learners with a balanced learning style for the active/reflective and the sensing/intuitive dimension, and those with a verbal learning style, tend to have a higher memory capacity. Learners with high working memory capacity may be those with a verbal or visual learning style. I propose to use the Felder and Silverman learning style model (1988) because this has been frequently used in e- and m-learning systems. As discussed earlier, different learners have different goals and LS, and it is important that these are taken into consideration in an m-learning application.

Knowledge level **–** The selection of materials appropriate to a student's level of knowledge can enhance their effectiveness of learning/studying the materials (Cui and Bull, 2005; Martin *et al*., 2006c; Becking *et al*., 2004; Bouzeghoub *et al*., 2007) because students a) may become bored and unmotivated if materials are too uncomplicated and repetitive of concepts that they already know and/or understand, and b) may not be able to progress if materials are too advanced for them; this is ineffective and could cause additional stress to students. I propose that many students can benefit from the selection of learning materials based on their knowledge level – so that they do not have to re-learn materials that they already know or have to tackle problems that are too advanced for them.

Concentration level **–** Selecting learning materials based on the student's concentration level is important (Cui and Bull, 2005; Becking *et al*., 2004). The organizer's system requests the user to input their perceived level of concentration (as high, medium or low) at the beginning of a learning session. Together with the other contexts deployed in their system, this context determines the materials selected for a student for that particular session. A student's level of concentration could be lower, more unstable and prone to interruptions during m-learning. This is due to a potential 1) higher level of noise, and 2) busier environment with more possible distractions such as people coming and leaving. I propose that students working in mobile environments can benefit from having materials recommended to them based on the level of their concentration.

Frequency of interruption – Similar to the concentration level of a student, the frequency of interruption can be higher and more unpredictable during m-learning. For example, the frequency of interruption in a café is likely to be higher than that in a library (Cui and Bull, 2005; Becking *et al*., 2004; Martin *et al*., 2006c). The frequency of interruption in a location may affect a student's concentration level, and hence I propose that students working in mobile environments can benefit from having materials recommended to them based on the frequency of interruption at that location. Cui and Bull's (2005) system also incorporated this context and requests students to input their perceived frequency of interruption at that location, at the beginning of the learning session.

Available time – I propose that a student's available time should be used as one of the bases for recommendation of appropriate learning materials to them during m-learning. This is so that an adequate amount and/or size of learning materials can be appropriately recommended to them (Cui and Bull, 2005; Becking *et al*., 2004; Martin *et al*., 2006c).

The LS and knowledge level contexts have been deployed frequently in adaptive e- and m-learning applications (Grigoriadou *et al*., 2006). Therefore, these are significant internal (to the user) learning contexts that should be considered (see 2.4.2). The replacement of these contexts by other similar ones such as learning strategies or another learning style model would not invalidate the framework. Similarly, I consider the concentration level and frequency of interruption contexts in the framework because these appear to be important factors that should be taken into account in m-learning. Similar contexts can be used to replace these such as frequency of distractions, or perceived level of distractions. The available time context should be considered in the suggestion of m-learning materials to students.

At this point in the thesis, I have not considered certain other contexts to be important or relevant to the framework. These are, for example, users' current activities, mobile devices being used, noise and temperature of the environment and so on. A user's current activity is not considered relevant to the framework because it is assumed that they are interested in undertaking a learning task when they are using the system. Therefore, their activity is to undertake a learning task. Different types of mobile devices are not considered important to the framework because it is the pedagogical aspects of contexts I wish to focus on, rather than the technological aspects of different mobile devices.

Noise and temperature may potentially affect a student's concentration level; however I do not include these because these are already covered by the concentration level context, which is to be used in my framework. I am currently not aware of learning contexts such as noise and temperature, which are used in context-aware m-learning suggestion mechanism frameworks/applications. However, these have been used for mobile non-learning applications such as in Rarau *et al*. (2005) and Costa *et al*. (2006). An initial design of our framework used a microphone to detect the noise attribute (Yau and Joy, 2007), however, after deliberation, the noise context was removed because the data analysis from my interview study showed that different students were equally potentially distracted or not distracted from the same level of noise. I decided that this noise context should be replaced by the concentration level context.

4.4 The types of learning materials which are appropriate for recommendation to students under different circumstances

In this section, I address the research question – "Which types of learning materials are appropriate for recommendation to students under different circumstances?"

I examine the suggestion rules of the recommendation processes of Cui and Bull (2005) and Martin *et al*. (2006bc) for suggesting appropriate learning materials to students. Table 4.1 illustrates the selection of learning materials to students based on the adaptation rules of Cui and Bull (2005), which were specified by available time, concentration level and frequency of interruption context conditions.

Table 4.1: Cui and Bull's (2005) adaptation rules for recommendation

Learning Materials to be recommended	*Available Time*	*Student's level of Concentration*	*Frequency of Interruption*
Tutorials, exercises and revision materials	> 60 minutes	Any	Any
	30 to 60 minutes	Medium	Low
A tutorial and an exercise relating to a single topic materials	15 to 30 minutes	Medium	Low
	30 to 60 minutes	High	High / Medium
	30 to 60 minutes	Medium / Low	Low
A tutorial and a short exercise materials	15 to 30 minutes	High	High / Medium
	15 to 30 minutes	Medium / Low	Low
	30 to 60 minutes	Medium	High / Medium
A tutorial material	15 to 30 minutes	Medium	High / Medium
	15 to 30 minutes	Low	Medium
	30 to 60 minutes	Low	High
Revision materials	15 to 30 minutes	Low	High
Tutorial on a different topic materials	< 15 minutes	Any	Low
	< 15 minutes	High	Any
A new topic material	< 15 minutes	Medium / Low	High / Medium

The suggestion rules of the recommendation mechanism of Martin *et al*. (2006c) are specified collectively by three types of adaptations - *structured-based, content-based general* and *individual*, explained below.

- The goal of the *structured-based adaptation* is to adapt the navigational guidance of a set of activities for different students, who may require support through a variety of means. For instance, it may be convenient for novice students to be directly guided through a set of activities, whereas for advanced students, it may be more appropriate to allow them to navigate freely.
- The *content-based general adaptation* rules comprise (1) conditions relating to learning contexts such as location, available time, devices and LS, and (2) the types of activities which are appropriate for a particular type of user according to their situation, as specified in (1).
- When a user has either completed or disengaged with an activity, information about the activity is stored and/or updated, and a condition relating to the execution of the activity for that individual user is created. These conditions are used to ascertain the state of activities in order for an updated list of available activities to be created. The goal of the *individual adaptation* is to decide for users a list of activities which are available and are appropriate for them based on their contexts.

Currently, there does not appear to be a clearly-defined way of deciding which type of learning materials should be appropriate and recommended to students based on their situations, especially in terms of m-learning. This forms one of the main research questions in my thesis. The learning materials used in Cui and Bull (2005) and Martin *et al*. (2006c) appear to have been specifically designed for use on mobile devices. The form of learning materials to be viewed on mobile devices is also an issue and I propose the use of LOs as materials appropriate for my framework.

The definition of a *learning object* is as follows.

> "A learning object is a piece of self-contained pedagogic data which can be used and reused in many different contexts and which has a set of self-describing metadata [in different categories and in XML format] to facilitate search and retrieval learning materials [under these various categories]" (Yau, 2004).

LOs have been widely used in m-learning applications (Bradley *et al*., 2007). Some of these LOs also contain geo-referenced metadata for describing location information (Goh *et al*., 2005). Advantages of LOs are discussed in 2.7.4.

In this section, I presented the adaptation rules of Cui and Bull (2005) and Martin *et al*. (2006c). It was established that there does not appear to be a clearly-defined way of deciding which type of learning materials should be appropriate and recommended to students based on their situations in m-learning. I propose that LOs should be applied as the form of learning materials to be used in my framework. In 6.4, I attempt to address research questions relating to these aspects using the interview and diary study analyses.

4.5 Design modules of the framework

In this section, I address the research question – "What are the design modules of the framework?" This section is divided into three parts – *the background in the construction*, *the conceptual model* and *the system architecture* of the theoretical framework. I illustrate the importance on the use of learning contexts in m-learning applications, via the relationship mappings that were found between the established Dunn and Dunn learning style model (Dunn and Dunn, 1978) and the more recent context space (Wang, 2004) and the categories of contexts (Schilit *et al*., 1994; Chen and Kotz, 2000). This highlights the importance of particular learning contexts in m-learning applications, which I discuss in the background of the construction of the framework. The conceptual model describes and illustrates the three components of the framework – *Learner's Schedule/Profile, Suggestion Mechanism* and *Learning Object Repository*. The purpose of this model is to present an overview of my framework. Finally, the system architecture of the framework is presented. This is divided into three layers – *Learner Model layer, Recommendation layer* and *LOs layer*. The design and technical details of the components are illustrated.

Background in the construction of the framework

The Dunn and Dunn LS model (Dunn and Dunn, 1978) is an established model constructed over thirty years ago which targets students conducting traditional means of learning. Many factors within the components of this model were found by Yau and Joy (2006a, 2006b) to have a direct relationship mapping to the dimensions of the context space formed by Wang (2004) and the four categories of contexts defined by Schilit *et al*. (1994) and Chen and Kotz (2000). Recall that the context space consisted of the *identity, spatio-temporal, facility, activity, learner and community dimensions* and the four categories of contexts consisted of the *computing, user, physical* and *time*; these were described in 2.4.2 and 2.4.1 respectively. Many design considerations, which should be taken into account when developing learning materials for m-learning, were included within the five categories of the Dunn and Dunn model (Dunn and Dunn, 1978; Yau and Joy, 2006a, 2006b).

In view of this, I based the recent m-learning research on the Dunn and Dunn model (1978) as providing a solid theoretical foundation to the framework. The relationship mappings between the model and the context space as well as the four categories of contexts are depicted in Table 4.2. A description of the relationship mappings between the factors within each of the components of the Dunn and Dunn model (i.e. environmental, emotional, physical, sociology and personality components) against the context space as well as the categories of contexts is provided below.

Table 4.2: Relationship mappings between the Dunn & Dunn model and Contexts

Dunn and Dunn LS Model		**Context Space and the Categories of Contexts**
Environmental	Noise level; Temperature; Light	Physical context
	Seating	N/A
	Layout of Room/Location	User Context & Spatio-Temporal Dimension
Emotional	Motivation; Degree of Responsibility; Persistence; Need for Structure	Learner Dimension
Physiological	Modality Preferences	
	Intake (Food and Drink)	N/A
	Time of Day	Time Context & Spatio-Temporal Dimension
	Mobility	N/A
Sociological	Learning Groups; Help/Support from authoring figures; Working alone/with peers; Motivation from parent/teacher	Community Dimension
Psychological	Anxious/Depressed; Somatic Complaints; Aggressive Behaviour; Attention Problems; Delinquent Behaviour; Social Problems	Learner Dimension

The Environmental component **–** Many of the factors within this component can be mapped onto the *physical* and *user contexts* and the *spatio-temporal dimension.*

This component specifies that learners may have preferences to study in different locations and under different noise levels, as indicated by the location and noise level factors. When learners are performing m-learning, the learning impact may be particularly affected by the location of where the learning is taking place, for example, whether in a classroom, on a train/bus, or in a restaurant. The level of noise in the learning environment may also affect the student's concentration. Hence, the preferences of learners to study in different locations and under different noise levels should be taken into consideration when developing an m-learning application.

The Emotional component **–** The factors within this component can be mapped onto the *learner dimension*. This component specified that learners have varying levels of motivation and degrees of responsibility to carry out their learning. Similarly, m-learning often involves learning on one’s own and may require a lot of motivation and a certain degree of responsibility. Hence, it is preferable that the learners’ level of motivation and degree of responsibility are taken into account when developing an m-learning application.

The Physiological component **–** Some of the factors within this component can be mapped onto the *learner* and *spatio-temporal dimension* and the *time context*. This component specifies that learners may have different modality preferences (i.e. visual, auditory, kinaesthetic/tactile learning), and their performance in learning/studying may be dependent on their intake (food and drink), the time of day and how mobile they felt (mobility). In terms of e-learning or m-learning, there is evidence to suggest that, whilst using instructional technologies to learn material, a student’s performance can be affected by their preferred LS, and visual learners are positively affected (Hall and Pittman, 2005). Kinaesthetic learners may also prefer to learn in the situational context.

Concentration levels of students may be different depending on whether the study period was before, during or after intake of food and drink. The time of day can determine the location, which can affect learning/studying. For example, a learner may not be willing to learn/study in the bedroom when getting up in the morning or in a restaurant after an evening meal. Also, learners may have preferences for learning during different times of the day. Some students may prefer learning whilst they are on the move, whereas others prefer to learn/study in fixed locations. Hence, it may be preferable to consider these factors - *modality preferences*, *intake, time of day* and *mobility* – when developing an m-learning application.

The Sociological component – the factors within this component can be mapped onto the *community dimension*. This component specifies that learners may have preferences to study in a learning group and/or working alone or together with peers. Hence, these factors should be considered when developing possibly either in an independent or a collaborative m-learning application.

The Psychological component – the factors within this component can be mapped onto the *learner dimension*. This component specifies that learners may have varying levels of attention. Whilst learners are performing m-learning, their attention may be affected more easily because there are possibly elements of increased noise, movement, interruptions and distractions. Therefore, this should also be considered in the development of an m-learning application.

The importance on the consideration of a number of factors was described in the background in the construction of the framework. These include the following.

- The location of study and noise level (environmental component).
- Motivation and degree of responsibility of a learner (emotional component).
- LS, food and drink, time of day and mobility (physiological component).

- Independent/collaborative learning (sociological component).
- Attention level (psychological component).

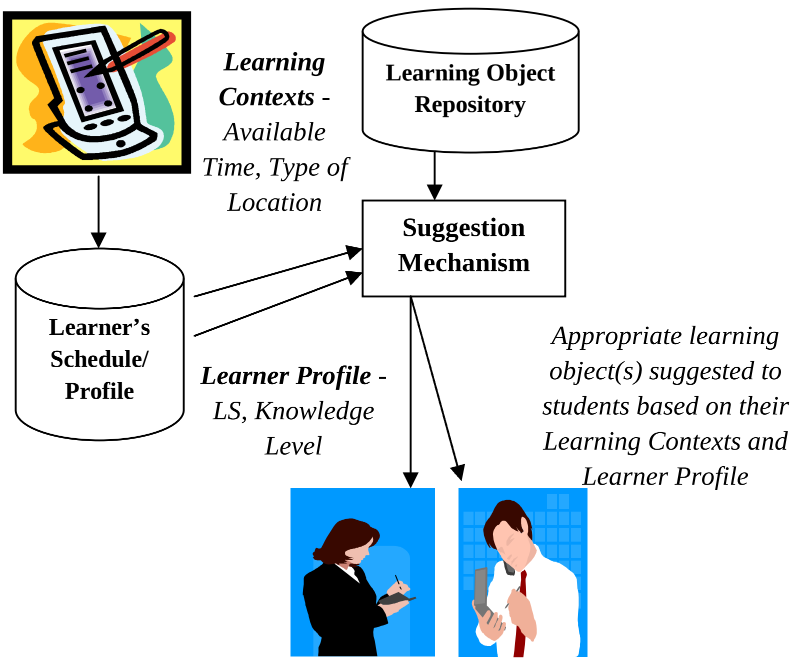
These factors are potentially important learning contexts that should be considered within m-learning applications. At this point in the thesis, I consider only the location of study and LS contexts (from the above list of factors) to be incorporated into my framework. As mentioned in 4.3, noise level is not considered. I consider food and drink, time of day and mobility to have less relevance relating to the recommendation of materials than the ones I have chosen to be incorporated. I target independent learners in the framework, therefore collaborative learning is not considered. Motivation, degree of responsibility and attention level may be incorporated into the framework, as part of the future work. It was, however, decided in chapters 5 and 6 that the motivation of a learner is critically important and has a strong positive correlation with the concentration of the learner. Therefore, my refined framework, described in chapter 6, uses the motivation level context in place of the concentration level of the learner.

Conceptual model of the framework

The conceptual model of my framework consists of three components – *Learner's Schedule/Profile, Suggestion Mechanism,* and *Learning Object Repository*, as illustrated in Figure 4.1. The learner's learning contexts (i.e. the available time and the type of location) are captured via the user's learner schedule. The learner profile (i.e. the LS and knowledge level) is input into the device by users. The suggestion mechanism is expected to suggest appropriate LOs to students based on their learner profile and contexts.

The initial scope of learning materials to be made available to students through the framework is the Java programming language, in the form of LOs. The initial target of students to use the end application includes undergraduate computer science students (i.e. typically novice programmers). The reasons for the decision to incorporate these materials were that usually a large amount of time and motivation are necessary to learn an object-oriented programming language such as Java. The three components – *Learner's Schedule/Profile, Learning Object Repository* and *the Suggestion Mechanism* – are described in detail below.

Figure 4.1: Conceptual model of the mCALS framework



1. *Learner's Schedule/Profile* – Via the Learner's Schedule, the learner supplies to the system their daily study-related and -unrelated events. A unique identifier, event start and finish time, geographical location, type of location and event type are to be recorded. Via the Learner's Profile, personal information about the learner is recorded, including a unique identifier for the

learner, surname, forename, gender, date of birth, degree and modules undertaking and their preferred LS according to the Felder and Silverman model (1988), i.e. each of the learner's preferences under the following categories are recorded – (a) active/reflective, (b) sensing/intuitive, (c) visual/verbal and (d) sequential/global. Their knowledge level relating to the Java programming language is also ascertained by performing a simple test. The above-mentioned information is stored in the Learner's Schedule/Profile.

The use of a learner profile is important during m-learning because different types of users may require m-learning devices for different reasons and may require different capabilities of the devices (Parsons *et al*., 2006). For example, a music student may require audio capabilities whereas an art student may require drawing capabilities from the device.

2. *Learning Object Repository* – all LOs are stored in this database. Different types of LOs are stored including compulsory activities (such as assessments), non-compulsory activities (such as exercises) and revision activities (such as reviews). Each LO has the following attribute – a unique identifier, title, subject, description, activity objective, priority of activity to be undertaken (high, medium, and low), duration of time needed for completion and status of activity (unfinished or finished). If the activity is not finished then the remaining duration of the activity is recorded. The LOs for Java consist of factual information, examples and multiple choice exercises and tests. Different types of LOs to facilitate learners with different LS based on the Felder and Silverman model (1988) can be made available and incorporated into the database for possible selection to students.

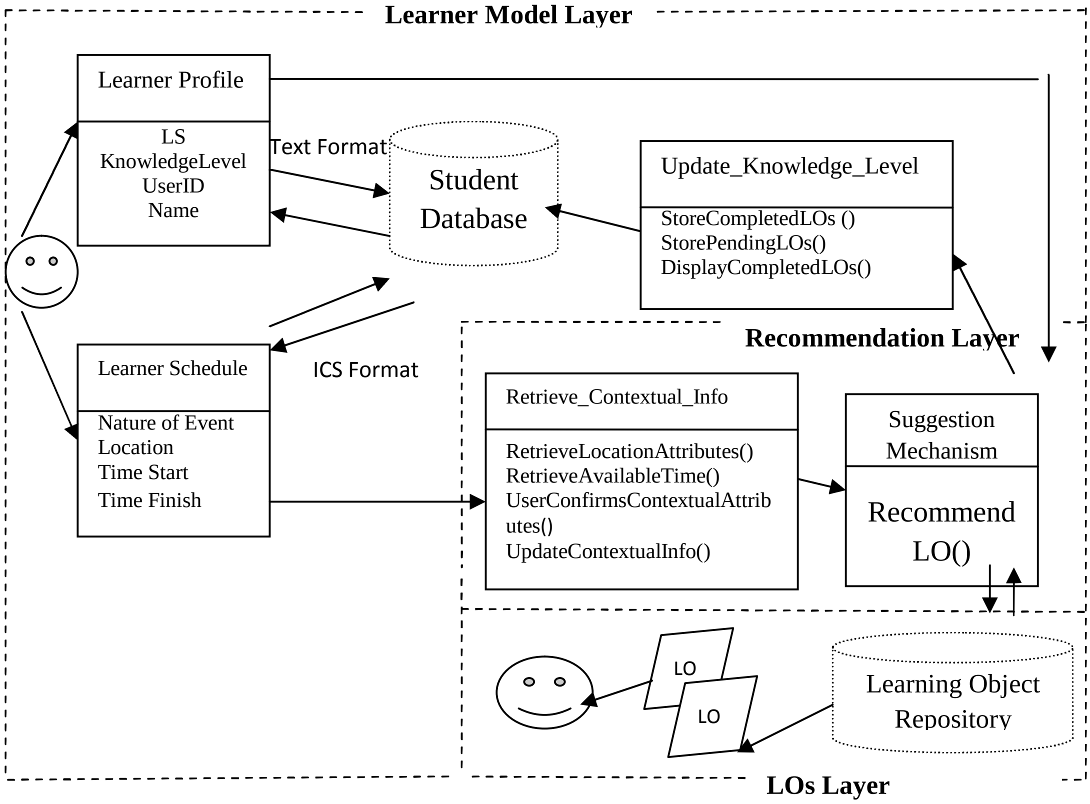
3. *Suggestion mechanism* – the suggestion mechanism is divided into *learner*

profile and *learning contexts* suggestion. The learner profile suggestion has two functions - to select appropriate materials to students based on a) their LS, and b) their knowledge level. The LS and the knowledge level of a student are taken from the Learner Profile as input, and appropriate LOs are selected and then are output to the learning context suggestion mechanism. The learning context mechanism then takes the values of the learning contexts – type of location and available time of the student – together with the filtered LOs according to the learner profile suggestion, to further select LOs that are appropriate to students in those contexts. Location information is later converted to information relating to the possible concentration level of the learner and frequency of interruption at that location, described in the next section.

System architecture of the framework

The system architecture illustrates the design and technical details of the components within the framework. It is logically divided into three layers - *Learner Model layer, Recommendation layer and LOs layer*, as illustrated in Figure 4.2. Each of the layers is described below.

Figure 4.2: System Architecture of the mCALS Framework



The ***Learner Model layer*** consists of four system components – *Learner Profile, Learner Schedule, Update_Knowledge_Level* and *Student Database*. A graphical-based calendar is displayed for ease of entry for users to enter their scheduled events (including nature of event, location, time start and finish), which are stored in the Student Database. For the purpose of retrieving and transferring the event details with ease to other system components, calendar events are transformed into ICS format, described in 9.1. LS, knowledge level, user ID and name are input into the Learner Profile, which is stored in the Student Database in text format.

In the ***Recommendation layer***, I use the location attribute to calculate two default values for the level of concentration and frequency of interruption typical for that type of location. The values of these attributes in relation to the location were obtained by a study performed by Cui and Bull (2005), where they found that different students had the same perceived level of concentration as well as frequency of interruption in the same location, although the noise levels may have been different. I propose to use these findings as default levels of the student's concentration level and frequency of interruption at the location, in place of the *type of location* context. Using the Time Start and Time Finish attributes, the available time that a student has at a particular point in time can be obtained.

The *Retrieve_Contextual_Info* component first retrieves the learning contexts information (location and available time) from the Learner Schedule and then transfers these into actual approximate values which can be used by the suggestion mechanism. The attributes taken from the Learner Schedule include Location, Time Start and Time Finish. A method is put in place to give the user the option to view and confirm the values of these attributes, or change these values, if necessary. The method is used to update this contextual information, as necessary. The parameters fed into the Suggestion Mechanism include *LS, knowledge level, concentration level, frequency of interruption* and *available time*. The Suggestion Mechanism then uses this context values to suggest appropriate LOs to learners.

In the ***Learning Object Layer*** – the LOs that have been recommended to students are stored along with the following information – whether the student has completed the task, in the case of a test or exercise, and whether the student has completed it correctly. This information is transferred to the student database and when the student has attempted an appropriate amount of material accurately, their knowledge level is increased. Three methods are used to support the updating of a student's knowledge level – *store completed LOs, store pending LOs* and *display completed LOs*.

4.6 User requirements of the framework

In this section, I address the research question – "What are the user requirements of the framework?" It is often not clear how engineers can accurately acquire the requirements of their framework/software. Maiden and Rugg (1996) have provided a framework consisting of 12 acquisition methods – observation, unstructured interviews, structured interviews, protocol analysis, card sorting, laddering, repertory grids, brainstorming, rapid prototyping, scenario analysis, RAD workshops and ethnographic methods. The initial requirements of my framework are obtained from an extensive literature review. Thereafter, I used a structured interview study, a diary study and brainstorming to refine the user requirements of my framework (see 6.5). The preliminary requirements of the framework are listed below.

1. A proactive approach in accurately retrieving the learner's current location and available time is in place, via the use of a learning schedule (See 4.2).
    a. With the ease of input via a graphical-based learning schedule, users are able to view as well as add, change and/or delete their scheduled events in order to keep them accurate and up-to-date (See 4.5).
    b. The framework is able to create and maximise the opportunities that self-regulated students have for learning/studying (See 4.2).
2. The form of learning materials, i.e. LOs is appropriate for deployment (See 4.4).
3. Five learning contexts – *LS, knowledge level, concentration level, frequency of interruption* and *available time* – are of pedagogical significance in relation to the suggestion of learning materials to students (See 4.3).

4. The types of learning materials/objects to be recommended to students based on their situations are appropriate (See 4.4).

4.7 Summary and conclusion

The theoretical mCALS framework has been extensively described in this chapter. I believe that the framework, deploying a learning schedule, can be an effective learning tool for students (especially those who are self-regulated). This is because the learning schedule can a) help them organise their work and facilitate time management, and b) be used for capturing and retrieving contexts and allowing the tool to create and enhance opportunities for students (who are willing to learn) to learn/study in various locations. Self-regulated students are those who are able to create and maximise opportunities they have for learning/studying. The research on this framework was motivated by the current lack of pedagogical knowledge in how different contexts can be made use of to enhance learning effectiveness of learners in different environments, and the lack of a standardised set of suggestion rules for recommending learning materials to students based on their learning situation.

The incentives and rationales for students to learn/study in various locations were described and I demonstrated the potential functions of my framework using four scenarios with four students of different Java proficiency levels who had different lengths of time available for study. I established that a proactive approach for the retrieval of learning contexts can be deployed, and which learning contexts are significant in the recommendation of appropriate learning materials, via a literature review. The types of learning materials that are appropriate for recommendation are discussed. Further analyses are required to determine appropriate suggestion rules for my framework. These are presented in 6.4. I then described and illustrated the design modules of the framework, including the background in the construction of the framework. The conceptual model was illustrated and described, giving an overview of the framework. The system architecture was presented, which was logically divided into the learner model, recommendation and learning object layers. Finally, I presented the user requirements of the framework.

The remainder of the thesis is as follows. In chapter 5, I present the data analysis of the potential use of a learning schedule for retrieving learning contexts. In chapter 6, I investigate the significance of the proposed learning contexts and suggestion rules in a context-aware suggestion mechanism framework. In chapter 7, I present the results of our context-based recommendations of Java LOs case study. In chapter 8, I examine how viable it is to incorporate high-quality reusable LOs into the framework. In chapter 9, I present the technological feasibility study of the framework. In chapter 10, I present my future work, research contributions, limitations and conclusions.

Chapter 5

The potential use of a learning schedule for retrieving learning contexts

In this chapter, I discuss the potential use of a learning schedule for retrieving learning contexts. I present two sets of data analyses and corresponding discussions – one relating to the qualitative data obtained from the interview study and the other relating to the quantitative data obtained from the diary study. These are presented in 5.1 and 5.2 respectively.

Via the interview study, I gained a detailed insight into the different strategies and techniques of how various students may use their diaries to help them manage their time and studies and the different manners in which diaries (whether paper-based or electronic) are used by different groups of students.

Via the diary study, I obtained quantitative data to determine whether students were able to keep to their planned diaries, to help me determine whether the learning contexts (i.e. location and time available) can realistically be retrieved by means of a learning schedule.

In 5.3, I discuss the views obtained from interview participants on mobile devices as a learning tool. Finally in 5.4, I provide a summary of the chapter, and determine the potential for using a learning schedule to retrieve learning contexts using the obtained qualitative and quantitative data.

5.1 Qualitative analysis of the potential use of a learning schedule for retrieving learning contexts

In this section, I address the research question – "How feasible is the adoption of a learning schedule for retrieving learning contexts from a **qualitative** perspective?" To answer this question, I investigated the following three aspects - 1) whether the participants did indeed make use of a diary in the first instance (and also which type of diary they used – whether paper-based or electronic-based), 2) why they used diaries and what benefits they obtained from them and 3) how closely participants conformed to their diaries (to determine the realistic accuracy of retrieving learning contexts from the learning schedule). I obtained data which showed the relationships between learner characteristics and the type of diary usage, which is subsequently presented. Finally, I conclude with an overall analysis of the section.

1) Do participants make use of a diary in the first instance?

In order to analyze the potential use of a learning schedule for retrieving learning contexts, I asked interview study participants whether they made use of a paper-based or electronic-based diary on a daily basis. A total of 17 participants made use of *paper-based* diaries, 10 participants made use of electronic-based diaries on their PDA, mobile phone and/or computer and 10 participants made use of a '*mental*' diary. I describe the reasons participants chose to use each of these types of diaries below.

- *Paper-based* diaries were used because some participants preferred to record new events by hand and cross off those that had been completed, thus updating their diary. They described feelings of satisfaction at ticking boxes by hand when tasks have been completed; the diaries were portable and more convenient as they do not require being switched on.

- *Electronic-based* diaries were used on a PDA, mobile phone and/or computer because some participants liked 1) their portability and the integrated approach of using the same device for other activities (such as reading and creating lecture notes, office applications, Internet browsing and phone services); and 2) the ability to synchronize their diaries with their other desktop and/or laptop computers. One participant has made use of Google Calendar because it allowed events to recur requiring minimal effort and because reminders as text messages were sent to the participant's mobile phone informing them of forthcoming events and deadlines. Many participants who had used an electronic-based diary as well as other software applications on their mobile devices were computer science students.
- A '*mental*' diary i.e. '*mental scheduling*' was used by some participants because a) it is potentially more flexible for more spontaneous students who do not wish to conform to a set of scheduled activities; and b) they would not be able to conform to a structured time-plan for each day. There were two types of 'mental' diary users – 1) users who regarded themselves as too lazy, and felt that the physical diaries required too much time and effort to keep and update, and they were often forgetful of events; 2) spontaneous users, who did not want to adhere to a strict schedule, but often performed 'mental scheduling' and knew what they were required to do each day.

The data analysis shows that a number of paper-based diary users would switch to and be willing to use electronic-based diaries if a) the input of diary events was sufficiently easy (or their lecture timetables were directly transferrable to the device), b) they had an electronic-based diary made available to them and/or c) they were not against the use of mobile technologies. Users would also be more inclined to use electronic-based diaries if they had used and found other accompanying software applications useful on the mobile device.

2) Why participants made use of diaries and what benefits they obtained from them?

I gathered the participants' opinions on why they found the use of a learning schedule to be beneficial for them. This helped me to further determine the real potential deployment of my framework utilizing a learning schedule, i.e. if most users used a diary, then the realistic applicability of my framework using a learning schedule would be higher. There are two main types of benefits of diary usage gathered from the interview participants. The first is those which are obtained through the act of planning either as *a time management technique* and/or as *a goal-setting and achievement technique*.

The advantages of using a diary for *time management techniques* include the following.

- The ease of assigning time to pending tasks because diaries allowed users to visually see the free blocks of time in day/week/month format, and urgent tasks/priorities could be viewed and scheduled.
- The ease of breaking down tasks and assigning each partition into free time slots.
- The ease of deciding whether they have sufficient time for other activities.

- The ease of planning tasks to be completed for the whole day/week/month so that no time is wasted.
- Having the feeling that they are in control of their activities and do not forget important events, deadlines etc, because at any one time a learner may have a number of complex and/or novel tasks to complete, and without a plan or learning schedule to assign time slots to complete each task the learner may forget to complete some of them (Kennedy *et al*., 2000).
- Help in alleviating or lowering stress as users know that their important tasks are assigned a time slot for completion and that they will not forget about these tasks/events.

Using a diary can be regarded as a *goal-setting and achievement technique* because the act of planning can be seen as a motivating, self-regulated and/or self-directed learning strategy to reach one's desired goals (Claessens, 2004). Self-regulated learning theories include deployment of motivational strategies such as elaborative planning, processing and monitoring (Code *et al*., 2006). Self-directed learning is a "student-centred approach to learning where learners take control of their own learning processes and experiences" (Ibid). The logistics of the learning/studying processes, such as how, where and when to learn, are decided and controlled by the learner through the act of planning. Most of the participants were able to describe techniques (including planning techniques) to motivate their studies as well as to actually carry out their studies, and identify study locations which best suit their learning requirements. This suggests that these participants have a number of self-directed and self-regulated learning characteristics, and through the act of planning, they are able to motivate themselves with their studies.

3) How closely participants conformed to their diaries?

I gathered information from interview participants on how closely they conformed to their diaries, as this can give an indication of how accurately the learning contexts (i.e. location and available time) can be retrieved through the use of their diaries. Three categories of diary conformance by interview participants were identified – *close conformance*, *loose conformance,* and *spontaneous*. Note that all categories of users had met all of their coursework deadlines.

- Users who *closely* conformed to their diaries usually attended all of their scheduled events, aside from when there were exceptional circumstances (such as illness or something more urgent came up). Some participants noted they would keep all their planned events if they have written them in their diaries.
- Users who *loosely* conformed to their diaries used these as a reference tool to remind them of possible events/tasks that they can attend or complete and not to record a set of events that they must strictly conform to. They may note down several events which they may or may not attend depending on their mood and/or whether they had sufficient time when the time arrived. They generally carried out a set of tasks that they had planned for each day. Some participants reported that they had not attended less important events (such as social meetings).
- *Spontaneous* users (i.e. the 'mental' diary users) did not follow a set of scheduled events. They carried out tasks selectively depending on their mood.

4) Relationship between learner characteristics and diary usage

I identified some relationships between a user's learner characteristic and their diary usage. This information can be used to indicate how successfully a user keeps to their diary given that information is known about their learner characteristics.

Throughout each individual interview with participants, it was possible for the researcher (i.e. myself) to obtain a clear picture of participants' views relating to the importance of their learning and studies. It was observed that those learners who closely followed their diaries were those who regarded their studies as more important, prioritized their studies as most important amongst other activities and were generally more hard-working. Learners who did not closely followed their diaries or did not use a diary often also regarded their studies as important, but performed studying tasks at a more personally suitable time and had a more laid-back approach to their studies.

Whether the student enjoyed their studies is sometimes arbitrary and may not have a positive correlation to how hard-working they are. This may be because they are working hard to achieve their goals, and not necessarily because they enjoy their studies. I observed both intrinsically-motivated and extrinsically-motivated students in the interviews, and both groups of students described a number of self-regulated strategies for motivating themselves regarding their studies.

Some of these strategies relate to the use of learning schedules whereas others relate to the choice of study locations, or general goal-setting and persistence in studying. These include 1) choosing and planning study locations in which they are less likely to be distracted and can concentrate better, 2) motivating themselves to finish studying tasks and then rewarding themselves afterwards with, for example, social activities. As described by many participants, the act of planning their study-related events can be 1) helpful for general time-management, 2) used as a motivating technique when they persist themselves with performing/continuing study activities that they have assigned a time slot for these activities or 3) used as a self-satisfying or rewarding mechanism when they tick off completed tasks in their diaries. Participants who noted such learning strategies were seen to have the following learner characteristics – *conscientious, self-disciplined*, *organised* and *routine-structure*.

Seven characteristics of learners were collected; see the *learner characteristics scale* in 3.2.1. A statistically significant strong positive correlation was found between the *hardworking* learner characteristic and how closely they conformed to their diaries ($r = 0.2917$, $p < 0.5$). This finding suggests that the more hard-working a student is, the higher probability that they closely conform to their diary events, when it is within their control. Most of the statistical correlations obtained between each of the other learner characteristics and how closely they conformed to their diaries were relatively weak and insignificant.

5) Overall analysis of the section

It can clearly be seen through the data obtained in my interview study that many students do make use of a diary to help them organize their time. From this, I can deduce that many students will not object to the use of electronic organizers for time management of their studies.

The majority of participants (27 out of 37) made use of a paper- or electronic-based diary to support their studies. Most of these participants had found the use of a diary (paper- or electronic-based) to be beneficial in terms of general time-management, as a motivating technique to themselves for performing/continuing study activities that they have assigned a time slot for or as a self-satisfying or rewarding mechanism when they tick off completed tasks in their diaries. Many participants also followed their events closely and would attend or complete all important lectures or tasks. These findings confirm that learning schedules can be used successfully by university students to record schedules, and that students will follow the events that are important to them. This would enable the learning schedule approach to effectively retrieve the learner's location and available time information accurately. Further data results and analyses from the quantitative perspective are necessary to support this claim. These are presented in 5.3.

5.2 Quantitative analysis of the potential use of a learning schedule for retrieving learning contexts

In this section, I address the research question – "How feasible is the adoption of a learning schedule for retrieving learning contexts from a **quantitative** perspective?" Two aspects are being examined in this question – 1) whether users can plan their schedule ahead, conform to it and keep it up-to-date, and 2) whether the location and available time can be retrieved from the learner's diary. The data sample was divided into batch 1 and batch 2. This is because students from batch 2 did not note down their study-unrelated events, presumably as the time of the diary study coincided with the onset of their exams. I analyzed and present below whether there were any discrepancies between a) the planned and actual locations, and b) the planned and actual start and finish times. I also present below additional results obtained from the '*diary-questionnaires*'.

1) Can users plan their schedule ahead, conform to it, and keep it up-to-date?

This question was answered from the viewpoint of potential users of the framework and whether they could conform to their planned schedule. Participants were asked to plan their schedule ahead and write down both their study-related and -unrelated events, at the beginning of each of the two days, as part 1 of the diary study. All three parts of the diary study are presented in Appendix B. These were also described in 3.3.1.

All 32 of the participants were able to plan their study-related events ahead for the two days required; this was demonstrated in part 1 of the diary study where students were given two diary schedule sheets each and asked to fill them in. Seven fields were required to be filled in for each event including a) whether it is study-related or unrelated, b) time (to and from), c) geographic location, d) type of location (e.g. library, home), e) task or activity, f) tick if completed or attended (after time has elapsed) and g) if not completed, state reason.

All of the participants from *batch 1* noted down both study-related and study-unrelated events. However, the *batch 2* participants only planned out their study-related events. A possible explanation of this was that the diary study coincided with the onset of their exam period; hence they were very busy attending revision lectures, classes and self revision, and omitted other study-unrelated events which they may have felt to be irrelevant and/or unimportant to them at that point in time.

A total of 275 events were recorded from the 32 students – 181 were study-related and 94 were study-unrelated. A total of 251 of the 275 events (91%) recorded by participants went as anticipated, implying that the events were either attended to or completed. Some 23 events (19 were *study-related* and four were *study-unrelated*) were indicated *not* to have gone as anticipated by eight participants from *batch 1*, an average of 2.875 events by the eight participants. Only one event was indicated by a *batch 2* participant as not to have gone as anticipated and this was due to boredom. Explanations for the events not having gone as anticipated include:

- *For study-related events* – a) their planned tasks required longer to be completed or were more complicated than expected, b) they were interrupted often, sick, tired or had low levels of productivity and decided either not to commence or to discontinue with the activity, c) their scheduled events were cancelled, delayed, postponed, rescheduled or exceeded the scheduled time and d) there were occurrences of delays in the transport that they had used.
- *For study-unrelated events* – a) they changed their minds regarding their planned activities that they had wished to carry out, for example from doing an assignment to answering emails, or decided to relax after a long day of study rather than doing more, b) the location of a meeting place with friends was changed and c) due to lack of time.

The following study-related and study-unrelated activities were scheduled by participants:

1. *Study-related* events – programming tasks, laboratory exercises, computer projects, meetings with peers and supervisors, assignments, coursework, writing reports and thesis, attending lectures, seminars, language studies, research, exam revision and brainstorming.
2. *Study-unrelated* events – reading leisure books, watching news and TV, writing emails, setting up software, chatting to friends online, travelling to university, sports, meeting friends, taking rests and breaks and eating.

Additional diary-planning information was obtained from the completed '*diary-questionnaires*' including 1) whether they normally kept a diary to remind them of both their study-related and study-unrelated activities; If so, whether they followed the events as planned, and if not, whether they had a problem planning the events for the two days; and 2) whether they had any problems updating the diary schedule.

The aim was to ascertain respectively 1) whether the participants who did not normally keep a diary could successfully plan out their activities on paper for two days, and 2) if participants had experienced any problems in keeping their diaries updated. In addition, information was obtained about whether they usually followed their planned events, and whether participants who did not normally keep a diary could plan out their events for two days..

12 out of the 16 participants from *batch 1* indicated that they normally kept a diary. One of these participants noted that they only kept the important events in their diaries. The remaining four participants who did not normally keep a diary noted that they had no problems in keeping and updating the diary for the duration of two days for the diary study. Only two out of 16 participants from *batch 2* indicated that they normally kept a diary. All of the 32 participants indicated that they did not have any problems keeping and updating the diary for the two days for the diary study.

The diary study results showed that, in general, participants did not have any problems planning, keeping and updating their planned events, at least for the duration of two days. This was supported by the interview study results where 27 out of the 37 participants (i.e. 73%) who had informed me of their regular paper- or electronic-based diary usage matched this result. Some 91% of the 275 events that had been scheduled had gone as anticipated in the diary study, whereas the remaining 9% had not, which was due to unforeseen circumstances. This is a relatively small percentage considering the large number of events that were recorded by a total of 32 participants. The hypothesis, shown below, is supported with a rate of 91%. This is because I consider 91% of events recorded by 32 participants constitute a significantly large percentage, and therefore the hypothesis is supported.

H_0: Users are able to plan their daily schedule ahead and conform to those activities that they feel are important to them.

Generally speaking, a) the interview participants had made regular use of diaries for their time management of study events; and b) while the diary study participants' mostly went about their schedules as anticipated, there may always be a small chance of discrepancies between their planned diary events and the actual events/tasks that they were to carry out. I conclude that the learning schedule approach can be used as a preliminary proactive source of retrieving the location and available time contexts of learners; however, additional methods should be in place to verify their actual location and time available.

2) Can the location and available time be retrieved from the learner's diary?

I checked against the times and locations of participants' scheduled study-related events for the two days noted in part 1 of the study against the times and locations indicated on the corresponding '*diary entry*' sheets in part 2. '*Diary entry*' sheets only needed to be completed for each study-related event and not for study-unrelated events. Participants were asked to round their start and finish times to the nearest five minutes.

91% of participants' events went as anticipated (see above); however, there were some discrepancies between the planned and actual start and finish times of the events, as described below. For the events which went as anticipated, the actual and planned locations were consistent. Out of the total 157 completed diary entry forms, 109 were from participants of *batch 1* and 48 were from participants of *batch 2*.

Batch 1 – discrepancies between planned and actual start and finish times

The planned and actual start and finish times of 52 out of the 109 study-related events (47%) were matched. There were discrepancies between the actual and planned start and finish times of the remaining 57 events. These events were recorded from 12 out of the 16 participants. This means an average of 4.75% of the events from the 12 participants with discrepancies between the actual and planned start and finish times. These 57 events are classified into the following two categories of events.

- 20 events were *scheduled classes or meetings*. These often started and finished five or 10 minutes earlier and/or later, with the occasional exception of finishing 35 minutes earlier. Participants often rounded the start and finish times of lectures to the hour in their diary schedules, when in actual fact, lectures at our university started at five minutes past the hour and finished at five minutes to the hour.
- 37 events were *self-study*. Due to the nature of these events, it was assumed that participants gave themselves the flexibility of starting and finishing at an earlier or later time, when it was convenient for them. The actual start and finish times ranged from a start of 20 minutes earlier to 95 minutes later and from a finish of 105 minutes earlier to 115 minutes later (depicted in Figures 5.1- 5.3).

Figure 5.1: Actual start times of self-study events (participants of batch 1)

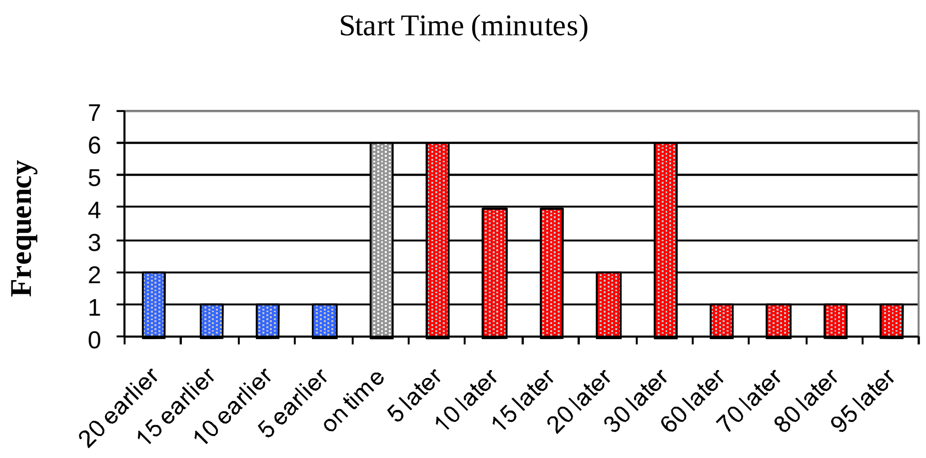
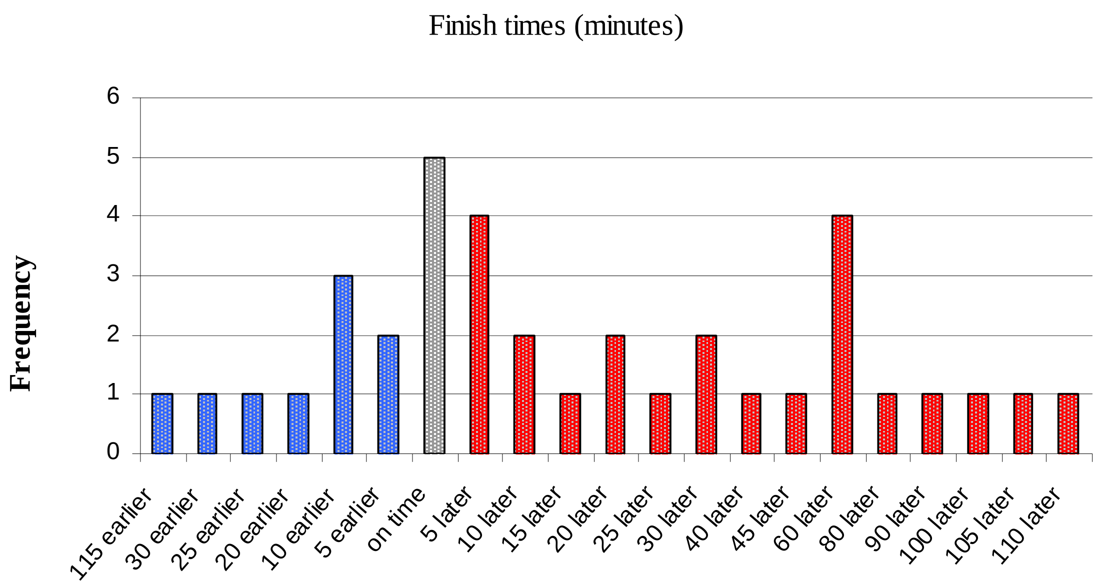
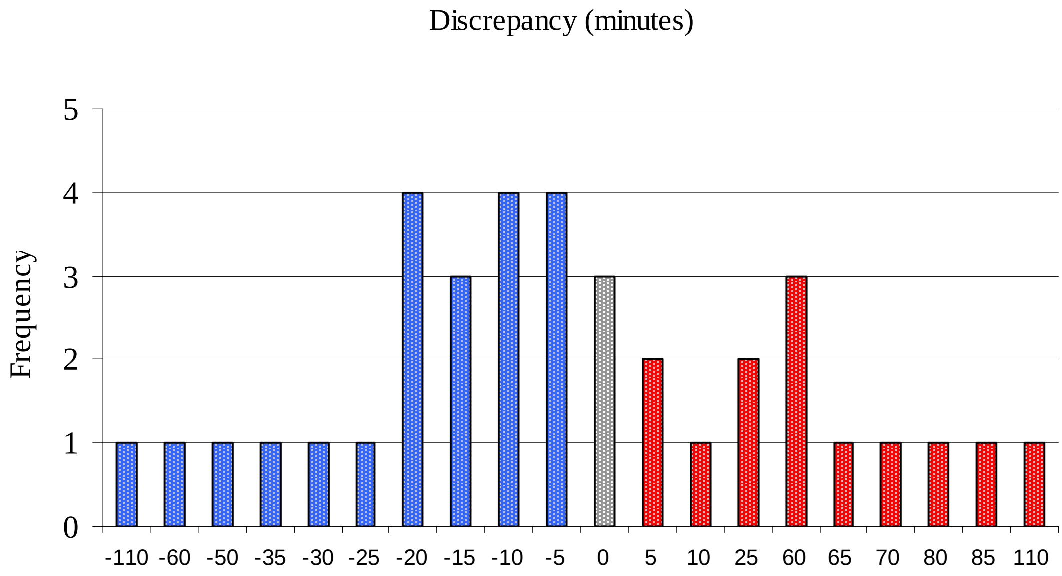


Figure 5.2: Actual finish times of self-study events (participants of batch 1)



As a result, the discrepancies between the actual and planned amount of time for the participants in *batch 1* spent on their self-study events ranged from -110 to +110 minutes.

Figure 5.3: Discrepancies between actual and planned amount of time for self-studies (participants of batch 1)



In Figures 5.1 to 5.3, it can be seen that participants had a later starting time for their self-study events than planned but generally not a later finishing time. This means that the actual studying times are less than those that were planned.

Batch 2 – discrepancies between planned and actual start and finish times

The actual and planned start and finish times of 44 out of 48 (92%) study-related events were matched, whereas the remaining four study-related events were not. The 44 events with matching actual and planned start and finish times were recorded by nine participants. One of the four events that did not match was a scheduled class and the remaining three events were self-studies; these were recorded by two participants. Five participants did not note down the actual start and finish times of their events on the 'diary entry' sheets; however common amongst these participants were two daily laboratory revision exercises classes, in preparation for their exams. I presumed that due to the importance and urgency of these events, these participants had attended these events from start to finish.

3) Results from the 'diary-questionnaires'

Participants were asked whether a) they were always doing the activities that they had planned at that location, and b) they were always in the location that they had planned. Note that one out of 16 participants from batch 1 had not completed the '*diary-questionnaire*'.

- *Batch 1* – a) 10 participants indicated that they had always carried out the activities that they had planned at the specified location, one participant usually did, one sometimes did and three did not always carry out the activities that they had planned at the location; b) 13 participants indicated that they were always in the location that they had planned and two noted that they occasionally would complete their previous activities together with their current one in the same location.
- *Batch 2* – a) 11 participants had always carried out the activities that they had planned at the specified location, one sometimes did, four participants did not always carry out the activities that they had planned at the location; b) eight, two and six participants, respectively, indicated that they were *always*, *sometimes* and *not* in the planned location.

5.3 Views on mobile devices as a learning tool

The research question in this section is “how do participants view the use of mobile devices as a learning tool”. Three different views regarding the deployment of mobile devices (including very small portable laptops) for learning are as follows. Note that some participants may not want to use mobile devices for learning, however they enjoy learning/studying in mobile environments.

1. *Enthusiastic about m-learning* – 11 participants were keen users of m-learning and had used mobile devices for internet-browsing and/or accessing their lecture notes (both on- and offline). They liked the convenience of using a small device to a) access learning content, b) make notes, c) record them using the recorder function and d) experiment with small programming examples, when and wherever they get the ideas.
2. *Possible/potential to use m-learning* - 16 participants were not technology-minded but would use mobile devices for learning/studying if they were travelling (to other places or around campus without their laptops), commuting, attending conferences, waiting in queues/for transport or searching for terms and ideas.
3. *Not useful* – 10 participants thought mobile devices would not be useful or that they had no need for them because they a) prefer to sit down at a desk to study/learn, b) do not want to study/learn when outside dedicated studying hours, c) do not like technology and/or would prefer to handwrite or d) do not feel comfortable using a small device. Wang and Higgins (2005) reported similar findings and noted that many people lacked the psychological motivation needed for m-learning.

Views on the use of location-tracking technologies

- 28 participants did not feel that the use of location-tracking technologies would be an intrusion to their privacy.
- Nine students felt that it would be an intrusion and would mind people knowing their locations because a) they would not want others to know if they were not in lectures or at work, or b) they did not want to be contactable at all.

It was noted that an option must be available to switch off the location-tracking.

Relationship between learner characteristics and m-learning views

Seven characteristics of learners were collected; see the *learner characteristics scale* in 3.2.1. A statistically significant strong positive correlation was found between the 'enjoy studies' learner characteristics and how enthusiastic they were towards m-learning, ($r = 0.4327$, < 0.1). This finding suggests that the more a student enjoys their studies, the more likely that they are enthusiastic about the use of mobile devices for learning/studying. Note that most of the other statistical correlations obtained between each of the learner characteristics and their views on m-learning were not significant. The qualitative data analysis also supports the obtained positive correlation as some participants whose opinions were that mobile devices would not be useful for learning or that they had no need for this learning approach because they did not want to learn/study outside dedicated studying hours, which suggests that they may enjoy studies less than other students who also study outside dedicated studying hours.

It was also revealed that whether a learner is enthusiastic towards m-learning is related to their study-related and -unrelated routines. For example, a learner who spends most of their studying time in the library, and has access to a personal laptop computer, Internet, and book and journal resources etc, is less likely to require the need of mobile devices for learning in other environments. However, a learner who may not like or always like to study in fixed environments, such as computer laboratories or libraries, and is usually ‘on the move’ may be more likely to require a small portable device for learning/studying tasks ranging from internet browsing to making and reading lecture notes.

The majority of participants were either enthusiastic about m-learning or thought that m-learning could be potentially useful for them. The range of software applications on desktop/laptop computers participants currently use for their studies include internet browsing. Internet browsing on modern mobile devices has been made much easier through the use of larger and colour screens, and web pages are designed to fit more appropriately on mobile devices and require less scrolling. Many participants supported the idea of using mobile devices for internet browsing and for searching for terms and ideas, and would use them for these purposes. It was found that participants who regarded m-learning as not being useful include those students who do not wish to study outside dedicated studying hours. These findings tell me that a student who is interested in learning/studying and enjoys their studies, particularly outside of dedicated studying hours, would welcome mobile devices for learning more than other students. The framework is useful for university students who are interested in learning outside dedicated studying hours and in non-fixed locations. The positive correlation found between learners who ‘enjoy studies’ and their enthusiasm about m-learning further confirms this.

5.4 Summary and conclusion

In this chapter, I reported the qualitative and quantitative data analysis from the interview and diary studies respectively, relating to the learning schedule approach and determined whether this can be effectively used to retrieve learning contexts within my framework.

A limitation of the learning schedule approach is that this requires a sufficient amount of work and self-discipline on the part of the user to input and update their scheduled events into an electronic diary on a mobile device and conform to them. Therefore, I wanted to investigate the validity of such a use, and envisaged that students may use a learning schedule for time management of their studies.

My vision was corroborated - many participants who kept a diary and had closely conformed to their scheduled events were students who had self-regulatory learning characteristics. The qualitative analysis showed that the learning schedule approach can be used an as effective and accurate means of retrieving a learner's (especially those who are self-regulated) location and available time contexts. It is not an additional burden on top of learners' workload to keep and update a diary because many of them had used a paper- or electronic-based diary (also on mobile devices) on a regular basis.

In the second part of the chapter, I reported how a diary study has helped me to establish whether intended users could in reality plan their scheduled events, conform to the plan and keep it up-to-date. Results gained from 32 participants who performed the diary study for a period of two days showed that they were able to plan and adhere to most of their events; the actual and planned locations of all recorded events matched in particular. Some 47% of the actual and planned start and finish times of events were matched, but there were discrepancies in the remainder of these events. These were largely due to the flexibility participants gave themselves when performing self-study activities and some were due to scheduled classes or meetings finishing earlier than recorded in the diary.

Results showed that the actual locations of participants were usually consistent with their planned locations, i.e. they usually adhered to their planned events, especially for scheduled classes and lectures. There were small discrepancies between the planned and actual start and finish times of events, of five or 10 minutes earlier and/or later than planned, with the occasional larger discrepancy of 35 minutes earlier.

For self-study events, participants were in the planned locations; however, there were more and larger discrepancies between the planned and actual start and finish times. This showed that location was a simpler context to be retrieved more accurately than the available time context. There is also a higher likelihood that important events are attended to, such as revision lectures and supervisory meetings. The hypothesis shown below is supported with a rate of 100% for the location context and 70% for the available time context ((47% for batch 1 + 92% for batch 2) / 2).

H_0: The location and available time can be retrieved accurately from the learner's diary for those events that they feel are important to them.

I conclude that two supplementary methods can be used to strengthen the framework to verify that the retrieved location and available time contexts are indeed accurate. The context values retrieved from the learner's schedule can be used as default values. Two methods – *location-tracking and user verification* are to be put in place, to verify the location and available time respectively. GPS and wireless LAN technologies can be used to verify outdoor and indoor locations respectively. The user is asked to verify and confirm the retrieved available time, and update this as necessary. These two methods are described in 9.2.

Chapter 6

Significant learning contexts and appropriate suggestion rules in a context-aware suggestion mechanism

This chapter is divided into four sections. In 6.1, I explore the significance of the proposed learning contexts (in chapter 4) from a qualitative perspective (i.e. using the interview study results) for use within a context-aware suggestion mechanism for recommending learning materials to students based on their situation. In 6.2, I explore the same question as in 6.1, but from a quantitative perspective (i.e. using the diary study results). In 6.3, I present a constructed set of suggestion rules for recommending appropriate Java learning materials to students based on their situation. These were constructed via the qualitative and quantitative analyses described in 6.1 and 6.2. In 6.4, I discuss related works on suggestion rules. In 6.5, I present the refined requirements of the framework using the obtained data results. Finally in 6.6, I present the summary and conclusion.

6.1 Qualitative analysis of significant learning contexts for a suggestion mechanism

In this section, I address the research question – “How significant are the proposed learning contexts to be used within a context-aware suggestion mechanism from a **qualitative** perspective?” I obtained the opinions from interview participants, which helped me to determine the significance of each of the five proposed learning contexts (LS, knowledge level, concentration level, frequency of interruption and available time), and the advantages and disadvantages of recommending materials based on each of these. The section is subsequently divided into the following:

*Views on recommendation of learning materials based on 1) **LS**, 2) **knowledge level**, 3) **concentration level**, 4) **frequency of interruption**, 5) **available time***

6) *Disadvantages of learning materials recommendation*
7) *Conclusion of the analysis of the significance of the proposed learning contexts*

1) Views on recommendation of learning materials based on LS

Most participants noted having learning preferences. Some of these were related to their course of study, for example, a) a law student is required to read complex notes or textbooks more than illustrated diagrams or pictures; b) a mathematics student is required to actively attempt many exercises rather than passively read. The importance of learning according to their learning preferences was noted by 28 participants, five participants were unsure and the importance of having a wide range of learning materials available to them was noted by two participants.

31 participants were in support of learning materials recommendations based on their *LS* and the remaining six participants were against the idea. Reasons in

support include that the personalization of materials would give a more effective learning experience, and it may be useful to present, for example, visual learners with animated materials or illustrative examples, and global users with an overview about the topic before the detailed texts. Reasons against include that learning preferences may change depending on what they are doing or from time to time, and that they may prefer to select or create their own learning materials as the act of searching can help them obtain the overview of a topic.

2) Views on recommendation of learning materials based on knowledge level

31 participants were in support of learning materials recommendation based on their knowledge level of a topic and six participants were against the idea. Reasons in support include that a) possible frustration can be eliminated when exercises are not at an appropriate or adequate level for them; b) learning efficiency can be increased by learning materials at an appropriate level; c) additional materials on learners' weak ideas can be provided to focus on improvement and/or when they are experiencing difficulties; and d) if the syllabus is known, the application can advance the learner to the standards required. Reasons against include that a) the application may not be able to find appropriate materials of the right knowledge level or of interest to them, and b) a chance to acquire additional knowledge is possible if they were allowed to view a wider spectrum of materials.

3) Views on recommendation of learning materials based on concentration level

Participants had several enquiries relating to this topic such as 1) they did not know how their concentration could be extracted and conveyed to the tool; 2) they must concentrate in order to learn and 3) if they stopped concentrating, a break may be beneficial for them rather than having different materials recommended. A suggestion in support of this was that when a learner has lower levels of concentration due to a noisy environment, they can be given podcasts to learn with using earphones, which would be easier than reading notes. A suggestion against this was that students still have to do questions with the same complexity level, whether or not they are in a distractive environment and the application should not give them easier problems to accommodate that they may not be as good at answering them.

4) Views on recommendation of learning materials based on frequency of interruption

Participants also had several enquiries relating to this topic such as 1) how the frequency can be obtained, and 2) how this would affect their learning. Suggestions in support of the recommendation include a) keeping track of the place of learner's materials in case they were interrupted, b) selecting smaller amounts of material for learners when they are subjected to high frequencies of interruption, c) using an outline and/or an abstract level of the presentation of materials if they are interrupted often and d) postponing detailed problem tasks until students are situated in a better environment where they can concentrate for a longer period of time.

5) Views on recommendation of learning materials based on available time

Most participants were in support of this recommendation and suggestions in support include the following.

- A learner has both reading and programming tasks to complete and currently has 30 minutes. Even though the programming task might be more urgent, it would not be possible for them to complete it in 30 minutes. Therefore, it would be ideal if this was known to the tool and the reading task is selected to the learner to complete.
- A summary can be selected for learners who have ten minutes prior to a lecture. A longer version can be selected if they have more time.
- An appropriate amount of material can be selected to students based on the amount of available time that they have, so that they are able to finish the whole topic in one session.

6) Disadvantages of learning materials recommendation

Two overall disadvantages of recommendation include *missed opportunity of learning* and *distrust*. 1) *Missed opportunity of learning* – the act of searching has sometimes helped some students to learn more widely and/or additional topics. Some participants may not be content with using only existing materials and may want to develop their own for revision purposes, for example, or they may wish to have the range of materials limited as they would like to view everything in all different possible directions. 2) *Distrust of using such an application* – issues include a) the question of whether an accurate representation of their LS (which is subject to change and may be different for performing different activities) and knowledge levels can be obtained (a level of knowledge may not exist for social sciences subjects), b) there may be unwillingness to use the application as they find it easier to search for materials themselves, c) learners may want to be active learners who choose their own learning materials, and not be passive receivers and d) they may be unwilling to pay for the tool even if they think it would be useful.

7) Conclusion on the analysis of the significance of the proposed learning contexts

Note that the following five learning contexts were proposed in the theoretical framework in 4.3.

1. *LS* – this is both significant and insignificant for m-learning in scenarios, where students do and do not have strong LS, respectively. Similarly, although a learner may have strong LS, it does not necessarily mean that they want to restrict themselves to learning/studying with only materials suitable for that particular learning style. An additional option can be incorporated to prompt users whether they would like materials based on their LS.
2. *Knowledge level* – this is significant for the selection of materials within a given topic. It is especially significant in time-restricted scenarios, as often is in the case of m-learning, to use the correct level of knowledge of materials to maximize productivity in the time available.
3. *Concentration level* – this is a significant learning context when performing m-learning. However, it is an attribute which is difficult to define, measure and quantify. A learner's motivation has a significant impact on their concentration level. For example, a highly motivated student is able to concentrate better, despite environmental distractions, and can also eliminate internal distractions. The motivation level of a student may be a more

significant learning context than their concentration level. Therefore, it may be possible to replace the concentration level context by the learner's motivation context, with the latter used for the suggestion of learning materials. In chapter 6, I triangulate the diary study results to determine this.

4. *Frequency of interruption* – this is not a significant learning context in the m-learning framework because no significant benefits would be gained from determining appropriate learning materials based on the frequency of interruption of a location. It is unavoidable that students would be distracted or interrupted either externally or internally, in both fixed and non-fixed environments.
5. *Available time* – this context is very significant because most learners would a) prefer to be able to complete a given task in the time that they have available, and b) like to work on small tasks in the short periods of time that they have available.

Based on the interview data analysis, I hypothesize that a) the *noise* and *busyness of environment* factors have a negative correlation with the student's concentration level; b) the *temperature* – if it is too hot or too cold – has a negative correlation with their concentration level; c) the *urgency of task* has a positive correlation with concentration; and d) *frequency of interruption (at the location)* has a negative correlation with concentration. However, this factor would be difficult to take into account during materials recommendation and no significant benefits were found for suggesting materials based on this factor because distractions/interruptions may be unavoidable in most situations. I thus decided to obtain further quantitative analysis from the diary study to support or reject the hypothesis.

6.2 Quantitative analysis of significant learning contexts for a suggestion mechanism

In this section, I address the research question – “How significant are the proposed learning contexts to be used within a context-aware suggestion mechanism from a **quantitative** perspective?” I present the quantitative data obtained from the diary study and any correlations between learners’ concentration levels and the other learning contexts (i.e. to determine whether these learning contexts have a statistical significance in affecting the concentration level and therefore should be taken into consideration when suggesting learning materials in different learning contexts). The section is divided into – 1) *statistical correlations between learning contexts and concentration level*, 2) *obtained information between learning contexts and concentration level*, 3) *consistencies of concentration throughout a learning session* and 4) *overall analysis*.

1) Qualitative and quantitative analysis between learning contexts and concentration level

I first present a qualitative analysis of the factors that can cause distractions to participants during their studies. These are categorised into *external* (relate to the environment), described in a) to e) and *internal* (relate to the learner), described in f) to g).

a. *Noise* – There is a different degree of influence and sensitivity between participants as to the effect this can have on their concentration. Two main sources of distractions include people talking and keyboard typing. Noises did not affect some participants in situations where they 1) had found their studies/tasks very interesting, 2) were absorbed in their work or concentrating hard and 3) if no one was to interrupt them.

b. *Busyness of the environment* (i.e. the number of people around, coming and leaving) was one of the main sources of distractions, together with *noise*.

c. *The temperature of a location,* for example, if it was too hot or too cold, could have a negative effect on how well participants could concentrate.

d. *Light* – Some participants had preferences for studying with sunlight, bright light (for intensive work) or dim light (for reflecting, gaining inspiration and ideas).

e. *Layout of the room* (including the tidiness of desks) – This could be a source of distraction for some participants if the room was untidy or contained too much furniture or if they were working on an untidy desk.

f. *Motivation of the learner* had a huge effect on whether they would successfully carry out and complete their studies. The lack of motivation is a main source of internal distractions, and whether they want to do other things instead of studying.

g. *Urgency of the task* and whether there was a lot of pressure for completion due to tight deadlines can have both positive and negative effects on the participants' concentration levels. Some students are positively affected and can focus on the task until the completion of it. Some students are negatively affected and are unable to concentrate on the task because of the stress and anxiety caused by the task's urgency.

Although (a) to (g) were mentioned by participants as factors that could distract from their concentration, at this point in the thesis I consider these to be less relevant than the proposed learning contexts to be incorporated into the framework (See 4.3). I formed a number of hypotheses based on the above findings (listed in 3.3.4), and collected further data using the diary study to test these hypotheses. Data analyses relating to these hypotheses are presented in 6.3.

Other distractive factors include 1) *food and drink* – these are physical requirements that normally need to be met in order to carry out any activities; 2) *time of day* – some students work better in some parts of the day than in other parts, and could be less susceptible to both external and internal distractions.

Distractions are sometimes unavoidable and it was revealed that some participants may be easier to distract than others. This finding is also supported by Graetz (2006). For example, some participants could be distracted by the possibility of watching TV when studying at home and therefore would choose to study at another location to avoid these distractions. Two types of distractions have been distinguished – *helpful and non-helpful*.

- *Helpful distractions* are study-related and may be beneficial to students, for example, discussing programming assignments in a computer laboratory. In comparison, if students were to study elsewhere to avoid these distractions, potential helpful human interactions may also be eliminated.
- *Non-helpful distractions* consist of any type of study-unrelated distractions.

I now present the quantitative analyses. Participants were asked to provide information about each of their study-related events on a 'diary entry' sheet relating to the environment – *noise, busyness of environment, temperature* and *urgency of task, frequency of interruption*, and their *motivation, how urgent the task was* and their *concentration level.* I chose to investigate these attributes because they were noted by the interview study participants to have a significant impact on their concentration during learning (some attributes have a higher impact on concentration than others). Multiple choice responses were given on a scale of 1 to 5.

- *Noise* – 1 very quiet, 2 quiet, 3 average, 4 loud, 5 very loud.
- *Busyness* – 1 very not-busy, 2 not-busy, 3 average, 4 busy, 5 very busy.
- *Temperature* – 1 very cold, 2 cold, 3 neutral, 4 hot, 5 very hot.
- *Interruption* – 1 very infrequent, 2 not frequent, 3 average, 4 frequent, 5 very frequent.
- *Motivation* – 1 very unmotivated, 2 unmotivated, 3 average, 4 motivated, 5 very motivated.
- *Urgency of task* – 1 very not-urgent, 2 not urgent, 3 average, 4 urgent, 5 very urgent.
- *Concentration* – 1 very bad, 2 bad, 3 average, 4 well, 5 very well.

Statistical correlations between each of the listed attributes were calculated with the learner's concentration level. Each observation from the '*diary entry*' form had the underlying assumption that the responses were normally distributed because a parametric scale from 1 to 5 was used for the attributes; each having a mean and a standard deviation (Cohen *et al*., 2007):

- Noise – (Mean = 2.1592, STDEV = 1.03472, N = 157)
- Busyness of environment – (Mean = 2.2102, STDEV = 1.07436, N = 157)
- Temperature – (Mean = 3.0064, STDEV = .49996, N = 157)
- Frequency of interruption – (Mean = 2.1338, STDEV = 1,04449, N = 157)
- Motivation – (Mean = 3.5605, STDEV = .94284, N = 157)
- Urgency of task – (Mean = 3.2866, STDEV = 1.03187, N = 157)

- Concentration level – (Mean = 3.4395, STDEV = .93601, N = 157)

Table 6.1 shows the correlation matrix where correlations between each of the factors and participants' concentration levels throughout a session were calculated. I calculated the normal correlations, and subsequently the partial correlations where other factors were controlled, to ensure that it was not the other factors in the observations that were affecting the outcomes of the correlations. The significance of the normal and partial correlations of each factor is also displayed in this table.

Table 6.1: Normal and partial correlations between concentration level and factors

	Factors	**Normal***	**Partial***
1	*Noise*	-.271	-.310
	Significance (2-tailed)	.001	.000
2	*Busyness of environment*	-.029	.183
	Significance (2-tailed)	.721	.024
3	*Temperature*	-.020	-.064
	Significance (2-tailed)	.806	.434
4	*Frequency of Interruption*	-.205	-.051
	Significance (2-tailed)	.010	.535
5	*Motivation*	.445	.425
	Significance (2-tailed)	.000	.000
6	*Urgency of Task*	.101	-.063
	Significance (2-tailed)	.208	.441

*Note: degrees of freedom are 155 for normal and 150 for partial correlations.

A normal correlation between the noise level and the concentration level was obtained (r = -.271 and p<.001), which was a statistically significant negative correlation and suggests that the higher the participants had found the noise level to be, the lower their average concentration levels were. The partial correlation between noise level and concentration level was even higher than the normal correlation with r = -.310, i.e. the correlations became stronger after controlling for the other factors.

Negative normal correlations were found between the *busyness of environment*, *temperature* and *the frequency of interruption* in relation to the concentration level. Of these, the normal correlation between the *frequency of interruption* and the concentration level was statistically significant ($r = -.205$, $p = .10$), indicating that the higher frequencies of interruption coincided with lower levels of concentration. However, after controlling for the other factors, this correlation was no longer significant (partial $r = -.051$, $p = .535$). This was due to the possibility of the other factors in the observation that had affected the concentration level.

Positive correlations were found between the *motivation* and *urgency of task* (normal only) in relation with the concentration level, of which the correlation between motivation and concentration level was significant ($r = .445$, $p < .001$). The results showed that the most significant factors in positively and negatively affecting participants' concentration level were *motivation* and *noise*, respectively.

Table 6.2 shows the results of a regression in the concentration level on all the other factors that were thought to predict changes in the concentration level. The regression model significantly predicted changes in concentration level, $F(6, 150) = 10.889$, $p < .001$, adjusted $R^2 = .276$. This revealed that motivation was the most important factor in determining participants' concentration level, such that higher motivation led to higher concentration levels after controlling for the effects of all other variables. Moreover, *noise* also independently predicted changes in concentration level, such that more *noise* indicated decreased concentration level.

Table 6.2: A regression analysis showing correlation between concentration and factors

Factors	*Standardize Beta Coefficients*	*t*	*Sig.*
Noise	-.399	-3.994	.000
Busyness	.223	2.282	.024
Temperature	-.054	-.784	.434
Motivation	.439	5.745	.000
Urgency of Task	-.058	-.772	.441
Freq. of Interruption	-.052	-.622	.535

2) Obtained information between learning contexts and concentration level

Additional information was provided by participants, via the '*diary-questionnaires*' regarding whether they thought the factors affected their concentration of studying.

- *Noise* had an effect on 25 participants, whilst six participants noted the opposite. Noise had a lesser effect on 19 participants when they were completing an urgent task and 12 participants noted that there are not usually any times when noises did not affect them.
- *Busyness of an environment* had an effect on 21 participants whereas this did not usually affect 10 participants.
- *Temperature* had an effect on 18 participants but not on the remaining 13 participants.
- *Motivation* had an effect on 27 participants but four recorded contrary findings. This had a significant effect a) on 24 participants in determining whether they would study at a particular location; seven noted the contrary, and b) on 26

participants in determining whether they would study a particular topic; five noted the contrary.

- *Internal distractions* had an effect sometimes on 25 participants; six noted the contrary.
- *Urgency of task* had a significant effect of eliminating a) general distractions for 19 participants; 12 participants noted the contrary, and b) noise distractions for 20 participants; 11 noted the contrary.
- 23 participants had *discontinued with their studies* due to distractions (such as noises, heat, phone ringing, fire alarm, busyness of environment, tiredness, motivation, mood, hunger and talking to others). Eight participants indicated that they had not discontinued with their studies despite distractions; the main reason was that they were determined to finish their study activities.

3) Consistencies of concentration throughout a learning session

I explored whether my framework should give users new suggestions of materials when their concentration changes throughout a learning session. To help in this, I first explored the consistencies of users' concentration throughout a learning session. It is found that there is a general slight drop in the learners' concentration levels. However, the concentration level is generally consistent with their motivation level, and is positively correlated. I therefore conclude that the concentration level context be replaced by the motivation level context.

The following scale was used for participants to select the level of their concentration *throughout*, at the *start* and at the *end* of each learning session (i.e. study-related event).

- *Concentration throughout* – 1 very bad, 2 bad, 3 average, 4 well, 5 very well.
- *Concentration at the start* – 1 much worse, 2 slightly worse, 3 roughly the same, 4 slightly better and 5 much better.
- *Concentration at the end* – the same scale used as for the *start*.

Two statistical tests were employed to calculate whether there were any consistencies of learners' concentration levels through their learning sessions – *t-test* and *analysis of variance*.

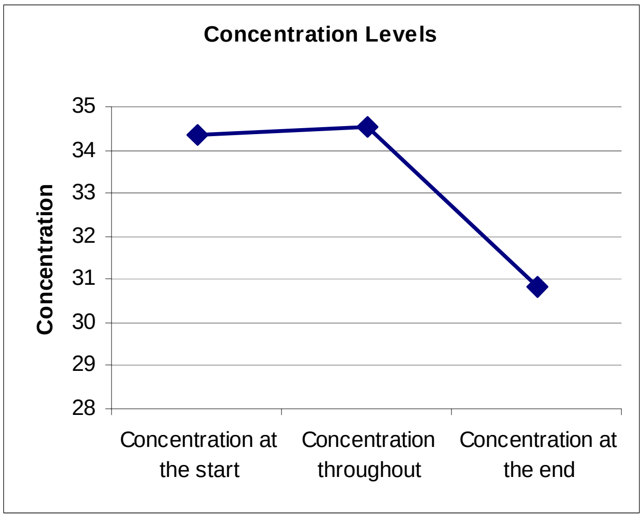
1. The means of two values at the start and end of the session were compared using a *t-test*. The means and standard deviations of the concentration levels are as follows:
   a. *At the start* – (Mean = 3.4340, STDEV = .90378, N = 159)
   b. *Throughout* – (Mean = 3.4528, STDEV = .93928, N = 159)
   c. *At the end* – (Mean = 3.0818, STDEV = .94781, N = 159)

The mean of the end concentration is 3.1 whereas the mean of the start concentration is 3.4. To test that this lower level at the end of the session was not due to chance, the observed difference (3.4 - 3.1 = 0.3) was tested against an underlying distribution based on the degrees of freedom (df), which was 159. I obtained results of $t(159) = 3.579$ and $p < 0.001$, showing that the concentration level from start to finish decreased significantly.

2. The means of the three concentration values were compared using an *analysis of variance*. Figure 6.4 shows that concentration peaked during a learning session and then fell steadily towards the end, and that concentration level depended significantly on the time that it was measured (Start vs. Throughout vs. Finish), $F(2, 316) = 10.58$, $p<.001$, $\eta^2 = .063$. Polynomial contrasts were run to explore how concentration level decreased over time. Results showed a

significant linear trend, $F(1,158) = 12.066$, $p=.001$, $\eta^2 = .071$, in addition to a significant quadratic trend, $F(1,158) = 8.130$, $p=.005$, $\eta^2 = .049$. These linear and quadratic trends suggested that while concentration levels decreased over time, they actually peaked very slightly during the study session, as can also be seen in figure 6.4.

Figure 6.4: Estimated marginal means of concentration levels



Additional information was obtained from participants regarding the consistency of their concentration levels throughout a learning session – changes were noted by all of the *batch 1* and 13 participants from *batch 2*; the remaining three participates noted that they could concentrate at the same level throughout a session. Reasons for changes in concentration include – a) tiredness after some time of studying, b) difficulty and progress of their studies, c) boredom, d) potentially better motivation or mood at the start and e) distractions.

4) Overall analysis of the section

The concentration level was considered as a significant context in m-learning. A positive correlation between a learner's motivation and their concentration level was revealed. I chose to explore the correlations of the factors – *noise, busyness of environment, temperature, motivation, urgency of task* and *frequency of interruption* – against the concentration level of a learner because the significance of these contexts were revealed in the qualitative analysis of the interview study. Statistical correlations showed that a) the more motivated a participant was, the more their concentration level was impacted positively, and b) the higher the noise level in an environment was, the more their concentration level was impacted negatively. Statistically insignificant negative correlations between the *busyness of environment, temperature* and *frequency of interruption* were found in relation with the concentration level of a student. A statistically insignificant positive correlation was found between the *urgency of task* factor and the concentration level of a student. I discuss below whether the hypotheses were supported:

1. H_0: There is a *negative correlation* between the concentration level of a student and a) *the level of noise in the environment*, b) *how busy the environment is* and c) *the frequency that they are interrupted*.

   Part (a) of the hypothesis is supported, whereas for (b) and (c), insignificant negative correlations were obtained.

2. H_0: There is a *negative correlation* between the concentration level of a student and *the temperature in the environment*.

   The hypothesis is not supported, as no significant correlation was obtained.

3. H_0: There is a *positive correlation* between the concentration level of a student and a) *their motivation,* and b) *the urgency of the task.*

   Part (a) of the hypothesis is supported, whereas for (b), an insignificant positive correlation was obtained.

4. *H_0: There is a degree of consistency between a students' concentration level throughout a learning session, providing that they are motivated.*

   The hypothesis is supported as there is a slow fall in concentration from start to end; however, during a relatively short learning session, and if the learner is motivated to complete the task, then it was found that there was a certain degree of consistency in their concentration level throughout the learning session.

I conclude that the two variables – *motivation of a learner* and *noise in the environment* – are significant for consideration in the selection of appropriate learning materials for students in different situations. The relative level of noise can be detected in a mobile environment using a device such as a microphone. The learning implications due to the detected noise level may not be significant because the noise level can be sudden and inconsistent – the noise level detected at the beginning of the learning session may not be at the same level throughout and at the end of the same session. Although it would be possible to continuously monitor the noise level throughout the entire learning session and alter the learning materials based on the increasing/decreasing level of noise, insight gained from the interview study suggests that learners mostly do not want their materials to be changed during a learning session. Therefore, the noise level is not considered in the framework.

In the interview study, I established the significance of each of the proposed learning contexts – *LS, knowledge level, concentration level, frequency of interruption* and *available time*. Learning style was established to be significant for those participants who wished to learn/study with materials based on their learning preferences. On the other hand, it was not significant for those who did not wish to use materials based on their learning preferences, even if they had strong learning preferences. The knowledge level and the available time contexts were established as significant.

6.3 Suggestion rules for recommending appropriate Java learning materials to students based on their situation

In this section, I address the research question – "*Can a set of suggestion rules be derived for recommending appropriate Java learning materials to students based on their situation?*" The section is divided into – 1) *qualitative data analysis relating to possible recommendations,* 2) *potential suggestion rules based on location and time available* and 3) *a set of suggestion rules for Java learning materials*.

1) Qualitative data analysis relating to possible recommendations

The data analysis shows that participants had different preferred studying locations for carrying out different learning/studying activities, as follows.

- *Studying-dedicated* and *home areas* are appropriate a) for participants who prefer this location to carry out intensive activities such as essay-writing and revision, and b) for participants who do not prefer this location to carry out light activities such as reading and taking notes.

- *On public transport or any other distractive environments including cafes* are appropriate for performing passive learning tasks and do not require much concentration for long periods or are easy to complete.

Further analysis showed that if a participant is confident about their work or completing simple tasks such as reading the news, then they are more likely to be able to study in noisier/more distractive environments and/or talking to others at the same time. The same does not apply to learners attempting to a) learn a new complex subject or perform more difficult tasks in terms of cognition such as Maths equations, b) learn/study something which requires a lot of reflection, analysis and concentration, and c) read a journal article where careful consideration would be required. Hence, there is a relationship between the type of materials being studied and how easily the learner can be distracted. The qualitative and quantitative data analyses presented in 6.2 and 6.3 showed that the motivation of a learner is related to their concentration level.

2) Potential suggestion rules based on location and time available

Possible recommendations according to location

Participants noted down all of their university studying tasks; these included writing (e.g. essay, reports, papers and thesis), reading, making presentations, assignments/coursework, research, programming and learning to program, class tests, studies topics (such as statistics, economics, biology), data analysis/processing and language studies (including speaking and listening).

Types of locations of where participants actually performed their study activities and the reasons for these choices were obtained from the '*diary entry*' sheets as follows:

- Coursework assignments (writing/updating reports, making notes, and reading) were completed in:
    a. *Dept office* because it was quiet, relaxing, their preferred study location, the availability of academic help and resources and the task(s) was urgent.
    b. *Library* because it was quiet, relaxing, comfortable, had few distractions, resources were available and in order to maximise productivity.
    c. *Home (kitchen)* due to the availability of resources.
    d. *Home (bedroom)* since it was relaxing, convenient and to maximise productivity.
    e. *Home (dining room)* due to the availability of resources and because it was quiet, convenient, comfortable and no distractions here, preferred location.
    f. *Home (study)* as it was quiet, convenient and comfortable and they could concentrate well here.
    g. *Train* and *student union building* in order to maximise productivity and not waste idle time whilst travelling or waiting respectively.
- Hands-on programming (learning how to program, programming exercises and projects) was completed in:
    a. *Computer laboratory* because it was relaxing, availability of both academic help and resources and preferred study location.
    b. *Library* because it was their preferred study location, in order to maximise productivity, can concentrate well here, comfortable and no distractions here.

c. *Home (bedroom)* because it was quiet and relaxing.

- Making a presentation was completed at home because it was quiet and relaxing.
- Lectures/classes were in lecture theatres/classrooms due to the scheduled locations.

14 participants normally planned a certain study activity to be completed at a particular location; 17 participants did not as they were able to perform studies in any location.

H_0: The more reflection a learning/studying activity requires, the higher the concentration level students require for the task.

The above hypothesis was supported from the interview data analysis, as many participants commented that the more reflection an activity required, the more they were required to concentrate on the activity. The diary data analysis shows that participants would choose their study locations in order to maximise their productivity to carry out their tasks. Although it can be assumed that students carried out tasks which required more reflection in locations where they could concentrate more, no evidence was collected in the diary study to support this hypothesis.

The taxonomy of Bloom (Bloom 1956) differentiates between reproduction, reorganisation, transfer and problem solving thinking, and this was a possible model which I wished to build upon for the learning materials taxonomy for the m-learning framework.

Possible recommendations according to available time

Participants were asked to name the study activities that they would perform when they had a) *less than 15 minutes,* b) *15-30 minutes,* c) *30 minutes to an hour,* and d) *over an hour, respectively*. The results revealed that participants would choose shorter and easier learning/studying activities such as *planning, brainstorming, reading* or none at all (because time was too short), when they had a shorter available time such as 15 minutes or less. When they had more time available, for example half an hour or more, students would carry out more difficult tasks requiring more concentration such as *writing coursework assignments* and *programming* etc. I can conclude that there is a possible relationship between the available time of a student and their motivation for carrying out a particular learning/studying task.

3) A set of suggestion rules for Java learning materials.

For the selection of Java learning materials to students, I decided to use a simplified version of Cui and Bull's (2005) adaptation rules for recommendation, as shown in table 4.1, on page 137. Instead of considering the student's concentration level and frequency of interruption, the student's motivation level was to be considered instead and the available time context was considered (as in their work), based on the results obtained in this chapter. For example, in their adaptation rule no. 1 where tutorials, exercises and revision materials are selected, if concentration level = any level and frequency of interruption = any level and available time > 60 min, I replaced the concentration level with: motivation and frequency of interruption is not considered important. No other suggestion rules in context-based suggestion mechanism have been explicitly presented, at the time of writing.

I have established the following new set of suggestion rules, which are based on Cui and Bull's (2005) work:

1. Tutorials, exercises and revision materials are selected
    - If motivation = any level and available time > 30 min
    - If motivation = medium and available time = 30 to 60 min
2. A tutorial and an exercise relating to a single topic materials are selected
    - If motivation = medium and available time = 15 to 60 min or
    - If motivation = high and available time = 30 to 60 min
3. A tutorial and a short exercise materials are selected
    - If motivation = high and available time = 15 to 30 min or
    - If motivation = medium and available time = 15 to 60 min
4. A tutorial material is selected
    - If motivation = medium and available time = 15 to 30 min or
    - If motivation = low and available time = 15 to 60 min
5. Revision materials (on a topic) are selected
    - If motivation = low and available time = 15 to 30 min
6. Tutorial on a different topic materials are selected
    - If motivation = any level and available time < 15 min
7. A new topic material is presented
    - If motivation = medium or low and available time < 15 min

Lastly, the learner's LS and knowledge level are also to be considered. This can be done by matching the learner's LS and knowledge level with the learning object metadata containing information relating to these attributes.

6.4 Related work on suggestion rules

There is limited research on suggestion rules in the recommendation of appropriate learning materials in different contexts within context-based/aware m-learning systems. This is resultant of the lack of such context-based/aware m-learning systems, except for the works of Martin and Carro (2009), Cui and Bull (2005) and Becking *et al*. (2004). Other related works on suggestion rules include the following - 1) the suggestion rules of Melis and Andres (2003) which are web-based for Maths learning materials; 2) Bang's (2009) system is context-aware and their context-aware agent conducts analyses on the students' learning process and subsequently provides teachers with timely suggestions on test questions; 3) adaptation rules mapping individual learning styles to learning object characteristics were developed by Karagiannidis and Sampson (2004). I list below a few of Karagiannidis and Sampson's (2004) adaptation rules relating to the Felder-Silverman Index of Learning Styles to show how these look.

- IF learner = sensing THEN LOM.educational.learningResourceType = exercise OR simulation OR experiment
- IF learner = intuitive THEN LOM.educational.learningResourceType = problemStatement OR narrativeText
- If learner = visual THEN LOM.technical.format = visual
- If learner = verbal THEN LOM.technical.format = verbal

6.5 Refined user requirements of the framework

In this section, I address the research question – "What are the refined user requirements of the framework?" Original user requirements of the theoretical mCALS framework were presented in 4.6. Additions/refinements have been added/made to the original user requirements, including 1c) and d), 2 and 3. Refined user requirements are:

1. A proactive approach in accurately retrieving the learner's current location and available time is in place, via the use of a learning schedule (See 4.2, 5.1, 5.2).
    a. With the ease of input via a graphical-based learning schedule, users are able to view as well as add, change and/or delete their scheduled events in order to keep them accurate and up-to-date (See 4.5).
    b. The framework is able to create and maximise the opportunities for self-regulated students have for learning/studying (See 4.2, 5.1).
    c. Additional methods – software and user verification methods are in place if the retrieved location and/or available time from the learning schedule are not accurate (to ensure that learners' contexts are accurate) (See 5.4).
    d. Learning materials should only be suggested at the beginning of the learning session and not be altered subject to contextual changes (See 6.2).
2. The form of learning materials, i.e. LOs is appropriate for deployment for the framework design of Java learning materials (See 4.4, 6.3).
3. Four contexts for the recommending Java learning materials - *LS, knowledge level, concentration level,* and *available time* – are of pedagogical significance. (Frequency of interruption was found to be *insignificantly* negatively correlated to students' concentration) (See 4.3, 6.1, 6.2).
4. The types of learning materials/objects to be recommended to students based on their situations are appropriate. Suggestion rules are in 6.3.

6.6 Summary and conclusion

In this chapter, I presented the qualitative and quantitative data analyses relating to the significance of the proposed learning contexts in chapter 4. I described, in qualitative terms, the significance of LS, knowledge level, concentration level, frequency of interruption and available time as well as disadvantages of the overall learning materials recommendation and the overall analysis of the five proposed contexts.

For the quantitative analysis, I formed a correlation matrix for calculating whether there were relationships between the six factors chosen for investigation - *noise, busyness of environment, temperature, motivation, urgency of task,* and *frequency of interruption* – with participants' level of concentration. A statistically significant positive correlation was found for the motivation factor, and a statistically significant negative correlation was found for the noise factor. A t-test was carried out to show whether there was consistency of participants' concentration levels throughout a learning session; there was a small decrease in the concentration level from start to finish.

Data from both the interview and diary study was analysed together to either prove or disprove the formed hypotheses for the diary study. I also examined whether the suggestion of learning materials to students should be changed during a learning session. This was done by determining whether a learner's concentration level during a learning session is usually consistent. Hence, I investigated the means and standard deviations of the learners' concentration levels at the start, throughout and end of their learning sessions. The results showed that their concentration at the end of the session was slightly lower than at the start of the session. However, it is better not to alert the learner and change their learning materials during a session. This is also supported by

Martin *et al*. (2006), who stated that if a task with a higher-priority requires being first completed, then "it is appropriate to alert the user about the availability of the recommended activities or, otherwise, the user should not be disturbed at that time".

Finally, I presented a set of recommendation rules that were formed for the suggestion of Java LOs, and the refined user requirements of the framework based on the research findings and described these in relation to the original user requirements.

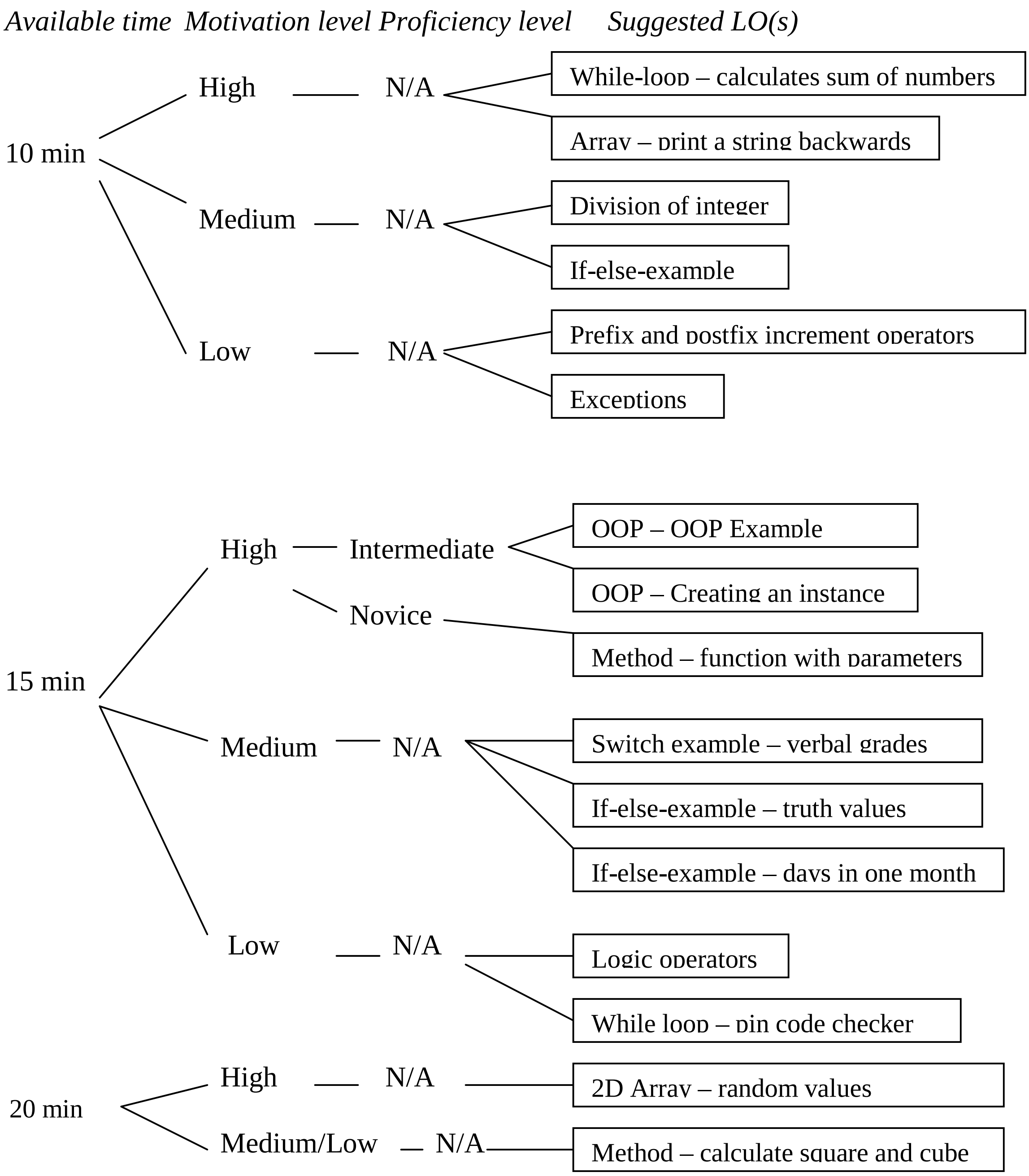
Chapter 7

Validation Study – Validation of the suggestion rules for Java learning materials in mCALS

In this chapter, I describe a validation study which I conducted to partially evaluate my mCALS framework. The study evaluates in particular how appropriate the deployed suggestion rules in mCALS are, using an online experiment which simulates the functionality of the framework. The case study makes use of Java LOs obtained from the Codewitz LOs repository, which are made accessible for students in this experiment. Appendix C shows the 16 LOs which were used in this experiment. The names and topics of these LOs are as follows: 1) While loop – calculates the sum of numbers, 2) Array – print a string backwards, 3) Division of integer, 4) If-else-example, 5) Prefix and postfix increment operators, 6) Exceptions, 7) Object-oriented programming – OOP example, 8) Object-oriented programming – creating an instance, 9) Method – function with parameters, 10) Switch example – verbal grades, 11) If-else-example – truth values, 12) If-else-example – days in one month, 13) Logic operators, 14) While loop – pin code checker, 15) 2D Array – random values, and 16) Method – calculate square and cube.

Depending on how much available time and the level of motivation that the student has at the point of studying, a number of LOs were presented to them and the student could select one to study with. Some of the suggestions also take into consideration the student's Java proficiency level. However, this level has not been considered in every case because of the short length of time (i.e. 10-20 minutes) that students spent on each LO. Thereafter, the student completed a feedback form about the study of the LO. This feedback form was described in 3.4 and is also presented in Appendix D. Figure 7.1 shows the suggested LOs given particular lengths of available time (in minutes), level of motivation and Java proficiency level (if applicable).

Figure 7.1: Suggested LOs based on contexts



I used the suggestion rules determined in 6.3 to recommend appropriate Java LOs to students. As mentioned in 3.4.1, I used my previous knowledge of the difficulty levels of Java topics as established in Yau (2004) to help me determine which Java LOs would be appropriate for which Java proficiency level of students.

In this chapter, I present the data analyses of this validation study. I attempt to answer the overall research question of how accurate and appropriate a proposed set of suggestion rules can be for recommending to students different learning materials based on their contexts. This is a difficult question to answer, especially given the time and resources constraints. I therefore try to seek answers to three sub-research questions on this basis, presented in 7.1 – 7.3. In 7.1, I describe how useful participants of my validation study found the learning/studying of Java LOs to be in the particular learning contexts being studied. In 7.2, I describe whether participants found that their learning experiences of studying the LOs were more enjoyable as a result of studying them in those contexts. In 7.3, I describe how appropriate participants found my set of suggestion rules. Relating to the learning schedule aspect of the framework, I obtained further reasons why participants chose those particular time slots to study. These are presented in 7.4. In 7.5, I describe the overall feedback obtained from participants relating to my framework. Finally, in 7.6, I present the conclusions to the chapter.

There are a number of limitations to this validation study. The first is that participants are required to provide a self-assessment on how useful or enjoyable they found the studying of LOs. Dishonesty in feedback cannot immediately be detected. The second is that the learning outcomes of participants in this study were not measured, and therefore, it is not possible to find out how much they really learnt from this study. The third is the relatively small sample size of the study – 14 students participated in the study. Despite these limitations, the main aim of this validation study was to corroborate that my proposed set of suggestion rules is viable for recommending appropriate Java LOs to students based on their contexts. The data analyses of this study have corroborated this. I present an overview below of the obtained quantitative results from the study, in table 7.1.

Table 7.1 – Overview of quantitative results

How useful had participants found the study of LOs in appropriate learning contexts?	Very useful 3	Useful – 8	Not useful 3
How enjoyable had participants found the study of LOs in appropriate learning contexts?	Very enjoyable 2	Enjoyable – 6	Not enjoyable - 6
Whether participants found the study of Los more enjoyable in their current contexts?	More enjoyable - 11	Not more enjoyable - 3	
How appropriate were the deployed suggestion rules for recommending Java LOs to students?	Appropriate – 12	Not appropriate - 2	
How feasible can the recommended LOs be studied in other contexts?	Very feasible – 1	Feasible – 11	Not feasible - 2

7.1 Usefulness of studying LOs in appropriate learning contexts

In this section, I answer the question – "How useful did students find the study of LOs in the proposed contexts?" I examine whether, in practical terms, participants had found the deployment of these learning contexts in the recommendation of LOs useful. The appropriateness of the deployed suggestion rules, as experienced by participants, is discussed in 7.3.

10 participants selected that they had 10 minutes of available time, one selected that he had 15 minutes and two participants selected that they had 20 minutes. The remaining volunteer did not participate in the study of the LO – this was during the pilot study and he was not able to view the LO, due to the lack of plug-ins. 11 of these participants studied the LOs in their home environment, whereas two studied them in their work environment. Three out of the 14 participants of the experiment stated that they found the LOs to be very useful studied in the particular learning contexts, whereas eight found them useful and three found them not useful.

I will give the following examples to illustrate in more detail in which contexts the participants studied the Los, as well as the type of feedback they subsequently provided on the usefulness of the LOs.

Examples of participants who noted that the study of LOs were very useful

A participant who studied the If-else-example at home, had a medium level of motivation and spent three minutes on this LO noted that the LO was very useful in that the “visual display of statement made it easy to understand and follow”.

Another participant who studied the If-else-example at home, had a medium level of motivation and spent one minute on this LO noted that the LO was very useful in that “the program was clear, well laid out and gave a very coherent explanation, much more effective than lecture slides.”

The participant who noted that the LO was very useful had studied OOP – OOP example at home, had a high motivation level and spent three minutes on the task. He did not provide any comments regarding why the LO was very useful.

Examples of participants who noted that the study of LOs were useful

Two participants studied the Division of Integer LOs; one studied at home and spent 10 minutes on the LO. The other participant studied in a computer laboratory and spent three minutes on it. They both had a medium level of motivation. The latter participant noted that they were "able to follow the object without too much effort". This is useful and important in an m-learning context because learners might be 'on the move' and might not be able to concentrate as much due to environmental and other distractions. One participant studied Exceptions, who had low motivation, spent four minutes on the task and noted it had been useful. However, the individual provided the following negative comment "there could have been a lot more information on each line of code explaining things a bit better. There was no explanation/definition of what an exception actually is". Regarding this, this is insofar related to the learning content, and not the learning contexts. I was attempting to provide evaluations of the learning contexts in the experiment rather than the learning content.

Examples of participants who noted that the study of LOs were not useful

A participant who studied 2D Array – random values at home, had low motivation level and spent two minutes on the LO noted that the LO was not useful because they "didn't learn anything from it, and the code was very straight-forward". Another participant who studied Method – calculate square and cube, spent 20 minutes on it and had a high motivation level noted that the LO was not useful because “code examples were a little too simple, despite choosing a high level of knowledge. It still seemed very rudimentary”.

Regarding these two comments, these were related to the difficulty level of the topic, not exactly appropriate for the knowledge level of the participants. Although I did attempt to assign the most appropriate LOs according to difficulty level for the proficiency levels of students, it is possible that these could not be precisely matched in every case. This is because of a two possible reasons – 1) the participants might have over- or under-estimated their proficiency level in Java and/or have selected an inappropriate or incorrect level for them; 2) the LOs were not exactly in the range of the proficiency level of an average student with that knowledge level. Or, if there was a particular topic that has been over- or under-studied by a student, then the LO could be more or less difficult than anticipated.

Other feedback

As can be seen from some of the types of feedback that were obtained from participants, most commented on the usefulness of the LO itself, rather than how useful the LO was in studying in the particular contexts. This occurred despite having explicitly explained to students on the feedback form that I would like to gain feedback on the usefulness of LOs relating to contexts that they are studied in, and having specifically explained what these contexts meant. This was inevitable because not all of the participants might have understood this in the manner that it was intended. Much of the feedback from participants was related to the learning content or the user interface of the LOs and the online learning environment.

Although not many of our participants provided comments regarding why it had been useful studying the LOs in the learning contexts, 11 of the 14 participants found it the LO to be either very useful or useful. Hence, I can deduce that a) the choosing of the LOs according to which learning contexts they should be studied under were mostly appropriate, and b) the usefulness of the suggestion of materials based on these learning contexts is important for enhancing the learning experiences and outcomes of learners in an m-learning context. The amount of feedback I received from participants was quite limited; this is often the case with online questionnaires. Martin and Carro (2009) also noted that many of their participants had selected the "I do not know" option, and this was particularly true in the days prior to the participants' exams. Some of the last participants in my validation study also had forthcoming exams.

Discussion

As described in 2.6.1 and 2.6.3, there are different groups of context-aware m-learning applications which are 'location independent' and 'situated learning' respectively. My framework can be categorized into the former group. Benefits can arise from recommending appropriate materials to students in their situations in both of these groups of applications. These benefits include a) in the mobile organizer (Ryu *et al.*, 2007) where students "appeared to find the contextual information both useful and informative in relation to their goals of being at the location, such as "library books due" messages when they were near the library. The participants with specific information appeared to feel more satisfied with the system, and its abilities. Therefore they were more likely to have a positive attitude to and respect for the system, gaining and learning more"; b) in the context-aware Chinese language learning support system (Chen and Chou, 2007), the learner's location is detected using RFID tag, and location-specific contents are then provided from a remote server. Their experiment showed that "learners were satisfied both with the reaction time of RFID and the learning content transmission. It also revealed that learners like the user interfaces and (sic) satisfied with the services that the system could provide".

To conclude this section, the majority of participants found the LOs to be useful for learning/studying Java. Most of the LOs selected for their current learning contexts were appropriate for them, which they found to be useful. A small amount of feedback indicated that participants had not found the LOs to be useful because they were too simple for them. In 7.2, I present further data results relating to whether participants had a more enjoyable learning experience whilst studying LOs in their current learning contexts. In 7.3, I discuss the appropriateness of my proposed suggestion rules for recommendation of Java LOs to students.

7.2 Enjoyment of studying LOs in the appropriate contexts

In this section, I answer the question "Were participants' learning experiences of the LOs more enjoyable as a result of studying them in the proposed learning contexts?" This section is divided into two parts – a) whether participants found the study of LOs enjoyable, and b) whether they found the study of LOs more enjoyable in their learning contexts.

Whether participants found the study of LOs enjoyable

Two students found the experience of learning with the LOs very enjoyable, six students found it enjoyable and six found it not enjoyable. The feedback obtained relating to this research question was also directed more at the learning content or the user interface, rather than the learning contexts itself. I presume that this is because participants were less aware and knowledgeable of what learning contexts actually were, even though these were explicitly described to them.

Positive feedback given by participants relating to how enjoyable the study of LOs was in their current learning contexts includes 1) having found it comforting given “the ability to follow easily the LOs and having the ability to click on each step in order to go to the next one” – the participant had studied the If-else-example LO at home and had found it very useful; 2) having found it convenient to have “the ability to skip forward and backwards at will” – this participant had studied the If-else example LO; 3) having found it “easy to understand and follow when inspecting the code as it was being processed, and it was a good way to illustrate program flow – this participant had studied the If-else-example LO; 4) having found the interactive LOs very appealing even though they were not motivated to concentrate on learning – this participant had studied Division of Integers LO. Both the If-else-example and Division of Integers LOs are intended for students with 10 minutes to spare and a medium level of motivation. These results suggest that students who studied shorter length LOs with an average/medium level of motivation found it enjoyable to study those LOs. These responses are similar to those obtained during the evaluation of the context-aware butterfly-watching learning system (Chen *et al.*, 2004). Their evaluation showed that their beginner-level learners could “more quickly and easily acquire information on [the] butterflies [that] they observe”. It also allowed their learners to take actions in dealing with their own learning, and they enjoyed their learning experiences as a result.

Suggestions to improve the user interface to make it look more professional and exciting were made by a participant who noted that this may help potentially encourage a larger set of audiences to participate in learning the LOs and also spend longer studying them. One participant suggested that the "representing memory & variables LO was very intuitive and would be very useful for beginners".

A few students who did not find the study of LOs enjoyable stated that it was because the content was too simple (as also mentioned in 7.1), and therefore it was boring and not enjoyable. Some participants found the LOs to be too precise and it took longer than necessary to explain some concepts when they had already previously understood the contents of the objects. Hence, they found the study of LOs less enjoyable due to these reasons.

Whether participants found the study of LOs more enjoyable in their current contexts

In terms of whether the participants found it more enjoyable studying the LOs in their current learning contexts, 11 participants found their learning experience to be more enjoyable and three participants found it not more enjoyable.

Positive reasons include 1) being in the "comfortable environmental surroundings of where they had conducted their learning" – the participant had studied the 2D Array values LO; 2) the study of LOs approach was "more enjoyable as it was a fresh approach to teaching that is more involving than a whiteboard" – the participant had studied Method – calculate square and cube. However, regarding 2), this does not directly answer our question in this section. Another participant noted that "if [their] motivation was lower, then it is unlikely that [they] would have continued through the object", who had studied the Division of Integers LO. Another participant noted **"**what mattered was the thorough explanation", after having studied the If-else-example LO.

Some of the feedback obtained for this question was directly related to how the learning contexts can be used to adjust LOs that are selected to higher- or lower-motivated students. For example, the participant who noted that they would not have continued with the LO if their motivation was lower. This implies that the LO was appropriately selected given their level of motivation and hence lower-motivated students can be accommodated as well as medium or higher-motivated students. On the other hand, some of the feedback concerned the quality and the content of the Los, such as the detailed explanations provided. One participant felt that using LOs was more of an innovative way of learning than other means such as teaching using whiteboards.

In Martin and Carro's (2009) case study, 78% of their participants preferred learning activities to be recommended to them based on their learning contexts and preferences. This implies that they also had an enjoyable learning experience with learning in the online environment. In particular, some of the noted comments on the usefulness of the learning environment by their participants include – 1) "these systems guide one over the whole set of activities and help to decide the starting point (what are the best activities to be done according to one's personal needs and learning process); 2) "it helps to know which topics have been wrongly (sic) learned, and it proposes review activities for consolidating these concepts"; 3) "it includes many exercises and [they] can train for the final exam since teachers do only a few exercises in class" - many of our participants had noted this in a similar way; 4) "these environments are more attractive because they allow [students] to do many types of activities, not only study theory from a book or [their] personal notes"; and 5) "this type of learning environment helps to organize one's free time, so they are very useful when one has only a few minutes available" (Martin and Carro, 2009).

In this section, I have described whether my participants enjoyed a) the study of LOs in general and b) the study of LOs in the participants' current learning contexts. Eight out of 14 students found it very enjoyable or enjoyable for part a); and 11 out of 14 participants found their learning experience to be more enjoyable for part b). The feedback obtained was limited as is often the case with online feedback questionnaires. I also described some of the feedback obtained from Martin and Carro's (2009) case study alongside their results, which showed that the participants found their online environment very useful and hence potentially very enjoyable, too. Context-based or context-aware technologies have the potential to provide more useful or appropriate learning materials to students based on their current contexts, and as a result the students' learning experiences and outcomes can be increased.

The two attributes looked at in 7.1 and 7.2 were the usefulness and enjoyment of the LOs, as experienced by my group of participants respectively. These data analyses suggest that it is possible to enhance the level of usefulness and enjoyment perceived by students, using appropriate context-based recommendations of Java LOs successfully. As supported by Martin and Carro (2009), they commented that the "results and feedback obtained from students in [their] two case studies support the confidence in the usefulness and acceptance of this type of educational environments for mobile learning". In 7.3, I attempt to provide some insight into the overall research question of how accurate and appropriate a proposed set of suggestion rules can be for recommending to students different learning materials based on their contexts, by way of data analyses of the results I obtained from this validation study.

7.3 Appropriateness of the deployed suggestion rules

In this section, I answer the question – "How appropriate were the suggestion rules for recommending Java LOs to students?" This section is divided into four parts. I obtained results from participants for the following – a) whether the recommended LO that they had studied had been appropriate for their current learning contexts, b) how feasible can the recommended LOs be studied in other contexts, according to the participants' opinions, c) other appropriate activities that can be recommended in the same contexts and d) inappropriate activities that should not be recommended in the same contexts.

Whether the recommended LOs have been appropriate for participants' contexts

12 participants noted that the recommended LOs were appropriate for them to study in their current contexts, whereas two participants noted that the recommended LOs were not appropriate for them to study in their current contexts. Positive feedback includes "the learning materials or code was relevant to the topic being explained and for [their] knowledge level and available time". Negative feedback includes 1) the LO was short in duration and did not require much time or effort to understand; and 2) the LO was too easy for the level of knowledge selected. As I had mentioned above, on a couple of occasions, the difficulty levels of the LOs were not appropriate for the knowledge level of the participant.

In the suggestion mechanism case study of Martin and Carro (2009), their participants considered the contexts to be slightly less important than their personal features such as learning styles. 66.5% and 75% of their participants selected very useful or useful relating to the contexts and personal features, respectively. Eight out of 22 activities from their data structures module were annotated as unsuitable by more than one student. All of these were compulsory learning materials such as atomic types in the C programming language, theory about atomic types, if and switch conditions, examples of operators and loops in C and review activities. 23 out of 79 activities from the operating systems module annotated as unsuitable were the most basic concepts such as tests related to basic memory management, theoretical activities and examples related to pagination and simple segmentation. Their results correspond to mine in that many of the participants in my study also noted that the basic and simplest topics/activities were inappropriate for them. This suggests that students often do not want to undertake learning materials that are too simple for them.

When Martin and Carro's (2009) participants were asked to indicate a preference of their suggestion mechanism between a) it being better with recommendations, b) it does not matter and c) it being better without recommendations, 78% of their participants indicated a preference for having recommendations. Some students chose b) or c) because they preferred to choose the learning activities themselves to be performed at each particular learning session. These results correspond with the results from my interview study where my participants noted that they would prefer to be the one who decide what to learn at each time.

Positive comments included from their case study include - 1) "these systems guide one over the whole set of activities and help to decide the starting point (what are the best activities to be done according to one’s personal needs and learning process)”, 2) “these environments are more attractive because they allow [them] to do many types of activities, not only study theory from a book or personal notes”. Their participants also considered the learning contexts slightly less important than the learning styles. 81.5% of their participants considered the online learning environment to be useful for learning because “they were able to support content adaptation according to the user context (available time and device used) at each time”. Their participants noted that this had contributed to their learning processes, and the environment guided them well through topics of a given subject and had helped them to approach the subject in a new way, and visualise it as “an incentive to study more in less time” (Ibid).

How feasible can the recommended LOs be studied in other contexts

One participant from my study noted that it would be very feasible to study the LO in other contexts, 11 participants stated that it would be feasible, and two stated that it would not be feasible. Positive feedback include 1) “it doesn’t matter where or when I study the LO, if I’m just reading a bit of code in front of me” – this was in relation to having studied the 2D Array – random values LO; 2) “some LOs could be completed when [they] had a lower level of motivation” – this was in relation to having studied Division of Integers LO; and 3) “people’s learning capabilities are different so it is good to recommend different LOs based on these” – this was in relation to having studied the If-else-example LO. There were limited responses to this question. Participants might not have understood the question and/or contexts fully in the intended way, despite having explained it explicitly, or have felt that there were not many inappropriate activities for different situations/contexts.

I asked participants to indicate other learning activities that may also be appropriate in their opinion in the same contexts. 10 participants noted that 'answering multiple-choice questions' would be appropriate; two participants noted that 'revising learning materials' would be appropriate and two participants noted that 'practicing tests' would be appropriate. For example, Martin *et al*. (2006) suggested the following general recommendation rules – a) if LS is active, place is unknown, and time > 15, then suggest review OR individual exercise OR simulation; and b) if LS is reflective, place is unknown, and time > 40 then suggest theory OR review OR simulation. Note that it could be that different types of learning materials are appropriate for the same contexts, as also suggested by the participants of our study.

I also asked participants to indicate other learning activities that would be inappropriate in their opinion to learn in the same contexts. 'Learning theoretical concepts' was indicated by two participants as inappropriate; 'answering multiple-choice questions' was indicated by three participants as inappropriate; 'revising learning materials' was indicated by one participant as inappropriate; 'Answering open-ended questions' was indicated by three participants as inappropriate. Reasons given include that 1) it would take too long to write essay answers to open-ended questions; however one word answers would be desirable in such a short time-frame; 2) open-ended questions and learning new concepts also would require more concentration and would not be appropriate for learning/studying in short available times. In Martin and Carro (2009)'s study, learning activities which required theoretical explanations were the type of learning activities that were most frequently noted by their participants as inappropriate/unsuitable.

To conclude this section, the proposed suggestion rules deployed in the online experiment have been found by participants to be accurate on the whole in recommending appropriate Java LOs to them, based on their contexts.

7.4 Time slots for studying LOs

In this section, I answer the question “what were the reasons that students chose particular time slots to study in?” 11 participants noted their reason to be having spare available time; two participants noted that they had interest in learning and in Java respectively; one participant noted that it was due to convenience. Additionally, 13 participants noted that it had been a good time slot for studying in – one participant had noted that “[they] were relaxed at home and so could absorb information easier”. The remaining participant noted that it had not been a good time slot for studying in, primarily because he was revising for his forthcoming exams at that point in time and should be concentrating on his revision instead.

Positive feedback obtained from participants in Martin and Carro (2009)’s case study include “this type of learning environment helps to organize one’s free time, so they are very useful when one has only a few minutes to spare”. Negative feedback obtained includes that students might have “preferred to choose the activities to be performed at each time”; this is also supported by the results obtained in my interview study. Some participants noted that they could not concentrate because they were tired.

My incentive to construct the mCALS is to allow students to participate in learning anytime, anywhere, using their mobile devices. Two examples of this are – 1) browsing lecture notes before a lecture in the corridor or lecture theater; and 2) studying Java LOs outdoors in a park. As the previous results in the thesis show, the learner's motivation for carrying out such studying is substantial in affecting whether they carry out the learning at all, and whether it is done in a successful manner, and enjoyably. By suggesting appropriate bite-size learning materials, i.e. LOs, based on their learning contexts to students, I hope this can help them to study more enjoyably and effectively. I found that the reason that most students studied in the time slot that they did was having available time. This reason corresponds to that in the literature review, where a number of m-learning applications have been constructed because there is a need to allow students to learn during idle time and so that this spare available time does not become wasted (Martin *et al*., 2006; Cui and Bull, 2005; Becking *et al*., 2004).

In terms of relating this back to the effectiveness of the proposed learning schedule of the mCALS framework, the results here do suggest that when learners have available idle time, have access to learning materials and are motivated, they are likely to want to carry out some bite-sized learning. This fits well to the proposed learning materials being LOs which are small and self-contained. Bradley *et al*. (2009) also noted that "such LOs can easily be used by the student whenever they have the desire or opportunity to engage in some learning, wherever they are, taking advantage of this 'always there, always on' technology". Therefore, the purpose of my work is to potentially enhance their learning experiences and outcomes when given the opportunity to learn anytime, anywhere. This is accomplished through finding out their current context values and correspondingly recommending appropriate learning materials. The bite-sized Java LOs are very suitable for students to undertake learning/studying in short intervals of time, and at anytime, anywhere. For longer periods of study, longer lengths of LOs are also appropriate.

7.5 Overall feedback of the case study

This section is divided into five parts. Additional data obtained from participants included a) whether they were aware of their LS and whether they feel that they would benefit from studying LOs that are recommended based on their LS, b) the quality of the learning content and whether they would use the LO again and c) any other comments provided by participants.

Whether participants were aware of their LS and whether they feel that they would benefit from studying LOs that are recommended based on their LS

I again visit the topic of whether suggesting learning materials to students based on their LS are a good idea. Contrary to the some literature (including Coffield *et al*., 2004) which suggests that it is not helpful for learners to learn according to their LS, the data analyses in my previous interview and diary studies suggest that students do want to study materials appropriate for their LS. I therefore obtained further responses in the questionnaire feedback of this online experiment. 13 participants noted that they were aware of their LS and were able to locate their learning style (hereafter abbreviated as LS) on the spectrum of the Felder and Silverman model (Felder and Silverman, 1988). Five participants noted that they had a sequential LS, one student noted that they had an active LS, two participants noted that they had a visual LS, four participants noted that they had an intuitive LS and one participant noted that they had a reflective LS. The remaining participant was not aware or did not have a learning style.

13 participants noted that they think that they would benefit from studying LOs that are suitable for their LS and one participant noted that they would not necessarily benefit. My interview results support these statements. Positive feedback by participants includes that 1) “it will provide a different way of learning the various Java concepts”; 2) they find “interactive diagrams fantastic for [their] style of learning and therefore would be great to use these for learning”; and 3) “it would make it more interesting to learn”. These results correspond to the earlier result obtained from the interview and diary studies. Martin and Carro’s (2009) case study also suggest that their participants felt a greater importance for learning activities to be selected appropriately according to their learning style more than according to their learning contexts.

Quality of the learning content and whether participants would use the LO again

In terms of the learning content, two participants found the LOs to be very useful, nine students had found them useful and three students found them not useful. Positive feedback includes 1) “[even though they] already had a firm understanding of basic Java, but [they still] found it would be very helpful for beginners”; 2) “some of the Java principle are fairly important to know and are well-developed”. Negative feedback includes 1) a participant felt that “there was nothing new or novel in the learning materials”; 2) the learning materials were “not useful in the sense that I did not learn anything new from the learning experience”, because they were already familiar with the topic. Eight participants noted that they would use the LOs again, five participants stated that they would not and one participant did not provide any answers. Negative reasons provided include that 1) “[they already] knew the material covered in it"; and 2) "the content was well below my current knowledge level of Java so it was too simplistic".

The m-learning environment sometimes does have an impact on the learning process of the student. For example, as mentioned by some of our participants, it might be more motivating for them to learn if the m-learning environment was appealing and inviting. Also, it is the case that these m-learning environments are used as additional learning resources, not to replace traditional lectures and computer laboratory work (Ibid).

Any other comments provided by participants

Further suggested comments by my participants include 1) "different levels of code for different levels of learners would be good"; 2) "nice way to teach, [they] could see this being useful for those students with no prior knowledge of computing, and are struggling with basics of programs, memory and logic flow."; 3) "[they] particularly liked the "memory" display, but [they] think that it should have more detail, such as having additional arrows to show where the variables would be stored in memory and to show it the source code". Similar comments to 1) were provided by the participants of the case study of Martin and Carro (2009). First, their participants considered "contents themselves more important than content adaptation to different devices. They prefer different versions of contents, with different levels of difficulty i.e. rather than contents adapted to devices, with not that many differences between them".

7.6 Summary and conclusion

I used this online experiment as a case study for validating the suggestion rules of the mCALS framework. Limited research has been conducted on such case studies and related case studies deployed alternative context information and therefore could not be used utilized. This case study provides me with evidence that the deployed suggestion rules were appropriate for each of the learners' situations, based on the information selected by learners relating to their contexts. After the completion of the analysis of the data, it suggests that the recommendation rules for Java learning materials are appropriate. A limitation of this study is the small sample size due to problems obtaining volunteers and the time constraints for my study. I had sufficient data in order for the results to be valid. However, I did not have more time to obtain further data to make the results stronger.

Limited work has been completed for validating the suggestion rules of a context-based suggestion mechanism, as well as any research methodology used to obtain data results concerning these. Evaluation of such rules would normally require a system to be in place. For example, Melis and Andres (2003) have developed a system which uses suggestion rules to recommend appropriate Maths learning materials to students based on their user model, in an e-learning context. Their suggestion rules have not been evaluated extensively; rather their work is concentrated on the evaluation of their system user-interface, adaptive hypermedia, semantic services for web-based exercises, and course generation (Ibid). The works of Becking *et al*. (2004) were concentrated on developing a profile or high-level framework of suggestion rules, and evaluation of this has not been located, at the time of writing. The only case study which I can make similar references to regarding suggestion rules deployed in a context-based recommendation system is that of

Martin and Carro (2009). I have provided discussions and comparisons of my results to theirs throughout the chapter.

In this chapter, I presented the results of the context-based recommendations of the Java LOs case study. The overall results suggest that a) the case study used suitable learning contexts and suggestion rules for recommending appropriate Java LOs to participants, and b) participants enjoyed studying the Java LOs in their learning contexts. I investigated the components related to the framework. In 7.1, I presented the results regarding the usefulness of studying LOs in appropriate learning contexts. Participants mainly found this to be useful; the minority of participants who did not find it to be useful were those who had encountered learning materials which were too simple for them. The same view was shared by the participants of Martin and Carro (2009), who noted precisely the same thing when they had encountered activities which were too simple for them. I then examined in 7.2 how enjoyable participants found the study of Los to be in the contexts. The majority of students found it enjoyable, though some negative criticisms include making improvements to the user interface or m-learning environment to make it more appealing and motivating for students to study. In 7.3, I examined the appropriateness of the deployed suggestion rules; these were found to be appropriate in most cases. I also investigated other materials which would be (and would not be) appropriate in the same contexts. In 7.4, I explored the reasons why participants used the particular time slots to study in. The majority of participants indicated that it was because they had available time. This fits well with the mCALS framework, which allows students to use their spare available time anytime, anywhere for studying/learning. In 7.5, I investigated whether students were aware of their LS and whether they would like learning materials to be appropriately selected on this basis for them to study. The majority of participants were aware of their LS and agreed that this would be beneficial. I then explored the views of participants on the quality content of the LOs and whether they would use these again. I concluded the chapter with any additional comments from the participants.

Chapter 8

Validation Study – Availability of high-quality Java LOs incorporable into mCALS

In this chapter, I present my objective, which is to investigate the availability of high-quality Java LOs from the public domain, which can be incorporated into mCALS. As described in 3.5, I gathered a list of English-speaking institutions which have computing departments and a list of computing-related LOs found on the websites of some of these departments. The motivation for this research activity is that I require a significantly large amount of good quality Java LOs for incorporation into the mCALS framework. I wish to determine whether those Java Los that exist on the World Wide Web for others to reuse can really be re-used successfully and effectively in terms of learning, and in m-learning applications/frameworks.

Kay (2007) listed many advantages of using LOs. He stated that "[i]n contrast to other learning technologies burdened with implementation challenges and costs, LOs are readily accessible over the Internet and users need not worry about excessive costs or not having the latest version… Well over 90% of all public schools in North America and Europe now have access to the Internet (and therefore LOs) with most having high-speed broadband connections…In addition, because of their limited size and focus, LOs are relatively easy to learn and use, making them much more attractive to busy educators who have little time to learn more complex, advanced software packages…Finally, reusability permits LOs to be useful for a large audience, particularly when the objects are placed in well organized, searchable databases…With respect to enhancing learning, many LOs are interactive tools that support exploration, investigation, constructing solutions, and manipulating parameters instead of memorizing and retaining a series of facts…A number of LOs have a graphical component that helps make abstract concepts more concrete [and this is therefore good for learning programming]…Furthermore, certain LOs allow students to explore higher level concepts by reducing cognitive load. They act as perceptual and cognitive supports, permitting students to examine more complex and interesting relationships. Finally, LOs are adaptive, allowing users to have a certain degree of control over their learning environments, particularly [in terms of how long they would like to spend on their studies and in how much detail].” It is particularly useful 1) to use LOs within my framework, due to the different situations that learners might learn/study in, and 2) to recommend appropriate LOs to learners in each different situation. In 8.1, I present the findings on the availability of high-quality Java LOs from the public domain. In 8.2, I present the quality assessment findings of these LOs based on administration criteria. In 8.3, I present the quality assessment findings of these LOs based on the *Learning Object Review Instrument* (LORI). In 8.4, I present conclusions to the chapter. Finally, in 8.5, I present some conclusions to my mCALS framework.

8.1 Availability of high-quality Java LOs from the public domain

In this section, I answer the research question “Which Java LOs available in the public domain are high-quality and reusable and can be incorporated into the framework?” I first list the institutions which contain LO or learning object repositories which contain computing-related LOs, as follows:

1. Dept of Computer Science, Rice University, USA - cnx.org/
2. Dept of Computer Science, Furman University, USA - cs.furman.edu/~kabernet/cte/
3. Dept of Computer Science, University of Manitoba, Canada - https://mspace.lib.umanitoba.ca/
4. JORUM ("a JISC-funded service in development in UK Further and Higher Education, to collect and share learning and teaching materials, allowing their reuse and repurposing") - www.jorum.ac.uk/
5. MERLOT (Multmedia educational resource for learning and online teaching) - www.merlot.org/
6. Faculty of Computing, London Metropolitan University, UK www.londonmet.ac.uk/ltri/learningobjects/objects/
7. School of Electronics and Computer Science, University of Southampton, UK - cogprints.org/
8. Central Michigan University - condor.cmich.edu/ Faculty and Business and Information Technology, University of Ontario Institute of Technology, Canada - education.uoit.ca/lordec/
9. Dept of Computer Science, University of Hong Kong, Hong Kong - hub.hku.hk/

There are also other institutions which contain computing departments. However, these are not included in this list because of the following reason(s) – 1) a login is required to view their LOs, 2) their LOs are copyrighted, 3) there are no metadata attached to the LOs or 4) their LOs do not actually contain learning materials. The motivation in obtaining this list of English-speaking institutions with computing departments and henceforth, whether they contain LOs, was to determine and gather a list of programming LOs. An exhaustive list of all programming LOs that are available in the public domain does not exist, which is why I conducted this study. One such existing LORs that contains programming LOs is Codewitz.

I further investigated the above list of institutions containing computing-related LOs. A variety of LOs in different computing or programming topics were found relating to the Java programming language and other object-oriented programming languages such as C++ and VC++, and additionally graphical programming languages such as LabVIEW. Other topics found include software engineering, programming methodologies, simulation software tutorials, integrated development environments, software testing, open source software and web-scripting languages such as JavaScript, HTML. The topics of LOs are listed below under each of the institutions (as presented above) and the number in brackets indicates the number of LOs available on that particular webpage relevant to that topic.

1. Dept of Computer Science, Rice University, USA –
    a. LOs for inheritance in Java - cnx.org/content/m31249/latest/ (9)
    b. LOs for constructors in Java - cnx.org/content/m31248/latest/ (8)
    c. LOs for methods in Java - cnx.org/content/m31247/latest/ (9)
    d. LOs for arrays in Java - cnx.org/content/m31245/latest/ (9)
    e. LOs for control structures in Java cnx.org/content/m31246/latest/ (9)
    f. VC++ tutorial for beginners – cnx.org/content/m14425/latest/ (1)
    g. Software engineering - cnx.org/content/m14618/latest/ (3)
    h. LabVIEW graphical programming - cnx.org/content/m14634/latest/ (4)

i. C++ programming fundamentals - cnx.org/content/m22453/latest/ (8)

j. Simulation software tutorial - cnx.org/content/m14269/latest/ (1)

k. Object-oriented programming - cnx.org/content/m22188/latest/ (1)

l. Integrated development environment - cnx.org/content/m18920/latest/ (1)

m. Software testing - cnx.org/content/m28939/latest/ (1)

n. Open source software - cnx.org/content/m12403/latest/ (1)

2. Dept of Computer Science, Furman University, USA –

   a. Javascript - cs.furman.edu/~kabernet/cte/javascript/index.htm (4)

   b. HTMLcs.furman.edu/~kabernet/cte/web_authoring/html_intro/html_intro_lesson.htm (17)

3. Dept of Computer Science, University of Manitoba, Canada

   a. What is plagiarism? - https://mspace.lib.umanitoba.ca/handle/1993/253 (1)

4. JORUM –

   a. Computer science concepts – (languages and grammar, prolog, strings and languages) - open.jorum.ac.uk/xmlui/handle/123456789/1229 (9)

   b. Java server pages, Java beans and Java servlets - open.jorum.ac.uk/xmlui/handle/123456789/1319 (10)

   c. Introduction to OOP in Java (classes and arithmetic, creating classes, generic lists, inheritance – extending classes, AWT, making decisions, menu and switch, mobile phone case study, searching software quality and testing) - open.jorum.ac.uk/xmlui/handle/123456789/1986 (86)

   d. Object-oriented software design (building GUI in Java & Design patterns, class design & testing, classes and objects, Java object serialization, inheritance and polymorphism, OO design process) - open.jorum.ac.uk/xmlui/handle/123456789/1712 (36)

e. Rapid application development - open.jorum.ac.uk/xmlui/handle/123456789/1764 (79)

f. Web design and objects - open.jorum.ac.uk/xmlui/handle/123456789/2325 (16)

5. Faculty of Computing, London Metropolitan University, UK - While loops, if-statements, arrays in Java, and library of classes (4)

6. Dept of Computer Science and Engineering, Hong Kong University of Science and Technology, Hong Kong - www.cse.ust.hk/learning_objects/

   a. Arrays - www.cse.ust.hk/learning_objects/array (8)

   b. Creating wikis, podcasts, and blogs - www.csus.edu/atcs/tools/learning-objects/ (3)

7. Codewitz programming LOs including Java, C++ (202).

Through the investigation of this study, I gathered 540 LOs which relate to programming languages. The complete list of LOs that are computing-related totals 1607. The number of LOs is quite low considering the large number of English-speaking institutions containing a computing department that I located. Although many educators might be aware that they should develop LOs for the reuse of other students or learners, it often requires too much effort and time to put this into practice. The development of LOs is usually voluntary and the researcher/educator does not receive financial or other benefits, and it is a time-consuming task to convert ordinary learning materials into reusable LOs free of contexts (i.e. can be used and applied in different topics of learning). For example, a LO which teaches about the drop of an apple to illustrate gravity, can be used by students learning about physics or mechanics, among other subjects. Therefore, I was not surprised about the results of this investigation.

The next stage of the research activity is to assess the quality of the LOs themselves – first using an administrative criterion as presented in 8.2 and second using the Learning Object Review Instrument as presented in 8.3.

8.2 Quality assessment of LOs based on an administrative criterion

For the purposes of this validation study as well as part of a research project funded by Higher Education Academy Information and Computer Sciences (HEA-ICS), I investigated the list of 1607 computing-related LOs which had been gathered (see 8.1). For each LO, I gathered the following additional information– institution name, department name, country, URL to view LO, title, topic, license, URL to download or view source, date/time of creation/edition, date/time accessed by myself and metadata tags (if any). The six criteria developed by HEA-ICS were that 1) the granularity must be large (each LO must be one of lecture, tutorial, assessment or further reading), 2) the LO must clearly relate to a topic (taught within a module) that relates to a computing discipline, 3) the LO must have been developed and used as part of a validated course of study (thus, the assessment schema will have been scrutinised – at least in theory – by an external examiner or equivalent, and the LO will integrate with the existing course material), 4) the LO has a open license such as Creative Commons or equivalent, 5) the LO can be edited, if desired and 6) the LO is in English. LOs must pass all six criteria in order to be accepted in this quality assessment. 1112 (69%)

passed the criteria, whereas 494 (31%) did not. Appendix E shows a sample of LOs, some of which passed the criteria and some which did not.

I will now give two examples on how I assessed the LOs based on this administrative criterion. This criterion is mostly objective and for each of the six criteria, a LO either passes or not, i.e. yes or no. The first one is one of the Java LOs, developed at the in the Faculty of Computing in the London Metropolitan University. The LO is about if-statements and the URL is http://www.londonmet.ac.uk/ltri/learningobjects/objects/lm_jav1_if1_x/lm_jav1_if1_1.htm It was last updated on 7 Aug 2008 and the last time I accessed it was 5 May 2010. This LO passed all six criteria. The second example is the LOs developed for the Codewitz repository at the Tampere Polytechnic, University of Applied Sciences, Finland. The LOs that they developed are Java and C++ LOs for learning to program. These did not pass the criteria because they require users to be members of the Codewitz network in order to view the contents of the repository. Thus they did not pass the overall criteria as there is not an open license.

A goal of this research as part of the HEA-ICS funded project was to develop a database resource to allow users to search for computing-related LOs currently on the Internet. As a result, I incorporated the 1112 LOs (31%) which had passed the criterion into the database. The main reasons that the remaining 494 LOs out of1607 did not pass the criterion were that 1) they did not contain metadata or keywords and therefore cannot easily be searched and located, 2) they required a login in order to view the learning content, 3) they were not in English, 4) the page of the LO was not found/accessible and/or 5) the LOs did not actually contain learning materials.

Similarly to 8.1, I was not surprised by the results of the investigation described in this section. This is because it can be a time-consuming task to convert online learning materials to LOs and even more time-consuming to develop an LO from scratch. Therefore, some of the claimed LOs were not actually LOs as they did not contain metadata. Since LOs are usually developed voluntarily, the incentive for developers to spend a large amount of time ensuring all criteria of the LO is often quite low, and this can be used to explain the outcomes of this investigation. In this section, I described the quality assessments of my obtained list of LOs using an administrative criterion. In the next section, I will describe the quality assessments of these LOs using the Learning Object Review Instrument (LORI).

8.3 Quality assessment of LOs based on the Learning Object Review Instrument (LORI)

In 8.2, I described whether or not the LOs in the gathered list pass or do not pass the deployed administration criteria, i.e. yes or no answers. In this section, I describe how I used the Learning Object Review Instrument (LORI) (Nesbit *et al*., 2003) for quality assessment of these LOs by measuring them based on the nine different categories of the LORI. Earlier and current versions of the LORI were developed by Boskic, Archambault and Vargo for the E-learning Research and Assessment Network (eLera) and the Portal for Online Objects in Learning (POOL) with support from TeleLearning NCE, CANARIE Inc. and eduSourceCanada. The purpose of the LORI is to allow the quality of each LO to be measured against the nine items of the LORI. For each item, quality of the LO is given a number on a rating scale consisting of five levels (5 being the highest, and 1 being the lowest). “Not applicable” can be selected under two circumstances – 1) “if the item is judged not relevant to the LO”, or 2) “if the reviewer does not feel qualified to judge that criterion” (Nesbit *et al*., 2003).

Vargo, Nesbit, Belfer and Archambault (2003) have investigated the reliability of LORI.

A review instrument such as LORI is needed because "a search through a large web-based learning object repository can return hundreds of objects. Reviewers help users to select for quality and suitability. LORI and similar instruments facilitate comparison among objects by providing a common review format" (Nesbit *et al*., 2003). The nine items of the LORI are, as follows (taken from Nesbit *et al*., 2003):

1) *content quality* – veracity, accuracy, balanced presentation of ideas, and appropriate level of detail;
2) *learning goal alignment* – alignment among learning goals, activities, assessments, and learner characteristics;
3) *feedback and adaptation* – adaptive content or feedback driven by differential learner input or learner modelling;
4) *motivation* – ability to motivate and interest an identified population of learners;
5) *presentation design* – design of visual and auditory information for enhanced learning and efficient mental processing,
6) *interaction usability* – ease of navigation, predictability of the user interface, and quality of the interface help features,
7) *accessibility* – design of controls and presentation formats to accommodate disabled and mobile learners;
8) *reusability* – ability to use in varying learning contexts and with learners from differing backgrounds; and
9) *standards compliance* – adherence to international standards and specifications.

Defude and Farhat (2005) noted that it was important to design LOs that are high-quality – one reason being that users must be able to search for them effectively via their metadata using, for example, Learning Object Metadata (LOM). Ochoa and Duval (2006) proposed alternative instruments for measuring the quality of LOs, which measure the quality of the metadata instead of the content and other aspects relating to the LOs themselves. Their proposed quality parameters for metadata include completeness, accuracy, provenance, conformance to expectations, logical consistency and coherence, timeliness, and accessibility. They suggested that there should be two requirements for the quality of learning object metadata – a) to be able to automatically calculate and b) "to infer, to a degree of accuracy, the score that a hypothetical human expert would assign to the metadata record" (Ibid). However, for the purpose of the quality assessment of LOs, I have used the LORI as it is the content of the LOs and other aspects directly related to the LOs that are more important for the purposes of my research.

8.3.1. Quality assessment ratings using the LORI

I selected a random sample of 200 LOs out of the list of 1112 LOs which meet the administrative criteria, as presented in 8.2, to be assessed, in terms of their qualities, using the LORI (Nesbit *et al.*, 2003). I only assessed 200 of the 1112 LOs due to time constraints. I also considered the ninth item – standards compliance – of the LORI which concerns the adherence to international standards and specification, i.e. Learning Object Metadata, SCORM etc. A level five rating of this item requires a LO to adhere to all relevant international standards and specifications including LOM, SCORM, and technical guidelines developed by IMS and W3C. A level three rating of this item requires a LO to pass certain SCORM metadata tests but fail other compliance ones relating to interoperability and content packaging. I decided that it would take too long to run each of the 200 LOs through some metadata tests in order to determine which ones they pass or otherwise. Additionally, I decided that this item is less relevant to the purpose of this study than the other eight items. This is because the pedagogical aspects of the LOs are more important to my study than the technical aspects such as concerning which metadata tests the LOs pass.

I, therefore, assessed the selected 200 LOs based on the first eight items of the LORI. In the LORI manual (Nesbit *et al*., 2003), suggestions are given to which level rating should be given to LOs for each item, are as follows (taken and adapted from Nesbit *et al*., 2003).

1. For *content quality*, to obtain a level 5 – the content of the LO must be free of errors and presented without bias; to score a level 3 – there may be important or relevant information that is missing from the LO which could mislead the learner; and to obtain a level 1 – the content is inaccurate, presented with bias or omissions, or the level of detail is not appropriate, i.e. too little information.
2. For *learning goal alignment*, to obtain a level 5 – the learning goals must be specifically declared; to obtain a level 1 – no learning goals are apparent.
3. For *feedback and adaptation*, to obtain a level 5 – the LO has the ability to adapt instructional messages or activities to the needs of the learner; to obtain a level 1 – there is no feedback concerning the correctness of a student's response.
4. For *motivation*, to obtain a level 5 – the LO offers multimedia, interactivity, or game-like challenges; to obtain a level 1 – the activities are too easy or too

difficult for the intended learners, or the content is not relevant to the goals of the intended learners.

5. For *presentation design*, to obtain a level 5 – the presentation of the LO must minimize visual search, using graphs and charts. Writing is clear, concise and free of errors; to obtain a level 1 – the font size is inappropriate, or the information design produces unnecessary cognitive processing.
6. For *interaction usability*, to obtain a level 5 – the user interface is interactive; to obtain a level 1 – there are no interactive features.
7. For *accessibility*, to obtain a level 5 – the LO can accommodate learners with sensor and motor disabilities and can be accessed through assistive and highly portable devices; to obtain a level 1 – the LO is unusable for disabled learners.
8. For reusability, to obtain a level 5 – the LO is a standalone resource that can be readily transferred to different courses, learning designs and contexts without modification; to obtain a level 1 – the LO refers to the module, course or instructor for which it was originally designed, or that the LO requires students to read particular books or learning materials, in order to be able to use the LO effectively.

8.3.2. Quality assessment results using the LORI

Table 8.1 shows the number of counts for the 200 LOs on the ratings 1-5 each of the eight items of the LORI.

Table 8.1 – Number of counts of the ratings 1-5 for each of the eight criteria of LORI

	1	**2**	**3**	**4**	**5**	**N/A**
1. Content quality	21	64	103	11	1	0
2. Learning goal alignment	160	21	3	13	3	0
3. Feedback and adaptation	0	0	0	0	0	200
4. Motivation	168	28	2	2	0	0
5. Presentation design	19	81	92	8	0	0
6. Interaction usability	0	0	0	0	0	200
7. Accessibility	0	200	0	0	0	0
8. Reusability	35	17	1	1	146	0

Description and explanation of the statistics are as follows:

1. Regarding the *content quality* item of the 200 LOs that were investigated, 51.5% were rated 3, followed by 32% which were rated 2, 10.5% were rated 1, 5.5% were rated 4, and 0.5% were rated 5. This suggests that the content quality of the majority of the LOs was average or below average. This result was not surprising because a lot of time and effort needs to be invested into the development of a high-quality LO, and it was likely that these were constructed voluntarily. In many cases, these LOs were online html pages with text and the content of these were around average.
2. Regarding the *learning goal alignment* item, 80% were rated 1 (i.e. no learning goals were stated), 10.5% were rated 2, 6.5% were rated 4, 1.5% were rated 3 and 5, respectively. The majority of the LOs did not have learning goals specified, as they had not been intended for any particular group of students with any specific learning aims. This does not, however, automatically imply that the LOs which obtained low levels for this item are of poor quality due to the lack of specific stated learning goals. In fact, many

of these LOs were of very good content quality and/or had obtained high levels for the other items.

3. Regarding the *feedback and adaptation* item, this criterion was not applicable for any of the selected LOs because the LOs primarily contained static content and did not contain any adaptive content or feedback.
4. Regarding the *motivation* item, this is used to describe the relationship between the content and the learning goals of a LO and whether the content matches the requirements of the learning goal. 84% were rated 1 (because no learning goals were stated and therefore there was no relationship between the content and learning goals), 14% were rated 2, 1% were rated 3 and 4, respectively, and 0% were rated 5. Many of the LOs had no stated specific learning goals, which automatically led to ratings of 1 for the *motivation* item. However, through the quality assessments of these LOs, it does not appear that the motivation for students to learn these LOs would be necessarily low.
5. Regarding the *presentation design* item, 46% were rated 3, 40.5% were rated 2, 9.5% were rated 1, and 0% were rated 5. Around half of the presentation were rated 3, i.e. average, whilst around 40% were rated slightly below average. The low level ratings were primarily due to the large amount of text and very little of multimedia images and graphs etc being used. Text is considerably easier and less time-consuming to write and develop than images and multimedia. Therefore, this could be one of the main reasons for these levels of ratings for this item.
6. Regarding the *interaction usability* item, this criterion was not applicable for any of the selected LOs because all the LOs contained primarily static content

and not any multimedia user interfaces, therefore this item was not judged to be applicable.

7. Regarding the *accessibility* item, all of the selected 200 LOs were rated 2 as the LOs were either word documents, powerpoint, pdf or HTML, in which all of these files could be magnified if required, in order to accommodate disabled learners. Much of the existing available learning content on the Internet is in the above-mentioned formats, and this is the main reason many of the LOs consist of these files.
8. Regarding the *reusability* item, 73% were rated 5, 17.5% were rated 1, 8.5% were rated 2 and 0.5% were rated 3 and 4, respectively. 73% of the LOs had no reference to the lecture/module for which they were developed – and therefore are given high ratings of reusability such as 5. The lower levels are rated on LOs when they a) specify the particular week that the lecture was originally used in, b) specify the number of the lecture in which it was originally taught and/or c) require students to read particular books or learning materials. Additional time is required for educators or developers of the LOs to convert their original lecture, tutorial or assessment materials to stand-alone materials to ensure high levels of reusability. This appears to be one of the main reasons why some of the LOs obtained a low level of rating. However, 73% is a considerably high percentage in which the selected LOs obtained a level five for this item, implying that the reusability of LOs available in the public domain is generally at a high level, and can be reused in different applications or systems, for various contexts or subjects.

8.3.3. An example of quality assessment ratings using the LORI

An example of how I assessed the quality of an LO using the LORI on each of the eight items is as follows. Note that although a rating between 1 and 5 can be given to LOs for each item, following the manual of the LORI, there is a degree of subjectivity when deciding which level to rate a LO for a particular item.

I will use the LO named ‘Lesson: Organization of Memory’ developed by the Department of Computer Science at the University of Furman to illustrate how I had assessed its quality. The list of keywords/metadata for this LO include random access memory; read only memory; computer memory; RAM; ROM; bit; byte; kilobyte; megabyte; and gigabyte. The URL is http://cs.furman.edu/~kabernet/cte/computer_basics/memory/memory_lesson.htm. I have given the following levels of ratings for the eight items: (Refer to 8.3.1 for the summary of quality assessment ratings using the LORI for each item, or refer to the LORI manual (Nesbit *et al*., 2003) for more details).

1. *Content quality* – I assigned level 2 for this item because there is a relatively sufficient amount of accurate learning materials for the topic. This LO should not be assigned level 1 because the content is *not* a) inaccurate, b) presented with bias or omissions, or c) not appropriate. It should, however, not be assigned level 5 because a) the presentations do *not* emphasize key points and significant ideas with an appropriate level of detail, and b) differences among cultural and ethnic groups are *not* represented in a balanced and sensitive manner. I assigned the LO a level closer to level 1 because the LO itself is fairly simple, mainly consisting of text in black font. The content itself also consists of mainly generic materials about the topic and none of it is especially outstanding.

2. *Learning goal alignment* – I assigned a level 5 for this item because five learning goals relating to this LO are explicitly stated. These are - a) distinguish RAM and ROM, b) describe the basic organization of addressable memory, c) define the terms bit, byte, kilobyte, megabyte, and gigabyte, d) explain what the ASCII code does and how it is related to the definition of a byte and e) understand the difference between a memory cell's address and its content.
3. *Feedback and adaptation* – I assigned N/A for this item because I judged that the item is not relevant to the LO.
4. *Motivation* – I assigned a level 1 for this item because the feedback of the assessment questions does not inform learners of their level of competence relative to learning goals.
5. *Presentation design* – I assigned a level 2 for this item because the presented information is relatively simple, only black font in html is used. It is sufficient for its purposes; however, the presentation design is not outstanding.
6. *Interaction usability* – I assigned N/A for this item because I judged that the item is not relevant to the LO.
7. *Accessibility* – I assigned a level 2 for this item because the LO is an html document and therefore the presentation format can be magnified for disabled learners. I did not assign it any higher level because there is not a high degree of accommodation for learners with sensory and motor disabilities.
8. *Reusability* – I assigned a level 5 for this item because it is a standalone resource, which can be readily transferred to different courses, learning designs and contexts without modifications. Furthermore, it does not refer to the module, course or instructor for which it was originally designed.

8.4 Discussion and conclusion

The outcomes of this validation study were not surprising in that not all of the 200 LOs obtained a level 5 rating for every item; in fact, this was far from the actual case. There are many explanations for this, some of which are provided in 8.3.2 and 8.3.3. The results to the investigation using the LORI to measure the quality of LOs can be interpreted in different ways. The levels of ratings for each LO give an indication of the level of its quality. However, the results gathered suggest that these are merely an indication of the level of the LOs' quality and do not necessarily reflect the true quality of the LOs. For example, a LO could be of excellent quality while obtaining a level 1 for *learning goal alignment*, because it does not have any stated learning goals. Similarly, an LO obtaining a level 5 for reusability because it is a standalone resource does not necessarily mean the quality of the LO itself in terms of content and presentation is good. I, therefore, conclude that the LORI can only be used as a guideline for comparing different LOs using the nine items, but the ratings using the nine items cannot be used as 'hard' facts about the overall quality of LOs.

The overall results from this investigation suggest that there are plenty of LOs that are of high-quality and can be used within my mCALS framework. Perhaps not all the investigated LOs rated very highly on each criterion; however, after the investigation, I discovered that there are a large and sufficient amount and number of learning materials/LOs available in the public domain, which would meet the learning needs of Java learning students, and can be feasibly incorporable into my framework. First, I established that LOs are available in the public domain, and second, I established that the qualities thereof mostly meet a minimum threshold.

The obtained results of this study indicate that the quality of the LOs available in the public domain is equivocal. I did not obtain a large number of high ratings (such as 4, or 5) on many of the criteria except on reusability. It was observed that most of these LOs were learning materials which have been authored for an individual course or lecture and then made available as a LO for others to use and reuse online. Only a very small number of these can be seen to have been created as LOs from scratch, taking into account each of the criteria to be a high-quality LO.

I obtained an overview of the Java LOs, and the topics of these include inheritance, constructors, methods, arrays, control structures, building GUI in Java & design patterns, classes and arithmetic, creating classes, generic lists, inheritance – extending classes, AWT, object-oriented software design., while-loops, if-statements, arrays. Other programming languages available include VC++, LabVIEW, C++, simulation software, software engineering, object-oriented programming (in general), software testing, open source software, also Javascript, and HTML. These can all be used to help students learn Java programming and related concepts. There are also a variety of document formats for the LOs such as Word, PDF, HTML, Powerpoint and so on. For the purposes of incorporating these LOs into my framework, they can be selected based on topics/subjects and levels of ratings for some items which would be more important to learners such as content quality and presentation design.

8.5 Conclusions to the mCALS framework

This thesis is focused on the design of mobile context-based suggestion mechanisms to support students learning/studying in different situations, by recommending appropriate learning materials to them suitable for the situation. Previous research efforts relating to context-based suggestion mechanisms indicate that we lack a well-defined mobile context-based suggestion mechanism that has been fully evaluated and one which uses a learning schedule approach to retrieve the learners' location and available time contexts. The central questions on which I focus in this thesis are 1) whether the use of a learning schedule approach can be used to retrieve learners' contexts effectively, and 2) which suggestion rules are appropriate for recommending Java learning objects to students. Two human-centred studies – interview and diary study – were initially conducted to acquire and refine the user requirements of the framework. Thereafter, two validation studies were conducted – online Java experiment and investigation of high-quality publicly-available Java LOs. In chapter 9, I present a software engineering design of my framework and how it can currently be implemented. In chapter 10, I conclude the thesis by presenting future works to the thesis, my research contributions and limitations to this research. The findings presented in this thesis indicate that the proposed mobile context-based learning schedule (mCALS) framework can be effective in recommending appropriate Java learning materials to students based on their learning context. The learning schedule approach, strengthened by additional location-aware technologies and direct user requests, can be used to accurately retrieve learners' location and available time information. The mCALS framework appears to be more effective for students to use in different mobile situations than ordinary standard learning applications.

Chapter 9

A Technological Feasibility Study via a Technical Design Approach

The pedagogical and usability studies have helped to refine the requirements of the framework more suited for intended users. In view of time and resources constraints, software programming activities were not carried out on the implementation of the framework. A large number of different context-aware m-learning architectures and software systems currently exist that have been developed for facilitating different learning activities and purposes. In this chapter, the research activity focuses on demonstrating the technical feasibility of implementing the refined framework with the use of current technologies, allowing future implementation work to be carried out, when necessary. Five research questions are addressed from 9.1 to 9.5. These are related to 1) *how location and available time contexts can be retrieved*, 2) *the use of location-retrieval and direct user request methods to strengthen the framework*, 3) *how learning contexts can be incorporated using LOs*, 4) *the technologies required to implement each framework component* and 5) *the final system architecture and configuration of the framework*, respectively. The summary and conclusion of the chapter are presented in 9.6.

9.1 Implementation of the proactive learning contexts retrieval approach

In this section, I address the research question – "Can the proactive learning contexts retrieval approach be implemented?" The section is divided into – 1) *related works on the use of electronic diaries*, 2) *background information on* a) *electronic diaries,* and b) *iCalendar format* and 3) *an iCalendar script to illustrate contexts retrieval*.

Related works on the use of electronic diaries

The use of electronic diaries has not only been adopted for learning purposes but also for medical purposes. For example, such diaries have been used for asthma patients; in fact, the conventional types of computers or mobile devices had presented problems for some of these patients. Therefore, the authors developed an electronic asthma diary on the Apple Newton. Using a stylus on the screen, entries are made by tapping choices (Tiplady *et al*., 1995). Particular requirements relating to screen and text displays and layout, font size, controls and navigation were proposed for designing handheld computer systems for electronic collection of patient diary and questionnaire data in clinical trials (Palmbald and Tiplady, 2004).

Table 9.1 displays the strengths and witnesses of electronic diary data and has been taken from Raymond and Ross (2000).

Table 9.1 – Strengths and weaknesses of electronic diary data

Strengths	Weaknesses
Includes all the strengths of written diary data (such as available for entry concerning current symptoms, medication consumption, episodes)	Requires training to familiarize subjects with use of the technology
Greater subject compliance because of ease of entry; possibility of monitoring compliance	Cost of the device and communication of data of monitoring compliance
Enhanced data integrity because of internal validity checks, time stamps.	Possible errors in local time settings or programming requires time stamps pretrial testing
Possibility of interim access to diary data—direct transfer from subject's device to central database aids in subject and trial management	Logistics of distribution, maintenance, and recovery of devices and communications infrastructure
Little or no need for study staff to enter data, actively manage database, or clean data	Design, implementation, validation of a system to collect, display, and deliver data
Dynamic display permits a variety of user-friendly data entry elements and formats	Each data entry element or format requires programming and planning
Permits comments by subjects	Reading and transcription of comments may require user to have a computer

Background information on electronic diaries

Most current Windows CE-, Apple Mac- and Linux-based mobile computers, smartphones and PDAs contain built-in electronic diaries/calendars, which can also be used and accessed offline. Online diaries can be accessed via the web, for example, through Microsoft Outlook 'web access' features or using a web calendar such as Google Calendar. Events stored on the latter calendar can be synchronised with

Microsoft Outlook, Apple iCAL and Mozilla Sunbird calendar applications. A read-only version of Google Calendar can be viewed offline.

The Microsoft Office Outlook Mobile calendar application can be installed on most Windows-based mobile phones or computers. If necessary, calendar events stored on the desktop or laptop computers can be synchronised to the mobile device (and vice versa), via the mobile network, a wired or wireless connection. Outlook Mobile is compatible with Windows Mobile 5.0 and 6.0 and works on both touch and non-touch screen mobile phones or devices.

'Palm Pilot', 'Psion', and 'Timex Data Link watch' were found to be popular personal organisers (Brown and Crawshaw, 1998). An investigation of PDAs for the use of electronic diaries was conducted, which showed that a) the 'Psion Series 5' PDA was useful for users who require additional office applications; b) the 'Franklin REX PRO' was useful for users who wished to simply replace their paper-based diary; and b) the '3COM Palm Pilot III' was suitable for users who were in-between these two scenarios (Drury, 1999).

The proactive approach in obtaining a user's location and available time at a particular point in time can easily be retrieved from the learner's events stored on any of the calendar applications built into or installed onto mobile devices, such as those mentioned above. For each of their events users are to include the following information – *geographic location, type of location, time start, time finish* and *nature of the event*. This event information can be automatically converted into iCalendar format, explained below, and an iCalendar script can be easily written for contexts retrieval, as shown in the last sub-section.

Background information on iCalendar format

Via the standard Microsoft Import/Export (from and to vCal/iCal) feature, Outlook calendar applications can automatically convert events information into iCalendar format (and vice versa); this format is known as .ics or .ical format. vCal was the standard used prior to iCal. The Import/Export feature also enables calendar events (or calendar-based data) to be easily sent to other users via email and the receiver can easily accept or decline the proposed events. An add-in for Microsoft Outlook, for example SyncWiz for Outlook, gives additional benefits such as allowing Outlook calendar events (and contacts) to be exported, imported, backed up and synchronised to other mobile, desktop and laptop computers.

Overall, the purpose of the iCalendar format is to provide compatibility for capturing and exchanging calendar and scheduling information between events stored on a calendaring and scheduling application (such as Personal Information Manager (PIM) or a Group Scheduling product) and other applications. The iCalendar format is a suitable exchange format between different applications or systems because it is defined in terms of MIME content type. iCalendar objects can be exchanged via several transports - such as SMTP, HTTP, a file system, desktop interactive protocols, point-to-point asynchronous communication, wired-network and unwired transport (Dawson and Stenerson, 1998).

The iCalendar Core Object Specification (Ibid) is primarily used for providing a standard capturing means for calendar events, to-do and diary/journal entry information. Additionally, it can be used to convey free/busy time information as well as allowing iCalendar object methods to be defined. Such a method is a set of usage constraints for an iCalendar object. Dawson and Stenerson (1998) identified a number of methods that can be defined to carry out certain tasks such as a) to request an event to be scheduled, b) reply to an event request, c) send a cancellation notice for an event, d) modify or replace the information of an event, e) reply to a free or busy time request and so on.

An iCalendar script to illustrate contexts retrieval

In order to illustrate how the location and time available at a particular point in time can be retrieved from users' events, the following two examples are given. The first batch of code illustrates the first event on the day, occurring on 14 August 2009, 09:00:00 until 09:59:59, and taking place at Warwick campus in a lecture theatre. The second batch illustrates the second event on that day, occurring from 11:00:00 until 11:59:59, and taking place at Warwick campus in a seminar room. These are examples of iCalendar objects i.e. Internet Calendaring and Scheduling Core Objects defined by the iCalendar Core Object Specification which can be used to store single or multiple iCalendar objects; multiple objects are grouped sequentially together (Ibid).

```
BEGIN:VCALENDAR
VERSION:2.0
PRODID:-//hacksw/handcal//NONSGML v1.0//EN
BEGIN:VEVENT
DTSTART:20090814T090000Z
DTEND: 20090814T095959Z
GLOCATION: Warwick campus
TLOCATION: Lecture theatre
SUMMARY: Lecture
END:VEVENT
END:VCALENDAR

BEGIN:VCALENDAR
VERSION:2.0
```

```
PRODID:-//hacksw/handcal//NONSGML v1.0//EN
BEGIN:VEVENT
DTSTART:20090814T110000Z
DTEND: 20090814T115959Z
GLOCATION: Warwick campus
TLOCATION: Seminar room
SUMMARY: Seminar
END:VEVENT
END:VCALENDAR
```

An open source Python library for parsing iCalendar data was constructed by Max (2006). The class method `Calendar.from_string()` can be used to parse the text representation of the calendar data in order to create a Calendar instance with their attributes described in the input data. When a Calendar object is instantiated, the `walk()` method can be used to process each attribute in the calendar event. In order to access individual attributes, the `getitem()` API can be used (Hellman, 2007). I wrote the following script in Python for retrieving a learner's location and their available time. This script has been adapted from (Ibid).

```
from icalendar import Calendar, Event
cal_data = Calendar.from_string(open('events.ics', 'rb').read())
//For parsing the text representation of calendar data, as described above.
for event in cal_data.subcomponents:
    if event.name == 'VEVENT':
        print 'GEOGRAPHIC LOCATION:', event['GLOCATION']
   print 'TYPE OF LOCATION:', event['TLOCATION']
   // The above 2 lines obtain both the geographic and type of locations of the event, then outputs them.
   getCurrentTime() = currentTime
   availableTime = event['DTSTART'] – currentTime
   print availableTime
  // The above 3 lines obtain the current point in time and the start time of the learner’s next event to determine their available time, which is then outputted.
```

In this section, I showed that the proactive approach of using a learner schedule for retrieving learners' location and available time information can be achieved by learners storing and keeping their events up-to-date using modern built-in calendar applications contained on mobile devices. Their events information can then be exported to iCalendar format into a separate folder with minimal effort; in my case this information is exported into the adaptation mechanism of the framework for forming the values of the learning contexts required for selecting learning materials to learners. The iCalendar Core Object Specification contains built-in methods and allows new necessary methods to be defined. This information can then be transferred to the adaptation mechanism.

9.2 Strengthening the contexts-retrieval aspect of the framework

In this section, I address the research question – "Can the contexts-retrieval method of the framework be strengthened?" The section is divided into – 1) *overview of technologies used for location-retrieval*, and 2) *methods used for strengthening the contexts-retrieval aspect of the framework.*

Overview of technologies used for location-retrieval

An overview of 1) *GPS technologies using a GPS receiver*, 2) *the WLAN positioning technique,* 3) *direct request methods from users*, 4) *hard-coding and storage of locations in a database,* and 5) *RFID writer and reader tags*, for location-retrieval is presented below.

1. *GPS technologies* were used for detecting the location of learners using a *GPS receiver* in Fithian *et al*. (2003), Ogata and Yano (2004a, 2004b) and Ryu and Parsons (2008). Unreliability and inaccuracies of the GPS technologies include the recording of travelling GPS data (such as travelling from location A to B) (Kochan *et al*., 2006); however, my research does not consider transition period as important; only the location and available time of a learner at the beginning of a learning session is important. This assumption is based on the findings that learners may not always want materials to be altered if there was a change in their learning situation. Where a GPS receiver is not built-in to the mobile device, a separate Bluetooth GPS device such as *GlobalSat BT -338* can be physically attached to the device. A Bluetooth connection can then be established between the Bluetooth GPS receiver and the mobile device such as in the work of Ryu and Parsons (2008).
2. The *WLAN positioning technique* can be used for location-retrieval in indoor and outdoor locations, where signals are retrievable from the WLAN being accessed. The location of a learner can be implied by the access point or station that they are connected to. It can be implemented with minimum effort, as modern mobile devices have built-in wireless access capability, and WLAN is commonly available within educational institutions. The signal strengths of WLAN are one of the most accurate in positioning technologies (Li *et al*., 2006). This technique was used in the language learning application of Chen *et al*. (2007b) to detect the location of a learner in the school playground for the suggestion of English vocabulary learning. WLAN was also used in the butterfly- and bird-watching applications (Chen *et al*., 2002, 2004) respectively. However, it was not used for positioning learners but rather for enabling transmissions to be sent to and from

learners and the instructor. A WLAN card built-in or inserted into a laptop computer functioned as the local server, and learners each using a PDA equipped with WLAN acted as clients. Transmissions were sent wirelessly to and from the learners' PDAs and the local server for immediate information retrieval concerning the butterflies and birds being observed. Note that the locations of these learners can also be tracked, using this technique, if appropriate.

3. A *direct request* method from users was used in the applications of Cheverst *et al*. (2000), Cui and Bull (2005) and Chen *et al*. (2007b). In the latter application, learners were asked to make modifications to their current locations, if necessary, using a default list of locations supplied by the system.
4. *Hard-coding and storage of locations in a database* (or SQL server) – the WLAN positioning technique is used to a) determine the types of locations (such as library, lecture theatre) using the retrieved access points or stations, and b) locate the position of the learner on the university campus map. The database or server is accessible using a mobile network (such as Vodafone New Zealand was deployed in Ryu and Parsons (2008)) – their contextual information and location data are related using a Microsoft SQL server and Microsoft Visual Studio 2005 was used to implement each software component to enable the location-tracking. Similarly, *semantic markers* can be used to associate and replace locations with specific geographic positions, such as from actual geographical co-ordinates to 'movie theatre' (Fithian *et al*., 2003).
5. *RFID writer and reader tags* were used for location-retrieval in Wu *et al*. (2008) and Ogata and Yano (2004a, 2004b). Typically, RFID writer tags are attached to locations of interest and a RFID reader tag is attached the learner's mobile device (usually onto a Compact Flash memory card which was then slotted into the

memory slot of their PDA). The RFID tags can read/write within a five cm distance. The learner's location can be retrieved by reading the writer tag in a specific location using their reader tag. In the Japanese language learning (JAPELAS) application (Ogata and Yano, 2004a), RFID writer tags were attached to the entrance door to a room to identify the formality of room, which was required for their language learning. In the English language learning (TANGO) application (Ogata and Yano, 2004a), RFID writer tags are attached to objects of interest in a classroom to display the corresponding English word. A student using the RFID reader tag which is attached to their mobile device reads the objects to learn the corresponding English word associated with that object. In the simulated evaluation experiment of their Chinese language learning application (Chen and Chou, 2007), RFID writer tags were attached onto different parts of the walls within a classroom to represent different underground stations in Taipei.

Additionally, an overview of location technologies has been provided by Cope and Jorgenson (2009). A major issue of using location-aware technologies from the user perspective is privacy. Mobile devices, which facilitate wireless connectivity, are power-exhausting. WiFi is good for indoors but not outdoors, and GPS is good for outdoors but not indoors. "No single technology can be used in all situations. Hybrid approaches are now becoming common in order to overcome these limitations, such as A-GPS" (Ibid). Below is list of factors that affect the take up of such technologies, and which has been taken from Cope and Jorgenson (2009).

- The purchase cost of the devices – particularly for consumer products.
- The maintenance of systems, for example regularly updated maps.
- Reliability of the technology.

- Accuracy of the technology (for example, GPS vs. WiFi).
- Perceived 'usefulness' of the applications.
- Commercial viability of the devices.

Methods used for strengthening the framework

To counter the possibility that learners are not adhering to their schedules, leading to the retrieval of the location and available time being inaccurate, 1) *location-retrieval methods using GPS and WLAN, and* 2) *a direct request method* are incorporated into the framework.

1. *Location-retrieval* – I propose to use a) *GPS technologies* and b) *WLAN* for retrieving and verifying the location of a learner for outdoors and indoors, respectively. The retrieved location information is used alert the system a) if the retrieved and scheduled locations do not match, and b) for identifying the learner's actual location in order to confirm whether they are keeping to their schedule. The use of GPS technologies and the WLAN positioning technique are reliable and easily implementable methods for outdoors and indoors, respectively (Wang *et al*., 2003), and these are the reasons I have chosen to adopt these two types of technologies. Most modern mobile devices contain a) built-in *GPS receivers*, if not, a Bluetooth GPS can be easily attached to achieve the same capability, and b) built-in WiFi; therefore, given a WLAN was available; the learners' location can be retrieved.

   Within our university, a strong wireless connection is available in most of the departments and buildings including Maths, Engineering, Computer Science, Physics, Chemistry, Biology, Education, Science Education, Social

Studies, Business School, Digital Labs, and Library and in a number of social and administrative buildings (University of Warwick, 2009). Some universities may have more WiFi coverage than our university and some may have less. The WiFi coverage between those buildings mentioned above may be weaker or non-existent. We propose that the GPS technologies are used for the circumstances where WiFi signals are unobtainable.

Given the wide and robust availability of the WLAN, I believe that the WLAN positioning technique can be used successfully to retrieve the location of a learner located within these buildings within our university campus.

2. *A direct request method* – I propose to use this method to ask users to confirm that their available time is retrieved accurately. This prompts the user at the beginning of a learning session to check and indicate whether their retrieved available time is accurate, and this information is used to update the schedule. The user is asked to input their available time into the system, when necessary.

9.3 Incorporation of learning objects into the framework

In this section, I address the research question – "How can LOs be incorporated into the framework design?" I describe 1) mobile learning metadata (MLM), 2) incorporation of Java LOs, 3) methods for converting LOs into MLOs (taking into account different mobile technologies/devices with different screens and specifications) and 4) a summary of the section.

Mobile Learning Metadata (MLM)

A proposal of an extension to LOM and IMS Learner Information Profile (LIP) Standards has been proposed by Chan *et al*. (2004) to cover mobile and informal learning scenarios, called Mobile Learning Metadata (MLM). The necessity for this proposal was to include these forms of learning in the current usage of LOM and other standards alike, as these had previously been aimed at web-based learning using desktop and/or laptop computers. MLM comprises three top level classifications – *Learning Object*, *Learner* and *Setting*s (describes the context state of the learning environment such as the location of the learner or learning object).

The Learner classification is divided into two sub-categories – *Learner Profile* (contains static information about the learner and their preferences) and *Learner Model* (contains dynamic information relating to the learner's knowledge and learning history). Conceptually, the relevant learning object is located by the context-aware engine of an m-learning system using the information provided by the Learner and Setting classifications by accessing the metadata of the learning object. Information within the Setting classification is generated dynamically to describe the current values of the context information.

Incorporation of Java LOs

I address here the incorporation of each of the learning contexts – a) *LS,* b) *knowledge level,* c) *motivation* and d) *available time.*

The LS and knowledge level contexts can be incorporated through the utilization of LOM. However, I have chosen to deploy MLM because this contains additional m-learning metadata tags for describing information regarding the m-learning aspects of LOs. The LS (or learning preferences) are described in 2.1.2.2 in the Learner Profile of the MLM (as per IMS LIP); knowledge level is described in the Learner Model of the MLM, which is currently a work in progress.

Two possible ways of ascertaining the knowledge level of learners to identify which Java LOs are appropriate are described. First, a number of prerequisites on certain Java topics which students must learn before attempting other topics were defined in the Java learning object ontology (Lee *et al*., 2005). The ontology allowed different learning strategies and/or paths to be utilized in order to facilitate adaptive learning. Second, difficulty levels within topics of introductory Java programming based on a large number of students' perceived difficulty levels within basic Java were established (Yau, 2004). These range from easy to difficult - *comments, assignment, expressions, if-statements, input-output, arrays, methods* and *classes*. A learner's knowledge level in introductory Java can be used to ascertain which Java LOs would be appropriate for them.

The *motivation* context is not modelled in LOM or MLM and therefore I propose to add an additional tag for this attribute in MLM for describing the motivation level of the learner, which is usually a dynamic entity because their motivation for learning may vary at different times during the day, week and month etc. This attribute is appropriate for placement in the dynamic Setting classification of MLM. The amount of available time context which applies in both of the framework designs can be inferred using the duration attribute described in 1.4.7 of LOM and MLM, which state the duration of time the learning object is required to take for completion.

Methods for converting LOs into MLOs

My research methodology includes investigation on existing LOs that have been created for use on a) specific mobile phones, and b) generic mobile devices. I examine and present the criteria/guidelines, which are necessary in order for mobile LOs to be reusability in different m-learning environments, with different specifications and utilizing different devices. LOs have been used in web-based learning environments much more prevalently than in m-learning environments due to the nature of these learning materials in the form of reusable LOs. For example, LOs have been used to teach a) science in Dumbraveanu and Balmus (2006), and b) programming (Brennan, 2005; Adamchik and Gunawardena, 2003). LOs for use on mobile phones have been designed, developed and evaluated by Bradley *et al*. (2009).

The learning object metadata used for these LOs are LOM (IEEE LTSC, 2005) or a subset thereof. In order to incorporate them into the mCALS framework, it is possible to add further metadata related to m-learning to the LOs such as knowledge level and motivation level. Chan *et al*. (2004) have proposed a Mobile Learning Metadata which was extended from IEEE LOM and contained three top-level categories: 1) *Learning Object* which consists of metadata that describe the learning resources, 2) *Learner* which consists of metadata that describe the learner and 3) *Settings* which consists of metadata that describe the context state of the learning environment such as location of a learner or a learning object, temporal information and relevant resources available to the learner or the learning object. Further work on this has not been continued, either by these authors or other authors on mobile learning metadata.

Other works have been published in relation with how to incorporate LOs for use on mobile devices. These include personalized metadata by extending SCORM for m-learning environments by Nakabayashi and Hoshide (2007) and using CanCore to implement LOM for mobile devices (McGreal, 2006).

In the work of Nakabayashi and Hoshide (2007), the authors extended the SCORM 2004 specification to enable offline learning materials to be viewed using mobile phones and the sharing of course structure and learner tracking information for learning activities using both personal computers and mobile phones. Due to the varying application-programming environment of mobile phones from different makes and models, they specified a common content format for the learning content delivered to the different browsers. A number of issues needed to be resolved before SCORM 2004 could be used for implementation on mobile phones. One of the limitations was the "inability to run JavaScript (ECMAScript), which the SCORM runtime environment (RTE) specification relies on for communication between LMS and sharable content object (SCO)" (Ibid). Another limitation was the difficulty in delivering rich media content to the browsers of mobile phones due to their small screen size and lack of plug-in software. Therefore, they derived three design principles – 1) "Manifest file, which describes content course structure and sequencing rules for learner adaptation, is shared for learning from both mobile phones and personal computers", 2) "RTE specification for LMS-SCO communication will be extended to mobile phones" and 3) "Two types of SCOS and assets, one for mobile phones and one for personal computers, are prepared. During learning, a suitable type of content is selected by checking the type of terminal device" (Ibid). In order to retrieve content for use on mobile phones, one possibility is to use a built-in mobile phone browser. Another way is to "implement learning content using an application program downloaded and run on the mobile phone" (Ibid). A third possible way is to install a general-purpose content browser on the mobile phone. “This browser will download and display learning content compliant to a specified format. Although it is necessary to implement multiple content browsers, each of which runs in the different carriers’ programming environments, a standardized content format that is independent of the carriers’ formats can be introduced” (Ibid). Similarly, Alkouz (2006) proposed a generator which allows web-based LOs to be used on m-learning applications on different devices.

In the work of McGreal (2006), CanCore, an application profile for LOM using a subset of the IEEE LOM elements, was used, providing simplified guidelines for describing pedagogical metadata. The IEEE LOM is considered to be “complicated for effective implementation”. CanCore has been “specifically developed and adapted to facilitate the description of rich, bandwidth-intensive multimedia resources, and is particularly appropriate for supporting implementations that are to be accessed using a wide variety of technological and pedagogical environments, including mobile devices. CanCore specifications allow for greater reuse and portability of resources, systems and content of many kinds across applications and operating systems. Educators implementing mobile learning environments can take advantage of a wide variety of international standards-based resources already available online in learning object repositories” (Ibid). Similarly, Moulin and Piras (2006) proposed the use of additional geo-referenced metadata for LOs for enhancing m-learning.

Summary of the section

I described the advantages of incorporating LOs into the m-learning framework due to the benefits of LOs being compatible among different applications and systems.

Bradley *et al*. (2007) have also extensively examined various techniques of how to design LOs appropriately to fit onto the screens of mobile devices. Specific LOs in introductory Java programming have been created and a Java learning object ontology (Lee *et al*., 2005) was created to facilitate different learning paths and strategies for different learners; hence creating different Java learning courses and a reusable and sharable ontology. Java LOs are also widely available from learning object repositories such as Codewitz (www.codewitz.org).

Different LOs standards/specifications were presented including *Learning Object Metadata (LOM, Dublin Core Metadata (DCM), IMS Learning Resource Metadata (LRM) Specification* and *Sharable Content Object Reference Model (SCORM)*. These were originally designed to cater for web-based learning environments to be used on desktop or laptop computers. An extension of LOM and LIP was then constructed to take into account necessary attributes when performing m-learning on mobile devices - *Mobile Learning Metadata (MLM)*. In particular, MLM takes into account LS and many attributes of contexts in the learning environment as well as duration of time to complete the learning object. Additional metadata can be added, such as motivation of the learner. The flexibility of MLM allows me to incorporate the different learning contexts required within the design framework and subsequently be deployed and incorporated into the framework.

9.4 Incorporation of a set of suggestion rules

In this section, I address the research question – "Can a set of suggestion rules be incorporated?" In answering this question, appropriate technologies are necessary for the implementation of the *Suggestion Mechanism*, which is usually where a set of adaptation rules of an m-learning application is stored and is written in XML. I additionally discuss appropriate technologies for each of the framework components - *Learning Schedule, GPS and Wireless capabilities, Learner Profile* and *Learning Object Repository*. The section is divided into – 1) *overview of deployed mobile technologies* (including mobile devices, operating systems and programming language used for implementation), 2) *overview of deployed LOs in m-learning applications* and 3) *the proposed mobile technologies for implementation*.

Overview of deployed mobile technologies

Software applications are usually implemented, compiled and tested on desktop and/or laptop computers, and then synchronised to be run on a compatible version of the programming environment on mobile devices. Implementation details of seven context-aware m-learning applications are provided. These applications are 1) *JAPELAS* (Ogata and Yano, 2004a), 2) *TANGO* (Ibid), *Knowledge Awareness Map* (Ogata and Yano, 2004b), 4) *ULSJPE* (Yin *et al*., 2005), 5) *English vocabulary learning* (Chen *et al*., 2007b), 6) *CLLS* (Chen and Chou, 2007), and 7) *learning reminder* (Ryu and Parsons, 2008).

- Applications (1), (2), and (3) used the same mobile device for implementation - Toshiba Genio-e PDA with Pocket PC 2002 operating system and Visual C++ 3.0. Application (3) also used a server program implemented with a Java servlet via Tomcat. Prototype of application (2) was constructed using server-client architecture - the server was implemented with a Java servlet and each client (i.e. a learner) used a Toshiba Genio-e PDA with Pocket PC 2002, equipped with Personal Java (a Java edition for mobile and embedded systems).

- A prototype of application (4) was implemented using a data server-client architecture using Embedded Visual C++ 4.0, the data and client server configuration was implemented on a desktop computer and a Pocket PC (2003) respectively. The application was based on application 1) and improvements made included the ability to a) obtain the learner's location automatically, either via their personal schedule or using GPS or RFID technologies, and b) upload the learning records of learners to the server, which are transmitted and shared by other learners. The Data server consists of four components – *Location manager* (manages the scheduled, GPS and RFID location data), *Learner Info manager* (facilitates for learners the retrieval and reading of learning records of other learners), *Education manager* (facilitates the retrieval and reading of learning materials) *and the Server communication* (manages the communications with the mobile devices). The Client server consists of three main components – *Learner-module* (contains learner information which is entered by the learner before using the system), *Environmental-module* (provides location information about the areas where learning is being conducted using schedule, GPS and RFID location methods, and the *Educational-module* (manages learning materials, i.e. polite Japanese expressions). Based on a set of rules for polite expression of the Japanese language, the Polite Recommender Manager selects appropriate expressions for learners based on each different situation.
- Application (5) consists of a Context Analysis agent which analyzes a combination of factors including the learner's location, learning requirements

and preferences (including leisure learning time). The English Learning Materials searching agent then searches and selects appropriate learning materials to students based on these factors. The application begins by sensing the learner's location when they select the 'learning by context' button within the application. The positioning result is shown, which users have the possibility of correcting, if necessary, via a constructed list of locations. Learners are able to adjust the current leisure degree, which the system uses to infer an appropriate number of vocabularies for learning.

- Application (6) used embedded Basic 3.0 and Visual C++ for implementation on a HP IPAQ with Pocket PC 2003. It consists of three components – *location detection, learning materials* and *record/play function*.
- Application 7) used Microsoft Visual Studio 2005 for implementation of the client/server architecture on a HP IPAQ 6700; one of its main functions was to direct users to various lecture theatres as new students were often unaware of where these were. The user's current position is represented on the screen map of the application and a path to their selected position is displayed to direct them to requested locations on campus. The user's location, movement and any rotations are synchronised with the map. Their next destination can also be selected from their course calendar and the path to the location appears on the map. The authors noted that a major challenge was related to the privacy protocols imposed by the university to store student's data, however, consent of each student was obtained. A MySQL Server database was used to store locations (latitude, longitude, campus and type of location) and students' information (e.g. name) and networked with the PDA server; the purpose was to provide contextual information to students in the locations that they were

situated in. PDA clients access the server via the WLAN and have GPS receiving capabilities.

Overview of deployed LOs in m-learning applications

Two systems for LOs deployment in m-learning applications are described:

1. A *Web Services Oriented Rendering Architecture* (WSORA) (Alkouz, 2006) was designed and developed to combine the LOM editor with any web browser or services available on different mobile devices (such as mobile phones, smart-phones, PDAs, palmtops, mobile computers). Its aim was to generate device-independent LOs because various devices have different sizes of screens, availability of memory, and may be using different bandwidth and there are possible constraints within each of these. WSORA attempts to tackle two current challenges - a) mobile web browsers such as Opera (www.opera.com) displays web pages in their entirety regardless that these were not designed for small screen displays, which also burdens the limited bandwidth of devices, and b) to compensate for (a), LO producers may be required to construct specific LOs for each mobile device, for example, WML and CHTML versions of HTML are necessary to facilitate display on different devices. This is a time-consuming process, which is impractical and uneconomical. WSORA includes a *Device-independent LO Generator* (DLOG) and a web server (which acts as a proxy server between mobile devices and the DLOG. Via HTTP requests, the client mobile device can communicate with the WSORA server to retrieve some LOs. The server a) detects the device type via the data sent in the HTTP requests, b) checks if the requested LO

format is available in their learning object repository and if so, selects to client device , and c) if not, the desired LO format is generated on-the-fly and sent to the client device.

2. Multimedia LOs for mobile phones (Nokia N70) were designed, developed (using Flash Lite 2) and evaluated (Bradley *et al.*, 2007). The Nokia N70 mobile screen size measures 176 x 208 pixels; application navigation and user interaction had to be readdressed. The Flash objects were loaded in as XML files, FLV video and MP3 audio. Their evaluation showed that many of the student participants a) thought that it was important to be able to access learning materials on their mobile phone, and b) appreciated being able to learn materials 'on the move'.

The proposed mobile technologies for implementation

The purpose of this subsection is to present a set of compatible technologies which can be used to implement the framework. Other technologies may also be used effectively to implement the framework. The technologies appropriate for each framework component are described – 1) *operating system and programming language for development*, 2) *GPS and WLAN technologies*, 3) *Learning Schedule*, 4) *Suggestion Mechanism*, and 5) *Learner Profile and LOs databases*.

1. A *Windows-based* mobile device is to be used, together with the *Microsoft Visual Studio programming environment* for software development, which a) has been extended to create, utilize and debug applications suitable for use on Pocket PC and Windows-based devices, and b) supports any object-oriented and visual programming languages. Visual Studio is an *Integrated*

Development Environment (IDE) and supports the .NET Compact Framework, which is a subset of the full .NET framework and contains many capabilities for use within resources-constrained mobile devices; features include rapid development; comprehensive class libraries and functions are readily available (Microsoft, 2003).

2. Modern mobile devices already contain built-in *GPS receivers* and *WiFi capabilities*; these can be switched on to enable automatically the retrieval of the learner's location. Signal strengths detected by the WiFi capability from different access points or stations can be used to identify a learner's location.
3. A built-in *learning schedule* can be deployed and the diary events can be converted to ics events with minimal effort, and such that contexts information can be stored in the *Learner Profile*, transferred to and readable by the *Suggestion Mechanism*. Python scripts such as that written in 9.1 for retrieving the location and available time information from the calendar events are embedded, interpreted/compiled and run within the .NET Compact Framework within Microsoft Visual Studio.
4. The *Suggestion Mechanism* is used to store a set of suggestion rules embedded in C#; this is compatible for use within mobile applications and embedded within the .NET Compact Framework. Almost 250 million Java-enabled mobile devices were existent on the market up until 2006, and by 2006 there would be an estimated increase of 1 billion Java-enabled devices (Meawad and Stubbs, 2006). The number of Java-enabled devices world-wide currently tops 1.5 billion (Sun Microsystems, 2009).
5. *Learner profile and LOs databases* – a database server such as Microsoft SQL can be used for allowing information in the *Learner Profile* and *Learning*

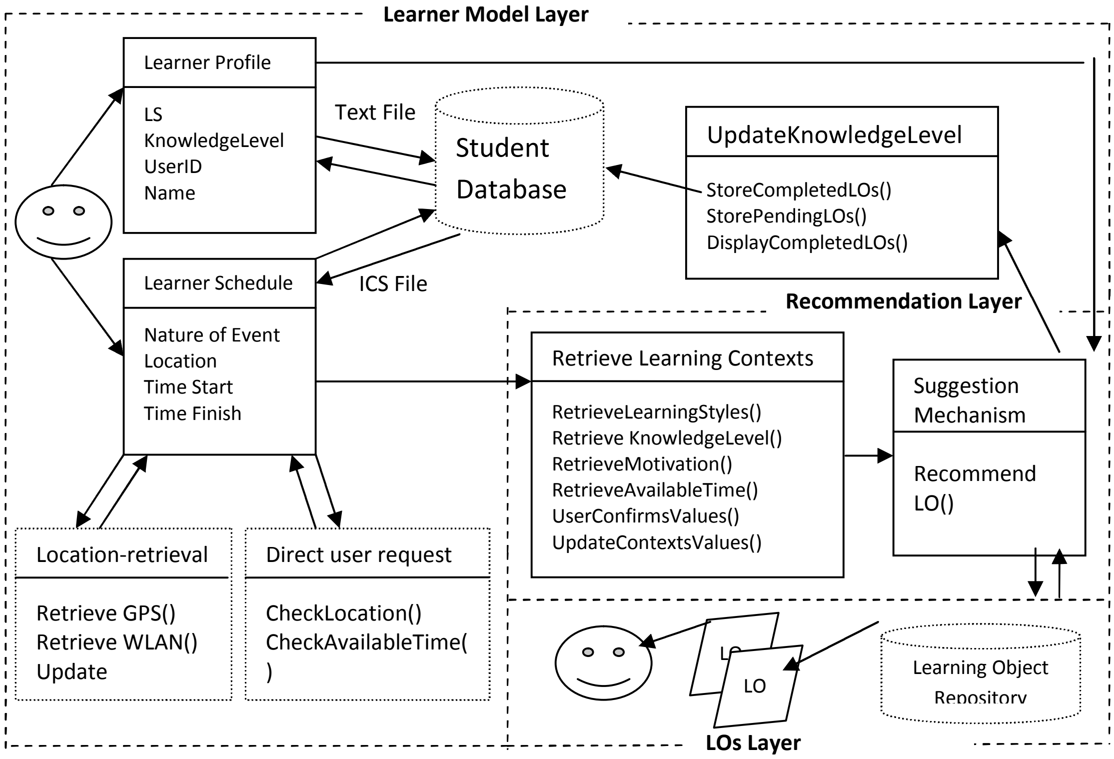
Object Repository databases to be stored, and transmitted to other system components such as the *Suggestion Mechanism*. Learning object repositories are usually built on client/server architectures (Yau, 2004) and database servers such as SQL Server Compact Edition are compatible for use on mobile devices. A Java learning object repository such as www.codewitz.org or Java LOs created by Lee *et al*. (2005), Leeder *et al.* (2004) and Chalk & Qi (2005) can be incorporated into the framework. LOM tags are specified in XML. XML is a platform-independent language; its files are compatible for use within any web-based system and data can be transmitted between many incompatible formats. Wireless Marktup Language, a subset of XML, can be used to create content to be displayed on mobile devices (Yau, 2004).

9.5 System architecture and configuration of the final framework

In this section, I address the research question – "What are the system architecture and configuration of the final framework?" I illustrate and describe a) *the system architecture*, in Figure 9.1, and b) *the system configuration*, in Figure 9.2, of the final framework.

System architecture of the final framework

Figure 9.1: System architecture of the final framework



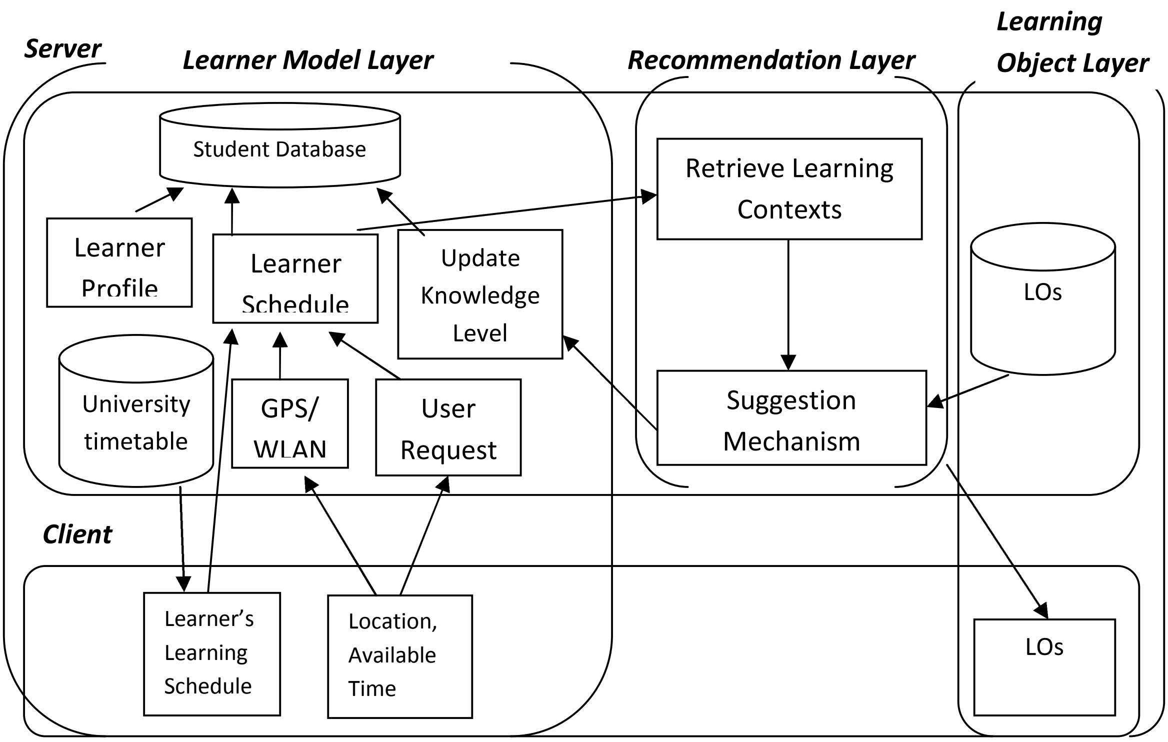
Refined components from the original system architecture in 4.5 include:

- *Recommendation layer* - modifications to learning contexts being deployed in the framework. *LS, knowledge level, motivation* and *available time* are considered.
- *Learner Model layer* - the two potential *location-retrieval* and *direct user request* methods are required in the refined system architecture.

System configuration of the final framework

A client/server architecture system is used for two reasons – 1) to store LOs on the server to allow access of these by the client mobile device, and 2) to allow learners' lectures timetables and deadlines to be automatically downloaded from university calendar websites (provided that these are available from the university). The server can be implemented on a desktop/laptop computer. Client/server communications can be enabled through a .NET web service application. Data can be retrieved from the server's databases using methods contained in the web service, and the data can be returned in a Dataset. The Dataset enables the client application to display, add, update or delete records, which can be passed back to the main databases using defined web services methods. An HTTP connection can be established between the server and the client to enable communications, which is an ideal communication protocol for mobile Java applications (Nokia, 2003).

Figure 9.2: System configuration of the final framework



The server is divided into the same three layers of the refined system architecture – *learner model, recommendation* and *LOs* layer, described below.

Learner model layer

This layer contains a *learning schedule*, which is facilitated by the built-in calendar/organizer application on mobile devices. The location of the learner can be verified by the GPS and WLAN modules, which can be accessed by the GPS and WLAN functions on mobile devices respectively. The obtained 1) GPS co-ordinates for determining the location of the learner in outdoor locations, and 2) WiFi access points or stations for determining the learner's location in indoor locations can be used for comparison with the learner's location as retrieved from the learner schedule. The scheduled events are in ics format and are retrieved using the Python script for location and available time retrieval, as presented in 9.1.

The events stored in the learning schedule in ics format can be stored in the *Student Database*, using Microsoft SQL database server. The User Request and Learner Profile are software components and can be written in Java, for example. These request users to 1) check and/or input the retrieved available time by the application, and 2) input their LS, knowledge level, User ID and name, respectively. The Update Knowledge Level component receives information about the learner's completed LOs from the Suggestion Mechanism; this information is then stored in the Student Database server in XML format. Uncompleted LOs are also stored and can be displayed if the learner wishes to view them.

The *University Timetable* database stores timetables and deadlines for different courses and years of studies. The *Student Database* contains *learner information* (such as name, age, gender, course of study, year of study etc), their *LS*, *knowledge level* (which is increased to a next level after having successfully completed a number of LOs), their *learning schedule information*. The learner's schedule is updated when there are updates with events stored in the *University Timetable* database.

Recommendation layer

This layer contains two components - *Retrieve learning contexts* and *Suggestion Mechanism*. The *retrieve learning contexts* component contains dynamic context information – *location, available time* and *motivation* of the learner (the latter is inputted into the system), and static context information – *LS* and *knowledge level*, and sends this information to the *Suggestion Mechanism* component. Each of the methods in this component – `retrieveLearningStyles()`, `retrieveKnowledgeLevel()`, `retrieveMotivation()` and `retreiveAvailableTime()`, `UserConfirmsValues()`, `UpdateContextsValues()` can be written in Java and incorporated into this component.

The *Suggestion Mechanism* component uses the suggestion rules (as presented in 6.4) to select appropriate LOs to learners on the client mobile device; these can be written in Java and incorporated into this component.

Learning Object Layer

LOs are stored in the *learning object repository* in a Microsoft SQL database server. LOs are selected using the suggestion rules from the *Suggestion Mechanism* in the *Recommendation* layer. The learner using the client mobile device has an updated learning schedule and lecture timetable and appropriate LOs to learn/study with.

9.6 Summary and conclusion

In this chapter, I addressed five research questions relating to the implementation issues of the framework, if it were to be implemented on a mobile device. I first discussed how the proactive approach using a learning schedule can be implemented; this was through the use of built-in electronic diaries contained within modern mobile devices. Events information on electronic diaries can be automatically converted to iCalendar files and an XML script can be written to retrieve information within these files to ascertain the learner's current location and their available time until their next scheduled appointment.

To counteract the possibility that learners may not adhere to their planned schedule, two methods can be incorporated into the framework – location-retrieval via technologies such as GPS and WLAN and direct user request method to ask users to verify the available time retrieved by the system, and update if necessary.

Four learning contexts are deployed for the first framework design, i.e. selection of Java LOs are LS, knowledge level, motivation and available time. The latter two are used in the selection of students' self-study materials. Appropriate LOs for students based on their LS and knowledge level can be determined using the relevant *Learning Object Metadata,* which describe information relating to the object that can then used for appropriate matching between learners and objects.

I provided an overview of the technologies, including mobile devices, operating systems and programming languages used for implementation of related research works on m-learning systems. I concluded with a set of technologies appropriate for the implementation of the framework for use on a mobile device and described these in relation to the different framework components. The final system architecture and configuration were illustrated and described, showing that each component has a feasible technical solution.

Chapter 10

Future Work, Research Contributions and Conclusions

In this chapter, I first discuss the suggestions and directions for future work, followed by research contributions of the thesis, and finally conclude with limitations of the research work.

10.1 Suggestions and directions for future work

This section is divided into seven parts – 1) proposal of a mobile learning preferences model, 2) a personalized m-learning application, 3) framework design for learner's self-study materials, 4) implementation of the mCALS framework, 5) enhancing motivation through new or different m-learning designs, 6) cognitive and education psychology research relating to m-learning and 7) technological investigation of the efficiency of hard- and soft-ware of mobile devices.

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10.1.1 Proposal of an m-learning preferences model

A model consisting of five dimensions of mobile learning preferences – location, level of distractions, time of day, level of motivation and available time – is proposed in this section. The aim of the model is to potentially increase the learning effectiveness of individuals or groups by appropriately matching and allocating mobile learning materials/applications according to each learner's type. The construction of the model is based on the interview study. No existing m-learning preferences model has been identified at the time of writing.

The model consists of five different dimensions, namely location of study, perceived level of distractions, time of day, motivation level of the learner and available time, as shown in table 10.1. Participants in my interview study have described their learning patterns/styles and I have found it useful to map these results into a model consisting of five m-learning preferences dimensions. Note that other preferences were commented on; however, I considered these of secondary importance in an m-learning context. The benefits of this model include a) construction of personalized m-learning applications, and b) appropriate matching of m-learning applications which suit learners' m-learning requirements. Some aspects of the five dimensions were mentioned in the Dunn and Dunn model (Dunn and Dunn, 1978).

Table 10.1 – A proposed model of m-learning preferences dimensions

Dimension	**Description**	**M-learning Preferences**
Location of study	Determining factors may include availability of resources or academic help, motivation by working peers, relaxing and comfortable elements, maximising available time, familiarity of location, allows for routine, and convenience.	a) *Study-designated areas* (study alone or with peers); b) *Study with peers* (location not specified); c) *Study in presence of others* (e.g. in cafes); d) *Making use of idle time* (e.g. in transport); e) *Indifferent*
Perceived level of distractions	Determining factors may include noise level, how busy the environment is, the learner's concentration level, and the level of interruption at the location.	a) *High;* b) *Medium;* c) *Low;* d) *With 'distracters'* (e.g. such as music or other distractions) (Dunn *et al*., 2002); e) *Indifferent.*
Time of day	Determining factors may include biological clock – awake or alertness during different parts of the day.	a) *Morning*; b) *Afternoon*; c) *Evening*; d) *Night*; e) *Indifferent*
Learner's level of motivation	Determining factors may include intrinsic and extrinsic motivations, urgency of task, pressure of performing well, and how enthusiastic the learner is towards learning/m-learning/mobile devices.	a) *High*; b) *Medium*; c) *Low*; d) *Conditional*; e) *Fluctuating*; f) *Indifferent*
Available time	Determining factors may include productivity level of learner and tiredness.	a) *>=60mins*; b) *ca45mins*; c) *ca30mins*; d) *ca15mins*; e) *<=10mins*; f) *Indifferent*

First dimension of preference – location of study

Using the content data analysis method, I classified participants' preferred studying locations into four different types of environments. Reasons for preferring the various locations to study in were specified by participants, and these corresponded to the four different types of environments. A number of participants may have also specified more than one preferred type of environment for studying in.

1. *Study-dedicated areas* comprising departmental offices, computer laboratories, libraries, the Learning Grid[1] (this is a technology-rich, flexible and informal learning space within our university for studying in, it provides 24x7 access to a range of learning technologies including SMART boards, practice presentation facilities, video edit suites and document visualisers), quiet rooms around campus and lecture corridors (This is not typically a study-dedicated area but is university-based). *Wanting to study in designated studying areas* - 23 participants were motivated to learn/study in *study-dedicated areas* because a) these locations were generally quieter with fewer work-unrelated distractions, b) they were encouraged and motivated by seeing others studying and/or c) they required library/computing resources. Good facilities within the computer laboratories were noted, including the use of computers, wireless internet access, a food and drinks machine and a sofa for relaxing on and taking breaks. Group project students preferred to study in the Learning Grid because it had good group-work facilities such as presentation areas and whiteboards. A number of computer science students found it productive to study in the computer laboratories where they were able to collaborate and discuss programming problems with others. Learning in groups was a preference of some participants as they worked more effectively on a collaborative basis. These participants did not like to work at home as they associated their home as an environment for relaxing in.
2. *Home areas* comprising students' bedrooms, living rooms, dining rooms and kitchens. *Preferring to study alone* - 24 participants preferred to study in their

[1] More information on the Learning Grid here - http://www.sconul.ac.uk/publications/newsletter/38/2.pdf

bedroom of their *home areas* because they a) preferred to study in a closed environment free of distractions from other people, b) found it more convenient and relaxing as they might listen to music in the background, take breaks and talk to others and eat/drink as and when they wished. Opposing reasons for studying in this type of environment included that some students a) wished to distinguish between their work and home life or b) found that there were too many distractions here and must go to another location (such as the library) to learn/study.

3. *Café areas* comprising student lounges, the cafe library and cafes. *Enjoying the presence of others* – four participants preferred to learn/study in *café areas* because they a) enjoyed the presence of others when they were reading/brainstorming for ideas and gaining inspirations, and it was nice for them to have human contact despite the small potential loss of time, b) must have their freedom whilst studying, for example, to make phone-calls, eat/drink, talk to people, listen to music (this can often help students to block out other distractions such as internal ones), as the *study-dedicated areas* would not be suitable for these students and/or c) found it psychologically motivating that they were progressing with their study whilst others were typically talking and relaxing. One participant noted that they must work in noisy environments, surrounded by many others because they would become distracted by the absence of distractions, and they could concentrate well in noisy environments. Another participant who lacked self-discipline noted that they must work in this type of environment and have their laptop screens where others could see it, as they found this would help them to be motivated to do their work; otherwise they would not study and instead just browse the

Internet. Some participants suggested that cafes were not good places to learn/study in because of potential distractions.

4. *Transport* comprising buses, trains and planes. *Making use of idle time* – six participants have studied or studied regularly on *transport* such as buses, trains and/or planes with the typical reason given of making use of idle time. Some participants found it comfortable and enjoyable to read in an effort to make commuting time pass more quickly. Other reasons included their tight coursework deadlines and the urgency of their tasks necessitated them to make use of available idle time. Often work was only partially completed whilst using transport. They may listen to music to block out surrounding noise and distractions, and this helped students to become more absorbed in performing their tasks. The effect was that possible distractions in the surrounding environment affected them less. Whether a student would study on transport may be dependent on their lifestyle, for example, how busy they are and how much spare time they have. Reported problems of working on transport include difficulties to become comfortable due to the tight working spaces.

A varying degree of preference for studying in different locations was revealed. For example, some participants must study in a certain location due to their specified study requirements and could not study elsewhere; whereas for others it was a matter of habit and/or convenience. Two examples are given to illustrate the latter – a) a student may study in the library on university campus during lecture gaps because of the convenience, even though this may not be their preferred location, and b) they find it convenient to study at home on their home computer where all of their software programs were installed and available, even though they would be more productive in the computer laboratories. In this sense, it did not matter where they studied, they were more concerned about where their required resources were available, and they were also able to be productive in other locations. A change of environment can sometimes help participants to study better and/or to gain psychological motivation, especially if they are procrastinating and cannot be productive.

21 participants described locations/situations that they found undesirable for studying in. For example, a) in laboratories for scheduled classes where it can sometimes get very hot and noisy, b) in a department office due to the large amount of work necessary to be completed and in order to attend required meetings, c) at the family home during holidays because of the possibilities of spending leisure time instead of studying and d) in general not particularly wanting to study in a location but having no other alternatives. For some participants, it was not the actual locations that they did not wish to study in, but rather it was because they did not wish to study. The remaining 16 participants always had alternative places to study in, and were not restricted to studying in undesirable locations.

Second dimension of preference – perceived level of distractions

The questionnaire/checklist was presented to participants at the end of the interview, with a list of factors which they were to indicate on a scale of 1 to 5 (1 being least significant and 5 being most significant) the significances of each of the factors in affecting their concentration for studying. Table 10.2 presents the results obtained from the interview checklist of the 37 participants, showing that participants had the opinion that their motivation had the most significance towards their concentration. The following external and internal factors also had high levels of significance in affecting their concentration including *noise, temperature* and *type of location* (external) and *how responsible they felt towards their learning, persistence in learning, how organised they were, learning preferences,* and *how anxious/depressed they were* (internal) as well as *food and drink* and *time of day*. Motivation was revealed to be most significant in affecting their concentration. Noise level and type of location were revealed to be more significant than lighting level, layout of room and motivation from teacher, in affecting their concentration.

Table 10.2: Significance of factors gathered by participants

FACTORS	**5**	**4**	**3**	**2**	**1**
Noise level	13	13	7	3	1
Temperature	3	15	12	6	1
Lighting level	3	9	9	14	2
Your seat	2	10	13	11	1
Layout of room	0	4	8	12	13
Type of location	9	17	9	2	0
Motivation	26	7	3	1	0
Responsible felt towards learning	6	14	14	1	2
Persistence in learning	4	17	14	2	0
How Organised	3	16	13	5	0
Learning Preferences	6	13	12	5	1
Food and drink	9	8	7	12	1
Time of day	3	13	14	6	1
How free/restricted	3	12	15	3	4
Working alone	6	8	17	2	4
Working with peers	3	10	16	4	4
Motivation from teacher	3	4	12	12	6
How anxious/depressed	6	15	10	5	1

A relationship between external and internal distractions was revealed and supported by Graetz (2006), who argued that 1) learners can be affected emotionally by the physical characteristics of learning environments resulting in difficulties in their cognitive achievement; and 2) there is a varying degree of emotional reactions across individuals and their activities in relation to environmental distractions. For example, a highly motivated student wishing to complete their work is more likely to continue working on their activity despite possible environmental distractions. A less motivated student is more likely to discontinue with their work if they are studying in a non-ideal environment and have been distracted/interrupted. There is a relationship between the *mood for studying* and *busyness of the environment,* in that when a student is extremely motivated, the busyness of the environment would not affect them. Likewise, if a student has a lot of work, which they are determined to complete, then distractions may not affect them. When a student does not wish to study, then they are more likely to be distracted, even if there are no distractions.

Various views of learning/studying in distractive environments were portrayed by different participants including 1) they would not study, or discontinue with their studies, in such environments because it is ineffective, 2) they found brief distractions to be acceptable and can partition their work accordingly and return to it in a more refreshing manner. This may not necessarily be beneficial in terms of their studies, but can be helpful for their emotional state of mind resulting in a better mood for studying, 3) they consider making themselves comfortable to be relatively important and when they perform non-urgent tasks, they are comfortable with allowing/including a small number of distractions/interruptions. When performing urgent tasks, participants would deliberately ensure that possible distractions were to be eliminated and/or to study in a location with minimal distractions/interruptions.

Negative effects of studying in undesirable locations/situations include:

1. Learning/studying could be less effective and productive, students may absorb and interpret materials in an unintended way and there is a higher possibility of making mistakes. A longer time may be required to complete the work.
2. It is more difficult to a) hold longer sustained thoughts and b) give a higher level of reflection, in locations prone to distractions/interruptions. These may

be required in carrying out tasks such as essay-writing, data analysis and computer programming. Students performing less intensive tasks such as reading may be less affected.

3. A higher potential tendency to procrastinate and a higher possibility for students to discontinue with their studies.

Potential strategies of helping students to study in undesirable locations include the following.

- To perform a simpler task – such as reading rather than essay-writing.
- To read different items of interest to maintain their concentration/interest.
- To have a change of pace, which can help them maintain their focus on the task.
- To take more breaks to refresh their minds and to recapture their concentration.
- To listen to music to potentially block out other environmental distractions.
- To situate themselves a) in more hidden places, b) in empty rooms on campus or c) close to a wall, to avoid being seen and interrupted by friends.

Third dimension of preference – time of day

Most participants were aware of when they studied best and are most productively, but four participants had no time preferences for studying. Participants' preferred times of study are as follows.

- Mornings – seven participants
- Daytime (including mornings) – seven participants

- Mornings and evenings – two participants (one participant noted they can memorize better in the mornings, and do other study activities better in the evenings).
- Afternoon – four participants
- 12pm to 12am – one participant
- Nights and evenings – 12 participants

Most participants had preferred times of study, however I have not further explored this context because I consider this to be less relevant in the framework than, for example, the available time context, and most participants have a long period of time which constitutes their preferred times of study.

As to the fourth and fifth dimensions of the model, it became clear that learners had different motivation levels for carrying out different tasks during different parts of the day and depending on how much available time they had at that particular moment. Therefore, these are also essential dimensions of the model. More dimensions to the model may be added as part of the future work, if they are of primary importance concerning m-learning. When matching appropriate materials/activities to mobile learners, other learning styles dimensions and factors may also be considered such as knowledge level, visual/verbal styles and concentration level. More difficult learning materials can be recommended to learners with a higher motivation to learn, at the current time. Highly-motivated learners may be recommended to use self-regulated applications. Individual and collaborative m-learning applications can be recommended to learners who prefer to study alone and with peers respectively. Suggestions for future work include conducting empirical studies to validate our model.

10.1.2 A personalized m-learning application

Insight gained from the interview study revealed that the preferred location of study of one participant may be an undesirable study location for another participant. This informs me that a generic m-learning application, for example, one that uses suggestion rules to select learning materials to students based on their location of study, would be inappropriate. Such suggestion rules may specify for example 1) a learner is to undertake a task which requires high levels of concentration and is to be conducted in the library, and 2) a learner is to undertake a task which requires lower levels of concentration in a café area. Whereas for some students, this suggestion for dealing with materials is appropriate for them in those locations because they can concentrate better in the library than in the café area. This may not hold true for other learner types.

The learners' preferred locations are related to the distractions (whether real or perceived) in the location. Hence, the decision for choosing a location of study is usually based on the distractions in the location. A number of participants had the same preferred locations of study. However, the distractions (perceived or real) in these locations may not be the same. Similarly, although general trends were found amongst participants that certain factors can have a strong positive or negative impact on their concentration level, the interview study results reveals that each learner may have their own preferred value for the factor or learning context. For example, a learner may prefer a certain level of noise.

Using six scenarios, I illustrate the m-learning preferences (*location of study, perceived distractions within a location* and *time of day*) of six different types of mobile learners. The scenarios distinguish between different learners' preferred locations of study, their preferences for the levels of noise/distractions in a location and how strongly they feel towards these preferences. In addition, each student described may prefer a different time of day to conduct their studies.

- Student A has strong preferences to study in quiet environments and can concentrate best when there are no distractions. His most preferred location of study is the library.
- Student B has strong preferences to study in noisy environments and can only concentrate when it is noisy and/or there are people around. His most preferred locations of study include student lounges and cafes.
- Student C has medium preferences to study in quiet environments although he can concentrate in noisier ones. His preferred study location includes the computer laboratory.
- Student D has medium preferences to study in noisy environments although he can also concentrate in quieter environments. His preferred study location is a cafe.
- Student E has weak preferences to study in quiet environments and can concentrate on his studies in most locations.
- Student F has weak preferences to study in noisy environments and can concentrate on his studies in most locations.

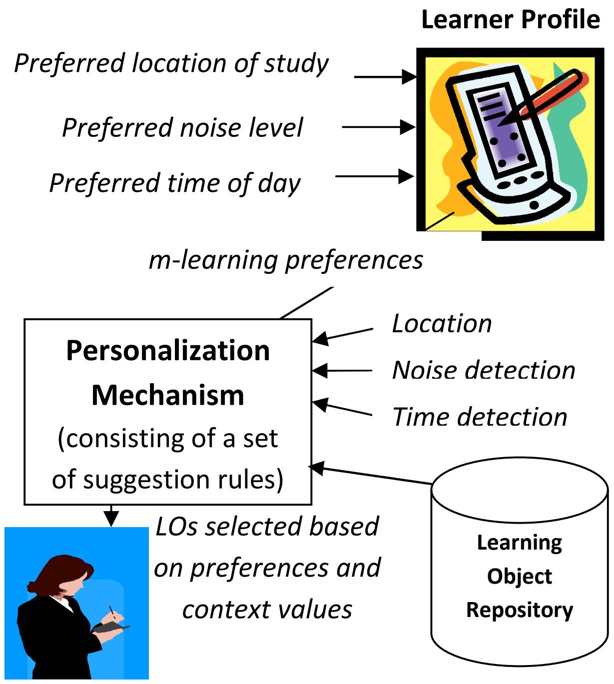
I propose a personalized m-learning application to accommodate mobile learners of different types. At present, literature and applications related to m-learning have not dealt with different m-learning preferences of learners and using these as the basis for creating a personalized m-learning application. The pedagogical benefits for students of using such an application and whether it will be successful in terms of the students' learning outcomes had yet to be determined, evaluated and proven. I believe that the results gained from evaluating such an application will help form future m-learning pedagogy and would constitute a useful contribution to the community. This will help us to advance towards successful development of m-learning applications which can respond to the individual and contextual needs of learners. The challenges lie within a) being able to define the different m-learning preferences, b) deciding which of these are significant, c) being able to describe a mobile learner in terms of these preferences and d) constructing an effective m-learning application for providing appropriate suggestions and/or adaptations based on these.

I present below the *system architecture* including the *overview, learner profile, personalized mechanism* and *learning object repository* of the proposed personalized m-learning application.

System architecture – overview

The proposed personalized m-learning application based on m-learning preferences consists of three components - 1) a learner profile for storing m-learning preferences, 2) a personalization mechanism and 3) a LOs repository. Techniques (including context-aware technologies) are used to automatically detect the values of surroundings to retrieve the current location, noise level and time of day. These values are used to determine which learning materials are appropriate for the student taking into account their individual m-learning preferences. Figure 10.1 illustrates the system architecture.

Figure 10.1: System architecture of the personalized m-learning application



System architecture – learner profile

The learner profile consists of an initial simple m-learning preferences questionnaire, which is generated for students to input their m-learning preferences on a one-time basis before the user commences with their learning activities; the information is stored in the application. Data analysis showed that m-learning preferences of participants were usually static and fixed. However, there is always likelihood that these are subject to change. Therefore, the application allows the option for users to change their preferences, if they wish to.

Three preferences are to be input in the application – *location of study, level of noise/distractions, time of day* – together with how strongly students feel towards these preferences (strong, medium or weak). Such an m-learning preferences questionnaire is similar to the existing learning preferences/styles questionnaires, for example Felder and Silverman (1988) and Honey (2001), for applications to find out the LS of students prior the use of web-based or m-learning applications. At present, I am not aware of any m-learning preferences questionnaire being researched or deployed.

System architecture – personalized mechanism

The personalization mechanism has two inputs, a set of suggestion rules for personalization and an output of appropriate LOs retrieved from the learning object repository for learners to learn/study.

The inputs include the learner's m-learning preferences and the current values detected by the context-aware technologies. I first describe how the latter are retrieved. The learner's current location can be detected using GPS technologies (for outdoors) and Wireless LAN positioning technique (for indoors and outdoors); the latter technique uses the retrieved signals from the wireless network being accessed to imply the location of the learner by the access point or station they are connected to (Li *et al*., 2006). The level of noise can be detected using a microphone built-in or attached to the mobile device being used. The current time of day can easily be obtained from the device's internal clock.

Potential suggestion rules for the suggestion of appropriate LOs to learners based on their m-learning preferences can be constructed by matching the metadata of LOs to the current values of the location, noise/distractions level and time of day. M-learning preferences should also be taken into account. For example, if the learner concentrates well in noisy environments, then a learning object requiring a higher level of concentration can be suggested to a learner. Whereas if another learner can only concentrate well in quiet environments, then a learning object requiring much lower levels of concentration can be suggested to the learner in the same noisy environment.

System architecture – learning object repository

A Java learning object repository such as www.codewitz.org can be used for providing Java LOs required for this application.

10.1.3 Framework design for learner's self-study materials

Findings from the interview study show that there is a potential need for a framework which suggests to a student their self-study materials. A set of well-defined suggestion rules for students in different situations of studies may therefore be appropriate, in order to increase their learning productivity.

Learning materials in terms of learners' paper-based materials and/or studies to be undertaken on their desktop/laptop computers (provided they have these with them) are used for students to select their materials which may be appropriate for that situation. The range of self-study materials must be input by the user or detected via their lecture timetables and tasks for each module. Criteria that students often use for selecting materials for them to learn/study depend on a) how much available time they have at that point in time, b) urgency of their tasks and c) the sequential order that some tasks need to be completed in.

Similar recommendation rules to the above can be established for students to perform self-study events. The difficult, medium and easy levels of tasks are in terms of cognition of materials. The recommendation rules are based on the fact that students usually required a minimum of 30 minutes in order to carry out their self-study tasks to achieve a certain level of learning efficiency and productivity. I, therefore, based on the recommendation rules 1) – 3) on more than 30 minutes, and 4) on less than 30 minutes. The rules are constructed based on the assumption that students are more capable of completing more difficult tasks when they are more motivated.

1. If motivation = high and available time > 30 min then difficult tasks are selected.
2. If motivation = medium and available time > 30 min then medium tasks are selected.
3. If motivation = low and available time > 30 min then easy tasks are selected.
4. If available time < 30 then easy tasks are selected.

The *motivation* of learners and their *available time* are considered for the selection of their self-study materials. The learner's motivation is to be input by the learner and the available time is retrieved by the learner schedule and then verified by the user. The qualitative data analysis from the interview study showed that over two-thirds of the participants were either enthusiastic or would find mobile devices a possible or potential means for learning. Participants who were opposed to the idea of learning with mobile devices had frequently made use of learning/studying in different mobile locations with the use of paper-based materials; this I also consider as m-learning. Due to this finding, I decided to construct an additional design of the framework, for incorporating learners' self-study materials (including on- and offline) in order to suggest appropriate materials to them in different learning situations. The original framework design using Java learning materials is addressed first, followed by the additional framework design using learners' self-study materials.

In these scenarios, students in four different courses – computer science, engineering, mathematics and law – are used to illustrate the extent that the final framework can be generalised to support students in other courses of study. *Scenario A* – John is a first-year computer science undergraduate student, an active learner and a novice to the Java programming language. He has three hours until his next lecture, and is currently in the computer laboratory – he can concentrate very well there and will probably not be interrupted often. John has a number of activities awaiting completion – *a Java programming coursework assignment*, *some un-assessed Java review exercises* and *some lecture notes* to read before his lecture. He chooses this location to initially carry out his coursework assignment because he can concentrate very well here, the available time that he has is sufficient for completing it and actually it is due today. He plans to a) spend 20 minutes of his available time after the completion of his assignment to read the lecture notes before the lecture, and b) leave the un-assessed Java review exercises until after the lecture as these are not urgent.

Scenario B – Peter is a second-year engineering undergraduate student, a reflective learner and has approximately an intermediate level of knowledge relating to this course/topic. He has half an hour until he meets his friends for lunch, and is currently in the student lounge – his level of concentration there is usually around average and he may possibly be interrupted by some of his friends who may also be there. The materials which he needs to complete include *an assessed engineering problem sheet*, *a project report to be handed in next week*, and *a review of some problem examples*. He chooses this location to do the review of the problem examples, and additionally think about the structure of the project report and write down some notes. His available time before his lunch date does not allow him to start and make significant progress on the problem sheet and project report, and he plans to start these after lunch.

Scenario C – Sarah is a third-year mathematics student, a visual learner and has an advanced knowledge of the mathematics topic. She has half an hour until her next seminar, and is currently in the library cafe – she cannot concentrate very well there and may be interrupted by some friends who may also be in the cafe. The materials she has yet to complete include *an assessed mathematics problem sheet* and *an assessed Java programming assignment* both to be handed in next week. She decides that she will make an attempt to work on her mathematics problem sheet because she really enjoys this topic and feels that she will make some progress with it even though she may not be able to concentrate so well. She will also read through the problem sheet and see if there are questions/difficulties with it, as in this case she can ask the tutor in her next seminar. She decides to attempt her Java assignment when she goes to study at another location where she can concentrate more.

Scenario D – Amy is a fourth-year law student, a verbal/audio learner who has an advanced knowledge of the law topic. She has one and a half hours until her next meeting with her project supervisor, and has currently just boarded her train which takes an hour to arrive on campus. After she gets off the train, she will need to take yet another bus for the duration of 20 minutes. The train she takes every day is usually quiet and she can concentrate well; however, on her bus journey, it is noisier and she cannot concentrate well there because she also needs to often look up to see where her stop is. The materials she must complete include *some seminar reading*, *some lecture notes reading* and *an assessed essay of 5000 words*. On her one-hour train journey, she chooses to continue writing her essay on her laptop. She plans that when she is on the bus for 20 minutes, she will either do some seminar or lecture notes reading or nothing at all because of the short duration and lack of concentration.

The original proposed learning materials to be used within the mCALS framework were Java LOs. However, due to the insights gained from the interview study, it was revealed that although some students may oppose to the use of mobile devices, they frequently made use of learning/studying in different non-fixed environments. Hence, if the framework were to consider students' offline (i.e. paper-based) studying materials, there may be pedagogical benefits for suggesting materials to them which may be appropriate for the environment that they were situated in. It may also be useful to consider the individual m-learning and/or learning environmental preferences of learners within such an application. Subsequently, I proposed a personalized m-learning application based on the preferred location of study, perceived distractions in a location and time of day. The system architecture was presented, including the learner profile, personalized mechanism and learning object repository.

Learning materials in the form of LOs are used for selection to students to learn Java programming. Learning Object Metadata (LOM) and/or Mobile Learning Metadata (MLM) are used for describing, searching and retrieving the Java LOs stored in the learning object repository. The difficulty in building this prototype is to obtain accurate suggestion rules for each scenario as it could be too varied for different students in different contexts.

10.1.4 Implementation of the mCALS system

The mCALS framework can be implemented and used by university students of different courses and degrees. I have suggested in chapter 9 the available technologies that can be used for the implementation of the framework. Although developing of technologies is currently ongoing, other approaches may be feasible and are worthy of investigation. Additionally, the framework can be used for supporting knowledge workers ‘on the move’, as discussed in 2.7.5.

10.1.5 Enhancing motivation through m-learning designs

Motivation proved to be crucial in the framework and has the potential of determining whether an m-learning application would be used successfully by students. Future research can be conducted on how to increase the motivation of a learner using mobile devices, for example, using friendly m-learning software environments and possibly using a competitive gaming environment in connection with learning materials as already implemented by some Wii and Nintendo applications (Klopfer *et al*., 2009).

Another potential way of implementing a playful (i.e. games-based) and motivating software environment would be to expand the idea of a traditional pedagogical learning approach onto Lozanov’s suggestopedia (Lozanov, 1979), which is currently mostly used for learning foreign languages in non m-learning software environments. A suggestopedic or suggestologic approach focuses on making students feel confident and comfortable so that they are better able to learn. My scenario will constitute the mobile device becoming a ‘partner’ of the learner. This approach hugely differs from traditional learning, as it employs the theory of lowering the particular demands of a learner for absorbing materials. It emphasises a playful and motivating approach to learning instead of using strict enforcements such as deploying tests to assess students in traditional learning, and insists that the suggestopedic approach is far more effective because it offers a playful and motivating environment for learning (Ibid).

In cases where students did not enjoy or perform well in tests offered in an m-learning software environment, they may cease to use the application to avoid the possibility of performing badly. A suggestopedic approach can be used in an m-learning software environment to eliminate the potential avoidance strategy by a learner, which was also shown in the interview study data analysis, and to encourage this group of learners to participate in m-learning.

10.1.6 Cognitive psychology research relating to m-learning

Insight related to educational and cognitive psychology into how a possible effective learning process with mobile technologies might look can be inferred by obtaining and assembling further data collection and analysis from students. In particular, research work related to information processing as well as attentiveness can give essential insight into how a learner will cope with information on a mobile device under the constraints of different environmental contexts. An investigation of memory structures, in particular of how long it takes to perceive, process, store, retrieve and forget certain information learnt by a student on a mobile device, may provide interesting results that differ from traditional learning. Additionally, experiments can be conducted to show how cognitive load differs between traditional learning and m-learning, based on the cognitive load theory (Sweller, 1994).

Mobile devices present learning materials differently than a book or a classroom/lecture theatre experience would (visually and/or acoustically), such that an extraneous cognitive load is generated as described in Pollock *et al.* (2002). In examining cognition, the importance of the presentation of information on a mobile device becomes clear. A visual split-attention effect (Chandler and Sweller, 1992) might arise when the learner has to deal explicitly with graphical representations on a mobile device, which is small and has a limited way of showing visual information in particular ways. According to Multi Media Learning theory (Mayer and Moreno, 2007), the modality principle suggests that although the brain must decode information stimuli simultaneously, visual information assisted by audio information actually enhances learning. This type of learning would be possible on new generation smart phones, such as the I-phone.

10.1.7 Technological investigation of the efficiency of hard and software of mobile devices

Mobile and context-aware technologies at the present time have a wide range of capabilities such as eye tracking devices (for detecting where the learner is looking at on the computer screen), voice recognition, location-tracking and mood-sensing capability. However, these are not without their limitations and may not be entirely accurate. Future applications may consider updating the learner's schedule automatically if a lecture is known to have cancelled, a group meeting is known to have rescheduled, a deadline is known to have been extended and so on. A temporary or permanent internet connection with the mobile device from a home desktop or laptop computer, or central university server, can be established to allow the mobile device to be synchronised to the daily schedule stored on the central server and updated by university staff, with the learner’s schedule is automatically updated. Shared and collaborative diaries can be another future research topic.

10.2 Research contributions

The first contribution is the classification of the four m-learning generations presented in chapter 2, which was a research outcome of a literature review in m-learning.

The second contribution is a five-phase research methodology for investigating and evaluating a proposal in the development of the mobile context-aware learning schedule (mCALS) framework. The methodology includes the development of a theoretical framework based on an extensive literature review, an interview pedagogical study, a diary usability study, an online experiment study to validate the proposed suggestion rules, a case study for determining the availability of high-quality LOs from the public domain and a technical design technological feasibility study. The pedagogical, usability and technological studies collectively form three important evaluation approaches and perspectives of the framework. Results of the pedagogical and usability studies were analysed together to form the refined user requirements of the framework and in order to build the technical design of the framework, for future implementation.

The third contribution of the research is the establishment of a proactive approach for retrieving learners’ locations and available time contexts via the use of a learning schedule for use within context-based or context-aware m-learning software applications. The underlying design mechanism of the learning schedule approach is simple and the learner is responsible for recording and conforming to their learning schedule (i.e. diary or planner on a mobile device). The proposed advantages of this approach include making a learner's learning status or situation throughout the day known to the mobile device via the learning schedule. The learning schedule approach has the potential a) to eliminate the use of context-aware technologies, b) to tackle inaccuracies and unreliability in location-tracking technologies and c) to overcome technological constraints of memory limitations on mobile devices for operating additional location-tracking programs.

The learning schedule approach has been partially successful in accurately retrieving the learners' contexts, as demonstrated by the findings of the diary study. The findings showed that a learner's planned and actual location is more likely to match than their available time. The framework could in principle retrieve a learner's location and available time contexts from the learner's schedule. Appropriate recommendations of materials suitable for students in their learning situation can be made using the established suggestion rules. The retrieval of learning contexts from students' learning schedules appears to be more effective for students who are more self-regulated. The approach appears to be a successful technique for students to self-motivate and manage their studies. In order to strengthen the framework, I proposed to use additional GPS and WLAN technologies and a direct request method from users to ensure that their location and available time contexts are accurate.

The fourth contribution is the establishment of the significance of learning contexts that should be considered in pedagogical context-based m-learning applications. Via the interview study, opinions and insight from participants were obtained to construct a well-informed qualitative analysis of whether the proposed learning contexts were significant. Via the diary study, real-time information was gathered from students to inform about their levels of concentration and their perceived values of various external and internal contexts in the learning sessions.

Findings from both the interview and diary studies were analysed together to show the significances of the learning contexts. A highly significant (user-generated) learning context was the learner's motivation, which positively affected their concentration level throughout a learning session. A significant negative correlation was found between the noise level at a location and the student's concentration level. However, it was shown that sometimes this can be overcome if a learner was very motivated to carry out their studies. The motivation learning context should therefore form an important part of context-aware suggestion mechanisms, where students are recommended materials based on their learning situations.

The fifth contribution is the validation of my proposed suggestion rules for learning Java via the online experiment with undergraduate students. This study has shown that these suggestion rules are appropriate for those situations of use, taking into consideration the learner's motivation, their available time and their Java proficiency level. Volunteers noted that their learning experiences were enhanced as a result of consideration of their current contexts in the recommendation of LOs. I was able to build on previous relating works such as Martin and Carro (2009), Cui and Bull (2005) and Becking et al. (2004). References to these works were made in my analyses of this study.

The sixth contribution is the learning objects study which helped me to determine the number of high-quality Java LOs in the public domain, which can potentially be incorporated into the framework. A representative sample of LOs was assessed in terms of their quality, using the Learning Object Review Instrument, and analyses of these were presented.

The seventh contribution is the proposed model of m-learning preferences, as described in 10.1.1.

10.3 Limitations of the research work

In this section, I consider the drawbacks to the mobile context-aware learning schedule framework and research work.

The learning schedule approach can be unreliable because it is expected that learners would plan and keep to their study-related and study-unrelated events. Any changes in the learner's events would not be captured in the schedule unless these were updated manually by the learner before the times of the changes. Results show that planned location information from the learner completely matched their actual locations at various times; however, this cannot be relied upon as empirical evidence. The details of the events in a learner's learning schedule may also be subjective; a possible error in the self assessment of events might occur, leading to inaccurate context information being stored and retrieved by the framework and then subsequently inappropriate materials selected for the learner.

The set of suggestion rules established in 6.4 may require more empirical evidence to support their feasibility and applicability for selection of materials under different m-learning circumstances. The derivation of a set of suggestion rules proved demanding and problematical due to the novelty of context-based adaptive mechanisms and the lack of an adequate amount of completed research work in the construction of a set of suggestion rules supported by empirical evidence. General consensus has not been agreed to suggest which learning contexts should be important for deployment in m-learning suggestion mechanisms. As a result, the process of generating a set of suggestion rules according to important learning contexts is complicated.

Other drawbacks include the small sample size of the interview and diary studies, the subjectivity of learners' opinions on learning-related topics in the interview study and the subjectivity of their perceived values of context values in the learning sessions, recorded as part of the diary study. Due to time constraints in conducting and analysing the studies and their results respectively, sample sizes were sufficient but not large. The interview study was concluded when feedback given by participants started to recur. The recruitment of interview participants was easier as this study only required 20-30 minutes of their time. It was not an easy task to convince students to volunteer to conduct a diary study for the duration of two days. As a result, the diary study was rather simplistic and designed to be minimally time-intensive in order to increase the number of potential participants as well as to ease the process of data analysis and interpretation. However, the studies showed reliable and valid data which were triangulated.

In the online Java LOs experiment, I had difficulty in recruiting students to participate in the study, despite the numerous times it was advertised via lectures and emails. I decided against paying volunteers to participate in this experiment in order to avoid random and inaccurate completion of the experiment.

In the LOs experiment, I made the utmost effort to gather an exhaustive list of LOs; however this is not a guarantee that I did not miss any that may perhaps have been more difficult to identify. I did not include password-protected LOs in my quality assessment using the Learning Object Review Instrument (LORI), and therefore may have filtered out those which are of higher or lower quality than those in the representative sample that we had used. The assessment using LORI is also subjective, based on the judgement of the researcher, i.e. myself.

The framework may not consider various issues across different cultures and was investigated with the knowledge of currently available mobile technologies.

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Appendix A – Interview Questions

Personal Details

Name:
Course:
Year of Study:
Gender:
Age:

Studying in *Various Locations*

1. *Where* do you usually study?(Include all locations)
2. Which places do you *like* studying in and *why*, and for which *activity*?
3. *Where* do you study better?
4. Do you sometimes have to study in a place where you *don't want to study in*, and does this affect how much you can engage with your activity?
5. Which *factors* in a location can affect your ability to concentrate, and to what degree?
6. Suppose you are studying in a place *where you may become distracted* by noises/people/movement around you, how does this affect you?
7. Suppose you are studying in a place *where you are likely to be interrupted such as in the café library*, how does this affect you?
8. Do you use any strategies in helping you concentrate in such an environment?

Schedule/Personal Information Management

9. Do you *use* a diary for managing your studies, or personal events and/or both?
10. **If so,** is your diary paper-based or electronic (phone/laptop/computer/pocket PC)?
11. **If electronic**, which *software*/*product* do you use for it?

12. **If so**, do you find that using a diary is an effective way of managing your time?
13. **If so**, can you explain how it helps you manage your time?
14. **If so**, how likely is it that you *follow* your diary?

15. **If not**, do you think that you can benefit from using a diary for managing your time?
16. **If not**, the reason that you don't use one, could it be that your foresee that you will not be able to follow your diary? Or other reasons?

17. Suppose we'd ask you to provide your diary events purely for time management purposes which will be stored on a secure electronic diary tool, would you be willing and feel comfortable enough to have this information held there?

Characteristics or personality

18. How would you describe your *personality* as a student?

Very Hardworking	Hardworking	Not so hard-working	Lazy
Enjoy studies very much	Enjoy studies	Don't enjoy studies	Hate it
Very Conscientious	Conscientious	Careful	Careless
Complete work ASAP	Last-week	Last-day	Last-minute
Very Self-disciplined	Quite self-disciplined	Not self-disciplined at all	
Very Organised	Quite organised	Not organised at all	
Very Routine-structured	Semi-routine-structure	Spontaneous	

19. Which *devices* do you use for learning/studying (computer, laptop, mobile phone, pocket PC, smartphone, PDA)?
20. *Which device do you prefer to use*, and for which *activity*, and at which location?
21. Which *software* do you use for your studies? Name 3 main ones and also others.
22. *Would you use a mobile device* for engaging in learning/studying in different locations? If so, where would you use it? If not, why not?
23. Do you have any preferences on the *time of day* you prefer to study, and why?

24. Suppose you have a mobile device which knows where you are (via GPS), and the reason you have that on is to help you track location information. Would you mind it knowing where you are? Would you feel intruded or would want your privacy to be protected?

Preferences for types of learning

25. Do you have preferences to how you learn (pictures, text, reading notes, learning by examples)?
26. Do you think it's important for you to learn according to these preferences and why?
27. If there was a tool which knows your learning preferences and can select appropriate learning materials for you according to them, do you think you will find this helpful towards your learning/studying, and why?
28. Now in terms of your *knowledge level on a particular topic*, if a tool knows your *knowledge level* for Java, say, and can give you learning materials appropriate for your knowledge level, do you think you will find this helpful, and why?
29. If a tool can adapt to your *concentration level* at the time when you are engaging with learning/studying, do you think you will find this helpful, and why?
30. And if a tool can adapt to how often you might be *interrupted* at a location when you are engaging with learning/studying, do you think you will find this helpful?
31. And finally if it can adapt to *the time that you have available* when you are engaging with learning/studying, do you think you will find this helpful, and why?

Interview Checklist

A short checklist to summarise the interview – should just take a couple of minutes.

Can you rate on a scale of 1- 5, the significance of each of the following factors in how they affect how well you learn/study.

(If you don't understand what I mean by a certain factor, please stop me and I shall explain).

5 – substantial significance
4 – very significant
3 – quite significant
2 – little significance
1 – no significance whatsoever

Factors	**Significance**
Sound/Noise level	
Temperature	
Lighting level/Sunlight	
Your Seat	
Layout of Room (furniture)	
The type of location (e.g. library, bus, station, home)	
Your motivation for learning	
How responsible you feel towards your studies	
Your persistence in your learning	
How organised you are	
Learning Preferences (e.g. pictures, text, reading notes, learning by examples)	
Intake (Food and drink)	
Time of day	
How free/restricted you feel in your location of study	
Working alone	
Working with peers/group	
Motivation from parent/lecturer	
How anxious/depressed you feel	

Appendix B – Diary Study - INSTRUCTIONS AND INFORMATION FOR PARTICIPANTS

Each participant will receive the following sheets required for this experiment –

- *A Diary Schedule sheet for Day 1*
- *A Diary Schedule sheet for Day 2*
- 20 sheets of *Diary Entry*

Instruction for filling in the *Diary Schedule* sheets for Day 1 and Day 2 –

1. Please fill in your diary schedule for 2 typical weekdays where you have a number of studying activities which require you to attend to. For example, lectures or self-study time for coursework. The diary schedule should be filled in **before** the beginning of the day and in chronological order. This should include all of the events that you plan out for the day, primarily studying events, and also should include other non-academic activities such as social meetings and lunch etc. On the *Diary Schedule* – please indicate
   a) Whether the event is studying-related (S) or non-studying related (N).
   b) The time (from and to) that you plan for the event
   c) The geographic location (such as Coventry, Warwick Campus)
   d) The type of location *(e.g. lecture room, library, home)*
   e) The actual task or event (*e.g. reading, writing assignment, programming, lunch, meeting)*
   f) After the time has elapsed for a scheduled event, please tick in the box whether the task was completed or attended.
   g) If a task was not completed or attended, please state the reason for this.

Instruction for filling in the Diary Entry sheets -

1. For each of your *Studying* events (S) (as indicated in column A of the *Diary Schedule*), please fill in a *Diary Entry* sheet as soon as possible after it has been completed or attended.

2. Please enter the *Diary Schedule* reference number into each of the *Diary Entry* sheets, and proceed to selecting the appropriate multiple-choice answers which apply to your event.

Upon completion, please return the completed sheets to

Jane Yau, Room CS329, Dept of Computer Science

And I would like to interview you for 10-15 minutes to ask you a few related questions about this experiment, which will be recorded for research purposes.

Information about the project -

Project Title – Context-aware Mobile Learning

Researcher – Jane Yau

Our study involves looking at –

1. Whether students can stick to their planned schedule?
2. If there is any correlation between the following attributes – noise, temperature, how busy the environment is, student's motivation level, the frequency of interruption of that location, and urgency of the task – and how well students can concentrate at that location?
3. Which type of learning materials would be appropriate for students to study under which situation and in which locations?

The information you provide to us will only be used for the purposes of this study and will be kept confidential. All data will be anonymised prior to analysis. If you wish to be informed of the results of this study, please email me j.y-k.yau@warwick.ac.uk. Any further enquiries can also be addressed to me.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION

Appendix B – Part 1 - DIARY SCHEDULE FOR DAY 1 – Please fill in the date here: ______________________________

Ref No.	a) Studying (S) or Non-Studying (N) event	b) Time (From and To)	c) Location (Geographic)	d) Type of Location (e.g. library, home)	e) Task(s) or activities	f) Tick if completed or attended (after time has elapsed)	g) If not completed, state reason.
1-1							
1-2							
1-3							
1-4							
1-5							
1-6							
1-7							
1-8							
1-9							
1-10							
1-11							
1-12							
1-13							
1-14							
1-15							

Appendix B – Part 2 - DIARY ENTRY (Please fill in one of these for each of your studying events listed in your *Diary Schedule*)

Please enter the Diary Schedule Ref No. here: ____________________
(To nearest five minutes) **Actual Time started: ______________Actual Time finished: _____________**

1. Where did you carry out your learning/studying? (Tick one)
☐ Warwick University ☐ Coventry
☐ Leamington Spa ☐ Kenilworth Other: ____________________________________

2. Which type of location was it? (Tick one)
☐ Library ☐ Home – Bedroom ☐ Restaurant
☐ Computer Laboratory ☐ Home - Kitchen ☐ Cafe
☐ Department Office ☐ Home – Dining Room ☐ Park
☐ Learning Grid ☐ Bus ☐ Other: ____________________
☐ Lecture Theatre ☐ Train

3. Why did you choose this location to carry out your task(s)? (Tick all that apply)
☐ Availability of academic help ☐ To maximise productivity ☐ Convenience
☐ Availability of resources ☐ Urgency of task ☐ Comfortable
☐ Preferred studying location ☐ Can concentration well here ☐ No distractions here
☐ Quiet ☐ Relaxing ☐ Other: ____________________

4. What task(s) did you perform during this session in this location? (Tick all that apply)
☐ Doing Coursework ☐ Programming exercises ☐ Writing essay
☐ Doing Assignment ☐ Programming project ☐ Writing report
☐ Learning how to program ☐ Team project ☐ Making notes
☐ Hands-on programming ☐ Making presentation ☐ Reading ☐ Other: _____________

5. How NOISY did you find the environment? (Tick one)
☐ 1 Very Quiet ☐ 2 Quiet ☐ 3 Average ☐ 4 Loud ☐ 5 Very Loud

6. How BUSY did you find the environment? (The number of people, coming and going etc.) (Tick one)
☐ 1 Very Not-Busy ☐ 2 Not-Busy ☐ 3 Average ☐ 4 Busy ☐ 5 Very Busy

7. What was the TEMPERATURE like? (Tick one)
☐ 1 Very Cold ☐ 2 Cold ☐ 3 Neutral ☐ 4 Hot ☐ 5 Very Hot

8. How MOTIVATED were you to carry out the task(s)? (Tick one)
☐ 1 Very unmotivated☐ 2 Unmotivated ☐ 3 Average ☐ 4 Motivated ☐ 5 Very motivated

9. How URGENT was the task(s) to be carried out? (Tick one)
☐ 1 Very Not-Urgent ☐ 2 Not Urgent ☐ 3 Average ☐ 4 Urgent ☐ 5 Very Urgent

10. How FREQUENTLY were you interrupted? (E.g. by people, noises, or other distractions) (Tick one)
☐ 1Very Infrequent ☐ 2 Not Frequent ☐ 3 Average ☐ 4 Frequent ☐ 5 Very Frequent

11. Did anything else distract you from your concentration? (Tick all that apply)
☐ Too stressed due to too many assignments ☐ Experiencing other problems e.g. family
☐ Wanting to do other things instead of studying ☐ Other: ___________________________

12. How WELL would you say you concentrated THROUGHOUT the session? (Tick one)
☐ 1 Very bad ☐ 2 Bad ☐ 3 Average ☐ 4 Well ☐ 5 Very well

13. Did you concentrate better or worse at the START of the session?
☐ 1 Much Worse ☐ 2 Slightly Worse ☐ 3 Roughly the same ☐ 4 Slightly Better ☐ 5 Much Better

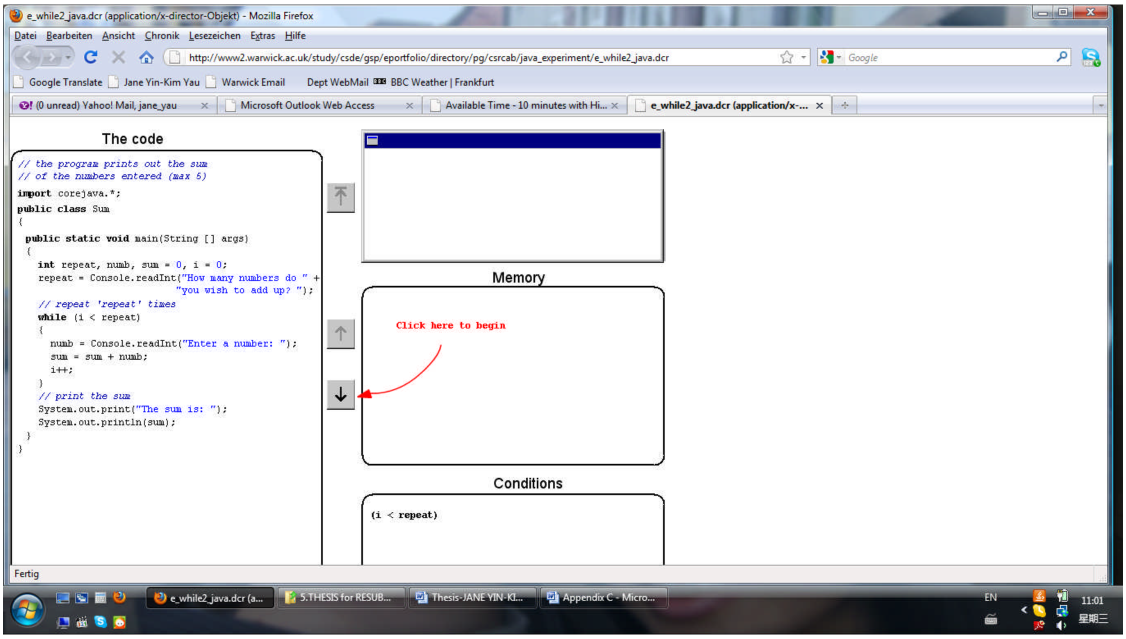
14. Did you concentrate better or worse at the END of the session?
☐ 1 Much Worse ☐ 2 Slightly Worse ☐ 3 Roughly the same ☐ 4 Slightly Better ☐ 5 Much Better

Appendix B – Diary Study Part 3 - POST-EXPERIMENT QUESTIONNAIRE

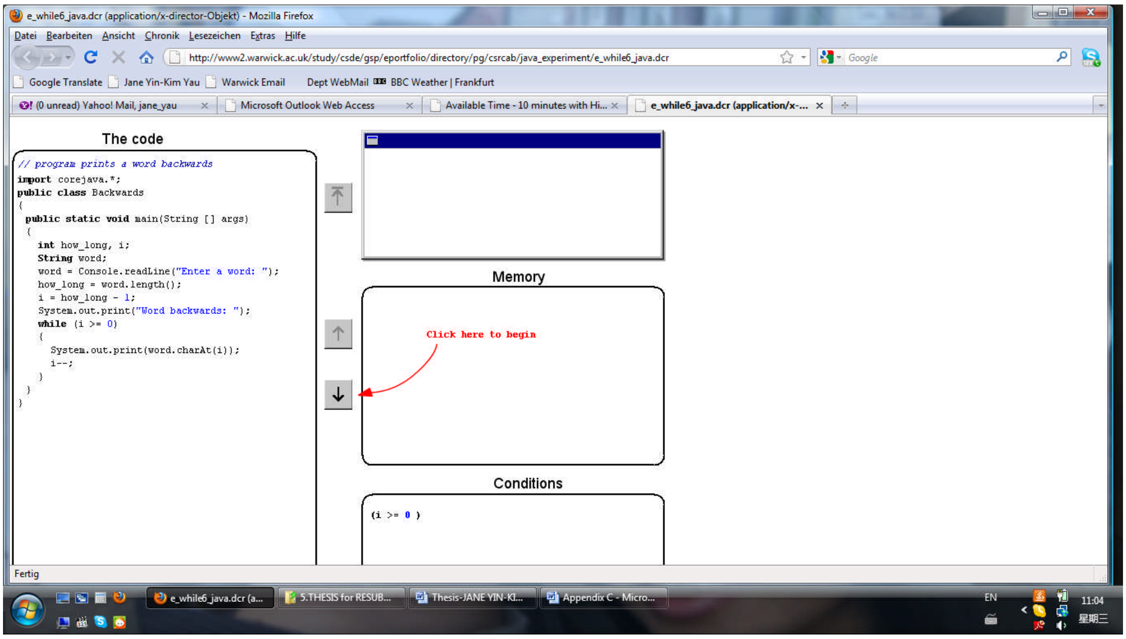
1. Do you normally keep a diary to remind yourself what you need to do throughout the day? ____ _____________________________
    a. **If so**, do you follow your events as planned? ______________________________
    b. **If not,** do you have a problem planning the events? _____________________
2. Did you have problems updating this diary schedule? ___________________________
3. Were you always in the location that you had planned? _________________________
4. Were you always doing the activities that you had planned at that location? ____
5. Does **noise** generally affect your concentration for studying? ___________________
    a. Are there times when it doesn't concern you, say if the task is very urgent? ____
6. Does **busyness of the environment** generally affect your concentration for learning? ____
    a. Or only in specific locations (e.g. do you think you can concentrate more in a lecture than in a café even though it may be busy in both locations? ____
7. Does the **temperature** affect how well you study/learn? __________________________
8. Does your **motivation** have a big effect on how well you study? _________________
    a. Does it determine whether you want to study at a particular location? ____
    b. Does it determine whether you want to study a particular topic? ____ _____
9. When you are studying, are you sometimes affected by **internal distractions** e.g. wanting to do other things, stress, problems etc? _____ ___________________________
10. When you have an **urgent assignment** to complete and submit, do all the other factors mentioned affect you as much in terms of completing it? ___ _____________
    a. Do you get distracted less from a noisy environment for example? ____________________________ __________________________________
11. Can you concentrate at the same level throughout a study session, or are there changes within it? ______________________ ____
    a. **If so**, can you give any reasons for these changes? ____
12. Can you name all the different tasks that you have to do for your course? (E.g. writing, reading, assignments, research, coursework, presentation)? ______________ ____
13. Do you plan a certain task/activity to be completed at a particular location? **If so, why?** ____
    a. **If so,** can you carry out these in other locations too? **_____________________**
    b. **If not,** can you carry out these in any location? **________________ __________**
14. When you are carrying out a task at a particular place, have you ever discontinued with it, because there were too many distractions? ______________ __
    a. **If so,** what were these distractions? **_______ _______________________________**
    b. **If not**, do these distractions not distract you, or are you just more determined to finish it? ____
15. Please name the activities that you would carry out when you have
    a. Less than 15 minutes: _______________________ ___________
    b. 15 – 30 minutes: ____________ ___________________________
    c. 30 minutes to an hour: ____
    d. Over an hour: ____

Appendix C – Java learning objects used for the validation study in Chapter 7

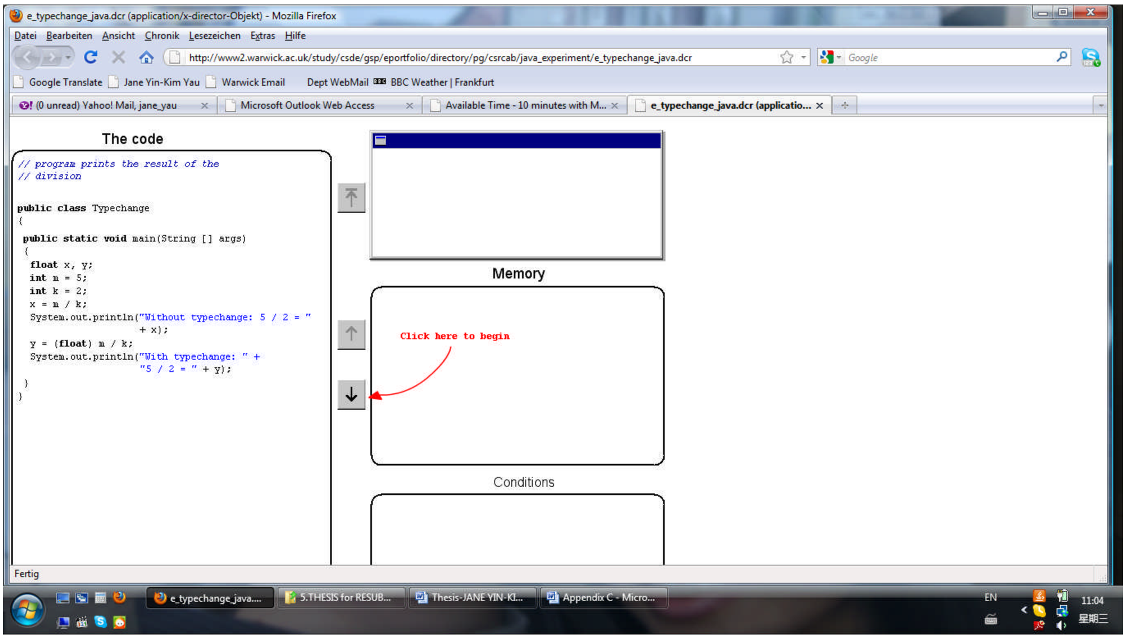
While loop – calculates sum of numbers



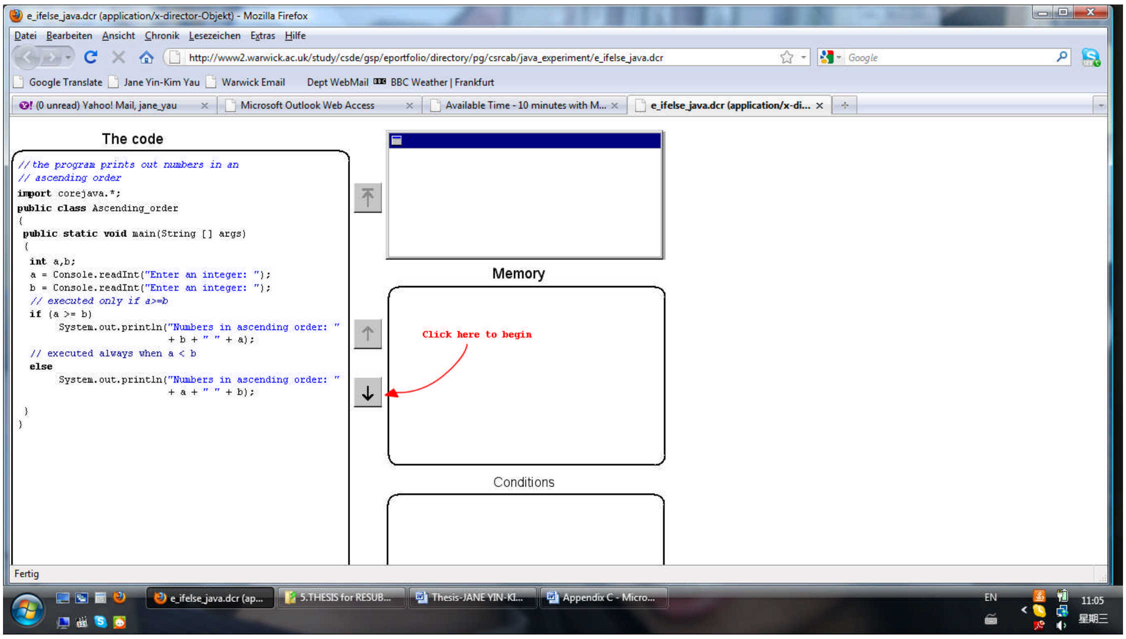
Array – print a string backwards



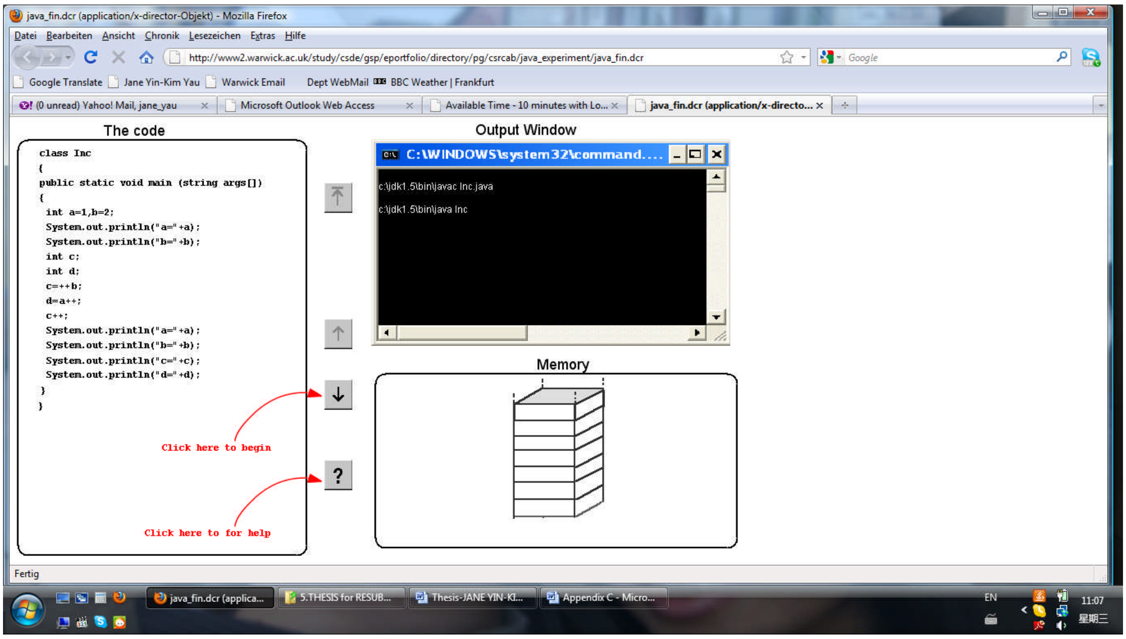
Division of integer



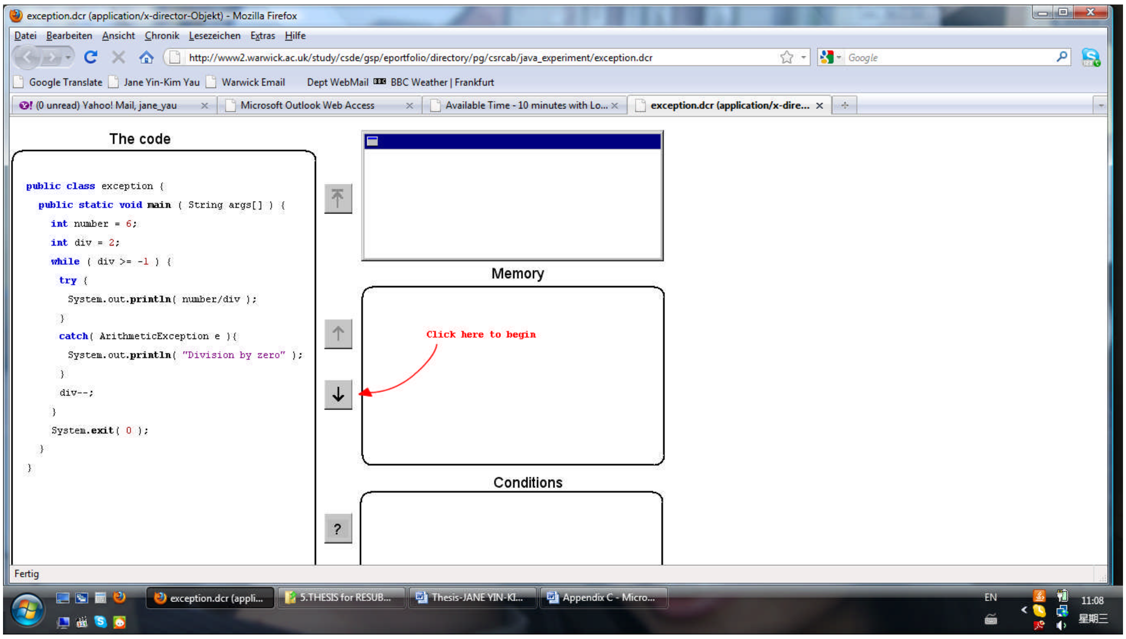
If-else-example



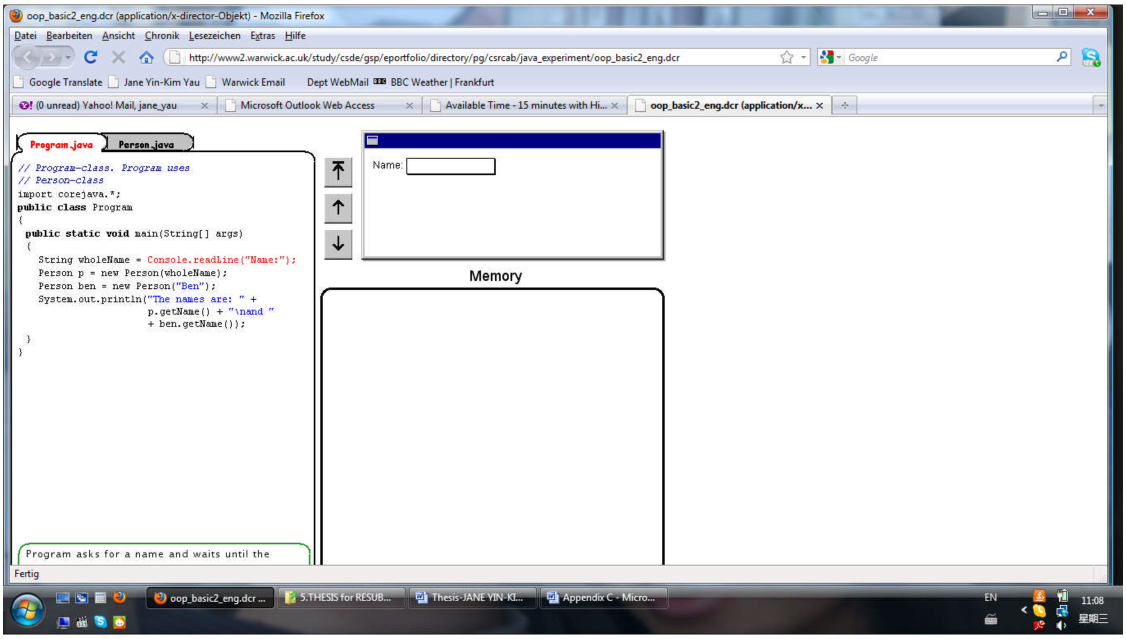
Prefix and postfix increment operators



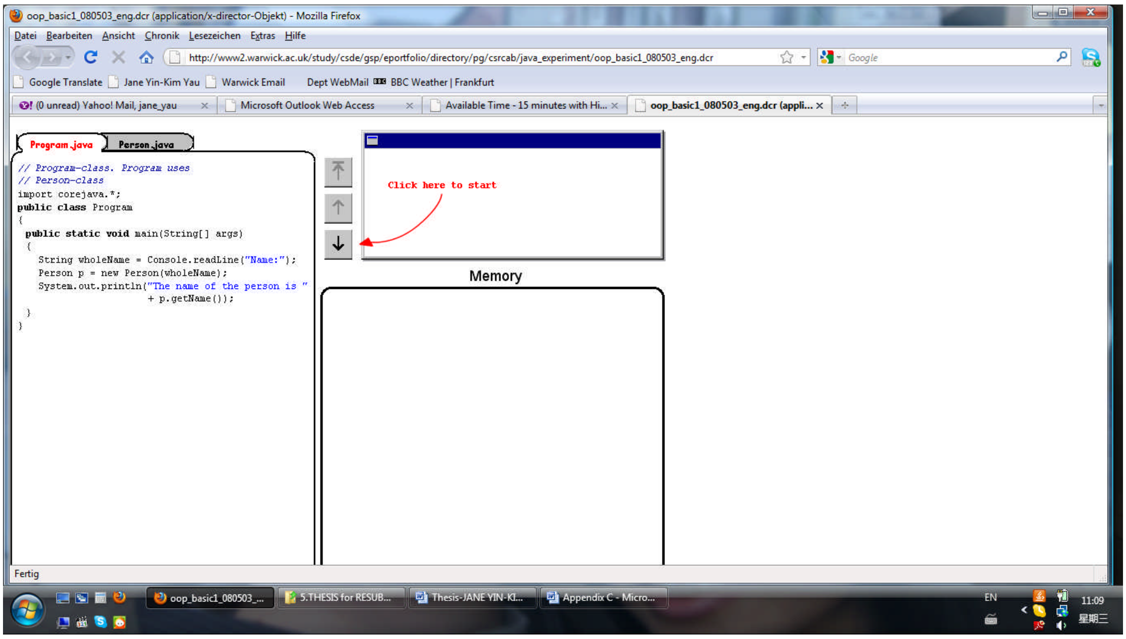
Exceptions



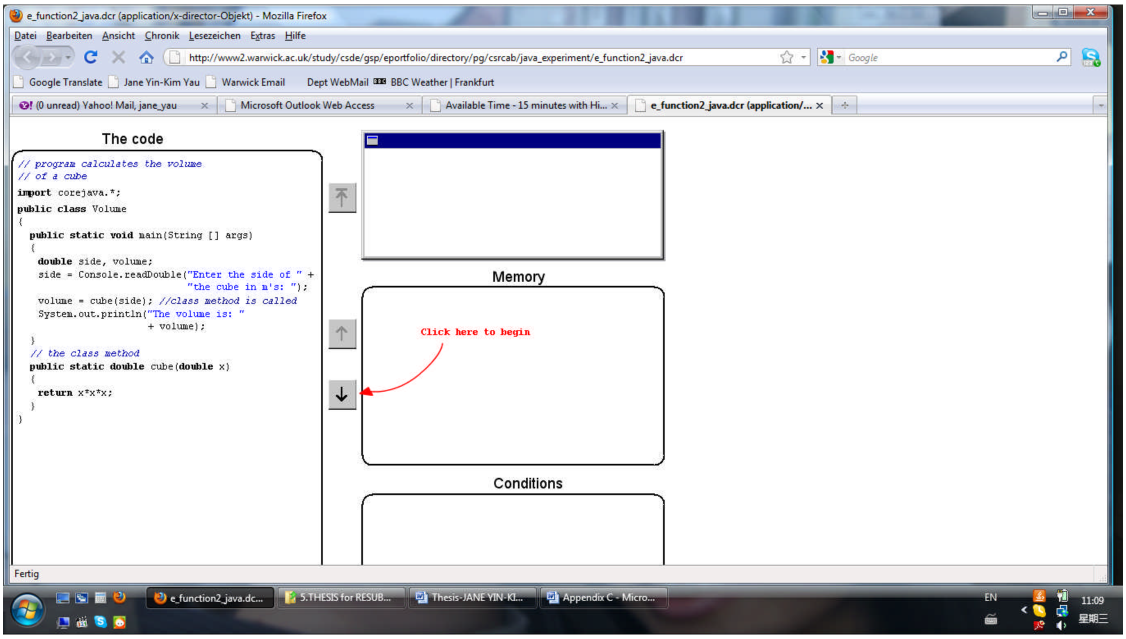
Object-oriented programming – OOP example



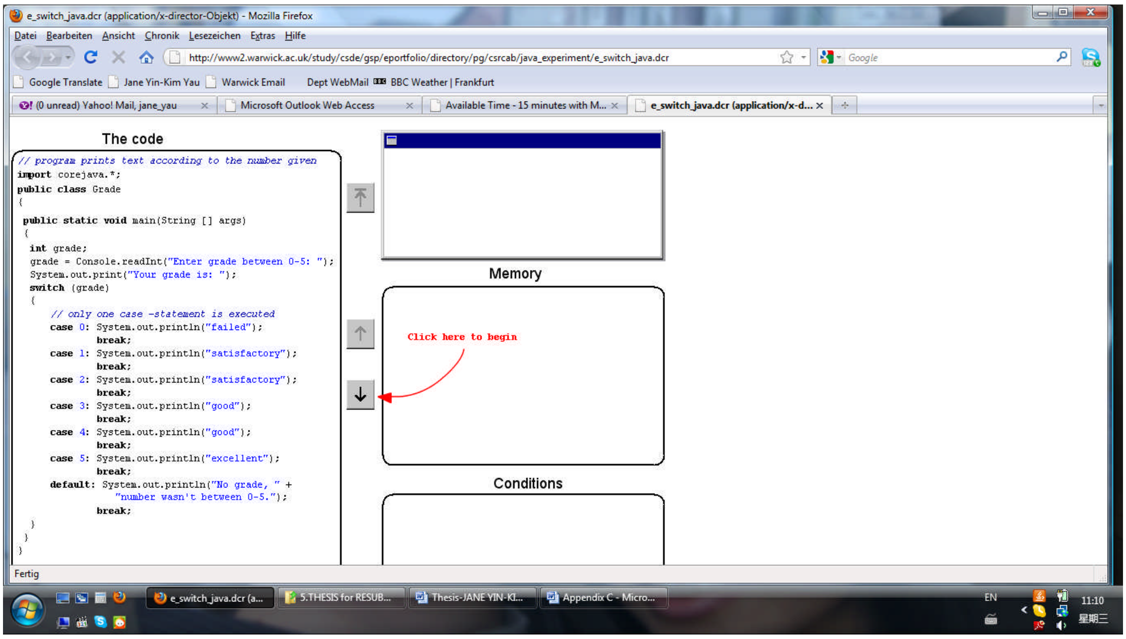
Object-oriented programming – creating an instance



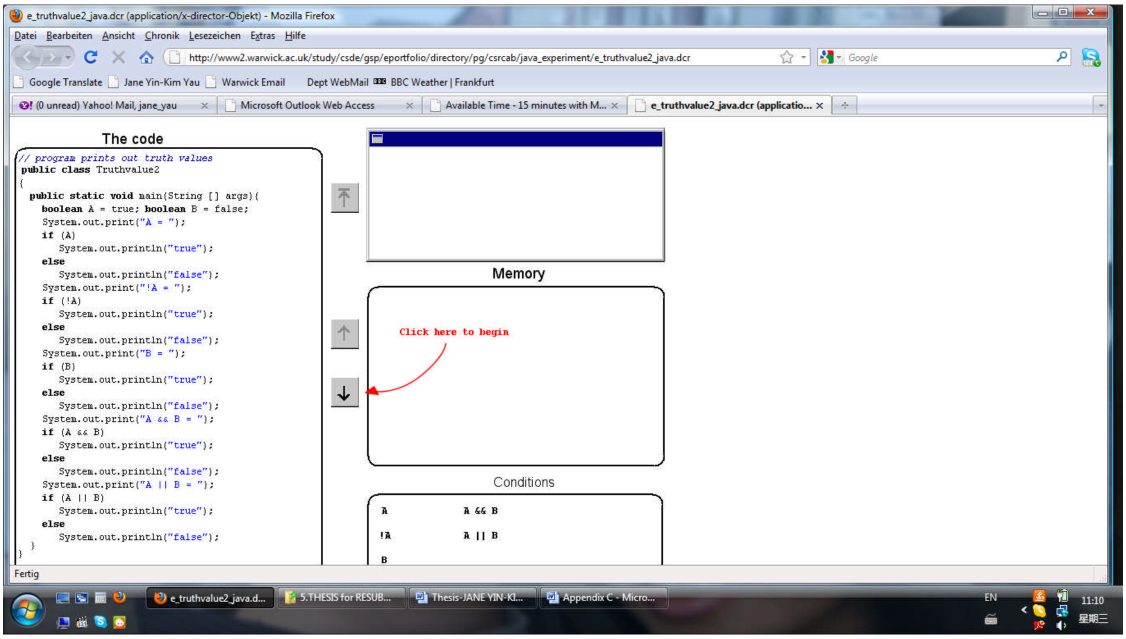
Method – function with parameters



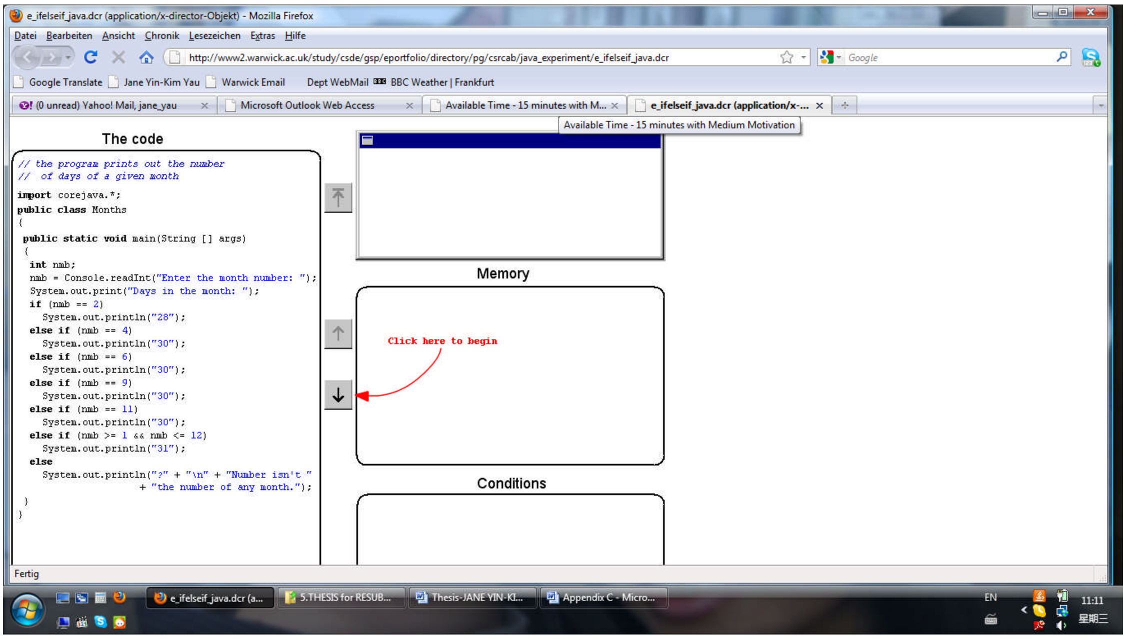
Switch example – verbal grades



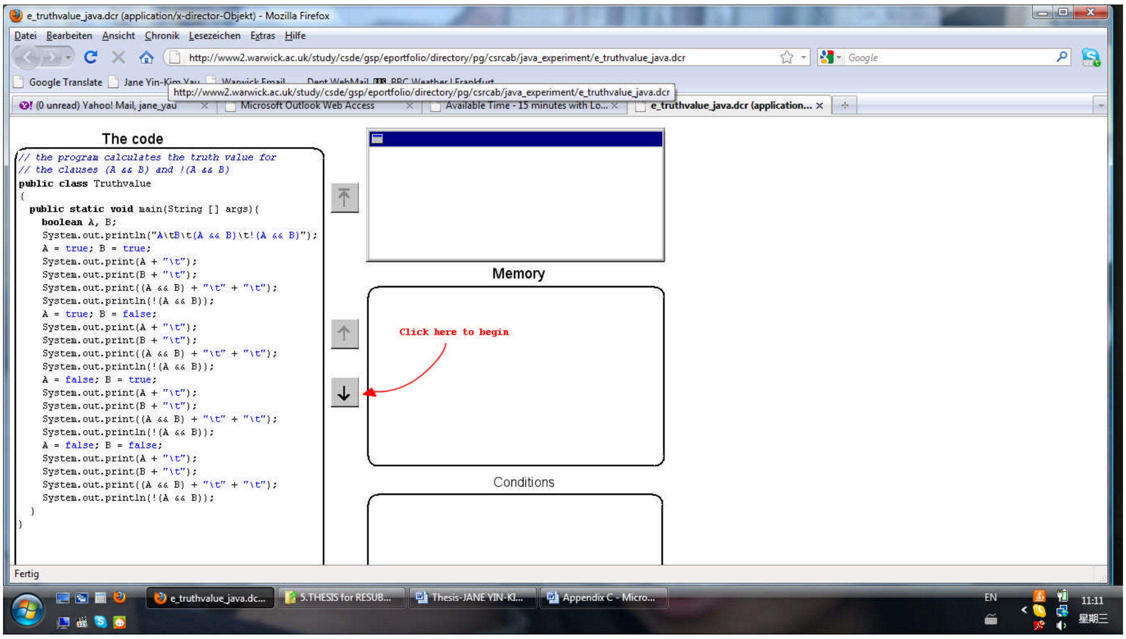
If-else-example – truth values



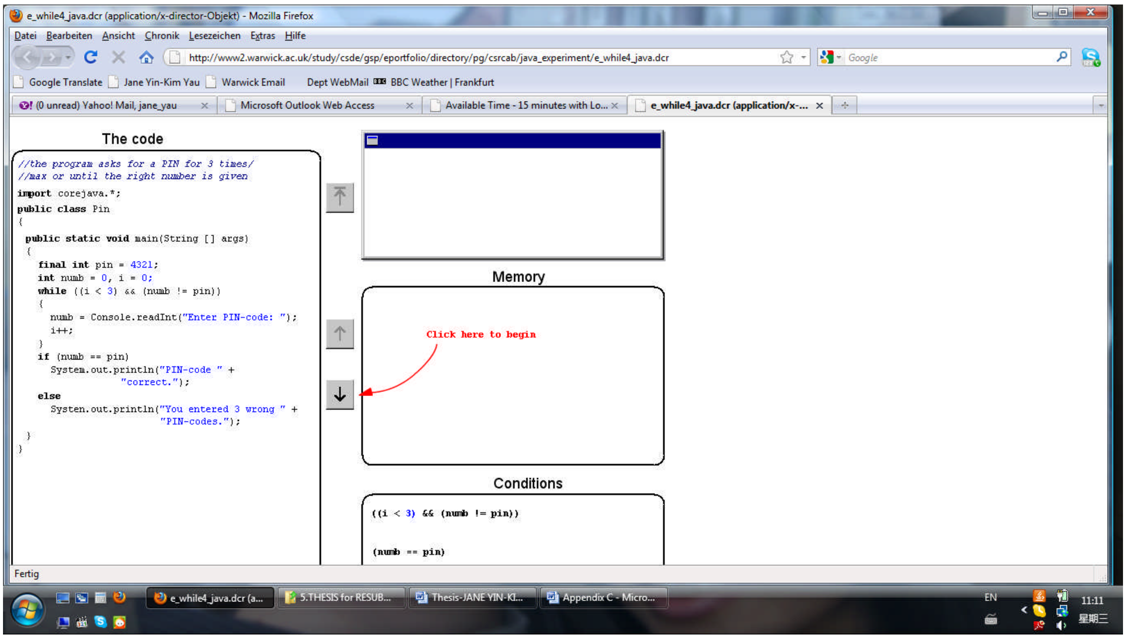
If-else-example – days in one month



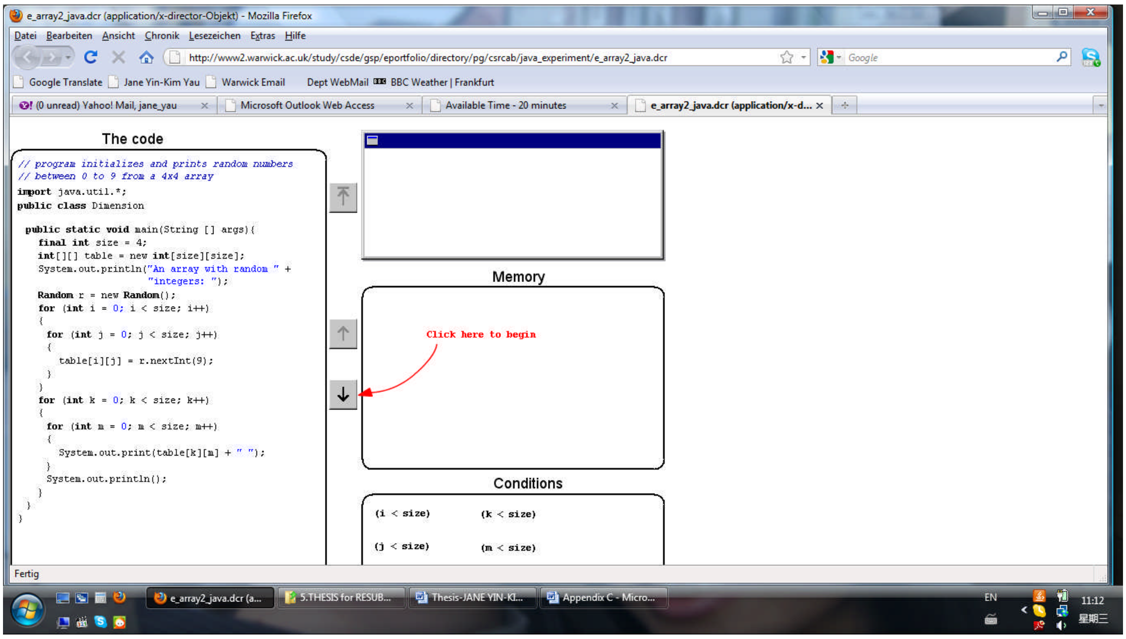
Logic operators



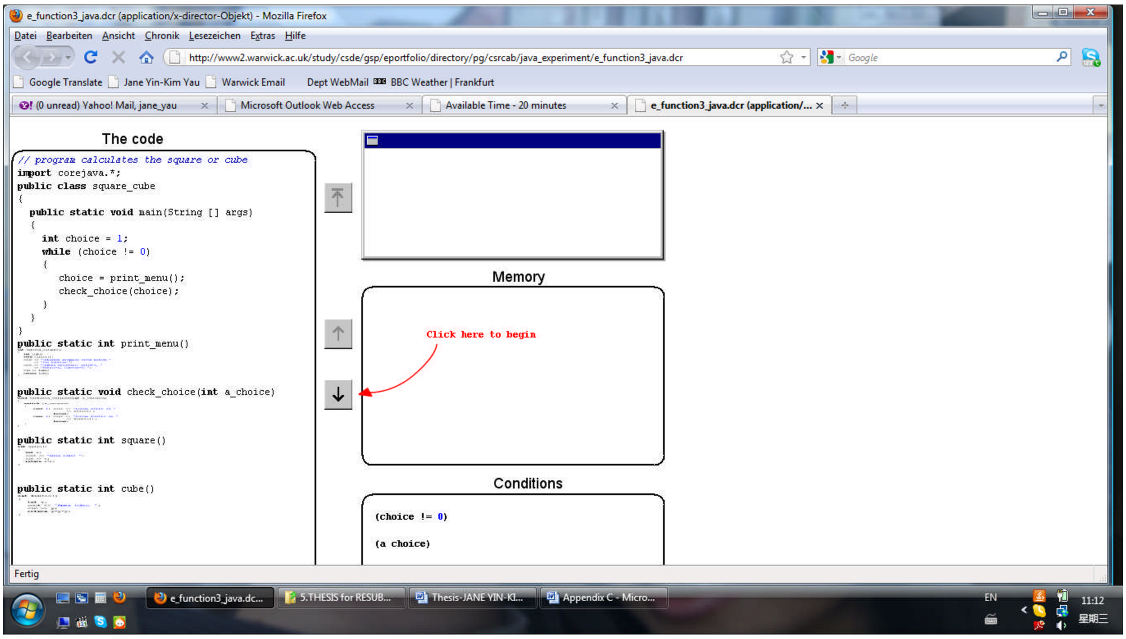
While loop – pin code checker



2D Array – random values



Method – calculate square and cube



Appendix D - Java Learning Objects Feedback Form

Dear Student,
Thanks for completing the learning object!
Please provide some information about it. We require two sections of feedback, as follows:
1) basic information – name of the learning object, the parameters information that best describe the situation when you were studying the learning object, date, time and location of completion, and length of time required; and
2) feedback of the learning object relating to a) its chosen set of parameters, b) its learning content and c) the time slot that you have chosen to study it.
The data entered into this feedback form will be completely confidential, and will not be revealed to anyone except the research team.
If you would like to be informed about the results, please email me (j.y-k.yau@warwick.ac.uk).
Jane Yau
Doctoral Researcher
Department of Computer Science, University of Warwick

Part 1: Basic Information

1. Please select the learning object you studied:*

2. Date of Completion:*

3. Time of completion: (Hours:Minutes)* :

4. Location of completion (such as lab, library, home, cafe, park, etc):*

5. Length of time required for completion (approx. in minutes):*

6. Please rate your motivation level during this study session:*

Part 2: Feedback of the Learning Object
Relating to the chosen set of parameters for the study of the learning object:

1. Please rate how useful the studying of this learning object was in the set of parameters (i.e. particular motivation level, amount of time required and Java knowledge level) that were chosen for it to be

studied in:*

Please provide a brief reason, if possible:

2. Please rate how enjoyable your learning experience was:*

Please provide a brief reason, if possible:

3. Was your learning experience more enjoyable or enhanced as a result of studying it in the proposed set of parameters:*

Please provide a brief reason, if possible:

4. Was this learning object or its type of learning activity appropriate to be studied in the proposed set of parameters:*

Please provie a brief reason, if possible:

5. How feasible do you think it would have been to study this learning object in any other set of parameters:*

Please provie a brief reason, if possible:

6. In your opinion, which other learning activities CAN be studied effectively and enjoyably in the

- [ ] Learning theoretical concepts
- [ ] Revising learning materials

same set of proposed parameters: (Tick all that apply)*

- [ ] Practising tests
- [ ] Answering open-ended questions
- [ ] Answering multiple-choice questions
- [ ] None of the above

Other – please state:

Please provide a brief reason, if possible:

7. In your opinion, which other learning activities CANNOT be studied effectively and/or enjoyably under these parameters:*

- [ ] Learning theoretical concepts
- [ ] Revising learning materials
- [ ] Practising tests
- [ ] Answering open-ended questions
- [ ] Answering multiple-choice questions
- [ ] None of the above

Other – please state:

Please provide a brief reason, if possible:

8. Are you aware of any learning styles or preferences that you may have (such as visual verbal active reflective sensing intuitive sequential global):*

9. If so, tick all the preferences that apply to you:

- [ ] Visual
- [ ] Verbal
- [ ] Active
- [ ] Reflective
- [ ] Sensing
- [ ] Intuitive
- [ ] Sequential
- [ ] Global

Other – please state:

10. In your opinion, would you have benefited from studying a learning object which is suited to your particular learning styles/preferences:*

Please provide a brief reason, if possible:

Relating to the learning content of the learning object:

11. How useful did you find the learning content of the learning object to be:*

Please provide a brief reason, if possible:

12. Would you use this learning object again:*

Please provide a brief reason, if possible:

Relating to the time slot that you have chosen to study the learning object:

13. Why did you choose this time slot to study the learning object:*

- Due to convenience
- Boredom
- Interest in Java
- Interest in learning
- Had some spare time
- None of the above

Other – please state:

14. Was this time slot a good time for you to study in:*

Please provide a brief reason, if possible:

15. Please provide any other comments regarding any aspects of this experiment (especially concerning this learning experience), if any:

16. Course of Study:*

Other courses – please state:

17. Year of Study*

Other – please specify:

18. Name of your university/institution:*

19. Where did you hear about this experiment?*

Other – please state:

Appendix E - Sample of learning objects examined against the administrative criteria

Institution name	Department name	Country	URL to view LO
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid7
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid10
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid17
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid25
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid32
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid35
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid38
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid55
Rice University	dept of computer science	USA	http://cnx.org/content/m31249/latest/#uid61
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid1
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid19
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid25
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid33
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid40
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid46
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid52
Rice University	dept of computer science	USA	http://cnx.org/content/m31248/latest/#uid58
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid1
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid10
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid20
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid30
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid37
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid45
Rice University	dept of computer science	USA	http://cnx.org/content/m31247/latest/#uid55

Title	Topic	License	Author (if known)
Los for inheritance in Java (top-level)	Los for inheritance	Creative Commons	Mordechai (Moti) Ben-Ari
Inheriting fields	Inheriting fields	Creative Commons	Mordechai (Moti) Ben-Ari
Inheriting methods	Inheriting and overriding methods	Creative Commons	Mordechai (Moti) Ben-Ari
Dynamic dispatching	Dynamic dispatching	Creative Commons	Mordechai (Moti) Ben-Ari
Downcasting	Downcasting	Creative Commons	Mordechai (Moti) Ben-Ari
Heterogeneous data structures	Heterogeneous data structures	Creative Commons	Mordechai (Moti) Ben-Ari
Abstract classes	Abstract classes	Creative Commons	Mordechai (Moti) Ben-Ari
Equals	Equals	Creative Commons	Mordechai (Moti) Ben-Ari
Clone	Clone	Creative Commons	Mordechai (Moti) Ben-Ari
Overloading vs. overriding	Overloading vs. overriding	Creative Commons	Mordechai (Moti) Ben-Ari
Los for constructors in Java (top-level)	Los for constructors	Creative Commons	Mordechai (Moti) Ben-Ari
What are constructors for?	What are constructors for?	Creative Commons	Mordechai (Moti) Ben-Ari
Computation within constructors	Computation within constructors	Creative Commons	Mordechai (Moti) Ben-Ari
Overloading constructors	Overloading constructors	Creative Commons	Mordechai (Moti) Ben-Ari
Invoking an overloaded constructor from within	Invoking another constructor	Creative Commons	Mordechai (Moti) Ben-Ari
Explicit default constructors	Explicit default constructors	Creative Commons	Mordechai (Moti) Ben-Ari
Constructors for subclasses	Constructors for subclasses	Creative Commons	Mordechai (Moti) Ben-Ari
Constructors with object parameters	Constructors with object parameters	Creative Commons	Mordechai (Moti) Ben-Ari
Constructors with subclass object parameters	Constructors with subclass object paramete	Creative Commons	Mordechai (Moti) Ben-Ari
Los for methods in Java (top-level)	Los for methods in Java	Creative Commons	Mordechai (Moti) Ben-Ari
A void method	A void method	Creative Commons	Mordechai (Moti) Ben-Ari
A method returning a value	A method returning a value	Creative Commons	Mordechai (Moti) Ben-Ari
Calling one method from another	Calling one method from another	Creative Commons	Mordechai (Moti) Ben-Ari
Recursion	Recursion	Creative Commons	Mordechai (Moti) Ben-Ari
Calling methods on an object	Calling methods on an object	Creative Commons	Mordechai (Moti) Ben-Ari
Calling a method on the same object	Calling a method on the same object	Creative Commons	Mordechai (Moti) Ben-Ari
Objects as parameters	Objects as parameters	Creative Commons	Mordechai (Moti) Ben-Ari

URL to download source	Date/time of creation (	Date/time acces	Metadata t	Granularity	Relating to	Used part c
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31249/latest/inheritance.zip	Aug 12, 2009 5:46 am G	3 May 2010	yes	yes	yes	yes
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http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
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http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31248/latest/constructor.zip	Aug 12, 2009 5:32 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes
http://cnx.org/content/m31247/latest/method.zip	Aug 12, 2009 5:27 am G	3 May 2010	yes	yes	yes	yes

English	Editable	Open licen	Passes overall criteria
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
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yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes
yes	yes	yes	yes

Appendix F - Sample of learning objects measured against LORI

Institution name	URL to view LO
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/cpu_lesson/cpu_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/memory/memory_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/binary_numbers/binary_integers.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/binary_numbers/binary_fractions.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/input-output/InputOutput.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/storage/storage.htm
Furman University	http://cs.furman.edu/~kabernet/cte/computer_basics/operating_sys/os.htm
Furman University	http://cs.furman.edu/~kabernet/cte/network_basics/intro_networks/intro_net.htm
Furman University	http://cs.furman.edu/~kabernet/cte/network_basics/types_networks/type_net.htm
Furman University	http://cs.furman.edu/~kabernet/cte/network_basics/components_networks/comp_net.htm
Furman University	http://cs.furman.edu/~kabernet/cte/web_authoring/web-intro/web_intro_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/network_basics/more_internet/more_intnet.htm
Furman University	http://cs.furman.edu/~kabernet/cte/operating_sys/operating_sys/os.htm
Furman University	http://cs.furman.edu/~kabernet/cte/project_mgmt/processes/pm_processes_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/ethics/ethics/ethics_ppt.htm
Furman University	http://cs.furman.edu/~kabernet/cte/web_authoring/web-intro/web_intro_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/web_authoring/html_intro/html_intro_lesson.htm
Furman University	http://cs.furman.edu/~kabernet/cte/web_authoring/html_att_links/html_att_links_lesson.htm

Title	1. Content	2. Learning	3. Feedbac	4. Motivat	5. Present	6. Interacti	7. Accesibi	8. Reusabi
Lesson: Central Processing Unit (CPU) and Memory	3	4	0	2	4	0	2	5
Lesson: Organization of Memory	2	5	0	1	2	0	2	5
Lesson: Binary Representation of Integers	1	2	0	1	1	0	2	5
Lesson: Binary Representation of Fractions	3	4	0	1	2	0	2	5
Lesson: Introduction To Input and Output (I/O)	2	2	0	2	2	0	2	5
Lesson: Introduction To Storage	1	2	0	2	2	0	2	5
Lesson: Introduction To Operating System	2	4	0	2	3	0	2	5
Lesson: Introduction To Networks	2	4	0	1	1	0	2	5
Lesson: Types of Networks	4	4	0	2	2	0	2	5
Lesson: Components of Networks	3	4	0	2	2	0	2	5
Lesson: Introduction to the World Wide Web	1	4	0	1	1	0	2	5
Lesson: More on the Internet	3	5	0	1	1	0	2	5
Lesson: Introduction To Operating Systems	2	3	0	1	2	0	2	5
Lesson: Basic Project Management Processes	3	4	0	2	2	0	2	5
Lesson: Ethical Issues in IT	1	1	0	1	1	0	2	5
Lesson: Introduction to the World Wide Web	2	2	0	1	1	0	2	5
Lesson: Introduction to HTML	2	2	0	1	2	0	2	5
Lesson: HTML -- Attributes and Links	2	2	0	2	2	0	2	5

Appendix G

Declaration of Trademarks

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