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A Classification of M-Learning Applications from a Usability Perspective

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Abstract

One of the possible barriers to the successful integration of mobile learning (m-learning) into mainstream education is the set of issues associated with the usability of applications designed for mobile devices. Applications delivered on mobile devices have many specific usability issues. The designer must meet and overcome all of these constraints, challenges and context of use issues in order to design a usable application. A first step in addressing these challenges is to be clear on their exact nature. This paper clarifies the notion of m-learning and the usability issues peculiar to m-learning applications. Beginning with a very general definition of m-learning as "learning with the aid of a mobile device", we classify m-learning into several distinct categories. These categories focus on the role of the mobile device in the learning. The categories are: Learning Management, Supportive, Content-Based, Context-Based, and Collaborative. The issues and challenges associated with developing usable m-learning applications within each of these categories are identified and outlined. In conclusion we identify plans for future work towards a framework for the design and development of usable m-learning applications.

Keywords

Mobile Learning; M-Learning; Usability

Introduction

M-learning has long been on the academic agenda as a new form of education delivery. Pedagogues and parents on the other hand have been notably cautious about the introduction of mobile devices to education, as noted by Shuler (2009), believing them to be more of a distraction to learning than a tool for learning. One of the restricting forces of the successful integration of m-learning into mainstream education is the set of issues associated with the usability of applications designed on these m-learning devices.

Usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." (International Organization for Standardization [ISO 9241-11], 1998). Simply put, if people find m-learning applications dissatisfying or difficult to use then m-learning will be dismissed as an unrealistic infrastructure for education. These applications must accomplish not only the goals of the educator, but also those of the individuals being educated and they must do this effectively and efficiently whilst also providing a satisfying experience to the users.

For an application to be usable it must do what it is supposed to do, it must allow the user to perform tasks well, and the user must be satisfied with its use. This sounds quite straightforward, but unfortunately applications are often designed by designers who assume (albeit subconsciously) that the end users differ little from themselves. The result is often that when the end user finally tries to use the application it is, from their point of view, too complicated, ineffectual, task inefficient and hence, dissatisfying. The cornerstone of good usability design is knowledge of the specific user group and the context(s) of use. This is a major challenge for m-learning application designers.

This paper attempts to clarify the usability issues peculiar to m-learning applications. We classify m-learning into several distinct categories in order to help clarify what we mean by m-learning. Then, within those categories, we sketch the usability issues that need to be dealt with. The purpose here is to provide a basis for further work towards a better understanding of the usability implications of each category and possible sub-categories. Finally, we present conclusions and an outline of future work.

Defining M-Learning

E-learning (electronic learning) has traditionally meant learning that takes place at a computer anywhere and at anytime. M-learning is seen as either an extension of e-learning or a completely new paradigm that lets you learn as you "move" anywhere and at anytime.

M-learning is a term that has many different connotations and definitions. The definitions focus on the concepts of mobility, ubiquity, and wireless ability. Costabile et al. (2008, p.145), define m-learning as "*the combination of e-learning and mobile computing*"; Yordanova (2007, p.IV.23-1), defines m-learning as "*learning that is wireless and ubiquitous*"; while Wains and Mahmood (2008, p.31) define it as "*a type of e-learning which blends wireless and mobile technology for the learning experience*".

We choose a simple initial definition for this paper: *"Learning with the aid of a mobile device."* However, in order to explore usability issues more deeply we need a more structured classification of m-learning and what it can achieve.

Established Classifications of M-Learning Applications

Learning can take place anywhere and anytime. Sharples, Taylor, and Vavoula (2005) contend that humans learn in any social setting, predominately where humans converse. Sharples et al. (2005) imply that most learning at its essence is conversational. It is a very real fact that learning takes place with the use of technology and as new technology emerges we must both adapt the users to the technology and adapt the technology to the users (Norman, 2007). Mobile devices provide a unique set of opportunities for learning. However, our inability to overcome the possible obstacles to their use (and to build on the benefits that mobile devices can offer) is the predominant reason that mobile devices are not more common in education.

A classification of mobile learning applications enables us to understand specific issues, challenges, and benefits of mobile devices in education, but unfortunately there has been very little progress in attempting to classify mobile learning. There have been some attempts to classify mobile learning and their applications, but these attempts have not been specifically focused on usability issues or concerns.

Pedagogical Classifications

Naismith, Lonsdale, Vavoula, and Sharples (2004) determined that there are six categories of activities in relation to mobile learning, and these are all based on pedagogical theories. The categories are: Behaviourist, Constructivist, Situated, Collaborative, Informal and Lifelong, and Learning and Teaching Support.

This classification divides the categories according to their dominant pedagogical theory. For example, a constructivist application would be one where learners will generate knowledge and meaning from their experiences. Constructivist learning on mobile devices can include participatory simulations, for example by using the devices to track and demonstrate the spread of a virus (Naismith et al., 2004).

This classification also follows important pedagogical concepts that explain user activity when interacting with the application, but they do not inform the designer about design characteristics, especially for usability. Secondly, there is a lot of overlap between categories. The above example of an m-learning application may be constructivist but it also has situated and collaborative elements. These categories help to classify m-learning concepts and theories but they do not offer a framework to help design usable applications.

Contextual Classifications

Frohberg (2006) introduced a classification of mobile learning based on ‘context’. He argued that all mobile learning takes place within a context and so it makes sense to classify based on this. His categories are: Free Context, Formalised Context, Digital Context, Physical Context, and Informal Context.

Frohberg argues that m-learning applications can be used in several contexts. This approach moves away from pedagogical concepts and attempts to classify applications according to the learner’s ‘context’. For Frohberg this ‘context’ is created out of the learner’s activities, goals, interests, and available resources.

In the area of software usability, the term ‘context of use’, as used by the ISO (2009) refers to the characteristics of the following: The tasks the user will need to perform (what will be completed, degree of criticality, etc.), the physical environment in which those tasks are carried out (e.g. sitting in a quiet room or standing on a noisy bus), and the technological equipment employed (screen size, input/output methods, etc.). We can also include here the characteristics of the user (age, education level, etc.) as used in Context of Use Analysis (Kirakowski et al., 1999). Context of Use Analysis in usability is performed with the intention of making manifest any underlying assumptions about the user, tasks, equipment used, and environment of use. This helps to clarify what is required of the final software product.

So, when Frohberg refers to ‘context’ he does not mean the same thing as when a usability person uses the word. His context has a whole different motivation and set of connotations. In fact that is precisely why Frohberg’s classification does not work for usability purposes – the divisions are motivated by different concerns.

Blended Classifications

In 2008, de Jong, Specht and Koper put forward a separate classification of m-learning applications. They suggested the following dimensions of a reference model: Content, Context, Purpose, Information Flows, and Pedagogical Paradigms. These dimensions would all contribute to a classification of an application. ‘Content and context’ both focus on the application itself and how it will be used, ‘purpose’ focuses on the designer’s goals, ‘information flows’ focus on the application information architecture (i.e. users: one to one, one to many, many to one, many to many), and ‘pedagogical paradigms’ focus on the learning theories contained within the application.

For our earlier example of participatory simulations (Naismith et al.’s virus game) it is difficult to classify this (and apply the dimensions) using de Jong et al.’s system. The content can be either a simulation or a game; the context can be dependent on the individual, time, location, relations, etc.; the purpose can be anything from engagement and immersion to discussion and social interaction; the information flows can be many to many, one to one, etc.; and the pedagogical paradigm can be constructivist, situated, collaborative, etc.

This is quite a useful approach in trying to understand the different types of applications, but it traverses many different approaches and you end up with an almost unlimited set of categories (as long as variables such as content and context remain). Our own model uses similar categories to the first two dimensions of de Jong et al.'s model (content and context), but again, for the same reasons as outlined for the pedagogical and contextual classification approaches, the final three dimensions offer little support to the designer in creating usable m-learning applications (and again it is also fair to note that these classifications have not been created for usability purposes).

Application-Based Classification

Roschelle (2003) defined three types of application type: Computer response systems, participatory simulations, and collaborative data gathering.

Roschelle's application-based classification is useful from a usability perspective. Quite obviously the participatory simulation, virus-based m-learning application will fit into the participatory simulation classification. The categories are distinct and can offer real help to designers, but they are incomplete and do not include many m-learning application types. Roschelle (2003) himself stated in a critique that there are potentially more categories, but he only focused on the most popular ones at that time.

The Best Application Classification

In summary, there are already several attempts at classification of mobile learning applications and from their authors' perspectives they are successful in their goals and objectives. However, they are not ideal for achieving our goals of a better understanding of the usability issues associated with m-learning applications, and the creation of a framework for the development of usable applications. With that in mind we have built on the existing classifications as described above and created a new set of categories that better suits our needs with regards to usability issues.

Classification of M-Learning Applications for Usability

We conducted a review of mobile learning applications and attempted to insert the applications into the above frameworks and models. We manipulated the classifications until we found a way to classify each and every application. From this review we concluded that m-learning applications could be organised into five distinct categories: Learning Management, Supportive, Content-Based, Context-Based, and Collaborative. We describe each of these in greater detail below.

Learning Management

In m-learning there is an emerging trend in the use of the mobile device to remotely manage the VLE (virtual learning environment). Using a mobile device you can register for courses, see course schedules, view grades, retrieve homework, submit assignments, participate in group discussions, and annotate common artefacts (Roschelle, 2003). Giving the learner this control is seen as having good motivational effects. For example, Theng et al. (2007) describe medical students at Wake Forest University School who used PDA's to access, retrieve, record, and store patients' information. They also detail how law students could use a similar application to download legal resources, and organise and manage their schedules.

Learning management applications are metadata based, that is, they contain information *about* learning content (or material) as opposed to the actual learning content. Depending on the type of information accessed (and its purpose), Theng et al.'s Wake Forest application could also be construed as falling into the context or content-based categories (see below). For example, the application could be further developed to make use of the mobile nature of the device by using Radio Frequency Identification (RFID) tags or barcodes with patients to create a truly context-based application.

Supportive

Mobile devices can be used to support traditional learning (in a classroom or lecture hall), e-learning, or distance learning in many ways. There are two strands to these supportive applications: direct communication between lecturer and student, and clicker-type work (see e.g. www.classroomclickers.com) which can be used to survey opinions or check for understanding of content presented.

The first strand can make use of many alternative media. Voice calls (including conference calls) are one of the most basic forms of supportive mobile learning. SMS (Short Messaging Service) is a standard technology on all mobile phones, and provides a simple way to form a feedback loop between teacher and student. It is also a highly effective way to deliver personalised information in a timely fashion (Wains & Mahmood, 2008). More novel methods such as video calls, social networking applications such as Twitter (http://twitter.com/), and instant messaging (IM) can also be used.

SMS feedback has also been used to supplement distance learning, for example where the SMS system was utilized in real time via TV learning (lectures aired over the television), as described by Wains and Mahmood (2008). This allowed students to communicate directly with the teacher. The same study noted that in Japan, English lessons have been delivered via SMS, and SMS is also already being used in distance education in the Philippines, to provide a channel of direct communication between teacher and student.

These forms of supportive learning tools are not without their problems. For example, Lindquist et al. (2007) studied the use of SMS to receive quiz answers. They noted that the cognitive load was very high: Students had to think about complex questions while also trying to enter complex answers into a difficult-to-use interface that was not designed for complex text and symbol entry. These problems resulted in students not abbreviating common terms and hence taking longer to enter the answer and complete the task than was necessary. Photo MMS (Multimedia Message Service) was also used in the same study (when hand-drawn formulas were a better representation than a hand-typed SMS) and were found more suited to solve complex problems than regular SMS.

The second strand is the clicker-type application. Traditionally, clickers have been used to harvest opinions from a classroom (Roschelle, 2003; Scornavacca, Huff, & Marshall, 2009), but mobile systems have also been introduced as a viable and cost effective replacement for this technology (although Lindquist et al. (2007) have voiced a concern about the costs of SMS amongst students). Typically, a user will text a phone number, this phone will forward the message to a database, the message will then be interpreted by a computer, and that interpretation will be displayed on screen during the class. For example, a lecturer can ask a multiple choice question and the class will answer. The results can then be displayed as a bar chart to show the overall class opinion. Similar ideas can be implemented with internet-enabled mobile devices and IM software or Twitter, etc.

Content-Based

When traditional classroom learning moved to e-learning, academics recorded their classes and users could watch or listen to them from a remote computer. Now content delivered on mobile phones usually means accessing small versions of what a user can already access on a desktop.

There are even some moves toward the introduction of TV and radio services specific to the mobile device as suggested by Wains et al. (2008). Such a transition to mobile devices is becoming less of a problem as screen size, resolution, processing power, memory, and battery life improve. However, it remains the case that content to be delivered to mobile devices must be different from content that is delivered to desktops. In desktop environments you are usually in a quiet room with a comfortable chair, and you can happily spend an hour or two at the desktop. With mobile content, there are numerous usability issues to consider. For example, you must create it for short bursts of a few minutes and you must also consider the distractions that will be presented to the learner, for example on a noisy bus.

When m-learning first started to make an appearance attempts were made to directly copy the digital content that was delivered to a desktop computer and present this on a mobile device. These attempts missed an important point. The reasons users employ a mobile phone are different from those that motivate users to log on to a desktop. Perhaps a user is in a location without access to a desktop, or maybe a user may only need a very short interaction (maybe less time than it would take to power up a desktop). Therefore, not only should we provide different content due to technical and ergonomic reasons, we must also provide different content because the user expects it.

Context-Based

Context-based learning is a true MLE (mobile learning environment). A context-based learning application will focus learning objectives in the environment in which it is being used. Learning outcomes and materials can change based on the environmental context. Sensors such as thermometers, light sensors, accelerometers, microphones, and GPS that are embedded in the mobile device can help to interpret the environment. The analysed environment can then have an impact on the learning methodology and content. Moreover, this can be done either without the user's participation or the user can initiate or assist the process by capturing images (with camera) or RFID tags that are then interpreted by the device. The user can also manually change the context by explicitly telling the device about the current context (e.g. multimodal settings like silent or library mode).

Augmented reality is considered context-based, as it is the combination of real-world and computer-generated data (virtual reality), and computer graphics objects are blended into real footage in real time. This is a great way for mobile devices to overlay a previously interpreted context with metadata (data about other data). Morrison et al. (2009), for example, described how users of a mobile device can use the camera function to display a map in real time while the application overlays metadata on the map. Schroyen et al. (2008) presented a museum-based game that has the ability to utilise three types of context (socio-cultural, physical, and personal) and integrate them into a rich user experience. Socio-cultural context is supported by the ability of users to interact with each other "directly" via VOIP (Voice over IP) and "indirectly" via data sent between each device in the museum to keep everything and everyone synchronised. The physical context is supported by localisation modules to interpret localisation information (WiFi in this case as GPS does not work well indoors). The personal context provides different interaction schemes as well as personal avatars to enrich the experience. Schneider, Bleimann, and Stengel (2009), Silva, Pestana, and Lopes (2008), and Theng et al. (2007), describe a range of software for context-based learning.

Collaborative

Collaborative learning refers to the notion that a learner is not a passive participant when learning but takes an active part in the learning process. A learner may collaborate with other learners, teachers, technology, and applications. Black and Hawkes (2006) describe collaborative learning as a methodology where students acquire and build their knowledge base by interacting within a group. Their studies have shown that students can often learn better in this environment than in a more traditional classroom setting as the success of the individual often depends on the success of the group.

Roschelle (2003) uses participatory simulations as a type of collaborative learning, which occurs when a group of students are equipped with mobile devices that are capable of data exchange with other mobile devices. Students may act as agents and active participants in simulations. Examples of participatory simulations used in Roschelle's study include decentralised systems (ants, traffic jams, and flocking birds), mathematical functions, and tracking the spread of disease. These types of simulations lead to a much deeper level of engagement by students in the subject matter.

Collaborative data gathering is similar to participatory simulations in that a group of students is equipped with mobile devices. However the students are not involved in a simulation. The mobile devices are used as ‘probes’ with which to gather live data. The gathered information is then promptly interpreted and fed back directly to the group members so that they can immediately see the results of their collaborative work. A typical task for this is to take readings from a stream for water quality evaluation where results are aggregated and fed back immediately and accurately (due to the use of multiple probes and readings).

Edutainment refers to the recent phenomenon of educational entertainment (i.e. games). Mobile devices can be used as gaming platforms with objectives based on learning outcomes. Recently, there has been a strand of edutainment that focuses on collaborative game play between learners. Costabile et al. (2008) created an m-learning game called ‘Explore!’ in which learners visit an archaeological park and learn about the site and related history by completing a game based on the same archaeological site and its history. Schroyen et al*.* (2008) and Scornavacca et al. (2009) also report on game-based learning.

Issues and Challenges

A central concern when designing any interaction between a computer and a human is the context of use. As discussed above, the term ‘context of use’ refers to the characteristics of the tasks the user will need to perform, the physical environment in which those tasks are carried out, the technological equipment employed, and the characteristics of the user.

Specific to m-learning there are certain aspects in each section that will demand a stronger focus. For example, with regard to user characteristics there are challenges of user experience and acceptance (young people are very accepting of new technologies and can envision their potential, but older people find it difficult to accept such technologies in their work and education). A lot can be learned by examining current user practice on similar devices. In terms of task characteristics, the most important are pedagogical and cognitive concerns. For example, the need to achieve learning outcomes while facilitating ease of interaction and balancing cognitive load is a crucial balance.

With regard to the characteristics of the physical environment, the main usability challenges are the number of potential learning environments and the distracting ability of the devices and the surrounding environments. Mobile devices by their very nature are used in hundreds of different contexts (m-learning and non-m-learning related), such as working at your desk or in a meeting, waiting for a bus, travelling by car, sitting in the park. It is practically impossible to design for every potential context. The physical environment will sometimes be noisy, sometimes quiet; sometimes the user will be moving, sometimes stationary, etc. Typical issues here are the effects of noise, motion, length of interactions, and varying user experience.

The device itself has considerable display, input, battery life, storage, memory, and processing constraints in comparison to desktop computers. Also, there are several categories of device including mobile phone, smart phone, PDA, entertainment device, gaming device, netbook, and tablet PC. Within these categories there are also hundreds of variations in terms of processing power, connectivity, display, input, operating system, etc. It is unrealistic to develop a solution application that will work on every device in the same manner, but there needs to be consistency across multiple devices. Berri, Benlamri and Atif (2006) suggest that limited resources available on mobile devices, specifically related to user interface input (keypad) and output (screen), restrict the ability of the learner to view and interact properly with learning content.

Attwell (2005) further describes the difficultly of selecting a suitable technological approach to mobile devices. Each choice (see Figure 1) will change some aspect of the device’s usability and this must be considered. Similar diagrams could be considered for tasks, users, and environmental characteristics.

Moreover, the problems and solutions will vary according to the category of m-learning application being designed, not just the technological choice. Without some analysis it is extremely difficult to address the challenges that will be encountered with every category of m-learning. Hence the next step is to determine some direction or focus for usability-related concerns through analysis of each category. Future research can then delve more deeply into these concerns.

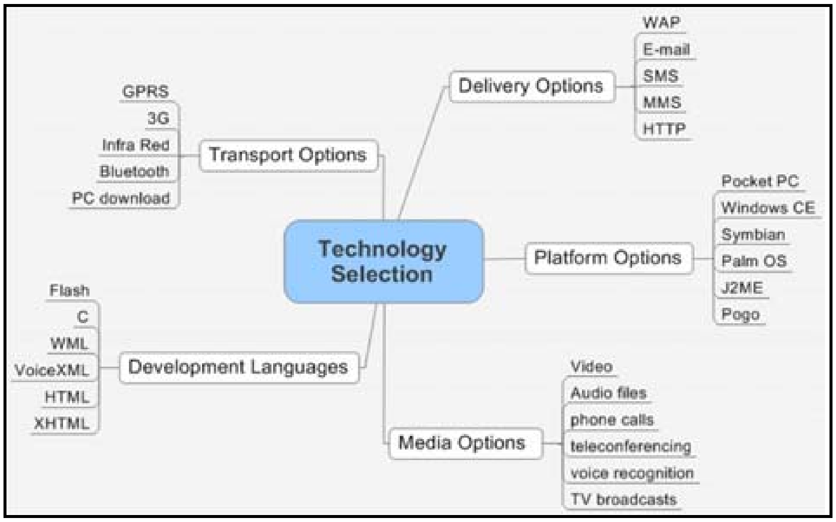

Figure 1: Technology Selection for Mobile Device Applications (Attewell, 2005)

Heuristics as a Framework of Usability

As already stated, usability is defined by the ISO standards as being concerned with specific users completing specific tasks in a specific context of use with the goals of efficiency, effectiveness, and satisfaction in mind. Thomas, Schott, and Kambouri (2004, p.173) stated, “Usability is [therefore,] in a sense, the extent to which heuristics can successfully operate.” Thomas et al., recognise the importance of using heuristics to analyze mobile learning applications and recommend creating a specific set of heuristics for mobile learning.

Generally we try to apply heuristics to usability in order to help with the design and evaluation of artefacts. A good baseline for heuristics is Nielsen’s ten heuristics of usability (Nielsen, 1994): Visibility of System Status; Match between System and the Real World; User Control and Freedom; Consistency and Standards; Error Prevention; Recognition rather than Recall; Flexibility and Efficiency of Use; Aesthetic and Minimalist Design; Help Users Recognize, Diagnose, and Recover from Errors; and, finally, Help and Documentation.

This list provides us with general guidelines for analysing any artefact from a usability perspective, both informing the designer of good practice and also providing a means of evaluating a finished artefact. If these guidelines are adhered to we can almost certainly agree that the application will become more usable. But what about learning applications, especially ones delivered on a mobile device? Are Nielsen’s heuristics enough to explain and assist in developing usability of m-learning applications? Can Nielsen’s heuristics be applied directly to m-learning applications or will they have to be tweaked or altered? If they are applied, will each heuristic carry the same weight for every category? These are questions that can be addressed in future work now that the basic classification is in place. The following section begins to sketch some of the issues that arise here.

Specific Usability Needs of the Classifications

Tasks associated with learning management and support applications should minimise the cognitive load associated with completing the tasks. The main focus of these categories of application is to facilitate activities required for learning and teaching, not to help the user learn the content. For the other categories it is quite the opposite, as they require the designer to target a specific cognitive load or way of thinking, to ensure the learner thinks about the content to be learned (van Nimwegen, 2008). As also pointed out by van Nimwegen, the cognitive load focused on an interaction can have drastic impact on our behaviour when approaching a task. This is especially important when considering a student's motivation and applied effort. A badly designed interface will affect the motivation of the student and thus the effort the student will apply to the learning tasks. Ultimately, the learning objectives would suffer.

Applications in the learning management category will be used by students with wide and varied backgrounds and varying levels of experience and expertise. As stated, knowledge of the specific user groups is a critical cornerstone of good usability design. The varied nature of the user groups for this category means that deep knowledge of the interface and how it operates cannot be assumed. Hence users are more apt to make mistakes, will fall back on their familiarity with similar applications, and will need help from the application to reduce the cognitive load of operating in an unfamiliar environment. Therefore, designers should emphasise error prevention, consistency and standards, and smooth task flow.

For supportive learning, a strong usability goal is to match the 'system and real world.' This means that the mobile device must be well integrated with the learning environment (e.g. the classroom) and not provide any distractions. To achieve this, the application must seem as formal (or informal) as the environment, it must speak the same language, and it must respond as a teacher would.

The main usability concern with content-based learning is satisfaction and comfort. What kind of learning does the user want to complete with a mobile device? Will the user be sitting or standing, will the user retain concentration for 5 minutes or 1 hour? As the device is mobile the content must be flexible enough to work with despite distractions and in a number of different environments. It must allow the user to pause and resume learning without loss of effectiveness or efficiency.

The usability needs are particularly demanding in context-based learning precisely because the context is changing. For instance, to develop an application like Mobile G-Portal (Theng et al., 2007), a developer must try to design an application for both indoor and outdoor use (e.g. perhaps gloves will be needed outdoors, making data input difficult).

The usability concerns of collaborative learning applications are quite similar to those of context-based applications in that they will be used in multiple environments and contexts, but the key difference is that the device will not necessarily be aware of this. As such, this category of applications is more user-focused than environment-focused. It should be possible for learners to understand how to use an application without necessarily understanding the final learning outcome or having knowledge of the specific domain. This is particularly important in collaboration as learners are interacting with each other and will most likely have varying levels of knowledge of the domain. However, as long as everyone understands the process involved all the learners can work together contentedly.

Framework of Usability for M-Learning Applications

At this stage, analysis of the usability concerns of the categories is superficial at best. Future work will investigate each category for more detailed and specific usability challenges. Before we consider specific usability concerns, though, we must first attempt to understand the user and their tools, in our case, mobile devices and applications. This will allow us to fine-tune the usability issues. Specific HCI approaches such as scenarios, persona generation, context of use analysis, competitive analysis, interviews, and ethnography, can help us gather the requirements necessary to develop early prototypes of effective m-learning applications.

It is at this stage we hope to begin generating usability heuristics specific to m-learning applications. These heuristics will hopefully be weighted somehow for each specific category so we can see if and how a simple list of heuristics can be applied differently to each category.

Conclusions and Future Work

This paper presents a classification of m-learning applications which provides solid groundwork to help in the identification of specific usability issues that will be encountered when designing an m-learning application. The importance of a suitable framework for the design and evaluation of the usability needs are paramount in successful development of m-learning applications and successful integration and use of m-learning applications in the educational system. Computer scientists, pedagogues, and learning content creators need to fully understand the importance of usability to the learning process. We have highlighted the main concerns of usability of m-learning applications as the varying context of use and the consideration for cognitive load balancing. Once these issues have been addressed we will be in a position to truly create and evaluate m-learning solutions; until then we will be using our best guesses.

The evaluation of m-learning applications is not a simple task. There is an interdisciplinary disconnect within this field. Computing professionals are reluctant to fully enter into the field of pedagogy and pedagogues are often out of their comfort zone in the technological arena. HCI is commonly seen as a bridge between disciplines and in this domain that is certainly true. Of course, usability experts are not expected to become pedagogical experts, but they must know the implications that usability has for learning. Therefore usability evaluation of m-learning application must focus on the context of use (task, user, environment, and technology) and also the pedagogical aspects (e.g. cognitive load).

Further research will investigate each category and elaborate on their specific usability challenges. In addition, the concept of a new set of m-learning heuristics was presented and these will be developed further. Based on the classification of m-learning applications, future research will also attempt to establish a usability framework for m-learning application development by creating and evaluating usable m-learning applications.

In sum, the main strength of this paper is in providing the foundations for further investigation into usability issues specifically concerned with m-learning. These foundations are the classification of types of m-learning and our central positioning of the context of use in application development. As stated, the discussion of the usability issues associated with the categories of m-learning is superficial at this stage and simply serves as an indication of future directions.

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