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Research Articles

A Mobile Context-Aware Framework for Managing Learning Schedules:
Data Analysis from an Interview Study

Jane Yin-Kim Yau, University of Warwick, UK

Mike Joy, University of Warwick, UK

ABSTRACT

Mobile learning applications can be categorized into four generations: non-adaptive, learning-preferences-based adaptive, learning-contexts-based adaptive and learning-contexts-aware adaptive. The research on our learning schedule framework is motivated by some of the challenges within the context-aware mobile learning field. These include being able to create and enhance students' learning opportunities in different locations by considering different learning contexts and using them as the basis for selecting appropriate learning materials. We have adopted a pedagogical approach for evaluating this framework, an exploratory interview study with potential users consisting of 37 university students. The observed interview feedback gives us insights into the use of a pedagogical m-learning suggestion framework deploying a learning schedule subject to the five proposed learning contexts. Our data analysis is described and interpreted leading to a personalized suggestion mechanism for each learner and each scenario and a proposed taxonomy for describing mobile learner preferences.

Keywords: *Context-Based, Interview Study, Pedagogical Perspective, Learning Contexts*

INTRODUCTION

The importance of the deployment of learning contexts into mobile learning (m-learning) applications, and making these applications aware of the context (or circumstances) it is being used in, is currently a very significant part of their development (Sharples, 2006). Since portable mobile devices can be used for learning anytime anywhere, learners have the flexibility to choose practically any location that suits them. For a full-time university student living on campus, this choice may not seem as crucial as for a part-time student who has family and work commitments and commutes onto campus every day, for example. The latter student typically has many more time limitations than the former, and because of this constraint, it is much more important and necessary for the latter student to be able to utilize whatever available time they

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have and to be able to learn and study at any location. For example, it might be necessary for them to make use of the time when they are commuting each day on public transport. Becking et al. (2004) also noted similar difficulties that distance learning students face because of this time constraint.

Given the possible different circumstances surrounding the learner at the point of learning and studying (such as the location, length of time available, their concentration at that point in time, or the frequency of interruption at the location), there may be pedagogical benefits to the learner if their m-learning application were to be aware of these circumstances and be able to suggest appropriate materials for the learner's context. Our research is motivated by the fact that students may want to carry out their learning tasks and activities at every given opportunity with sufficient time available. Naturally, this may not 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."

In this article, we describe the design of a theoretical framework to support those students who wish to carry out their learning at different locations with variable amounts of time available to them. Our goal is to recommend (the most) appropriate activities to them, given the particular circumstances, in an attempt to maximize their learning productivity. In achieving this goal, the following three research questions will need to be resolved. The motivation for resolving these is also described.

1. *Can a proactive method of retrieving learning contexts, without the use of context-aware sensor technologies, be successfully established?* Our theory investigates the possibility of substituting context-aware sensor technologies with a simple, yet efficient, technique: the learner's learning schedule. This relies on the self-discipline of students to tell their mobile device their probable learning schedule ahead of time. The device will then suggest appropriate study measures to the user at each particular point in time.

The possible methods used for retrieval of learning contexts have been investigated in many related m-learning studies and are divided into *direct* and *implicit* retrieval methods. Direct retrieval from the user (see Cui & Bull, 2005) requires time and effort and may interfere with what the user is doing. Alternatively, retrieval may be done implicitly by using sensors to detect the features of different learning contexts (see Schmidt, 2002).

2. *Which learning contexts are necessary attributes of a pedagogical mobile learning framework?* Through our literature survey, we identified five learning contexts which are highly significant pedagogically. These are learning styles, knowledge level, the student's concentration level, the frequency of interruption at a location, and the amount of study time available. Recent m-learning applications are attempting to establish which learning contexts are important for creating rich m-learning applications (Parsons, Ryu, & Cranshaw, 2007); however, consensus on this has not yet been reached.
3. *Which learning materials should be recommended to students under different circumstances?* We obtained data to help answer this question from an interview study, as well as a diary study. Research has been conducted by Cui and Bull (2005) and Martin, Carro, and Rodriguez (2006) in specifying such materials but currently there is no general consensus for ascertaining the types of learning materials and activities that would be appropriate for learners to learn and study under different circumstances.

Our research is centered on the above issues. We have previously developed a Mobile Context-aware Learning Schedule (mCALS)

theoretical framework, which was presented in detailed in (Yau & Joy, 2008). We provide a brief overview of the theoretical framework here; however, the data analysis of our interview study corresponding to the framework forms the focus of this article. The eventual aim is to transform this framework, via user-centered evaluations, into a pedagogical m-learning application implementable on a mobile device and deployable by target users. Our theoretical framework draws upon existing and current related works in context-aware m-learning applications (Becking et al., 2004; Cui & Bull, 2005; Martin et al., 2006), and is supported by an extensive literature review.

Five main components of our framework have been constructed as a result: a method for detecting and retrieving learning contexts, a user model, a contextual model, a recommendation mechanism and a database of learning materials. The system architecture of our theoretical framework is divided into three layers: the *learner model layer* (containing the first three components, as mentioned above), a *recommendation layer* and a *learning objects layer*. The design of this framework includes the use of the student's learning schedule (i.e., electronic diary) on the mobile device. Primarily, this is utilized for capturing and storing the users' scheduled events which can be retrieved and translated as learning contexts; and secondly as a useful means for students (especially self-managed students) to organize their work and facilitate their time management, and they are more likely to self-motivate or self-regulate themselves through the act of planning their studies (Quenter, Bludau, Friederich, Schild, Riepe, & Zipfel 2009). A self-regulated student can be characterized by their "active participation in learning from the meta-cognitive, motivational, and behavioral point of view" (Montalvo & Torres, 2004). The *recommendation mechanism* recommends appropriate learning materials (from our Learning Object Repository) based on the user's learning context at the time of usage.

For the purpose of our research, the initial scope of learning materials made available to students through the framework was the Java programming language, in the form of learning objects, to be retrieved from our previous work. The initial target of students for the use of our framework included undergraduate computer science students (i.e., typically novice programmers). A principal reason for the decision to incorporate these materials was that usually a large amount of time and motivation are necessary to learn an object-oriented programming language such as Java (Yau, 2004), and we are currently investigating ways to facilitate this for novice programmers.

To decide upon which learning contexts are the most significant in the recommendation of pedagogically-appropriate learning materials in our framework, we examined the works of Cui and Bull (2005) and Martin et al. (2006), which are closely related to our framework. Subsequently, we selected the following five learning contexts to be incorporated into our framework; *learning styles, 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 learning styles, knowledge level and available time contexts were utilized in the work of Martin et al. (2006). We describe the reasons for the incorporation of these learning contexts below.

1. The importance of incorporating cognitive learning contexts, such as learning styles, into the design and development of context-aware m-learning applications has been emphasized by many authors, including Prekop and Burnett (2003), who noted that this dimension of context has often been neglected in the design and development of this domain. Similarly, learners may have different preferred styles of learning and psychological attributes which were shaped by their learning experiences, and these should be taken into consideration especially when they are conducting m-learning with mobile devices (Parsons et al., 2007).

2. The selection of materials appropriate to the students' level of knowledge may enhance their effectiveness of learning and studying the materials (Cui and Bull, 2005) because a) students may become bored and unmotivated if materials are too simplistic and repetitive of concepts that they already know and/or understand, and b) students may not be able to progress if materials are too advanced for them; this is ineffective and could cause additional stress to students.
3. A student's level of concentration may be lower, more unstable and prone to interruptions whilst carrying out m-learning in a non-fixed environment. This is due to a) a higher possible amount of unpredictable noise, and b) a potentially busier environment with more likely distractions such as people coming and going. Hence, the selection of learning materials based on the concentration level of a student is important (Cui & Bull, 2005).
4. Similar to the level of the concentration of a student, the frequency of interruption (at a location) can be higher and more unstable when conducting m-learning in a non-fixed location. For example, the frequency of interruption in a café is likely to be higher than that in a library (Becking et al., 2004; Cui & Bull, 2005; Martin et al., 2006). The frequency of interruption in a location may affect a student's level of concentration and hence, students working in a non-fixed environment may benefit from having materials recommended to them based on the frequency of interruption at that location.
5. A student's available time should be used as the basis for the recommendation of appropriate learning materials whilst performing m-learning so that the right amount and/or size of learning materials can be appropriately recommended to students based on the available time that they have.

Other learning contexts which have been incorporated by other authors in their context-based/aware m-learning applications include the following. This is not an exhaustive list, and we discuss below the reasons why it is not important or significant for our framework to incorporate these.

- Learning difficulties and misconceptions within a topic (Cui & Bull, 2005). The focus of our framework is on ascertaining appropriate materials based on the students' location circumstances, rather than on specific elements within a learner's user model. This may form the basis for future work.
- Type of mobile device used (Martin et al., 2006). Our focus is not on the different types of technologies/devices being used by students; rather, we are investigating the internal and external contexts from a learner's point of view.
- Information about the collaborative partner for group learning (Martin et al., 2006). Our current focus is on independent and self-regulated learning, rather than collaborative learning.

Additionally, the foundation of our theoretical framework was informed by the established relationship mappings between the Dunn and Dunn learning styles model (1978), the dimensions of the context space formed by Wang (2004), and the four categories of contexts defined by Schilit, Adams, and Want (1994) and Chen and Kotz (2000). 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 was presented in detail in (Yau & Joy, 2006a, 2006b). The relationship mappings which can be taken as guidelines and/or considerations for developing pedagogical m-learning applications are summarized as follows.

- Learners may have preferences to study in different locations with different noise levels.
- Learners may have varying levels of motivation and degrees of responsibility for their learning.
- Learners may have different learning preferences and their performance in learning/studying may be dependent on the time of day and how mobile they are.
- Learners may have preferences for studying alone, together with peers, or in a learning group.
- Learners may have varying levels of attention and they may be affected more easily when they are performing m-learning. This is potentially due to the increased noise levels, movement, interruptions and distractions.

We have adopted three types of research methodology studies for exploring the potential feasibility of our framework; *pedagogical, usability,* and *technical* feasibility studies. We deployed an interview study, which is the focus of this article, as part of the pedagogical study to ascertain the m-learning requirements of intended users and hence whether our framework could be potentially used by them. The usability study used a "diary: diary-questionnaire" methodology to determine whether a diary approach can be used as a successful way of retrieving user's learning contexts. The technical study consisted of a software engineering design of the framework to illustrate whether an implementation of our framework can realistically take place using current technologies and function successfully.

This article is structured as follows: A literature review is provided in the following section. In the next section, we describe the methodology we employed to collect and analyze data from our interviews. We then describe and interpret the results of the data analysis. Finally, we present our conclusions and future work.

LITERATURE REVIEW

In this section, we first present the four m-learning generations to give the reader an overview of the past and present m-learning applications, and the challenges as well as the advantages of applications within the most recent generation (i.e., learning-contexts-aware adaptive). Thereafter, related work on m-learning organizer applications is discussed. Finally, a brief overview of psychology literature is presented relating to the learning process.

The Four m-Learning Generations

We have categorized m-learning applications into four generations; *non-adaptive, learning-preferences-based adaptive, learning-contexts-based adaptive,* and *learning-contexts-aware adaptive*. Each of these generations motivates the practice of the subsequent generations.

The initial basis for the adoption of m-learning was the portability of mobile devices and the accessibility of learning materials from them, either offline or online. This represents the first *non-adaptive* generation that was seen as "e-learning through mobile computational devices" (Quinn, 2000). These initial m-learning applications transferred existing e-learning materials onto mobile devices to enable portability. Generic learning content viewed by students is a common characteristic between applications within this generation, that is, a "one-size-fits-all" approach, and the needs of individual learners may not be catered for. The main focus of these applications was on providing learning content in a mobile format to enable access irrespective of location and time (e.g., exam revision via a PDA, see Bull & Reid, 2004), as well as where the use of desktop and/or laptop computers is inconvenient or impractical (e.g., a PDA guided tour tool in the Tate Modern museum, see Proctor & Burton, 2004). Becking et al. (2004) noted that applications of this generation must consider the various form factor issues regarding how learning materials fit on mobile devices. Further studies were identified by them in order to advance m-learning

research which relate to the three subsequent m-learning generations.

The second *learning-preferences-based adaptive* generation focuses on the importance of adapting applications to learner profiles or models (attributes typically include learners' individual learning preferences, learning strategies and learning characteristics). The concept of *adaptive learning* has arisen as a result of the previously-developed generic learning materials. The aims of these applications are to a) move towards delivering personalized and user-centered learning content to learners and b) to enhance the learning quality and experiences that they may give to users by matching the content to students' learning preferences (Laouris & Eteokleous, 2005). Distance learning students may especially benefit from a personalized application (Meisalo, Torvinen, Suhonen, & Sutinen, 2002) for two reasons. First, the learning goals of a diverse range of distance-learning students may not be met by a generic course. For example, they may have significant differences in their ages, educational backgrounds, family commitments and responsibilities, proficiency levels, learning needs and requirements. Secondly, these students work independently away from their education institution. Intelligent customization of learning materials may result in a higher level of understanding, becoming more motivated to learn and study, and achieving an improved learning experience. Similarly, m-learning students may benefit from adaptive learning because of the limitations of mobile devices, possible restrictions or distractions in m-learning environments resulting in possible lower levels of concentration, and the special requirements of mobile learners (Parsons et al., 2007).

It has been argued that presenting learners with learning materials that are consistent with the learner's preferences or characteristics, with structure and content that suits the students' learning styles, results in additional pedagogical benefits. These include increased effectiveness in achieving understanding of learning concepts and simpler acquisition or absorption of learning content (Riding, 1996). Extensive research results from Graf (2007) established, via two evaluative studies, that a relationship does exist between a learner's learning styles (as defined by the dimensions of the Felder and Silverman learning styles 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.

The third and fourth m-learning generations deploy the use of *learning contexts* within the applications for representing different learning situations, and stipulate the importance of selecting appropriate learning materials and activities for students (or filtering out inappropriate materials) based on these. A learning context is used to define and describe pedagogical components which can be incorporated into the design of m-learning applications to facilitate learning services. An encompassing definition of a learning context is "the circumstances … or conditions that surround the learning" (Basaeed, Berri, Zemerly, & Benlamri, 2007). These 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" (Yang & Chen, 2006). A learning context space has been defined by Wang (2004) which describes many contextual factors within six different dimensions.

Many challenges are involved in the process of the deployment of learning contexts within m-learning applications. Two stages are involved, retrieval of learning contexts, and determining whether or not an action is to be performed as well which approach is to be used.

- A method of retrieval of learning contexts is required in order for learning contexts to be deployable. 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. Proactive applications automatically retrieve this information via sensor technologies such as GPS (Jones & Brown, 2002). The elimination of the need to input values aims to provide ease of use and convenience to users. For location-tracking, GPS is ineffective indoors and in public transport and alternative technologies such as RFID tags must be installed in specific areas beforehand in order to detect the user's location. A further issue is how to maintain users' privacy and integrity (Synnes, Nord, & Parnes, 2003). Additional challenges include detecting a user's internal contexts (such as their emotions, intentions, and motivation).

We have classified interactive m-learning applications as applications within the *learning contexts-based adaptive* generation.

- Once the information is obtained from the retrieved learning contexts, the application determines whether or not an action should be performed. Actions can be either *active* or *passive*, and the learning contexts which are associated with these actions are known as active and passive contexts. An active context influences directly the behaviors of an application. For example, a handheld learning organizer may automatically detect, when the user walks past the library, whether the library books which they have reserved are available (Ryu & Parsons, 2008). A passive context is retrieved by the system but may not necessarily cause an action to be performed. For example, in Martin et al.'s (2006) 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 context-aware if it can detect and become aware of contexts using sensor technologies without the user having to provide this information; these applications are classified into the *learning-contexts-aware adaptive* m-learning generation.

Advantages of deploying learning contexts and developing context-aware m-learning applications are centered on the following two concepts.

1. **Improving the learning/studying situation:** Context-aware m-learning applications can enable real-time situated-learning to take place in real physical environments and increase learning effectiveness for students (Basaeed et al., 2007). Some materials are not desirable for the learner to study/learn in some locations and under certain circumstances. By filtering these out and selecting appropriate learning materials, learning opportunities can be improved and enhanced (Cui & Bull, 2005).
2. **Providing convenience to learners:** This enables the user to focus more on the learning situation and less on the technology (Winters & Price, 2004) and eliminates the need for users to provide information to the system (Schilit et al., 1994). Timely information to learners can be provided (e.g., in a museum). The output of the mobile device can be adapted to suit the current situation (e.g., adjusting font-size, volume, brightness, and privacy settings) (Schmidt, 2000).

Real practical benefits of using user-context information have been demonstrated by a number of authors within the context-aware m-learning field, as follows.

- The Learning Chinese application (Chen & Chou, 2007) was designed to facilitate

learners who carried a PDA equipped with an RFID reader and used this to access Chinese dialogs in order to facilitate real-life conversations with others in the Taipei underground stations.

- JAPELAS (Ogata & Yano, 2004a) was designed for learning Japanese expressions as these differ when used in different formality and when used speaking with people of a different/higher/lower rank. The system uses RFID tags which are attached to different meeting rooms (to simulate different formality). The learner uses a PDA and plays a role of a certain rank. Only appropriate expressions for that room and ranking are displayed on their device for them to practice with.
- TANGO (Ogata & Yano, 2004a) has been designed to help Japanese students to identify English words with physical objects which read, via RIFD tags on the mobile device, the word corresponding to the object.
- Learning Reminder (Ryu & Parsons, 2008) was designed to help students to find their way to different locations on campus (such as lecture halls). GPS is used for location-tracking and finding directions. Also contextual help is given to learners such as the notification of a book which has become available when they walk past the library.
- English Vocabulary Learning (Chen, Li, & Chen, 2007) uses WLAN positioning technologies to identify the learner's location. Then, given the learner's location, time for learning, and individual abilities, provides appropriate learning content in order to promote learner interests and performance.
- JAMIOLAS (Ogata, Yin, & Yano, 2006) simulates and helps foreign learners to recognize different physical situations/scenarios by presenting the visualizations of them, and then providing the correct corresponding Japanese impression/mimicry for them to learn.
- CLUE (Ogata & Yano, 2004b) makes use of the community context (i.e., the learner themselves and other learners surrounding them) for helping them to gain collaborative knowledge or to aid collaborative learning; making use of a "knowledge awareness" map.
- Bird- (Chen, Kao, Sheu, & Chiang, 2002) and butterfly-watching learning system applications (Chen, Kao, Yu, & Sheu, 2004) were developed to allow students to simultaneously watch real-life living things outdoors and access specific information and details about these from their mobile devices.
- The Savannah situated learning application (Facer, Joiner, Stanton, Reid, Hull, & Kirk, 2004) was developed in order to encourage students' understanding of animal behavior. This involves children simulating and acting out different animals. A particular task of the game involves avoiding some animal types for survival.

Related Work on m-Learning Organizer Applications

Related work includes that of Corlett, Sharples, Bull, and Chan (2005) who noted that the built-in software in mobile computing devices was not designed particularly to support students' learning activities such as attending lectures, reading course content, revising and meeting course deadlines. Subsequently, they developed a student learning organizer which 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; however, this tool was not context-aware. 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 (Corlett et al. 2005). Learning organizers have been used in other

m-learning systems (Corlett et al. 2005; Ryu & Parsons, 2008); however, these have not been for the purpose of capturing and retrieving users' contexts.

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 long-term retention of the material. (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 summarized by Valentino (2002): artificial grammar, sequence learning, and process control. These test paradigms can be conducted to collect and analyze participants' implicit learning relating to concept knowledge, procedural knowledge and knowledge of specific instances, respectively.

RESEARCH METHODOLOGY

The initial decision to adopt an interview study as one of our research methodology approaches was to examine and evaluate our framework from a pedagogical perspective, prior to its technical implementation. An exploratory interview study was the most appropriate way to gain the users' perspectives and to achieve these aims. "Interviews can provide rich data and give considerable insight into perception and attitudes. Misconceptions of misunderstandings about what is being asked can be recognized 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 the interviewer and interviewee (Taylor, Mistry, Sharples, Bo, & Ahonen, 2002). Grasso and Roselli (2005) argue that due to the nature of m-learning which can occur in highly unpredictable places and conditions, a precise and accurate analysis of the requirements of target users is essential during the design phase of m-learning applications. Related work includes an interview study conducted for the design of a mobile personal learning organizer (Ryu & Parsons, 2008). Ten university students were interviewed in order to identify their requirements for a personal learning organizer, particularly in terms of a) in which contexts they would be using the tool, b) which tasks they needed support with, c) the design features of the tool, and d) information that the tool should contain.

This interview study phase is critical for the refinement of our framework so that the user requirements of the framework can be made consistent with the learning requirements of students. Our framework would not otherwise be useful.

Our framework originally targeted undergraduate computing students, as we planned to use specific Java learning objects exclusively. However, we decided to expand the scope of the framework by excluding these specific materials to include a broader range of students. We recruited the sample via lecture announcements and advertisement leaflets and asked for voluntary participation. However, we also wanted to obtain the perspectives of students from other university departments and also include postgraduate students in our study. The

subject areas of our 37 interviewees include Computer Science and related (17), Business Studies and related (7), Mathematics (6), Engineering (2), Physics (1), Law (1), History (1), Industrial Relations (1), and European Cultural Policy and Management (1). All participants were university students, including both undergraduate students (in their 1st, 2nd, 3rd, and 4th year of study), and postgraduate students (master's and doctoral). The age range was 18–34. Our interview study commenced with a pilot run involving 5 students over 2 days and subsequently 32 students participated in our final interview study over 3 weeks. The same researcher conducted each interview and the duration of each interview was approximately 25 minutes. After having conducted around 30 interviews, the responses started to recur, that is, there were a limited number of different perspectives on each interview question. We had decided that further interviews would not assist us in revealing much more information. Hence, our interview study concluded when it had reached 37 participants. We were also constrained by time and financial resources.

There were limitations to our interview study. The sample size of 37 participants consisted primarily of students within our university which may not be representative of university students in general. In order for participants to answer our interview questions, they were required to have an understanding of how best they learnt and studied and to be able to both reflect upon and articulate across this information. However, the level of reflection and maturity shown by the students varied. Our framework was targeted primarily at university students and may not be representative of learners at other levels, such as school students. Some students may not actually know in which location they were most productive in studying in, it might have been a matter of trial and error, and/or gained through learning experiences. Further work will include this empirical research once the framework is fully established. Students may also not know whether they may be productive in studying in one location until they have actually studied there. Although this sample is one which has been obtained by convenience, the exploratory nature of the study does not render it invalid.

DATA ANALYSIS OF OUR INTERVIEW STUDY

Our interviews were recorded and then later transcribed for analysis. The pedagogical and exploratory nature of our interview questions required a qualitative data analysis method to be used because of the descriptive meaning and perspectives we wished to gain from this data. It was decided that the *content data analysis* method (Cohen, Manion, & Morrison, 2007) was to be used for this to allow categories of findings to emerge from the raw interview data. This method is primarily used for analyzing qualitative data. This process included grouping together the responses from participants for each interview question to enable categories or themes to be identified. When these themes have emerged, the responses corresponding to each category can be grouped together for further analysis, and the categories or themes can be given appropriate names. The process of our data analysis together with our research questions of this study are as follows.

a. How do intended users of our framework make use of studying in different types of locations to increase pedagogical effectiveness?
b. Which factors can distract their concentration when studying?
c. How effective do intended users find the use of a diary for time managing their studies?
d. How do the intended users view the use of mobile devices for learning or studying in different locations?
e. What are intended users' views on having materials suggested to them based on the five proposed learning contexts?

We address these five research questions individually in the following sections. We then

present the interpretation of our results to answer the three overarching research questions provided in the introduction to this article. We follow this with some scenarios of our suggestion mechanism.

How Do Intended Users of Our Framework Make Use of Studying in Different Types of Locations to Increase Pedagogical Effectiveness?

The variety of locations specified by participants revealed the typical locations where they conducted their learning and studying. We had classified these locations into four different types of environment.

- **Study-dedicated areas:** Department offices, computer laboratories, libraries, quiet rooms around campus, corridors between lectures (this is not a study-dedicated area but is institution based).
- **Home areas:** Students' bedrooms, living rooms, dining rooms, and kitchens.
- **Café areas:** Student lounges and university cafés.
- **Transpor:** Buses, trains, and planes.

Reasons for preferring and choosing the various locations to study in were specified and they correspond to the four different mutually non-exclusive types of environments.

1. **Wanting to study in designated studying areas:** 23 participants commented that they were motivated to study in these areas because a) these locations were generally quieter with fewer work-unrelated distractions, b) they were encouraged by seeing others studying (some may have lacked the psychological motivation to study alone in private areas), and/or c) they required library or computing resources. Group project students stated that they preferred to study in the learning grid (within our university) because it had good group-work facilities (such as presentation areas and whiteboards). A number of computer science students noted that they found it productive to work in the computer laboratories where they were able to collaborate and discuss programming problems with others. Learning in groups was mentioned as a preference by some participants as they worked more effectively when collaborating.
2. **Preferring to study alone:** 24 participants commented that they preferred to study in their bedroom of their home areas because they a) preferred to study in a closed environment free of distractions from other people, and b) found it more convenient and relaxing as they may listen to music in the background, take breaks and talk to others, and eat and drink as and when they wish. Some students who did *not* prefer this type of environment explained that they wished to distinguish between their work and home life.
3. **Enjoying the presence of others:** 4 participants specified that they preferred to learn/study in café areas because they a) enjoyed the presence of others around them when they were reading and brainstorming for ideas and/or gaining inspirations, b) must have their freedom whilst studying, for example, to make phone-calls, eat and drink, talk to people (i.e., the study-dedicated areas would not be suited to these students), and 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.
4. **Making use of idle time:** 6 participants noted that they had studied or studied regularly on transport such as buses, trains, or planes with the typical reason of making use of idle time. Some of these participants noted that they found it comfortable and

enjoyable to read (which is the typical learning activity performed on transport) and to make commuting time pass quicker. Another reason is the tight coursework deadlines. However, reported problems included not having enough working space.

The locations in category 1) would be classified as *fixed* environments, whereas the locations in categories 2), 3), and 4) would be classified as *non-fixed* or *mobile* environments.

The data show that participants may have more than one preferred location (or types of locations) for learning and studying in, and also a varying degree of preference for studying in different locations. For example, some of the participants specified that they must study in a certain location due to their specified study requirements and cannot study anywhere else; whereas for others it is a matter of habit and/or convenience. Two examples are given to illustrate the latter. First, a student may study occasionally in the library on the university campus during gaps between lectures because of the convenience, even though this may not be their preferred location. Secondly, the student may find it convenient to study at home on their home computer where all of their software programs were installed and available, but they were aware that they would be more productive when studying in the computer laboratories. However, it was noted that they were still able to be productive in any of these locations, and that sometimes a change of environment could also help them to study better and/or to gain psychological motivation where necessary. This was especially if and when they realized that they were procrastinating with their studies and could not be very productive.

Twenty-one participants noted that they often have had to study in places where they did not wish to study, for example, a) in laboratories for scheduled classes which they noted could sometimes get very hot and noisy, b) in department offices due to the vast amount of work necessary to be completed and in order to attend required meetings, or c) at the family home during the holidays which could sometimes be distracting because of the possibilities of spending leisure time with family instead of studying. On the contrary, 16 participants had noted that they were not restricted to studying in places where they did not want to study because they always had alternative places to go to. Students reported that negative effects in terms of their learning/studying could be caused if they were studying in places where or when they did not wish to study, knowing that there was a possibility of frequent interruption.

Which Factors Can Affect Concentration when Studying?

Distractions and interruptions in specific locations could disturb some students' concentration. There was a tendency for them to procrastinate and there was a higher possibility of discontinuing the work altogether because they were aware that their acts of studying were not effective anyway. Distractions and interruptions could affect more those students who had to hold longer sustained thoughts (such as when writing original essays and analyzing data, and solving technical engineering, mathematical or computer programming problems). Participants distinguished two types of distractions, helpful and non-helpful. Helpful distractions were those which, for example, took place in a computer laboratory and are work related (such as discussing programming assignments). They noted that studying here may be more beneficial than studying at home without any distractions, but lacking any work-related human interactions. Participants were often aware of which environments may be more distractive than others.

The main recorded factors that could break participants' concentration when studying are specified below. They are categorized into *external factors* that relate to the environment (a–e), and *internal factors* that relate to the learner (f–g).

a. **Noises:** including constant and sudden, people talking and keyboard typing. Different participants had reported different degrees of influences and sensitivity towards the different types of noises which affected their concentration. Some students reported that noises and distractions sometimes did not affect them when they had found their work very interesting or were engrossed in their work.
b. **How busy the environment is:** (i.e., the number of people around, coming and going)**:** this was noted as one of the main sources of distractions.
c. **The temperature of a location:** (e.g., if it is too hot or too cold).
d. **Light:** some students had preferences for studying with sunlight, whereas others had preferred bright or dim lights. This was usually a matter of preference and students were able to still study under other types of lighting that they did not prefer.
e. **The layout of the room:** including the tidiness of desks—some students had commented that the layout of the room could be a source of distraction for them, if the room was untidy or contained too much furniture or they were working on a very messy desk, for example. Graetz (2006) also supports this.
f. **The motivation of the learner:** had a huge effect on determining whether they would successfully carry out and complete their study activity. The lack of motivation (and whether they wanted to do other things instead of studying) is one of the main sources of internal distractions.

Graetz (2006) had observed that some students were more easily distracted than others when they were studying and that there was a relationship between the external and internal 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 prone to distractions and interruptions.

g. **The urgency of the task:** and whether there is a lot of pressure for completion due to tight deadlines, had an effect on how well a student can concentrate. A positive effect could sometimes be caused, leading students to concentrate better until the completion of it. However, it could sometimes have a negative effect which may lead to stress and this may cause students to become distracted.

Other factors, such as food and drink, were mentioned, as being a physical requirement that normally needed to be met in order to carry out study activities and could be a source of distractions otherwise. The time of day was mentioned as a preference as some students could work much better in some parts of the day than other parts. They could be unproductive if they tried to study during the latter times and may be more easily susceptible to both external and internal distractions.

How Effective for Time Managing Their Studies, Do Intended Users Find the Use of a Diary?

Many of our participants had regularly been using a diary for time management of their studies. Two types of diaries were used by participants—*paper based* and *electronic based*.

- Seventeen participants had reported that they had made use of *paper-based* diaries, and gave two main reasons. First, they preferred to use their hand to write down new scheduled events, cross off events which had been completed, and to update their diary as and when necessary; the diaries were also portable. Second, they felt that the paper diaries were more convenient than electronic ones because they did not require being switched on.

- Ten participants had reported that they had made use of electronic-based diaries on their PDA or mobile computer. Participants reported that the main feature they liked about having their diary electronically on their mobile device was that it offered an integrated and portable approach. This meant that they were able to use the same device for other activities such as reading and creating lecture notes, office applications, Internet browsing and other mobile phone services, and would be able to synchronize the diaries with their desktop or laptop computers.

Many advantages were common to the two types of diary usage. Planning and assigning time for tasks to be completed were made easier because the diaries allowed them to visually see the free blocks of time in day/week/month format, and priorities at any point could be viewed and planned. In addition, it could make it easier for tasks to be broken down and assigned into free slots and then to decide whether they had enough time for additional events. Events which required immediate completion could be noted down. Users could plan out everything to be completed on a day so that no time was wasted and in order to assign time for other activities. Finally, the act of planning, including the decisions on which tasks were to be performed, how they should be prioritized, and how to deal with possible distractions, particularly when carrying out many tasks simultaneously, could also be a strategy for reaching the desired goals (Claessens, 2004).

A third type of diary user was revealed—these were users who kept a *mental* diary. Ten participants had commented that they kept a mental diary and did not use a physical paper-based or electronic-based diary. There were two main possible reasons for this. First, participants felt that physical diaries were unnecessary and were not helpful for their time management. Second, they felt that they would become forgetful as a result of using physical diaries and were generally not accustomed to the use of these. These users noted that they were able to remember the events and tasks which they needed to attend and complete, as well as the deadlines for these, and could also plan and schedule their events and tasks clearly in their minds.

Two more categories of people existed who did not use electronic- or paper- based diaries and only loosely use the concept of a mental diary. Learners in the first category regarded themselves as too lazy and felt that the physical diaries required too much time and effort to keep and update. These learners are often forgetful of events even using a mental diary. Learners in the second category did not want a planned set of events to be carried out each day, but rather wanted to be spontaneous. These participants noted that they often carried out "mental scheduling," which they did not necessarily have to stick to strictly but did have an idea of what they were required to carry out that day.

In terms of how closely students followed the scheduled events in their diaries, three categories were identified—*closely follow it*, *loosely follow it,* and *like being spontaneous*.

- The users who closely followed their schedules usually did attend all their events as planned, aside from when there were exceptional circumstances, such as if they were ill or if something more urgent came up, when they would rearrange their schedule. Some noted if they planned and wrote down the events in their diary, they would keep all of them.
- The users who loosely followed their schedule may put a lot of events into their diary which they may or may not attend depending on their mood and/or whether they had sufficient time when the time arrived. They used their diary more as a reference to remind them of possible events to go to, or possible tasks to complete at any one time. They noted that the diary was not used to record a set of events that they must strictly adhere to, although

they did generally carry out the set of tasks that they had planned each day, especially the important events and meeting coursework deadlines. Some users had reported that they had missed less important events, such as social meetings, due to tiredness, for example.

- The third category of users liked being spontaneous and not following a set of scheduled events. This corresponds to the "mental" diary users. They carried out tasks selectively depending on their mood. They commented that they would not be able to follow a schedule.

All three types of users commented that they would keep all of their coursework deadlines.

How Do the Intended Users' View the use of Mobile Devices for Learning or Studying in Different Locations?

Computers and laptop computers were the two most common devices that participants used regularly for their studies. The locations in which they would use these devices to carry out their studying activities included the four types of environments, study-dedicated areas, home areas, café areas, and transport. Participants had used the following programs frequently as part of their studies.

- Internet browsers (including Internet Explorer, Firefox).
- Office tools, including Microsoft Office (including Word, Excel, PowerPoint, Access), OpenOffice.org, Latex, Adobe Reader, translation tools, dictionaries, and notes-linking (such as Tomboy notes).
- Programming tools (including Netbeans, Eclipse, Python, and developing environments for C++).
- Statistical programs (including Matlab, SPSS, Minitab).
- Drawing programs (including Corel Draw and Solid Works for Engineering).
- Others that are subject-specific, including Clampex and LCS lite.

Our interview study revealed three different user perspectives regarding the deployment of mobile devices (which includes portable laptops) for learning or studying with, as follows. It is interesting to note that some students may not want to use mobile devices for studying but may want to carry out learning/studying tasks in non-fixed environments.

1. **Enthusiastic:** 11 participants reported that they would (or already did) use mobile devices for their learning activities, for example, by accessing lecture notes and audio files both on- and offline.
2. **Recognizing potential:** 16 participants noted that they would use mobile devices for learning/studying under specific circumstances, such as commuting or attending conferences.
3. **Not useful**: 10 participants thought mobile devices would not be useful or that they had no need for them because of the following reasons. Wang and Higgins (2005) noted that many people lacked the psychological motivation needed for mobile learning, which supports our findings.
    a. They would prefer to sit down at a desk to study/learn.
    b. They do not want to study/learn when outside dedicated studying hours.
    c. They do not like technology and/or would prefer to handwrite.
    d. The device is too small and they don't feel comfortable using it.

These users' perspectives are critical in terms of determining whether users would deploy a mobile device for their studies, and whether an m-learning application or project would be successful. One of the noted reasons that they may not want to do m-learning was that they did not wish to study outside their dedicated hours; this was not necessarily re-

lated to the actual use of mobile devices for learning/studying.

When asked whether they minded their location being tracked by the GPS function of mobile devices, 28 participants did not mind. However, it was noted that an option of being able to switch off the GPS function must be available. Nine students felt that the location-tracking would be an intrusion and they would mind people knowing their locations mainly because they would not want others to know if they were not in lectures or at work or did not want to be contactable at all.

What are Learner's Views on Having Learning Materials Suggested to Them Based on the Proposed Learning Contexts?

In this section, we present the learners' views on the advantages and disadvantages of learning material recommendation in the five proposed contexts; *learning styles, knowledge level, concentration level, frequency of interruption,* and *available time*.

Views on Learning Material Recommendation Based on learning Styles

Participants' views regarding whether they were aware of their learning styles are first discussed, followed by positive points noted about having materials suggested to them based on their learning styles.

Most participants noted that they did have preferences over the types of materials that they liked to use. These preferences may be related to their course of study where sometimes particular types of materials are used more than other types. For example, a law student is more required to read complex notes or textbooks rather than read illustrated diagrams or pictures; a mathematics student is more required to try out a lot of active examples or exercises to see whether they have understood a complex theory. Twenty-eight participants considered that it is important to learn according to their learning preferences and to have a wide range of learning materials available to them, five were unsure and two thought it was not important. Thirty-one participants thought that it would be useful to have learning materials selected based on their *learning styles* because personalizing materials would mean that they would have a more effective learning experience. Two examples are given: 1) For visual learners, it may be useful to present them with animated materials or illustrative examples and graphs, and 2) for global learners, it may be helpful to present first a brief overview before the detailed information. One student noted that "learning things is difficult and any kind of solution to make things easier would be good."

Conversely, six participants noted that they would not like to have learning materials selected for them because learning preferences may change depending on what it is that they were doing, or from time to time, and they may prefer to select or create their own learning materials themselves since the act of looking for materials could help them learn or gain an overview of a topic.

Views on Learning Material Recommendation Based on Knowledge Level

Thirty-one participants commented that they would find it useful to have learning materials selected according to their knowledge level because (a) it can eliminate possible frustration which students may experience when given questions not at the right level for them, and (b) learning efficiency could be increased if information presented to them were at the appropriate knowledge level. Extra information on their weak areas could be provided to them to focus on improvement, and options to expand could be provided if difficulties were experienced in certain topics. The application could push the students to the standards required, if the syllabus was known.

Six participants noted the disadvantages of recommending learning materials based on their knowledge level because of a) they were

being skeptical about the application being able to find appropriate materials of the right knowledge level or of interest for them, and b) if allowed to view a wider spectrum of materials, they may have the chance to pick up some extra knowledge.

Our proposed application has been described as a *convenient information access application*. Participants noted that it had the potential (1) of providing them with different types of learning materials (e.g., summaries, abstracts, or extended information), which would save them time and effort to search themselves; (2) of targeting it to users so that they did not have to filter through lots of irrelevant information. Note that this also applies to the learning styles recommendation section.

Views on Learning Material Recommendation Based on Concentration Level

A range of responses were received when participants were asked about whether they would find it useful to have learning materials selected according to their concentration level. For example, one student noted that it would be good if they were given podcasts to learn with using earphones in a noisy environment which would be easier than having to read notes. Or similarly, they would find something easier to concentrate on when they were aware of their lower levels of concentration. However, another student noted that this would not be helpful because although they were working in a non-ideal and distractive environment, they would still have to do questions at the same level of complexity. The application should not then suggest easier problems to accommodate the fact that they may not be as good at answering them.

Additional issues noted by participants were that 1) they did not know how their concentration could be extracted and conveyed to the tool. 2) One had to concentrate in order to learn. 3) Perhaps if they stopped concentrating, a break would be beneficial for them, rather than having different materials recommended or changed; because breaks were often necessary to sustain concentration over a long period. A refined requirement of the framework may be that the tool should only suggest materials at the beginning of the session and not make any alterations or further recommendations if the students' circumstances change, unless specifically requested. The level of reflection which is required to understand materials is important and this could determine which type of materials would be suitable for which location. Similarly, one participant noted that if they were reading the news, as long as they knew where they stopped before they were interrupted, they would be fine with simultaneously or intermittently doing other tasks. On the other hand, if they were reading for example a journal article, then much more careful consideration would be required. In the latter scenario, they would not be able to be distracted by distractions or interruptions and be equally efficient and productive.

Views on Learning Material Recommendation Based on Frequency of Interruption

Many students were concerned about whether materials could really be selected according to the frequency of interruption at a location, how this frequency could be obtained and how this would affect the students' learning in that location. Positive feedback included that this could be a useful feature for keeping track of the place of learner's materials if they were interrupted, and also selecting smaller amounts of materials for learners if they were in locations with high frequencies of interruptions. Suggested *strategies* that the framework could apply with regards to a certain frequency of study interruption were:

- If they were interrupted often, then an outline and/or an abstract level of the presentation of materials would be appropriate.
- It would be appropriate to delay the more detailed and prolonged problem tasks until students were situated in a better environment where they could concentrate for

a longer period of time.

Possible distractions and interruptions are almost unavoidable in any location, either internal (relating to the learner) or external (relating to the environment).

Views on Learning Material Recommendation Based on Available Time

Relating to the selection of materials according to the available time function, most students agreed that this would be a useful time-management feature. Participants had different preferences for the kind of tasks they would prefer to perform in different available time slots. The following examples are given by different participants:

- If they only had half an hour to spare and had both reading and programming to do. Even though the programming task might be more urgent, it would not be possible for them to do it in half an hour. Therefore, it would be appropriate if the tool knew that and selected the reading for them to do.
- A reasonable amount of time is required in order for them to be fully engaged in their work. For example, they would accomplish more in one session lasting one hour than two sessions lasting half an hour each. If the framework could suggest useful materials for longer periods of time rather than shorter periods of time that would be useful. Similarly a summary could be selected for students who only had ten minutes prior to a lecture. If they had more time, they could read more.
- Some participants would like to finish the whole topic at once, rather than being interrupted half way through. Thus, given that they knew how much time they had available, the level of detail and the conciseness would be dependent on the time available.

Additional noted disadvantages of the overall learning material recommendation include *missed opportunity of learning* and *distrust*.

Missed opportunity of learning—Some participants noted that sometimes it was the act of looking for something that helped them to learn. For example, they may not possibly have known about certain materials if they only used materials which they were given. Some participants insisted that they would want to find or make the materials themselves. For example, one participant noted that they would need to draw their own spider maps to obtain their understanding on a topic and would not be satisfied with any that had been reproduced. Another participant noted that it would be useful to be able to see everything and in all different directions and did not like systems which could possibly limit their potential.

Distrust of using such an application—Some participants noted that they did not think that a tool could suggest materials that would be suitable for them and/or what they would be looking for. For example, would an accurate representation of their learning styles and knowledge levels be obtained? In particular, one student noted that there may not be a knowledge level for fields such as social sciences, perhaps only more for factual topics such as sciences. Some participants noted that finding learning materials themselves would take less effort, rather than having to go through a program that they may not understand. Some participants noted that learning preferences might be difficult to identify, and they were also subject to change and could be different for different activities that they were performing. They noted that it might be initially that they wanted materials (such as some examples) then later something else, but they would like to be the ones who chose, and not be passive recipients, or forced into a specific way of doing things. It might be useful for initially suggesting the first materials at the beginning but then they would like to see the broad range of things to choose from. They noted that the application should still allow users the option of doing things manually. Some students commented that they

would not pay for the tool even if they thought it would be useful.

Interpretation of Data

Our data was interpreted to answer our three research questions presented in the introduction.

RQ1. Can a Proactive Method of Retrieving Learning Contexts, Without the Use of Context-Aware Sensor Technologies, be Successfully Established?

The motivation of the research exercise relating to this question is to ascertain whether a self-regulated learning approach of using a learner schedule could be used a) as a simple, yet effective and accurate method of retrieving the users' time and location contexts proactively, and b) as a means of time management for students' studies. This approach has a workload and would require a sufficient amount of self-discipline by users to input, update, and adhere to both their scheduled study-related and study-unrelated events in an electronic-based learning schedule on a mobile device. It is important to note that the participants who commented that they kept a diary and followed their scheduled events in their diaries were especially those students who showed that they had a number of self-regulatory characteristics. These included that they used their diaries as a motivational tool for planning important tasks that they would adhere to in the allocated time slots. Hence, we can conclude that the learning schedule can be an effective and accurate means of retrieving the learner's available time and location contexts, and especially those of a self-regulated learner.

Students have informed us, via the interview study, that they did follow their events, to a certain degree. However, the interview study cannot be relied upon as the only source of data for establishing whether they really did follow their events. Additional work was required, and we conducted a subsequent diary study, based on the "diary: diary-interview" approach (Zimmerman & Wieder, 1977). Preliminary results from our diary study showed that out of 275 events recorded by 32 participants during a period of 2 days, 251 of those events went as anticipated. This means that students did successfully adhere to their scheduled study-related and study-unrelated events, with a rate of 91%. (The research methodology and further analysis of our diary study will be the focus of a subsequent article.)

We had established that many learners did use a paper-based or electronic-based (mobile) diary on a regular basis. Therefore, for these users it would not be an additional burden on top of their workload. The analysis showed that a number of paper-based diary users would switch to electronic-based diaries if a) the input of diary events was sufficiently easy and trouble-free, b) they had an electronic-based diary made available to them, and/or c) they were not against the use of mobile technologies. An interview study consisting of 15 diary users was conducted by Brown and Cranshaw (1998), in which it was noted that one of their participants commented that they had never thought that they would use an electronic-based diary. However, the participant was convinced within only a period of one week and immediately switched their paper-based diary to an electronic-based one. Hence, it can be concluded that users would be willing to use electronic-based diaries, given that they had no objections to using mobile devices and the input was relatively straight-forward. Users would also be more inclined to use electronic-based diaries if they used and found other accompanying software applications useful on the mobile device. It is interesting to note that those students who used an electronic-based diary as well as other software applications on their mobile devices were computer science students.

RQ2. Which Learning Contexts are Necessary Attributes of a Pedagogical Mobile Learning Framework?

To answer this question, we first needed to ascertain which characteristics of an environment constituted a good or a bad learning environment for students, so as to distinguish which are the important learning contexts that should be considered. Students often chose environments in which they believed they could concentrate well for their learning/studying activities, and it was revealed that preferences for different learning environments, as well as characteristics within the environments, existed between students. The differences may be for different levels of noise, levels of busyness (in the environment, such as the amount of people coming and leaving), and the frequency of interruption. Similarly, they may have chosen environments which they found motivating for them to learn/study in. Hence, there may not be good or bad environments, because one environment may be good for one student, but bad for another student.

The differences in the preferences for the types of learning environments and the characteristics within them across students mean that a generic m-learning application would not be suitable for them. For example, if an application were to select a type of learning material for a specific type of environment (such as library), due to the fact that some students would be able to concentrate well here and others would not, a type of learning material with a pre-assumed concentration level required for the task may be adequate for some students but not for others. Hence, the construction of a personalized m-learning application may be suitable for suggesting or adapting learning materials to students based on their individual learning environment preferences.

We consider that this is a new finding within the context-aware m-learning field as past and current literature and applications have not dealt with the issue of different learners having different m-learning and/or learning environment preferences, and using these as the basis for creating personalized m-learning applications. The pedagogical benefits for students of using such an application and whether it will be successful in terms of the students' learning outcomes have yet to be determined, evaluated and proven. We believe that the evaluation results gained from such an application will help us form future m-learning pedagogy and would be an interesting and useful contribution to our community. This will move towards the successful development of m-learning applications which can respond to the individual and contextual needs of learners. This is still a challenging topic; we must first define what the different m-learning preferences and learning environmental differences could consist of, and then be able to describe a mobile learner in terms of these preferences, as well as constructing a pedagogically effective m-learning application for providing appropriate adaptations based on this knowledge.

Construction of a taxonomy for describing different learner's m-learning preferences relating to the possible recommendable learning materials for these preferences may also be useful for building personalized m-learning applications. A preliminary m-learning preferences taxonomy can be formed, consisting of a learning environment dimension with four attributes: *study-dedicated areas, home areas, café areas,* and *transport*. Further data collection, developmental and evaluative work is required in order to construct this taxonomy and a personalized m-learning application. Note that these are not the focus of this article, due to time and space constraints, but will form part of our future work.

The analysis of the significance of the five proposed learning contexts is presented, as follows.

1. **Learning styles:** This is both a significant and insignificant learning context for learning in a non-fixed environment and/or with mobile devices in scenarios, where students do and do not have strong learning styles,

respectively. Similarly, although a learner may have strong learning styles, it does not necessarily mean that they want to restrict themselves to learning and studying with only materials suitable for that particular learning style. It may be appropriate to incorporate an additional option to ask users whether they would like their materials selected with consideration of their learning styles. Note that this is only applicable for materials within a given topic such as Java.

2. **Knowledge level:** This is a significant learning context 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. It was revealed that the motivation of the learner has a significant impact on their concentration level. For example, a highly motivated student is able to concentrate better, despite environment distractions, and can also eliminate internal distractions. Using the interview data analysis, we hypothesized that additional factors—noise, busyness, temperature, frequency of interruption, urgency of task, and motivation—also have a relationship with the student's concentration level. Note that the first four relate to the characteristics of an environment, and the final two relate to the characteristics of a learner. Results were gained from our diary study, which suggested that the highest positive correlation existed between the motivation and the concentration level of a student. Hence, the motivation level of a student may be a more significant learning context than their concentration level. Therefore, we propose that the concentration level context can be replaced by the motivation of a learner context, and the latter to be used for the suggestion of learning materials to students.
4. **Frequency of interruption:** This is not a significant learning context in our 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 and/or interrupted either externally, and/or internally, in both fixed and non-fixed environments.
5. **Available time:** This is a very significant learning context because it was revealed that 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.

RQ3. Which Learning Materials Should be Recommended to Students Under Different Circumstances?

First, we describe the insights gained from our participants' responses. The data shows that a large proportion (over two thirds of our participants) were either enthusiastic about mobile devices or would find them a possible or potential means of learning. In addition, it was revealed that although some of the participants opposed to the idea of learning with mobile devices, they had frequently learnt/studied in different non-fixed locations, usually using paper-based materials; this we also consider a factor related to m-learning. We decided that as part of our framework, it would be appropriate to not only store learning objects in our repository, which would be recommended to students for learning on the mobile device based on their learning situation, but also to provide a recommendation mechanism for those students who may not be using a mobile device but would rather would like to learn/study with paper-based materials and/or on desktop/laptop computers in different fixed or non-fixed environments.

We believe that our framework has the potential to improve students' learning/studying processes by suggesting materials to them which are appropriate for different learning situations. In essence, one branch of the framework is a recommendation mechanism which suggests appropriate materials to learners for their learning situation, not on a mobile device. However, the mobile device would be used as a learner schedule and a means of retrieving the learner's situation so that appropriate materials can be suggested to them. Note that, however, the range of the different learning materials which a student is required to perform will need to be input by the user. The scope of our framework is, hence, expanded to include any student, and not limited to only students learning Java. Learning objects of other topics/subjects may also be incorporated into the suggestion mechanism, as part of our future work.

It was revealed that some students may not always like the selection of materials for them based on their learning situation because they would like to be the one who chooses and have control over their learning activities. However, the majority of students can benefit from recommendations of learning objects and/or learning materials appropriate for their learning situation, given that they are indeed appropriate for the individual learners. Note that often students themselves may select materials for them based on a) how much available time they have at the particular point in time, b) how urgent the task is, and/or c) the sequential order that some tasks need to be performed in. Generally speaking, the higher the motivation and concentration level a student has, the higher the possibility and capability of them performing a) more difficult tasks in terms of cognition, such as doing Mathematical equations, and b) tasks which require a high level of reflection such as data analysis, essay/report-writing; and vice versa.

The results of our diary study suggest that participants would choose shorter and easier learning/studying activities such as planning, brainstorming, reading, or none at all (because the time available is too short), when they had a shorter time, for example 15 minutes or less. When they had more time available, for example half an hour or more, they would carry out more difficult tasks requiring more concentration such as writing assignments and/or coursework, programming, and so forth. Hence, there is also a relationship between the time available that a student has and their motivation for carrying out a particular learning and studying task. Note that we are currently working on the recommendation rules within our recommendation mechanism framework.

Scenarios to Illustrate the Rationale of Our Framework

Four scenarios with four different users illustrate the potential outcome of the intended recommendation process of our final framework. Note that these relate to the suggestion of offline materials to students because a) we would like to illustrate in the scenarios the non-requirement of the use of mobile devices, and b) learning in different environments can and often take place for students in their everyday lives, without the use of mobile devices.

- **Scenario A:** John is a first-year computer science undergraduate student, an active learner, and a novice to the Java programming language. He has 3 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 at 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 for 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 await him for completion include *an assessed engineering problem sheet, a project report to be handed in next week,* and *a review of some example problems*. He chooses at this location to do the review of the example problems, and additionally think about the structure of the project report and write down some notes. His available time before his meeting does not allow him to start and make significant progress with 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 café. She cannot concentrate very well there and may be interrupted by some friends who may also be there. The materials which await her for completion 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 she feels that she will make some progress with it even though she may not be able to concentrate so well there. She will also read through the problem sheet and see if there are questions or difficulties with it in which case she can ask the tutor in her next seminar. She decides to attempt at 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 and audio learner, and has an advanced knowledge of the law topic. She has an hour and a half until her next meeting with her project supervisor, and has currently just boarded her train which takes an hour to arrive her station. After she gets off the train, she will need to take a bus for 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 she will get off. The materials that await her for completion include *some seminar reading, some lecture note reading,* and *an assessed essay of 5000 words*. On her 1-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 she cannot concentrate well there.

CONCLUSION AND FUTURE WORK

Research in context-aware m-learning and its applications is still in its infancy, especially in terms of its pedagogical components. We have developed a *mobile context-aware learning schedule (mCALS) theoretical framework* in an attempt to work through some of the pedagogical challenges within this field as well as to gain an insight and understand the m-learning pedagogy that is required for the construction of an m-learning framework, which meets the needs of learners. In this article, we report how an interview study has helped us to ascertain the potential feasibility of our m-learning framework for use within different learning environments. In particular, it has helped us to

determine the significance of our five proposed learning contexts, and the validity of using a learning schedule to store and retrieve time and location contexts. Due to the insights gained from the interview study, it was revealed that although some students may be opposed to the use of mobile devices, they frequently make use of learning and studying in different non-fixed environments. Hence, if our framework were to consider students' offline studying materials, there may be pedagogical benefits for suggesting materials to them which may be appropriate for the environment that they are situated in. It may also be useful to consider the individual m-learning and/or learning environmental preferences of learners within such an application.

Mobile technologies will continue to advance, but the research work on m-learning pedagogy to accompany this requires much more effort. Without an understanding of m-learners' needs in different learning environments, the potential use and success of m-learning applications may not be reached and cannot be maximized.

The contributions of our research are as follows.

- The development of a simple, yet effective and successful proactive approach in retrieving user's available time and location contexts, which can be especially beneficial for self-regulated learners.
- The proposal of a taxonomy to be constructed to incorporate students' individual learning environment preferences, which relate to the possible recommendable learning materials for these preferences. Future m-learning applications would benefit from this. Relating to this is the proposal of a personalized m-learning application, which takes into account learners' individual m-learning and learning environmental differences as the basis for suggesting appropriate materials for them.
- The significance of our five proposed learning contexts within a context-aware m-learning framework is shown. It was established that the motivation attribute of a learner had a high positive correlation to the concentration of the learner. Hence, we propose that the motivation of a learner in performing a particular task at a particular time at a particular location should be considered in m-learning applications. The awareness of this may result in understanding whether a learner would or would not perform a particular task successfully. Similarly, it may also be used to determine whether or not an application would be used successfully by students.
- The type of materials that may be appropriate for students in different learning situations.

Our future work includes a) the detailed analysis of our diary study for the triangulation of data together with our interview study to inform us about the results regarding our three research questions, b) a set of recommendation rules for suggesting appropriate materials to students based on their learning circumstances, c) a taxonomy for describing students' individual learning preferences, and d) the construction of a software engineering design of our framework, which can be used to implement a software application on a mobile device.

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Jane Yin-Kim Yau is a doctoral candidate from the Intelligent and Adaptive Systems research group at the Dept of Computer Science, University of Warwick, UK. She is expected to complete her thesis in September 2009, which is focused on a mobile context-aware framework for managing learning schedules. She obtained a MSc in computer science in 2004 from the same research group and her work was focused on learning objects and the teaching of Java programming.

Mike Joy is an associate professor at the Dept of Computer Science, University of Warwick, UK. His main research interests are educational technology, computer science education, agent-based systems as well as educational technology object-oriented programming and Internet software.