DESIGNING AND EVALUATING THE MOBILE CONTEXT-AWARE LEARNING SCHEDULE FRAMEWORK: CHALLENGES AND LESSONS LEARNT

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ABSTRACT

Challenges in designing and evaluating mobile learning (hereafter, abbreviated as m-learning) applications are well-documented and this applies especially to those applications that are context-based/aware. The purpose of this paper is to present the challenges faced in the design and evaluation of our mobile context-aware learning schedule (mCALS) framework (Yau and Joy, 2008) and to discuss the resultant lessons learnt. The aim of the mCALS framework is to suggest appropriate learning materials to students based on their learning preferences and current learning contexts, namely, their learning styles, knowledge level, concentration level (at the point of usage), and frequency of interruption (at the location). It uses the learner's learning schedule (i.e. electronic learning organizer) to determine their possible location and available time, at the point of usage. Activities from three different perspectives – pedagogical interview study, usability diary study and technological feasibility study – have been conducted to assist us in the construction of refined user requirements of the framework and to demonstrate that the framework is feasibly implementable at present. Further activities are required to be completed in order to validate our framework, which are also discussed.

KEYWORDS

Mobile Learning, Context-aware, Design, Evaluation, Challenges.

1. INTRODUCTION

Difficulties and challenges in designing and evaluating context-aware m-learning applications are well-documented (Sharples, 2006). Due to the intricacies of the issues prevalent to m-learning, an interdisciplinary and diverse research methodology should be deployed (Vavoula *et al.*, 2009). Three different perspectives – *pedagogical, usability* and *technological* – should be considered when devising design and evaluation methodologies for m-learning (Yau and Joy, 2009a), discussed as follows.

- A pedagogical evaluation assesses the user's learning experiences in terms of the learning process, opportunities, and/or learning outcomes. Challenges concerning evaluating an m-learning experience are a result of the unpredictable factors which it may constitute, for example, the location of learning, layout of space, social setting, learning objectives and outcomes, learning methods, activities and tools. A possible lack of well-defined m-learning objectives also makes it difficult for them to be measured or assessed against., The collection of m-learning experiences may necessitate the tracking of individuals or groups who are moving across different locations; the locations may include various public and their own private spaces (such as library, café, transport and home). Practical and ethical issues are involved for both the 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 (Vavoula *et al.*, 2007).
- A usability evaluation assesses the application in terms of its usability aspects and utility of functions. There are two main measurable aspects of usability. The first aspect is *system 'learnability' and efficiency*. This measures how easy the system or services 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 is the language of the system, how much feedback is given from the system and how much

technical maintenance costs. The second aspect is *system design*. This measures how easy the data is to be interpreted, how fast data can be inputted, how satisfied the users are with the system, if any errors occurred in the system, how visible the system is, the use of any physical constraints, whether actions can be invalidated, whether users have control over the system, if it is flexible, whether the design include the users' knowledge base, if there are any cultural constraints and if it meets existing standards (Taylor *et al*., 2002).

- A technological evaluation assesses the technology and the user's experience relating to it. At least an implementation of a prototype of the software application needs to be available for a mobile device for users to evaluate and provide feedback regarding it. The evaluation process typically involves a) an *evaluator* who plans and conducts the evaluation to be taken place, and b) a *volunteer* who tests the different implemented application functions on a mobile device for a period of time. The volunteer may be asked to provide information about the application usage before, during and/or after the hands-on experience with the device. Different ways of providing this information can take place – (1) an automatic data collection technique such as the use of data logs on the device can be used to collect dialogue responses, navigation information, and user choices, etc; (2) an interview may take place after the evaluation of the application to obtain feedback about the various aspects of the device usage; (3) a questionnaire may be filled in during or after the evaluation, for obtaining feedback.

The purpose of this paper is to present the challenges faced in the design and evaluation of our mobile context-aware learning schedule (mCALS) framework (Yau and Joy, 2008) and to discuss the lessons learnt. The aim of the mCALS framework is to suggest appropriate learning materials to students based on their learning preferences and current learning contexts. It can be viewed as a suggestion mechanism framework. It uses the learner's learning schedule (i.e. electronic learning organizer) to determine their possible location and available time, at the point of usage. This information is made available to the framework, and along with their learning styles, knowledge level, concentration level (at the point of usage), and frequency of interruption (at the location), appropriate learning materials are selected for students.

The initial theoretical framework was designed and developed via an extensive literature review. The review has helped us to establish five main components of a context-based/aware suggestion mechanism, based on the related work of Martin and Carro (2009), Cui and Bull (2005) and Becking *et al.* (2005). The five components are as follows:

1. *A method for detecting and retrieving learning contexts* – through either users' requests to input these and/or automatically retrieval of them 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 adaptive/suggestion mechanism* – for adapting and/or selecting appropriate learning materials, activities or services to learners, based on the information provided by their user and contextual models.
5. *A database of learning materials, activities or services* such as a learning object repository is made available for providing appropriate learning materials to students.

Two human-centered research methods – interview and diary studies - have been completed in order to refine the user requirements of our framework. A further technological feasibility study was completed in order to determine whether the framework can be feasibly implemented at the current time. The combination of these three studies, each was focused on pedagogical, usability and technological perspectives respectively, had assisted us with the overall design of the framework suitable for our intended users. A full implementation of our framework was not possible due to time constraints and logistical difficulties. Therefore, we intend to use alternative evaluation methods in order to determine how our proposed design may be received by its intended audience.

The remainder of this paper is as follows. In section 2, we present a literature review of context-based suggestion mechanism applications. In section 3, we discuss the research methodology that we have used in the design and evaluation of our mCALS framework, particularly focusing on the challenges and lessons learnt in the process. Finally, in section 4, we present the conclusions and future work.

2. LITERATURE REVIEW

Currently, there are three suggestion mechanism applications which are most related to our mCALS framework.

Martin and Carro's (2009) 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 learning styles, 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. There is an option which, if appropriate, according to the user's learning contexts, would alert them about the availability of an activity, and interrupt them. 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 for them. Their CoMoLE suggestion mechanism is presented in Martin *et al.* (2007) and a specific learning environment incorporating the subject 'Boolean Algebra' was implemented. This 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 further learning environments were developed – 'Data Structures' and 'Operating Systems', in order for first and second grade university students respectively to provide feedback on. Extensive results and discussion were presented on their two case studies.

Cui and Bull's (2005) TenseITS system 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 – *their knowledge level, misconceptions of the English language* and *difficulties in learning the language*. The application operates by first requesting the user to input the values of the four learning contexts, which are to be selected from multiple choices, 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. The TenseITS prototype which incorporates their set of suggestion rules has been completed and has been deployed by their intended audience i.e. Chinese learners. However, feedback on the usage of the system relating to, for example, the appropriateness of the suggested materials, was not obtained.

Becking *et al.*'s (2005) didactic profiling system includes four categories – *situation, learner, learning objects* and *participation*. 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, restrictions to read, write, listen or speak in that situation). The learner category includes *level of concentration/distraction* (self-evaluated ability to keep concentration despite of environmental interferences), *previous knowledge relating to the topic*, and *previous knowledge relating to technology*. The learning objects category includes *instructional goals* (standards appropriate for the conditions of mobile learning) and *learning content*. 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). The use of their first prototype was concentrated on the use of PDAs and Pocket PCs. During system usage, the user specifies their current situation by selecting multiple choices. Their suggestion mechanism provides a set of identified learning materials after the evaluation of all the relevant rules for the specified learner profile.

3. RESEARCH METHODOLOGY

The design and development of our mCALS framework has been an incremental process. Initially, we used an extensive literature review to inform us of the framework components (see Introduction). We deployed three research activities from three different perspectives – *interview study* (pedagogical), *diary study* (usability) and *technical feasibility study* (technological). These were conducted to inform and guide further design and more well-defined user requirements of the framework. In 3.1-3.3, we discuss the challenges and lessons learnt from the design and development of our framework from the three research activities. In 3.4, we provide a brief discussion of forthcoming evaluation research activities in order to answer our remaining research questions and to validate our framework.

3.1 Pedagogical Interview Study

Our mCALS framework was originally designed to be a generic suggestion mechanism framework, which would be targeted at learners in different subjects, and learning materials of different types can be supported. We obtained the views and opinions of 37 participants in our interview study relating to four topics – *studying in various locations, diary usage for time management, use of mobile devices* and *learner preferences and characteristics*. One of the difficulties was to decide on an appropriate group of students to participate in this study, in order to provide us with the requirements of the framework's intended users. We decided to have a diversified group of students in different courses and years of study, both undergraduates and postgraduates, to participate. Consequently, in light of the collected data, the opinions and feedback were much more diversified (for example, a diversified range of learning strategies was informed by participants who had used them for their different courses of studies). In hindsight, if we had used a group of only computer science students in the interview study, the collected data may possibly have been much more similar, as preferences and characteristics of computer science students may be more alike. For example, an investigation into the learning preferences of computer science students established that they preferred to use visual or diagrammatic aids to obtain information more than in a written or oral form (Benest *et al.*, 2003).

A qualitative data analysis of our interview study is presented in Yau and Joy (2009b, 2009c). The main findings in Yau and Joy (2009b) showed that 1) many participants had used a learning schedule for time management of their studies and it is seen by many of them as an effective self-regulatory organizational tool; and 2) the significances of the five proposed learning contexts were determined. Knowledge level, concentration level and available time were established as significant contexts in a suggestion mechanism. Significant benefits had *not* been established by determining appropriate learning materials for different frequencies of interruption at a location. Learning styles was considered as both a significant and insignificant context in a non-fixed environment and/or with mobile devices in scenarios where students do and do not have strong learning styles, respectively.

The main quantitative findings in Yau and Joy (2009c) showed that there were 1) a strong positive correlation between the *hard-working* characteristic of a learner and how closely they followed their schedules; and 2) a strong correlation was obtained between the *enjoy studies* characteristic and their views on m-learning. This 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. It has been shown through the qualitative and quantitative data analysis that the learning schedule can be used as a goals-setting tool for students to self-regulate and motivate themselves relating to their studies. Hence, these findings support that the mCALS framework can be potentially used as a self-regulated learning tool for supporting self-regulated learners.

Additional data collected in this study allowed us to design the preliminary architecture of a personalized m-learning application based on user's dynamic m-learning preferences (for example, location of study, noises/distractions in a location, and time of day) (Yau and Joy, 2010). As far as we are aware, existing and current research and studies on mobile learner preferences are very limited. We have currently only located one related publication – Bhaskar and Govindarajulu (2010). They had conducted a case study and their results show the relationship between *mobile learner preferences* of a learner and their preferred *mobile learning activity*. Some of their results indicate that 1) *texts* and *audio* content types were preferred by learners in the *walking* context; 2) when learners were *stationary*, they preferred to use *video* and *image* content types more; 3) *images* were highly preferred in group-learning situations; and 4) *audio* content was highly preferred by learners in *travelling* situations.

3.2 Usability Diary Study

Our mCALS framework deploys a learning schedule (i.e. the user's electronic organizer) to retrieve the user's current learning contexts. This means that users must be able to plan, update and adhere to their schedules. The diary study which was a paper-based activity was conducted to collect data to determine whether participants could plan and conform to their schedules. 32 volunteers had participated in the study, each for the duration of two days. Extensive results of this study are presented in Yau and Joy (2009a). We aimed to establish a set of suggestion rules for our framework for all learners using the data collected from the interview and diary studies. However, it came to light that materials that may be appropriate to learners may vary from person to person, even if they had the same learning preferences and contexts.

We have modified the suggestion rules of Cui and Bull (2005) as it was found that when students were highly motivated about their work, their concentration level was higher than if they were less motivated about their work; hence there is a positive correlation between a student's motivation level and their concentration level. Further activities will be performed to validate the modified suggestion rules, as discussed in 3.4. The modified suggestion rules are incorporated into our framework and are as follows (the concentration level and frequency of interruption contexts used in Cui and Bull's (2005) work are replaced by the motivation level context):

a) Tutorials, exercises and revision materials are selected
- If motivation = any level and available time > 30 mins.

b) A tutorial and an exercise relating to a single topic materials are selected
- If motivation = medium and available time = 15 to 60 mins or
- If motivation = high and available time = 30 to 60 mins

c) A tutorial and a short exercise materials are selected
- If motivation = high and available time = 15 to 30 mins or
- If motivation = medium and available time = 15 to 60 mins

d) A tutorial material is selected
- If motivation = medium and available time = 15 to 30 mins or
- If motivation = low and available time = 15 to 60 mins

e) Revision materials (on a topic) are selected
- If motivation = low and available time = 15 to 30 mins

f) Tutorial on a different topic materials are selected
- If motivation = any level and available time < 15 mins

g) A new topic material is presented
- If motivation = medium or low and available time < 15 mins

Refined user requirements of our framework are as follows:

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.

i. 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 it accurate and up-to-date.

ii. The framework is able to create and maximise the opportunities for self-regulated students have for learning/studying.

iii. 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).

iv. Learning materials should only be suggested at the beginning of the learning session, and not be altered subject to contextual changes.

2. The use of learning objects is appropriate for deployment in the framework design.

3. Four contexts for the recommending learning materials - *learning styles, knowledge level, concentration level,* and *available time* – are of pedagogical significance. (Frequency of interruption was found to be *insignificantly* negatively correlated to students' concentration) (Yau and Joy, 2009b).

4. The types of learning materials/objects to be recommended to students based on their situations are appropriate; recommendation rules are described above.

3.3 Technological Feasibility Study

The technological feasibility of implementing our mCALS framework as a software application on a mobile device using current technologies was conducted, prior to its full implementation. This process draws together a set of compatible mobile and context-aware technologies at present and can be used as a reference point for implementing generic mobile context-aware applications. Four research questions were answered in this process, as follows.

1. Can the learning schedule approach be implemented? Currently, most Windows CE-based, Apple Mac-based and Linux-based mobile computers, smartphones and PDAs contain built-in electronic diaries/calendars. A user's location and available time at a particular point in time can be retrieved from the learner's events stored on a calendar application. Users are to include for each of their events the following information – geographic location, type of location, time start, time finish and nature of the event. Via the standard Microsoft Import/Export (from and to vCal/iCal) feature, Outlook calendar applications can automatically convert event information into iCalendar format (and vice versa). The purpose of this is to provide compatibility for capturing and exchanging calendar and scheduling information between events stored on a calendaring and scheduling application. A programming script can be written to illustrate how a learner's location and their available time can be retrieved. This information can then be transferred to the framework's suggestion mechanism.

2. Can the framework be strengthened? To counter against 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* and *a direct request method* can be incorporated into the framework.

a) *Location-retrieval* – we propose to use both *GPS technologies* and location-based positioning using a *Wireless Local Area Network* (WLAN) connection for retrieving and verifying the location of a learner for outdoors and indoors respectively. The retrieved location information is used to 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 we have chosen to adopt these two types of technologies. Most modern mobile devices contain a built-in GPS receiver (if not, a Bluetooth GPS can be easily attached to achieve the same capability), and built-in WiFi.

b) *Direct request* – we propose to use this 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.

3. Can the learning contexts be incorporated? The learning styles and knowledge levels contexts can be deployed into our framework through the utilization of Learning Object Metadata (LOM) (IEEE LTSC, 2005) for describing learning objects. Additional metadata tags can be added to the specification so that suitable learning objects to fit the criteria of m-learning students can be easily searched and selected for different situations. A proposal of an extension to LOM and IMS Learner Information Profile (LIP) (www.imsglobal.org) standards has been proposed by Chan *et al*. (2004) to cover mobile and informal learning scenarios, called Mobile Learning Metadata (MLM). It is currently work-in-progress and further metatags can be added to it. The available time context can be inferred using the duration attribute in both LOM and MLM which states the duration of time the learning object is required to take for completion. The *motivation* context is not modelled in LOM or MLM and therefore we propose to add an additional tag for this attribute in MLM.

4. Can a set of compatible technologies be integrated into our framework implementation? We describe one possible set of compatible technologies which can be used to implement the framework. A Windows-based mobile device can be used, together with the Microsoft Visual Studio programming environment for software development. This is an Integrated Development Environment and supports the .NET Compact Framework, which contains many capabilities for use within resources-constrained mobile devices, and include rapid development, comprehensive class libraries and functions are readily available (Microsoft, 2003). Modern mobile devices 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. A built-in learning schedule can be deployed and the diary events can be converted to iCalendar events with minimal effort, and stored into the Learner Profile, and then transferred to the Suggestion Mechanism, when necessary. A programming script for retrieving the location and available time information from the calendar events can be embedded, interpreted/compiled and run within the .NET Compact Framework within Microsoft Visual Studio. A Suggestion Mechanism can be 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. Learner Profile and Learning Objects databases can be stored on a database server such as Microsoft SQL and can be 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) can be deployed by the framework. Learning Object Metadata tags are specified in XML and are compatible for use within any web-based system, so that data can be transmitted between many incompatible formats. Wireless Markup Language, a subset of XML, can be used to create content to be displayed on mobile devices (Ibid).

3.4 Case Studies to validate the mCALS Framework

Some of the challenges faced in the design of further research activities to validate our 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 our mCALS framework, we are currently designing further research activities in order to answer two research questions of the framework. The first one is *to validate the appropriateness and usefulness of our novel idea and concept of using a learning schedule to retrieve users' learning contexts and to select appropriate materials for them based on different contexts and available time slots*. The second one is *to validate the modified suggestion rules of Cui and Bull's (2005) work, which are incorporated into our framework*. The first of these activities will be an evaluation of a number of Java learning objects by first year computer science (and other related courses) undergraduate students, primarily at our university. The learning objects will be obtained from the Codewitz learning objects repository www.codewitz.org. Since these learning objects are primarily of *tutorial* type, we have adapted the suggestion rules in 3.2 for students to study particular Java learning objects. This will be based on the learners' level of motivation, their knowledge/proficiency level of Java, and their amount of available time. For example, when they have a lower level of motivation, they will be suggested easier learning objects to study, and vice versa. The proficiency level of the learning object and the length of time it requires to be completed will be matched with the knowledge level of the student and the amount of available time that they have.

Students are asked to complete a number of Java learning objects online in their spare available time during a single week. Subsequent to the completion of each learning object, students will be asked to complete a feedback form. Additionally, they will be asked to fill in their university timetable (including private activities) in a given blank timetable sheet. The reason for this is so that we can observe which of their available time slots they choose to perform the online Java learning objects (LO).

Some of the information requested on the feedback form include the following, relating to *learning contexts, learning content* and *the time slot the LO was studied in*. Relating to learning contexts - 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) was the LO appropriate to be studied in those contexts; 3) how feasible, in their opinions, it would be to study the LO in any other contexts. Relating to learning content – 1) how useful they found the LO to be; and 2) would they use it again. Relating to the time slot – 1) why they chose the particular time slot to study the LO; 2) did the use of a timetable help them organize their time for studying in general as well as for studying for LO.

4. CONCLUSIONS AND FUTURE WORK

Our research into context-aware mobile learning field included the design and development of a mobile context-aware learning schedule framework. In this paper, we have described three research activities – a pedagogical interview study, a usability diary study, a technological feasibility study. The results of the interview and diary studies were presented. The challenges and lessons learnt in the process of the design and development of our framework have been discussed. We have currently put online the Java Learning Object experiment described in 3.4, and are running the pilot study. The main case study will follow shortly after. This case study is intended to answer our research questions relating to our learning schedule approach, and the suggestion mechanism unit of the framework. The data analysis and results of this case study will partially address the validation of our framework; this will form the focus of our next paper. Our future work may include additional evaluation activities in order to further validate our mCALS framework.

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