Survey and Analysis of Current Mobile Learning Applications and Technologies

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Distance learning, electronic learning, and mobile learning offer content, methods, and technologies that decrease the limitations of traditional education. Mobile learning (m-learning) is an extension of distance education, supported by mobile devices equipped with wireless technologies. It is an emerging learning model and process that requires new forms of teaching, learning, contents, and dynamics between actors. In order to ascertain the current state of knowledge and research, an extensive review of the literature in m-learning has been undertaken to identify and harness potential factors and gaps in implementation. This article provides a critical analysis of m-learning projects and related literature, presenting the findings of this aforementioned analysis. It seeks to facilitate the inquiry into the following question: “What is possible in m-learning using recent technologies?” The analysis will be divided into two main parts: applications from the recent online mobile stores and operating system standalone applications.

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1. INTRODUCTION

This article presents an extensive study and review of the related literature surrounding the emergent field of mobile learning (m-learning). Taking into account the literature, encompassing conference papers, journals, technical reports, reviews, and research projects, it presents the state of the art and permits a critical analysis of this technology.

Learning is the ability to acquire new or transform existing knowledge, skills, or behaviors. It is a relatively permanent change in behavior or knowledge that comes from experience or training. This ability involves synthesizing several types of information over a period of time. Humans, animals, and even machines can possess such ability [Nicolescu and Mataric 2003]. Learning may occur as part of school education, self-education, or any other specific training in a conscious or unconscious way [Prince and Felder 2006; Leahey and Harris 1989]. The human being has unique features in the innate learning processes because the learning process begins in the pregnancy period, usually at 32 weeks [Ormrod 1998; Eppstein 2008].

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Learning requires at least two types of actors, the person who will be instructed and the content of learning itself [Moore et al. 2011]. In order to achieve it, the person can use three main types of learning—auditory, visual, and kinesthetic—which are categorized as associative and nonassociative [Todorova et al. 2008]. Auditory learners are persons that prefer to listen to things being explained than to read about them. It is all about the hearing process. Visual learners learn best by reading, looking at graphics, or watching a demonstration. Kinesthetic learners process information best through the touch experience. Currently, doing an activity can be the easiest way for them to learn. Most people use a combination of the three learning styles and usually have a clear preference for one. Knowing and understanding all types of learning styles help people to achieve greater learning [Riener and Willingham 2010]. However, the types are based on learning models [Preece 2006]. Learning models are the tools used to convey the same. Beyond the traditional learning, which occurs in a school classroom, mediated by a trained teacher, the evolution of technology offers a new way of forward information and knowledge [TSAI 2011]. The growing diffusion of devices with Internet access has improved the quality and flexibility of learning, thus providing a new learning paradigm called electronic learning (e-learning) [Oliveira et al. 2007].

E-learning began in the early 60s due to the Programmed Logic for Automated Teaching Operations (PLATO) project. Later, in the early 70s, the project Time-shared, Interactive, Computer-Controlled Information Television (TICCIT) promoted the development of e-learning. In 1990, e-learning comprises all forms of electronic supported learning or teaching and its main target is to realize a new kind of learning [Yan et al. 2010].

E-learning implements learning mechanisms through communications systems, usually networked, and takes advantage of modern information technology to reach applications and processes that include computer-based learning, virtual classrooms, web-based learning, or even digital collaboration [Svetlana and Yonglk-Yoon 2009]. Its content includes media in the form of text, images, animation, video, and audio, and it is delivered through the network, audio- or videotape, or CD-ROM, among others.

Through innovative technologies offered by recent mobile devices comes a new learning model called m-learning, and it offers people the opportunity to learn anytime, anywhere. This can be achieved by the use of mobile devices, such as personal digital assistants (PDAs), cell phones, smartphones, and tablet computers [Georgiev et al. 2004]. This technology has several approaches for an equal number of situations and is supported by a range of devices, such as e-book readers, hand-held consoles, personal audio players, tablet computers, and mobile phones. Figure 1 presents the authors' personal views about the evolution of learning models, with m-learning being the latest step in the inherent evolution. It receives contributions from the traditional e-learning and computer-supported collaborative learning.

This work aims to provide an extensive review of the state of the art of m-learning and provides some insights regarding new, innovative, fast, and technologically advanced types of applications regarding the new mobile devices [Georgieva and Georgiev 2007]. Emerging technologies regarding mobile operating systems (m-OSs) and the inherent advantages and disadvantages will be studied [Xin 2009]. For example, the specific characteristics of each m-OS and its directed supported hardware will be analyzed. A comparison is made between their global market share and even their current use in the teaching environments and schools.

The main contributions of this work can be summarized as follows:

—Extensive study, compilation, review, and critical analysis of the available literature surrounding the field of m-learning;

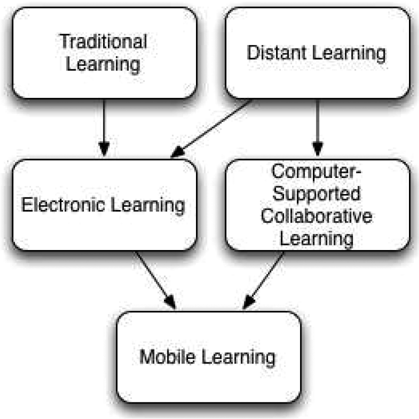

Fig. 1. Illustration of the evolution of the learning models.

—Study of the most promising m-OSs, including iPhone OS (iOS) and Android OS, highlighting their main characteristics;
—Analysis and comparison of the most recent tablet computers aimed at several m-OSs;
—Brainstorming on future approaches to be developed in order to substantially improve the process, applications, and methodologies of learning using mobile devices.

The rest of the article is organized as follows: Section 2 covers the mobile computing topic with particular focus on mobile operating systems, their market share, and a comparison between the Android OS, iPhone OS, and several tablet computers. The most relevant m-learning, standalone, and nonstandalone approaches are reviewed in Section 3. A discussion about the advantages and disadvantages of the available solutions, some insights about future trends, and new approaches that can be followed in mobile learning are presented in Section 4. Section 5 concludes the article.

1.1. Comparisons with Previous Reviews

There have been other related surveys on m-learning. The first review [Trifonova 2003] discusses basic and essential points of the beginning of the era of m-learning. The main focus of that article is to understand how mobile devices will help in achieving a better education. The following five types of applications for m-learning were also detected and briefly analyzed: courses for mobile devices; instant messaging; wireless application protocol (WAP) portals, tourism guides, and K-12 classes. Cobcroft et al. [2006] and Cobcroft [2006] reviewed the challenges for learners, teachers, and institutions to embrace a new methodology of teaching and learning. Their review focused especially on what is possible with m-learning and why it is necessary to pursue its possibilities. Orr provided a study that focuses on technical as well as pedagogical issues for instructional technology. The study reviews the affordances and constraints of m-learning and addresses how it is being deployed as a supplement to e-learning or in addition to a traditional classroom [Orr 2010]. However, most of the previous reviews have focused on the introduction and summarization of m-learning, emphasizing studies on how education and learning should be developed, but they do not provide means to the current reality of mobile devices or from its characteristics and huge potential [Oliver 2009]. Sha et al. [2012] presented a conceptual study of how theories and methodologies of self-regulated learning, an active area in contemporary educational psychology, are inherently suited to address the issues originating from the defining characteristics of mobile learning, enabling student-centered, personal, and ubiquitous learning.

Cox [2013] reviewed the wide range of technological and educational research changes that have taken place over the last 40 years, the affordances these provide, and the consequent implications for research methods and issues regarding investigating the impact of formal and informal learning.

Finally, Frohberg et al. [2009] provided a critical analysis of mobile learning projects published before the end of 2007. A mobile learning framework was created to evaluate and categorize 102 mobile learning projects and to briefly introduce exemplary projects for each category. All projects were analyzed with the following criteria: context, tools, control, communication, subject, and objective. Preliminary results show the design space and reveal gaps in mobile learning research. The presented studies were conceptualized giving use to a reality; however, it is already somewhat outdated, in particular regarding the current available hardware and related technologies. All reviews on the subject cover several essential characteristics of m-learning, although they focus on systems and devices that are currently completely outdated and do not fit in the current model for an excellent m-learning platform, framework, or solution. The current mobile devices provide a direct and new philosophy for teaching and learning methodologies since they can provide rich, fast, dynamic, and robust applications [She et al. 2009]. Their size along with their processing features, connectivity, screen resolution, and battery life offers those who use them a whole new world of opportunities [Saunders et al. 2010]. This review concentrates on brand new mobile devices and m-OSs, such as the Android OS or the iPhone OS, discussing recent research trends in mobile development focused on m-learning.

2. MOBILE COMPUTING

Mobile computing is a small component that is included in many computing environments [Imielinski 1996]. Its main goal is to develop system and software applications aiming small battery-powered devices equipped with wireless network connectivity [Neumann and Maskarinec 1997]. Mobile computing is characterized by three main aspects: (i) mobile communication that addresses communication issues, protocols, and data formats; and (ii) mobile hardware that manages its hardware and mobile software that deals with the characteristics and requirements of mobile applications.

Modern mobile devices possess a dizzying array of features and technologies [Welch 1995]. They are mass-produced to keep, per unit, low costs and have gained complete acceptance in the lives of most parts of the population in the entire world. While it was historically difficult to access the capabilities of many of these devices, successive generations have exposed more and more functionalities. Many devices have processor and memory capabilities comparable to desktop computers of yesteryear. The long- range, high-speed communication abilities, along with low-powered personal area network radios coupled with their inherent ubiquity, make them the perfect target for research of this nature.

The increasing number and importance of mobile devices has triggered intense competition among mobile OS creators and developers. Old companies, such as Nokia, Microsoft, and Apple, are in a bid to sustain and capture bigger market share, while newer companies that base their OSs on Linux attempt to gain their market share. A visual presentation of the market share is presented in Figure 2. It presents a graphic line display of the top eight m-OSs' market share from January to December 2009 in Europe. The results show that iOS and Symbian OS clearly lead the table.

The market is constantly evolving and changing. Therefore, Figure 3 presents the graphical display of the top eight m-OSs' market share from January 2010 to December 2010. In this table, emergent technology such as Google Android and Blackberry OS is gradually gaining market share, while older technology such as Symbian is decreasing.

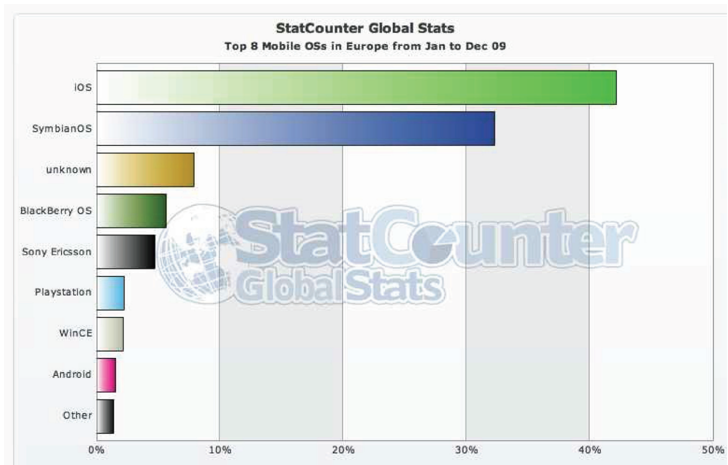

Fig. 2. Mobile Operating Systems StatCounter - GlobalStats 2009.

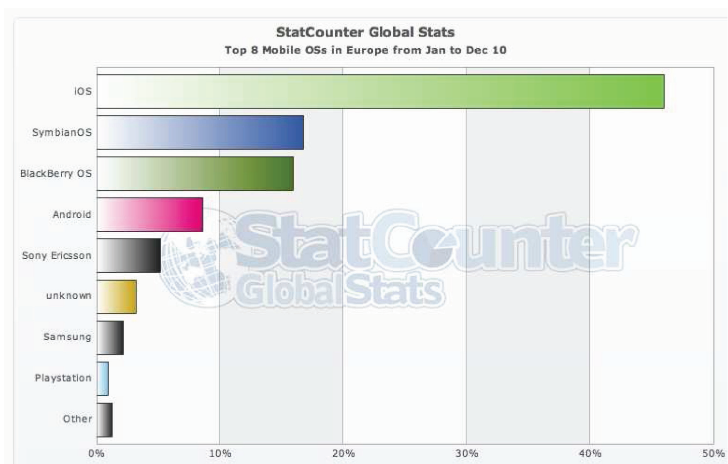

Fig. 3. Mobile Operating Systems StatCounter - GlobalStats 2010.

Figure 4 presents the evolution results of each m-OS of the year 2011. Looking at the table, it can be observed that iOS leads the way. Blackberry RIM and Android are gradually evolving, but they lack a very significant share compared to their direct rivals.

Figure 5 presents the evolution of each m-OS in the year 2012. Looking at the table, it can be observed that iOS leads the way but is closely followed by its rival Android. Blackberry RIM and Symbian are increasingly away from the lead since both lack a very significant share compared to their direct rivals. Nevertheless, the stats can change quickly and an m-OS that is currently low rated can climb the table and take the top of the same due to the fact that the technology is always evolving and every day there is a new chance for new features, characteristics, and fashions.

Analyzing the previous figures, one can conclude that the most used mobile OSs in Europe are iOS and Android OS. Similar to that conclusion, Gartner's latest forecast for worldwide smartphone OS market share predicts that Google Android will be present

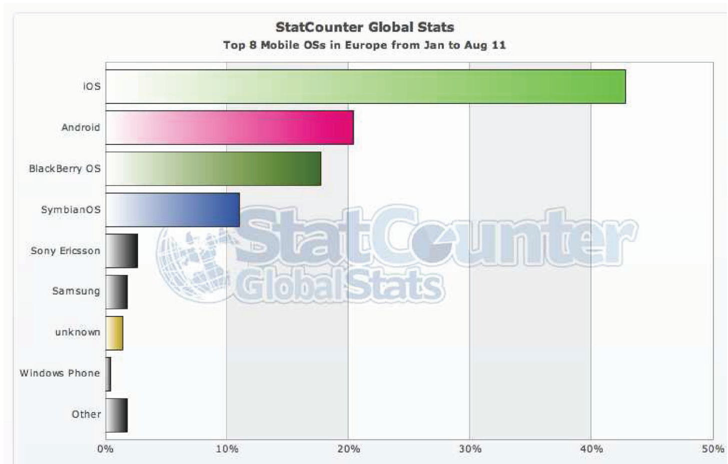

Fig. 4. Mobile Operating Systems StatCounter - GlobalStats 2011.

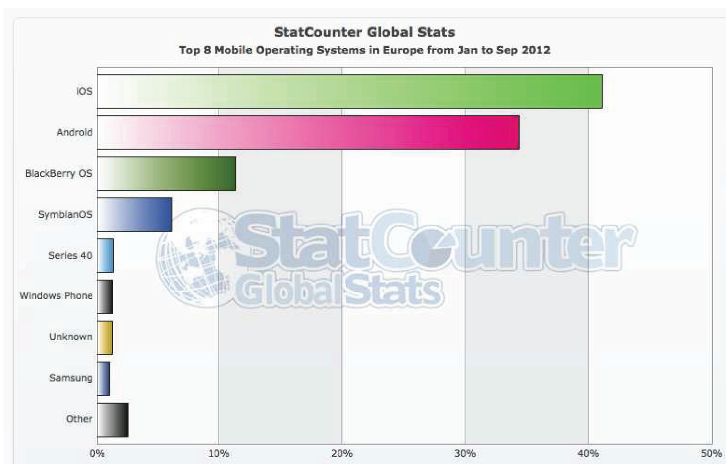

Fig. 5. Mobile Operating Systems StatCounter - GlobalStats 2012.

in nearly half of all handsets sold next year, while the iPhone and its iOS will account for around 19% of units sold. Gartner issued a prediction that worldwide smartphones should reach a number around 468 million units, in 2011 (tablets included), and should increase about 57.7% from 2011 to 2012 [Gartner 2011]. By the end of 2011, Android will become the most popular OS worldwide. And by 2015, Gartner predicts that Microsoft, with its Windows Phone platform powering Nokia handsets, will overtake Apple's iOS in smartphone OS market share. The research firm has forecast Microsoft to represent 19.5% of the market in 2015, compared with Apple's 17.2% share with iOS. Figure 6 presents the aforementioned data, and it can be carefully analyzed. Thus, due to the amount of m-OSs currently available, a slight revision of each of them is effectively necessary, paying special attention to their main features and characteristics.

In the current year, the market share follows the values presented in Figure 5, so the authors chose not to put another figure containing exactly the same information as the previous mentioned one.

OS	2010	2011	2012	2015
Symbian	111,577	89,93	32,666	661
Market Share (%)	37.6	19.2	5.2	0.1
Android	67,225	179,873	310,088	539,318
Market Share (%)	22.7	38.5	49.2	48.8
Research In Motion	47,452	62,6	79,335	122,864
Market Share (%)	16.0	13.4	12.6	11.1
iOS	46,598	90,56	118,848	189,924
Market Share (%)	15.7	19.4	18.9	17.2
Microsoft	12,378	26,346	68,156	215,998
Market Share (%)	4.2	5.6	10.8	19.5
Other OS	11,417.4	18,392.3	21,383.7	36,133.9
Market Share (%)	3.8	3.9	3.4	3.3
Total Market	296,647	467,701	630,476	1,104,898

Fig. 6. Worldwide mobile communications devices open OS sales to end-users by OS (thousands of units).

2.1. Common Mobile OS

Like a regular computer operating system, an m-OS is the software platform on top of which other programs run on a mobile platform. When the user acquires a mobile device, the manufacturer will have chosen the OS for that specific device. The OS is responsible for determining the basic functions and features available on the device, such as keyboards, communication with applications, wireless connectivity, text messaging, audio, and more. The m-OS will also determine which third-party applications can be used on each device. There are a multitude of technologies under use in the realm of portable computing. Some, such as Palm, have been responsible for the first incarnations of the ideal mobile computing [Carroll et al. 2005], while others have arrived recently, such as Android, and they hope to be the blurring point of distinction between phones and a PDA. Mobile OSs can be clustered into five main groups as follows: Symbian, Blackberry, Apple, Microsoft, and Linux. Some of the most common and well-known mobile OS include the following:

Android is one the latest OSs for modern mobile devices [Pereira et al. 2010b], proposed by Google and the Open Handset Alliance. Android is based on the Linux kernel and it is available under an open source license. The Java programming language forms the core of the entire Android OS. All Android applications have the same OS rights and privileges and can make use of the majority of the devices' functionalities, such as accessing the camera, multimedia, and acceleration features. This is in support of the Android philosophy that all applications are created equal and have the same rights and privileges [Matos and Grasser 2010].

Bada is an emergent m-OS developed by Samsung Electronics that was released in 2010 [Bada 2011]. It follows the open source Android philosophy. Bada has a kernel configurable architecture, which allows the user to choose and use either the Linux kernel or another real-time OS kernel. Bada devices are normally associated with use of sensors (such as accelerometer, face detection, and motion sensing, among others).

iPhone OS is an m-OS fully developed and marketed by Apple Inc. [iPad Apple 2011]. It is used as a default OS of the iPhone, iPad, and iPod Touch. The iOS is a stripped version of Mac OS X, and it is therefore a Unix like OS. Apple developed it as a proprietary OS. It has four abstraction layers, Core OS, Core Services, Media, and the Touch interface [Want 2010]. In terms of software development, Apple published a public Software Development Kit (SDK), allowing the developers to create applications using the Objective C programming language.

The LiMo Foundation is a consortium of several handset manufacturers including Motorola and Samsung that have joined together to develop the LiMo Platform. The Limo OS core is based on a standard Linux kernel [LiMo Foundation 2011]. LiMo has a modular plug-in architecture and supports Digital Rights Management (DRM). LiMo developers are able to create applications in three different ways, managed code, running in a Java virtual machine; native code; or browser applications.

Palm WebOS was one of the first m-OSs released in 1996. It was specifically created for the Palm PDA and related devices [Hewlett-Packard 2011b]. While initial versions were groundbreaking in providing mobile computing to a large group of people, subsequent versions have provided little in the way of new functionalities to compete with the newer developing mobile phone market. This has led to its overshadowing by Symbian.

PyS60 is an interpreter for the Python programming language that is compatible with Nokia S60 OS [Pereira et al. 2011b]. The interpreter is signed by Nokia and therefore can be installed in any S60-compatible device. It allows the creation of Python applications that do not need to be signed, as they are not directly interacting with the OS. Python applications created this way are somewhat limited in their functionality but offer more control over the device than traditional applications running in the J2ME (e.g., it is trivial to a user to create a script to initiate a phone call or even a socket connection).

RIM Blackberry is a proprietary software solution, created by Research In Motion, for a specific line of mobile devices called BlackBerry [BlackBerry 2011]. This platform has a more professional side because of its vast communication protocols and synchronization options with third-party software. Developers can easily develop applications through native J2ME code or through RIMlets. A RIMlet is a Connected Limited Device Configuration (CLDC)-based application that uses BlackBerry-specific API and therefore will run only on BlackBerry devices.

Symbian is a descendant OS of Psion EPOC originally developed by Symbian Ltd. and runs exclusively on ARM processors [Pereira et al. 2010a]. Symbian allows the installation of binary applications and opens up many aspects of the hardware devices to them (e.g., it is possible to completely replace the device manufacturer's default program for handling text messages with one purchased from a third-party developer).

Windows Phone was first released in 2000 and it is the second-oldest smartphone OS. The latest version of the OS is just called Windows Phone and was released in 2010 [Pereira et al. 2010a]. Applications may be developed for Windows Mobile using Microsoft's .NET framework. Applications written in any of the .NET languages compile to a common byte code that runs over the .NET virtual machine. Similarly to J2ME, the .NET libraries available on Windows Mobile are a reduced subset of the libraries available for the corresponding desktop edition. Programs written for one Windows Mobile device should work on any device running the same version of the OS.

2.2. In-Depth Study of Google Android and iPhone OS

By the end of the year 2013, billions of people will carry handsets capable of rich, autonomous, and long-term battery life providing a propitious environment for the convergence of mobility and the web as may be seen today. There are hundreds of thousands of applications for mobile platforms, so the quality of the experience of applications on these platforms, which can apply location, motion, and other context in their behaviors, is leading customers to interact with companies preferentially through mobile devices. Taking into account the previous results, it can be seen that the market is converging to a race with two competitors regarding mobile OSs. Thus, a study about the architecture that supports both the iOS and Android OS is considered.

2.2.1. Android System Architecture. The Android architecture is complex and considers the following four layers (from bottom to top): Linux Kernel, Libraries, Application Framework, and Applications. Each layer has its own responsibilities and characteristics. The Applications layer presents all the applications that run on a mobile device, such as text message client, Internet browser, Contacts, Calendar, and all the programs written by developers. The second layer is the Application Framework. The Android OS provides an open development platform, offering the ability to create extremely rich applications where developers can take full advantage of the device hardware. Programmers have full access to the same framework APIs used by the core applications. Any application architecture is designed to simplify the reuse of components, and any other application may use them to its own goal. The Application Framework layer is responsible for these Android-particular characteristics. It is compounded by several components, such as Activity Manager, Window Manager, Content Provider, View System, Package Manager, Telephony Manager, Resource Manager, Location Manager, and Notification Manager.

An extensive set of Views can be used to create a given application, including text boxes, lists, buttons, images, and so on. An application that needs to access data from another application must have the Content Provider component active. The Content Provider stores and retrieves data and makes it accessible to all applications. Resource Manager provides access to external resources that are only used by the developer code and compiled inside the application at the creation time. These data can be located outside the initial package and can include strings, graphics, layout files, videos, or any other external supported data type. The Notification Manager is responsible for enabling all applications to display custom information on the status bar, such as alerts and alarms. The Activity Manager handles the life cycle of applications and provides a common OS navigation through the application data flow. The Window Manager is responsible for all the windows' layout and interaction between views. Telephony Manager, as the name suggests, administers all the call functions. Location Manager provides access to the system location services and APIs.

Libraries and Android Runtime compound the third layer. Libraries have several components, including the following: Surface Manager, Media Framework, SQLite, OpenGL, FreeType, WebKit, SGL, SSL, and libc. All these components are the core mechanisms used to make all the Android OSs and applications running properly. The Android Runtime has its core Libraries and the Dalvik Virtual Machine, which is a custom virtual machine that runs the Java platform on any Android OS- supported mobile device. The virtual machine runs applications that have been converted into a Dalvik executable format.

The lower layer is the Linux Kernel and it is the base for all Android OS specifications and characteristics. This layer behaves as a regular Linux Kernel with the difference that it is tuned for mobile devices. The kernel has several modules and each one is adapted to a specific goal. The modules available at this layer are the following: Flash Memory, Power Management, Display, Camera, Binder, Keypad, Wi-Fi, and Audio Drivers.

Activity is a single functionality that a user can perform, and almost all activities interact with the user. In the system, activities are managed as a task stack. Every time a new activity is created, it is placed on the top of the stack and becomes the running activity. The previous activity remains below, in the stack, and it does not come to foreground again until the newest activity disappears. The activity has four main states (active, paused, stopped, and destroyed). If an activity is in screen foreground, it is active, and if it lost focus but is still visible, it is paused. If an activity is completely obscured by another activity, it is stopped, and, finally, if an activity is paused or stopped, it can be dropped from the system memory.

There are three main loops used for monitoring within an activity: the entire lifetime, the visible lifetime, and the foreground lifetime. Entire lifetime has two methods, the onCreate() and onDestroy(). The onCreate() is called when the activity is created the first time, while the onDestroy() is the last call received by the activity when it is destroyed. The visible lifetime includes onStart() and onStop() methods. The onStart() method is called when the activity is becoming visible to the user, while the onStop() is called when the activity is no longer visible to the user. The foreground lifetime happens between a call to onResume() and onPause(). The onResume() method is called when the activity will start interacting with the user, and the onPause() is called when the system is about to start resuming the previous activity.

2.2.2. iPhone OS System Architecture. The kernel of the iOS is based on a variant of the same basic Mach kernel that is found in Mac OS X. On top of this kernel are placed the services layers that are used to deploy applications on the platform. The iOS architecture is divided into four layers (from bottom to top: Core OS, Core Services, Media, and Cocoa Touch), and each one represents specific interconnected technology. Such architecture offers the developer several choices when it comes to developing their code.

The first layer is the Core OS and it is based on the following components: OS X kernel, Mach 3, BSD, Sockets, Security, Power Management, Key-chain, Certificates, File System, and Bonjour.

The second layer is the Core Services and includes the following components: Collections, Address Book, Networking, File Access, SQLite, Core Location, Net Services, Threading, Preferences, and URL utilities. The Core OS and Core Services layers contain the key interfaces for the iPhone OS, including those used for accessing files, low-level data types, Bonjour services, network sockets, and so on.

The third layer is the Media layer and considers the following components: Core Audio, OpenAL, Audio Mixing, Audio Recording, Video Playback, Quartz (2D), Core Animation, and OpenGL ES.

The fourth layer is the Cocoa Touch. It is subdivided into two middle layers called UIKIT and Foundation. The UIKIT is composed by the User Interface elements (Multi-Touch Events and Multi-Touch Controls), Application Runtime, Event Handling, and Hardware API (Accelerometer). The Foundation layer includes Utility and Collection classes (Localization and Alerts), Object Wrappers for system services, and a subset of foundation in Cocoa.

The frameworks are mostly C-based and provide the fundamental infrastructure used by developers on their applications. Moving to the upper layers, more advanced technologies that use a mixture of C-based and Objective-C-based interfaces are found. For example, the Media layer contains the core technologies used to support 2D and 3D drawing, audio, and video. This layer includes C-based technologies OpenGL ES, Quartz, and Core Audio. It also contains Core Animation, which is an advanced Objective-C-based animation engine.

2.3. Mobile Devices and Technologies

According to Barker et al. [2009], there are several challenges regarding the implementation of m-learning methodologies. The challenges can be related to the institution itself, safety, security, implementation costs, or simplly mobile device limitation. Up to now, the major limitations of these mobile devices were software and hardware related. Examples of limitations include the device capability for executing the program used in an m-learning environment, whether it manages to give response on real time or not, or if it has the correct specifications for an ideal data visualization and presentation. Besides, nowadays, mobile device technologies are also proprietary products of their developers. Variety of mobile OSs, screen size, and unique specifications become difficult for the developer to design for all. Thus, in order to overcome the previously mentioned limitations, a new type of mobile hardware was created, the so-called tablet PC [Stickel 2009]. A tablet PC is a full-fledged laptop with specific features and characteristics. The finger can be used directly on its screen, with all the functionalities that can be performed by a regular mouse. Tablets were redesigned and updated over time, but only when Apple released the iPad were tablets completely accepted and used by end-users [Yeh 2010]. Now, tablets are small and light, have a long battery life, but mainly they have a big screen and high resolution, providing the user with a rich, dynamic, and innovative display and a new way to access multimedia content.

Nowadays, there are five main Ttablet PC manufacturers: Apple, Samsung, Motorola, HP, and Blackberry. Each manufacturer has specific tablet configurations with its own set of special characteristics. Each tablet reflects its manufacturer's philosophy and tries to offer an optimal set of features that will appeal to the widest possible number of users. Despite the tablets having some characteristics in common, all of them have specific ones and use particular sets of hardware in order to reach a higher market share.

2.4. Tablet Overview

This section provides a brief overview of each main manufacturer's tablet and uses its main characteristics to directly compare all of them.

Apple iPad 3. Apple released the iPad 3 in March 2012. It was thinner, lighter, and more powerful then the first-generation iPad [iPad Apple 2011]. Despite all the hardware upgrades, the big update is based on new front- and rear-facing cameras, which enables real-time video between two people, and the high-definition screen resolution. The iPad 3 presents only a physical button on the display, which, when pressed, calls up the home screen. It comes complete with iOS 5 and a full range of preinstalled software, such as music players, video playback and edition, eMail client, and Internet browsers, among others. In terms of completion, in general, the iPad 3 has the advantage of the following characteristics: slick, thin, and fast; excellent battery life (more than 10 hours); and amazing application support though App Store. However, it also presents some disadvantages such as the standard display quality, no Flash support, lousy cameras, and no SD expansion.

Asus Transformer Prime. The Asus transformer prime is a 10-inch tablet running Google Android OS 4. The screen aside, Asus's tablet is completely crafted out of plastic, which makes it light. Given that the majority of other tablets have to be held in both hands, the Transformer Prime looks more like a big smartphone than other competitors' models. The Transformer Prime includes all types of mobile and wireless connectivity, including Bluetooth. It comes equipped with a wide range of software including all the services available from Google, and if it is equipped with a 3G card, users can make phone calls. In conclusion, the Transformer Prime has advantages like fast CPU, effective multitasking, great network connectivity, and Internet Flash support. Moreover, it also has several disadvantages, such as Flash-heavy sites hindering performance and the inaccessible battery.

Motorola Xoom. The Xoom is the first Motorola device of this segment [Motorola 2011]. It comes with a large display of 10.1 inches. One specific characteristic makes this tablet different from the rest, which is the inclusion of the new Google OS specifically aimed for tablets, called Honeycomb. The Xoom hardware is outstanding, but it lacks decent app support, since most of the apps are not yet adapted to the Honeycomb version. It presents the following advantages: amazing display, real- time 3D effects and transitions, and great CPU processing performance. It also has some disadvantages, such as Android tablet applications still being limited, basic on-screen keyboard, and awkward application management in Honeycomb.

HP Slate. The Hewlett-Packard Slate 500 is a new brand tablet that does not offer any new special characteristics [Hewlett-Packard 2011a]. The touch interface is a custom one called N-trig Duo Sense, and it has a capacitive multitouch part that supports up to four touch points. Its battery life really depends on the use. In standard desktop use, the Slate can handle up to 5 hours; the worst scenario happens when multimedia features are used. In continuous video playback, the battery life drops to 2 1/2 hours. In terms of completion, the HP Slate 500 has the advantage of the following characteristics: native Windows application support, good number of connection ports, and strong video playback capabilities. However, is also presents some disadvantages such as the following: it does not support lots of touch-optimized software, it has a very low battery life, and most of the applications only have landscape display mode.

Blackberry Tablet. The PlayBook is the first Blackberry Tablet, and it is based on the Blackberry's smartphone UI. In terms of ease of use and performance, it is easy to learn and smooth to navigate. It fully supports Flash applications with a very distinctive performance. On the other side, the PlayBook also has some disadvantages such as the following: it does not provide an email reader or calendar application by default, it has a very limited application repository, and the 7-inch display can sometimes be too small for web browsing and multimedia features. The web experience is excellent due to the fact that JavaScript and Flash performance is stunning. The Flash implementation is significantly smoother and more stable then the Flash Android implementation. The Playbook is the first tablet and mobile device that provides something very close to the full desktop web experience.

The next few years of m-learning seem to be bright since new types of mobile devices, wireless communication services, and technologies will be widely available and can be accessed and used by a large number of the global population. Plus, these new types of devices have specific characteristics such as larger display and resolution that make them completely viable for everyday use, mainly for data access, visualization, and presentation. Since the learning methods rely on information gathering, presentation, and demonstration, these devices are perfect for performing these tasks. Currently, there are several smartphones with the same processing power as the tablets, although they all suffer the same weakness: the screen size is very small for presenting a true learning environment without losing all the ease of use and access to data. Following, the authors present a review of the related literature focusing on the m-learning technology.

3. RELATED WORK

Mobile learning (m-learning) appeared as a new learning paradigm of the new social structure with mobile and wireless technologies [Chao and Chen 2009]. It offers an enhanced environment in different areas that may range from education to medicine, from industrial to business, or even multimedia and gaming [Munoz-Organero et al. 2011; Mateik 2010; Traxler 2007; Kong 2003]. Mobile technologies are increasingly used to facilitate the learning process and the use of these technologies creates new opportunities and challenges [Jiugen et al. 2010]. It aims to integrate mobile technology and services into various areas of teaching and learning and thus promote meaningful interactions with information.

M-learning is evolving and transforming the traditional educational way. It introduces a new learning environment due to the emergence of mobile and wireless technologies. It offers a new approach to delivering learning objects into users' daily lives, although most of the traditional and currently available e-learning system contents are not suitable for m-learning and mobile devices, so new interactive and dynamic content must be produced.

There are several different teaching and learning styles and methodologies described in literature. Thus, several differences in students' preferences about learning through experimental or concrete instruction are found. The type of evaluation is also a key factor for the learning process because it determines the performed study until the assessment moment.

In order to achieve and ascertain the current state of knowledge and research, including the identification of potential gaps in m-learning, an extensive and critical analysis of the related literature focusing on the latest technologies, applications, and devices was undertaken. The goal is to move beyond specific implementations to guide current and future action, thinking, and tools for teachers, learners, schools, and pedagogical institutions. Rather than presenting series of isolated case studies that may or may not be transferable from one specific learning or teaching scenario to another, the synthesis of the literature focuses on the presentation of a set of visions for the development of m-learning approaches. Each vision is focused on a specific scenario with its own characteristics.

3.1. Generic Tools and Applications

This section presents a set of scenarios categorized by two main groups: educational and gaming. Each subsection describes mobile learning projects, discussing its advantages and disadvantages.

3.1.1. Educational Area. Education is the foundation of the human learning process. It provides a way to evolve and understand all the information that is shared. Therefore, this section provides an extensive and critical analysis of the literature focusing on the latest technologies and applications for the educational area.

The Information Gathering and Lesson Tool (IGLOO) is a mobile technology that intends to support educators as well as students in a learning environment [Samuel et al. 2009]. The goal of its proposal was to supply educators with an application for mobile devices (independently of the used wireless connectivity) that could be used to facilitate pedagogical practices in both formal and informal learning scenarios. IGLOO is based on a conceptual framework that evolved from the incorporation of pedagogical and technical aspects in an m-learning solution. The application considers an administration system and a mobile application that runs on the educator's device. The mobile application supports only mobile devices running Symbian OS. The administration application allows the educators to set up the quizzes. Therefore, the quizzes are sent to students' mobile devices by text message using SMS or Bluetooth. In terms of system evaluation, the authors focused on determining the tasks the users achieved in using the system, rather than evaluating its performance. To attain this purpose, they conducted a direct observation of 37 high school learners, and 87% felt that IGLOO supported their needs.

The e-Learning Laboratory of the Shanghai Jiao Tong University designed and created an m-learning system that supports bidirectional communications among instructors and students in real time [Qi et al. 2006]. The system aims to solve the delay problem between the live class activities and the inherent broadcast onto students' mobile devices. It can deliver not also text messages or instant polls but also live broadcasts of real-time classroom teaching. The system allows students to customize their way of receiving data based on places and when they are connecting to the broadcast transmission. Through this solution, in real time, students can interact directly with the instructor, asking questions and making suggestions, and can receive quick feedback. It considers two main components, a logical and a physical system. The first component is oriented to the logical part of the system and includes the broadcast and the classroom management subsystems. The second component is physical related and contains three components regarding the instructor, the student, and the system administrator, where each one has its own responsibilities and actions. The system was successfully tested with a classroom of 50 campus students and 30 online students. The mobile application presents the limitation of only supporting the Symbian Series 60 OS.

Haitao et al. [2009] proposed a mobile independent learning system that can detect mobile devices' context and adapt itself not only to a device but also to the learner itself. The system is composed of a server and several learner devices that connect to the server via different types of networks. The learner devices include diverse equipment such as computer, mobile phone, smartphone, PDA, laptop, digital television, or any other device able to connect to the network, play digital media, and access the system server using a browser through standard communication protocols. Here the device sends a request of a learning content to the server and, after processing, provides to the mobile device the corresponding answer. The system created a virtual network that supports several devices. These devices can communicate among them through the server. When the m-learning system receives a request, it adjusts the parameters to answer, taking into account information such as mobile phone characteristics and available bandwidth. The learning system has five modules: communication server, information server, context information service, resource library, and infrastructure library. The communication server manages the connection with the user and the quality of data transmission. The context information captures and stores the context of user devices. The information server responds to the m-learning service user request and provides service on demand. The resource library maintains all the multimedia resources used for the service and the infrastructure library stores and manages the widgets for multifarious learners' devices, which need to be installed in the device.

The Malaysian government aims to increase the contact hours in the learning process between students and computers and improve the education standard in the country through the use of mobile technologies (m-learning) [Mahamad et al. 2010]. Smart School is one of the four flagship applications for the Multimedia Super Corridor (MSC) aimed at primary school students. It uses a new curriculum for mathematics to improve the learning quality, training, school organization, and student presentation. The project was born due to the fact that more than 35% of primary school students have failed the traditional courses. In Malaysia, there are four main problems in the current learning system: heaviness of textbooks, students and teachers having a hectic daily schedule, confusing e-learning function for primary school students, and high cost in commercialized systems and desktop usage. So, the authors think that with this new perspective they can improve and achieve better results in the near future. The system includes mobile quizzes and progress tracking to monitor the students' progress. About 100 students from various primary schools volunteered to participate in the survey. In general, most of the students already had experience using mobile devices and about 46% owned one. Around 50% of the respondents were ready to start m-learning, 12% were undecided, and 31% were unwilling to learn with the help of mobile devices.

Kumar et al. [2010] exposed a 26-week study of unsupervised m-learning in rural India to investigate how children will voluntarily make use of cell phones to access educational content. It aims to examine the feasibility of m-learning in out-of-school scenarios in underdeveloped areas, and to learn how to undertake similarly difficult studies around mobile and ubiquitous computing in the developing world. Usually, in rural India, about 43% of school-aged children cannot attend school regularly due to the fact that they must work. Thus, m-learning empowers those children with a tool to balance their educational and income earning goals, by enabling them to learn anytime, anywhere, in places and times more convenient than school. The mobile phones were preinstalled with a custom application whose goal was to teach the English language. The study was conducted in two phases: summer 2008 and spring and summer 2009. One of the main barriers faced was electricity, since many families do not use it on a daily basis and mobile phones need it for battery recharging. The authors concluded their presence could artificially affect participant behavior and results, but the results show a reasonable level of academic learning and motivation among the majority of the children involved in the study.

Following the aforementioned project, Viswanathan and Blom [2010] aim to develop mobile learning solutions that are grounded in the existing educational practices but have the potential of revitalizing the approach to learning technologies in a developing world context such as India.

Madeira et al. [2010] designed an m-learning framework for an analog electronics course that covers the following main topics: semiconductors theory; PN junction theory; diodes and applications; and transistor and applications. It was designed as a supplementary means to the classic course and was based on several interactive multimedia modules. The multimedia modules were adapted from the traditional module, including new, enriched, and animated examples. The application interface provides students with several figures and animations and a way to comment or give feedback about a specific image or animation. During the course duration, the students have both traditional and mobile classes. At the end of each module, students have several oriented quizzes to answer, which can be answered through SMS, e-mail, and MMS, and the feedback is received through the same way. The authors are also developing a module responsible for storing and managing the students' answers in a server where all the results are processed in a competitive learning-based methodology. The student application runs on Symbian-based devices and the technology that supports the information exchanged between them and the framework server is XML.

Potts et al. [2011] proposed an m-learning application for iOS and Android operating systems. It is used in two electrical engineering courses at the University of Tennessee at Martin, ENG 231 Digital Logic and ENGR 361 Digital Signal Processing. This application is quiz style and offers the user a multitouch interface to answer the relevant questions related to electric engineering courses. The quizzes have a large range of covered topics, including digital logic gate analysis, discrete signal evolution, and digital filter design. After concluding each work, the score results are sent to the instructors via email. Two evaluations using 18 students from both courses were conducted to measure its effect on them.

Majumder and Dhar [2010] created a message scheduling and delivery system using an m-learning framework. It provides the requirements to develop m-learning applications for Symbian devices that can be used to share academic and administrative information among people inside the university campus. In order to demonstrate the functionality of the system in simulated environments, a prototype application was developed. The system works both in bulk SMS and interactive SMS delivery mode. The authors combined both SMS and WAP browsers for easy and focused message delivery. The SMS format is mainly used for short and in-time information delivery, while the WAP is used for robust and detailed information. The main goal of the project is to facilitate access to normal and administrative information, financial statements, communication and interaction between actors, assessments via quizzes, feedback on assignments, and tasks from instructors.

Moura and Carvalho [2008] carried out series of educational experiments using mobile devices such as mobile phones and MP3/MP4 players to evaluate the implications of mobile technologies in individual and collaborative learning. Since 2005, users have been able to easily get automatic updates of recent podcasts. The authors created podcasts of Portuguese literature. Thus, the students have Portuguese lectures on audio files available for their mobile devices, listening to them when and where they want. The study included 15 students from a class of the Public Professional Education of Carlos Amarante Secondary School, in Braga, Portugal. The group is small but it was found that all the students had a mobile phone, 67% of them had an MP3 player, and only 27% had an MP4 player. Only 20% of students considered that by using podcasts they didn't need to attend Portuguese classes, 33% believed that podcasts can completely replace the teacher, and the majority (57%) of them were undecided about whether they prefer to listen to podcasts or the teacher. As regards the podcasts' educational value, the majority of students (80%) believed that podcasts are a complement to the classroom and they can achieve better learning results (53%). The preference for these technologies is directly related to their size, weight, and cost. Due to the fact that they are at the student's hands, they offer great potential in the educational system.

Another study was carried out to define the scope of functionality for the applications of m-learning with the potential to enhance the student performance and experience within the BSc Multimedia Technology and Design course at the School of Engineering and Design, Brunel University, United Kingdom [Garaj 2010].

In China, m-learning already contributes to a booming market and, in 2008, 6 million Digital Learning Devices (DLDs) were sold. Astonishingly, these devices are not mobile phones and the vast majority of them cannot even connect to a wireless network. Liu et al. [2008] portrayed a unique and novel education concept derived from the Chinese m-learning industry, in which Noah Education Holding Co., Ltd (Noah) acts as a premier provider of m-learning services and devices. Noah introduced a series of DLDs with a price ranging from 90 to 170 euros with a big screen of about 320 $\times$ 240 pixels of resolution. They supported an internal keyboard of only 64 keys and include an external connection to a monitor or video-projector. These devices can access a library of more then 30,000 multimedia courses. The learning material developed is mainly to complement prescribed textbooks used in China's primary and secondary school curriculum, covering English, Chinese, mathematic, physics, political science, and history. They come preloaded with some basic software such as mail reader, a graphics program, data analysis, searcher, and a calculator.

The English language is the most spoken language in the world. Zacarias et al. [2009] reported a proposal for learning English in an authentic mobile environment using a discourse analysis to analyze the perceptions of the students regarding their English learning using mobile devices. The mobile tool is based on the new paradigm that uses mobile technologies called "edutainment," and it is based on moving the education issue to the context of entertainment. This paradigm ensures that education is seen as an activity that provides entertainment and excitement. The authors have developed a system that makes lifelong learning something natural and effective for education in all fields of development. The system offers a permanent way to students to learn anytime, anywhere, and with any mobile device ranging from PDAs to smart-phones to and mobile phones. The learning mechanism allows authors to detect some key features that benefit learning in several contexts, such as exploring English through the vocabulary, learning through collaboration and teamwork, learning in a societal and humanistic environment, learning in real-life situations, learning in an easy way through mobile devices, and learning through gaming. It provides students several learning tools like sets of lessons, basic sentences syntax, exercises of pronunciation, multimedia videos, games, chat, and karaoke.

Ullrich et al. [2010] described a mobile live video learning system developed at the Shanghai Jiao Tong University. It is a mobile learning system that streams live lectures to the students mobile devices.

Bri et al. [2009] presented several studies for new models of education that rely on the new European learning model given by the Bologna process. It shows the level of popularity of each environment according to the number of entrances in two web searchers. This study will provide the details of their features and main differences between them. The authors also analyze existing environments to create online learning communities. In the last part of the article, a performance evaluation of the two main environments is presented.

Crane et al. [2012] described the development and implementation of two mobile applications to investigate the use of time- and location-based systems for delivering information to mobile users. The study is based on two RSS-based information retrieval widgets to support mobile learning within a higher education environment. The major function of both applications is to disseminate information surrounding course updates in a context of either time or space, aiming to identify if there is precedence between these two dimensions of context. The results indicate that both applications are evenly helpful for receiving information and that both are equally unobtrusive in their personal space.

Ogata and Uosaki [2012] presented several features and approaches of technology-driven research on educational system development. The article also describes research trends on mobile and ubiquitous learning and explains two mobile and ubiquitous research projects called LORAMS and SCROLL as a new trend of ubiquitous learning research.

Jaradat [2011] presented an extended technology acceptance model to explore the factors that affect intention for mobile learning. This study aims to explore the use of mobile phones in the educational environment in Jordan. The proposed model was empirically tested using data collected from a survey containing 21 questions. The study gives quantified indicators about m-learning and a model that might help in understanding the m-learning environment in Jordan.

Chang et al. [2012] described a mobile device learning initiative with physician trainees at the University of Botswana School of Medicine, focusing on their experiences with recent scale-up efforts to remote areas of Botswana. The authors also explored the potential impact of mobile learning in developing health capacity.

Kalloo and Mohan [2011] presented an investigation that was carried out to determine if mobile learning can be used to help high school students improve their performance in mathematics. A mobile application was developed targeting a subset of the mathematics curriculum. It offers the learner different learning strategies, game-based learning, and personalization. The paper also compares the students' performance with actual usage of the mobile learning application.

Timely farming guidance is currently achieved via web-based learning as agricultural information technology. In this paradigm, a registered farm can actively find the contents needed from a web-based platform and study them in a virtual community similar to the traditional classroom, although this kind of approach presents some limitations, including poor interactivity or obsolete evaluation mechanism. Yao et al. [2010] addressed the problem of timely farming guidance by integrating the advanced m-learning technologies with the relevant pedagogic theories. The authors proposed a three-layer model in order to overlap the above-mentioned limitations, featuring content management, effective interactivity, and a novel evaluation mechanism. The content management contains and handles all the learning content for the courses. All the information can be organized systematically as traditional teaching materials. It also contains specific problems and the corresponding solutions. The effective interactivity layer can be seen as the human-system interaction. Using mobile technology, this layer includes technologies, such as SMS and email, to contact the farmer in a fast, easy, and efficient way. Finally, the evaluation mechanism is the module responsible for students' performance evaluations. It can use simple, prediction, expert, or field-based evaluation, each one with specific evaluation characteristics.

Using the previous proposal, the authors expanded it for a mobile learning platform. In general, they proposed a peer-to-peer m-learning model, which shapes the essential interface between mobile devices and web applications [Yao 2010]. It uses the previously mentioned model but considers different contents. Here, they are more generic and not just related to a particular topic or set of questions. The proposed model is validated through an effective tradeoff among timely response, individual learning-oriented content management, and multimedia streaming based on a peer-to-peer network topology.

3.1.2. Gaming Area. Game-based learning harnesses the advantages of computer game technology to create a fun, motivating, and interactive virtual learning environment that promotes problem-based experiential learning. It is possible to learn through various kinds of games, such as casual, direct subject, or cooperative games. Thus, this section provides an extensive and critical literature analysis focusing on the latest technology and applications regarding gaming and its features.

Video games, an interactive entertainment form, have been repurposed for game-based learning in recent years. Many studies have presented the educational value that video games possess with evidence that supports the positive experiences of game-based learning. Tang and Hanneghan [2010] presented a new framework based on a mode-driven approach designed to aid nontechnical domain experts in the production of serious games. The authors presented three main specifications for the new model-driven serious gaming development framework considering its requirements, architecture, and the model itself. The requirements are a set of specifications that support the framework in order to sustain all its characteristics and features. Requirements gathered during game design are generated for a specific software framework. The model is the final result, which follows the aforementioned specifications. Although the authors have already defined the framework with unique characteristics, it is only at the testing stage.

PlayMancer is a serious 3D gaming environment that aims to introduce new concepts to the available 3D gaming engines overcoming several limitations, such as game development complexity, expensiveness, and long development cycles [Conconi et al. 2008]. The general architecture of the PlayMancer platform has been designed taking into account the following two major aspects: (i) functional and technical specifications derived from generic and specific domain user requirements, *and* (ii) the rendering of an open source game engine multimodal. It is based on three major modules: Game Engine, Game Manager, and Multi-modal Dialog Manager. The PlayMancer video game prototype was adopted for chronic mental disorder treatment (mainly eating disorders and behavioral addictions). It introduces the player to an interactive scenario where the final goal is to increase his or her general problem-solving strategies, self-control skills, and control over general impulsive behaviors. A controlled study is going to be conducted, where it will be used as an additional therapeutic tool.

Analysis and monitoring learning communities in a serious games context was the focus of Prasolova-Frland and Hokstad [2010]. The introduction of new technologies, such as serious games for the educational area, in organizations imposes new challenges in supporting the development of communities through the different phases of their life cycles. The authors proposed a framework based on several metrics such as the Domain, the Community, and time of Practice in order to achieve the proposed goal. The framework is used to do specific tasks regarding the learning process of the whole community.

Junior Doctor (JDOc) is a serious game for medical learning [Sliney and Murphy 2008]. It aims to improve the efficiency of junior doctor training within the restrictions imposed by the European Working Time Directive, making theoretical medical knowledge more accessible. The authors created a high-fidelity interactive framework with the objective to understand the potential for medical simulation in junior doctor training. The framework provides a 3D world of a medical center and all the users' actions are stored for future analysis. The user or the supervisor can later analyze and review all the actions, leading to a better performance on the next usage. JDoc was created using the C++ language and runs only on tablet computers with Windows OS.

Urban environments are usually complex, although they provide several specifications that can be used to improve the education and learning processes [Llanos and Forero 2011]. The authors presented a serious game about a public transportation system based on articulated buses. The objective of the game is to create awareness about the expected behavior of users within the system. The system uses 3D modules and the driver's perspective, and one can observe mistakes that are made by pedestrians and drivers. It aims to improve users' skills in the educational, functional, and entertainment areas.

The learning process through serious gaming and game-based learning is supported by some taxonomy [Jantke 2010]. Currently, there are several contradictions, and it is difficult to settle a dispute as long as there is no appropriate or standard terminology available for the gaming learning process. Thus, the authors proposed taxonomy of digital games, in general, and some taxonomic concepts of game-based learning, in particular. They focus on several specific questions in order to achieve the intended results. Taxonomic concepts such as extra game play and meta-game play prove successful for the understanding of game-playing impact as well as for guiding serious games' design.

Serious gaming is not just about playing alone; a team-based game can lead to better performance results, a better learning process, and better cognitive development [Allen et al. 2009]. The authors proposed a team-based assessment for serious games and achieved several interesting results. The tests were performed using the Infinite teams Island game as a learning tool, using a pre-/posttest method. The user might potentially overestimate his or her abilities pregame, but will receive a more accurate response to their skill postgame, having a greater understanding of what was being examined and being able to see the skills in action. Two hundred and four students from the University of the West of Scotland answered a prequestionnaire, played the game, and completed a postgame questionnaire. The results suggest that serious games, used as learning tools in education, could benefit from a generic team assessment system, and this offers a strong potential to the serious games industry, specifically involving team-based games.

Schwabe and Göth [2005] described the design of the MobileGame prototype, exploring the opportunities to support learning through an orientation game in a university setting. It introduces the scenario and then describes the architecture of the prototype.

Teaching and learning anatomy and physiology are both aspects of health care education, and together are considered the most problematic area of the curriculum [White and Ousey 2010]. White and Ousey created an on-line tool that uses problem-based learning strategies to contextualize anatomy and physiology education. Basing the learning on real-world scenarios will promote understanding and retention. Despite the fact that the system is not fully mobile, it can take advantage of the new devices to fully access the information.

Following the m-learning concept, the learning process can happen anytime and anywhere [Yu-mei et al. 2010]. Yu-mei et al. suggested a conceptual model as a framework for an m-learning system used in medical education. It is composed of multimedia interaction modules, information interaction modules, and management and monitoring modules, each one with specific characteristics and functionalities. The system was created for PDAs with Microsoft Windows, although it is only in the development stage and no experiments have been undertaken.

3.2. Web and Quiz Environments

Web technologies are evolving and providing users with rich and dynamic tools for content creation, access, and visualization. Those technologies are gradually being used in the educational and learning area. Thereby, this section provides insight about the web and quiz environments for m-learning.

The MOMO (Mobile Moodle) is an extension to the open source Learning Management System (LMS) Moodle for mobile devices [Moodle 2011b]. It brings the ability to create m-learning scenarios with Moodle as a back-end [Moodle 2011a]. Moodle is an open source course management system, also known as a learning management system. It has become very popular among educators around the world as a tool for creating online dynamic websites for their students. Mobile users install a MOMO client (a Java-based application). Through this client, users can access courses anytime and everywhere. System administrators install the needed MOMO extension on their Moodle server, making the contents available for mobile usage. They can configure and handle the system through the integrated administration user interface, all inside Moodle. Teachers can design courses with either several mobile elements or complete m-learning scenarios using tools and methodologies known from Moodle.

Go Test Go is one of the first companies to deliver an in-depth, functional, and effective presentation of quality educational content via mobile phones. Go Test Go provides an exciting new, low-cost solution of effectively delivering quality exams, tests, or quizzes through the convenience of a mobile device that the majority of people already carry [Go Test Go Inc. 2011]. Test subjects range from those covering the serious pursuit of professional and educational degrees, designations, certifications, and licenses, to self-awareness and self-assessment tests, to tests developed purely for entertainment.

Quizzler is the leading cross-platform quiz and assessment software used extensively by both students and teachers [Pocket Mobility 2011]. It offers products for Windows, Macintosh, and mobile devices, including the iPhone and the iPad. The Quizzler includes three main components: Quiz Library, Quizzler Reader, and Quizzler Maker. The library holds more then 15,000 questions that can be imported and accessed by any supported client. The Maker provides the user a set of tools, which can be easily used to create a quiz. Finally, the Reader is used to access (read) a quiz stored in the Quiz Library. The Quizzler has some single features, including multiplatform support, support for the iPad and iPhone, quiz creation using rich text editors, and support for various media files.

3.3. Frameworks

A software framework, in terms of computer programming, is an abstraction based on a collection of classes and applications, libraries of SDKs, and APIs helping the different components work together. Frameworks can be seen as software libraries in that they are reusable abstractions of code wrapped in a well-defined API, yet they contain three key distinguishing features that separate them from standard libraries: inversion of control, extensibility, and nonmodifiable code. Inversion of control dictates that the overall program flow of control is dictated by the framework and not by the caller. The extensibility characteristic permits the user to extend it usually by selective overriding or specialized by user code, providing specific functionality. The third characteristic concerns the code itself; in other words, the framework code cannot be modified. Despite this, users can extend the framework and implement new characteristics. Thereby, this section is focused on the existing m-learning frameworks.

Motiwalla [2007] created a project focused on SMS and WAP services that aims the extension of e-learning into mobile phones equipped with wireless connection through the help of an m-learning framework. This framework provides the requirements to develop rich m-learning applications that are mainly used to complement traditional classroom or distant learning. A prototype application was developed to link the mobile devices to three course websites, and it is supported only on Symbian-based devices. The framework was tested during two semesters with a total of 63 students from undergraduate and graduate courses from both online and on-campus classroom environments from the University of Massachusetts, United States. The students used the m-learning environment with a variety of mobile devices and reported their experiences through a survey at the end of the semester.

MADEE (Mobile Application Development and Execution Environment) is a platform that supports the development of mobile and wireless information systems for mobile devices [Licea et al. 2010]. MADEE allows a student to develop applications faster and easier than using conventional development tools. The architecture is divided into two parts: Clients and Object Server. Each client can interact with the server executing specific orders. The object server stores all application data divided by object catalogs. The technology associated with the platform is Java and all the clients and servers are written using it, and every mobile device supporting Java can be used to access the system. It was directly tested with the introduction of mobile and wireless information systems development concepts in the context of computer engineering courses.

Hudaya et al. [2006] presented the development of a server-side m-learning management tool in a campus-wide environment using the Microsoft .NET technology. In achievement of the mobility factor, the authors have adopted the Microsoft Mobile Internet Toolkit (MMIT) as the means to develop the application. It has been developed for use by students in the campus area. The management tool enables them to view the contents for courses they enroll in, timetables, assessment reports, and assignments anywhere and anytime on campus. The management tool is divided into four mobile web modules: My Courses, My Schedule, My Grade, and My Assignment. Some tests of user acceptance were carried out to measure the feasibility of the m-learning management application development. This study has adopted a survey method by the means of questionnaire to obtain feedback from users. One advantage of implementing the m-learning management tool over MMIT is that it will be able to support other means of access. The application was successfully tested on various devices with different mobile OSs and characteristics, such as Nokia 6210, Pocket PC, and Sony Ericsson R380.

The ubiquitous technology provides several ways for technology interaction. Chen et al. [2008] created a ubiquitous learning platform, providing functions enabling learning to take place anytime and anywhere with any available mobile device of students. The conceptual design of the ubiquitous learning environments is based on a four-layer model, divided as follows: Web-based learning server, User Model Adaptive, Device Adaptive, and Mobile devices or other laptop or desktop. The server is responsible for the learning environment architecture (database connection, discussion boards, assignments, homework submission, evaluations, and exams). The user model adaptive component determines what and when to deliver proper learning materials, such as announcements and reminders, to learners' devices through the device adaptive component. The device-adaptive component can record learners' behaviors and test results in various m-learning devices, enabling the user model adaptive component to generate the student model to provide adaptive support for learning. It also has the ability to detect the students' mobile device and redirect the correct information to it. Mobile devices, as the name implies, represents all the mobile devices used to access the learning environment. Some tests were conducted with 54 college students using the ubiquitous learning platform. The results indicate that the proposed system can enhance three learning performance indicators, namely, academic performance, task accomplishment rates, and learning goals achievement rates.

Currently, most m-learning environments are heterogeneous, so they always serve specific types of mobile devices [Passey 2010]. Yi [2010] presented a study and an implementation of an m-learning scenario using the eLesson Markup Language (eLML). eLML, which was created by the University of Zurich, Switzerland, is a kind of e-lesson markup language based on Extensible Markup Language (XML). It is independent on any special learning platforms and abides by the Sharable Content Object Reference Model (SCORM) standard. However, two main problems regarding eLML and m-learning: not all mobile devices directly support eLML contents, and eLML cannot recognize mobile devices and inherently cannot optimize the lesson contents in accordance with the capabilities of the device. To solve this issue, the authors proposed a system that could detect the target mobile device and adapt the contents accordingly. The device detection is made principally on the user registration to the system. It should register users' personal and academic preferences and the mobile device characteristics. This way the system can adapt the requested contents to a specific device and configuration.

3.4. Mobile Applications

Mobile applications are commonly also called mobile apps. These terms are used to describe Internet applications or small bundles of code designed and developed to run on mobile devices. They are intended to enhance features of mobile devices, providing additional functionalities and utilities that increase the devices' utilitarian and entertainment features. There are several kinds of mobile device applications, such as games, Internet applications, widgets, calendars, email utilities, sports information, and so on. This segment of mobile technology has ballooned with the widespread use of smartphones, portable music devices, and other mobile web-capable equipment.

Due to the single characteristics of mobile devices, a set of specific online stores were created to facilitate users' access to a wide range of applications. There are two main online applications stores for mobile devices: the App Store (by Apple) and Google Play (by Google) [Google 2011]. Both stores contain hundreds of thousands of applications in many categories, such as business, developing tools, education, entertainment, finance, games, graphics, news, music, medical, sports, utilities, video, and weather. In each category, applications are divided by their status (free or paid) and can be downloaded by users anytime and anywhere. Therefore, in this section several (paid and free) m-learning applications from both Apple Store and Google Play will be considered. The analysis will be divided into two parts regarding the aforementioned stores and will focus on applications that were exclusively created for tablet computers.

3.4.1. Apple Store. Within the learning category at the Apple Store there are various subcategories as follows: Read, Mathematics, Science, History and Geography, Language Development, Art and Music, Productivity, and Accessibility.

So, the list presented below is related to the top charts of the learning area. Note that the top charts are in constant motion since the store has hundreds of thousands of users and every day a new app is uploaded to the store.

MathBoard is a math learning application that is appropriate for all ages from kindergarten (with simple addition and subtraction problems) to elementary school where learning multiplication and division can be a challenge. The user can choose the amount of numbers to work with and the amount of questions and even assign a time limit per quiz. The specific features are random problem generation; addition, subtraction, multiplication, division, squares, cubes, and square root problems; intelligent wrong answer generation; problem solve; and a quick reference documentation.

How Rocket Learned to Read is an app to promote reading in young children in which individual words are highlighted as the story is read. The user has two main options: watch and listen as words are highlighted while the story is read aloud by a narrator, or turn off the narration and read at your own pace. The app has some specific characteristics such as over 40 pages of interactive text and illustrations with realistic page-turning interactions, vocal performance, hearing individual words spoken with the tap of the finger, and a save state that allows the user to exit the story and conveniently return to the page where he or she left off.

Shakespeare in Bits: Romeo and Juliet features the complete original text combined with all-new dynamic-text features to make understanding quick and easy. The app will read the text for the user using modern and smooth translations. Some specific characteristics, such as 3 hours of animation illustrating every line of every scene, summaries and analysis for each section, a unique in-line translation system for obscure words and phrases, biographies for each character, a character relationship map, and a text highlighted feature, are presented.

Grammar Up HD is a quiz app and features more then 1,800 grammar questions. It is a multichoice quiz system for English across 20 grammar categories. It was designed to replicate questions with a business focus commonly found in the TOEIC English proficiency test. It helps learners to improve their grammar, word selection, and vocabulary, helping them to improve their response times under exam time constraints. Under the specific characteristics the main ones are as follows: choose the number of questions, show test results in HTML format, progress meter to track personal records, and special algorithms that randomize questions.

Math Bingo is an app that teaches mathematics through a simple visual user interface. The object of Math Bingo is to get a pattern of five Bingo Bugs in a row by correctly answering math problems. Math problems are presented at the top of the game screen. Feedback is presented at the bottom of the game screen. Correct solutions to problems answered incorrectly will be displayed.

Wolfram Algebra Course Assistant is an app that focuses on the algebra learning. It covers the topics applicable to algebra, algebra II, and college algebra. It will help to quickly solve various problems, ace tests, and learn algebra general and specific concepts. Some specific characteristics were found: evaluation of any numeric expression; simplify fractions; plot basic, parametric, or polar plots of the functions; and factor numeric expressions, polynomials, and symbolic expressions.

Britannica Kids: Volcanoes is a portable encyclopedia aimed at the younger public. With this app users can interactively explore and learn about the world's major volcanoes, their eruptions, and lava plate tectonics. The learning process is done through several mini games like Memory Match, Jigsaw Puzzles, and Magic Square. The topics covered by the app are Eruptions, Lava and Magma, Types of Volcanoes, Birth of an Island, Plate Tectonics, and Decade Volcanoes. The Volcanoes has some specific characteristics such as an interactive map, various mini-games, quizzes for knowledge testing, and interaction with the social network Twitter.

Monster Anatomy–Lower Limb is an interactive lower limb radiology application. It was developed in the Medical Imaging Department of the University Hospital Center of Nancy, France, and is designed for health care professionals, as well for students, as a reference and learning tool. It contains 384 contiguous MR slices (4 to 5mm thickness) in the three anatomical planes and features the following: intuitive navigation; fluid display of images; 3D image volume; over 500 labels in accordance with the *Terminologia Anatomica*; over 10,000 tags, and high-quality images.

History: Map of World is a fun and educational app that contains a collection of high-resolution historic maps. This app offers the user the possibility to search for a particular map in a specific era or category and analyze it. It features the following characteristics: wide variety of historical displays, support for category/era view, dynamic search, and detailed information about the maps; it does not require a network connection.

Virtual History Roma presents a fantastic voyage to Ancient Rome, the capital of the latest empire in the ancient world. The app reconstructed in virtual form the city, which the user can explore in full-immersion panoramic experience. It provides high detail about the city's statues, models of the legionaries, gladiators, the Coliseum, the Circus Maximus, Hadrian's Mausoleum, and others. Another feature is the virtual tour, which presents Pompeii, Ercolano, and many other important Roman cities—in Europe and the Mediterranean—all with 3D models, information pages, and hundreds of high-quality images.

AP U.S. History 5 Steps to a 5 is a learning app that helps the user to gradually evolve in U.S. national history. The app will enable the user to assess his or her current knowledge level, review the relevant subject matter, and tests his or her skills, all at his or her own pace. Designed to assess a user's current knowledge of American history, this application mainly features five steps: Set the Study Program, Determine the Test Readiness, Develop the Strategies to Success, Review the Knowledge, and Build Up Confidence.

Intro to Letters by Montessorium is an app that teaches users to trace, read, write, and record letter sounds, names, and phonograms, based on the proven methodology of Montessori. A team of Montessori educators and parents created it and it aims to introduce a child to the world of language. Using this app, the child will learn basic foundations of language; to read, write, and understand letters from a to z; lowercase letter symbols and their sounds; capital letters; and consonants and vowels.

Symphony Pro is a complete music notation editor that allows the user to quickly write and play back music from his or her iPad. This app allows the user to write from scratch or open a saved composition, and it supports a multitude of file formats. It offers the possibility to teach music directly through the composition with an easy, interactive, and dynamic UI. It supports the following features: 114 high-quality instruments including drum kit, up to 12 tracks and four layers per composition, advanced editing support, and various music modes and portrait and landscape modes.

iStudiez Pro is a scheduler app that helps the user to organize all his or her activities and events. It is aimed at students and professors but can be used by anyone. It features a built-in planner that lets the user input and manage all types of schedules including classic, alternating, rotating, and block schedule. The user can not only enter the most common course details but also add instructors with all related information. Another feature includes tracking of homework and assignments. Through the assignments done and its grade a calculator is provided to track the grading process and its inherent evolution. It also supports an online backup mode that stores the user's data on a web server, which can be retrieved anytime.

Pocket Oxford American Dictionary and Thesaurus is a dictionary app with various specific characteristics that differ from a traditional dictionary. It is an all-in-one reference, with dictionary, synonym, and antonym entries. The text is fully updated with the latest contents and contains more then 2 billion words that allow the user to access the most recent picture of the English language today. It features the following characteristics: 150,000 entries, synonyms, and senses; brand new UI; off-line access; integrated dictionary and thesaurus texts; and in-text featured and extra reference information.

3.4.2. Google Play. The Google Play store does not use any subcategory division in the Education area. All apps are treated equally and the user must go through them all to find a specific one.

Once again, similar to the aforementioned review, the list of applications below are related to the top charts of Google Play.

Star Chart is an astronomy app that enables the user to have a virtual star chart in his or her pocket. Using GPS technology, an accurate 3D universe, and some high-tech algorithms, Star Chart calculates—in real time—the real location of every star and planet visible from Earth and shows precisely where they are, even in broad daylight. It features the following: point and view; dynamic device orientation viewing; accurately depicts more then 5,000 stars; displays all the planets of the solar system; displays all 88 constellations; very powerful zoom; and manually search for a location.

Color & Draw is a complete artistic solution for Android devices. It provides both a simple drawing and sketching app with white and black backgrounds or a more complex mode with a coloring book app with 50 exquisite drawings of fun topics including animals, professions, and landscapes. Color & Draw boasts beautifully crafted, specially designed springboard drawings; voice-recorded invitations for all drawings for children to add to or complete the drawings; a lovely color palette; multiple stroke sizes and erasers; and stickers. Kids or their parents can share their creations via email or save them to the device's gallery.

Kids ABC Letters is an app intended for kids ages 2 to 7. It is a dynamic app that teaches the alphabet in an easy and comprehensive way. Plus, it will teach and let children practice the letter shapes, letter recognition, and finding letters in context. The app is divided into four main sections: naming letters, forming letters, recognizing letters, and identifying letters in context. Every section is designed in order for children to enjoy success time after time and then receive positive reinforcement.

Human Japanese is an app that presents the Japanese language from square one in a warm, engaging tone. It goes much deeper than just vocabulary, drawing the student into the real mechanics of the language, all the while maintaining a warm tone and sense of humor. The goal of Human Japanese is not just to turn out students capable of repeating canned phrases, but also to lay the foundation for real linguistic and cultural understanding. The app features more then 500 pages of Japanese text, animations for every Hiragana and Katakana character, more than 1,800 recordings of vocabulary words, interactive games, and a dictionary of all Japanese words that appear in the text.

Mobile Observatory: The Astronomy is one of the most complete astronomy apps available for Android devices. It is a simple and intuitive tool for anybody interested in the sky's wonders, from the occasional sky gazer to the passionate amateur astronomer. The app not only includes a live, zoomable sky map telling you what sky object you are looking at but also provides you with loads of detailed extra information on stars, planets, deep sky objects, meteor showers, comets, asteroids, and lunar and solar eclipses, as well as detailed ephemeris of all included sky objects and an interactive top-down view of the solar system.

UK Driving Theory Test is an app that presents the official UK car driving theory test. It provides the student with access to more than 970 questions from the latest and official DSA question bank. It has several study topics, such as Accidents, Alertness, Attitude, Documents, Safety Margins, and so on. The app has three modes: detailed tests results, progress meter, and mock test results. In terms of characteristics, the main ones are as follows: option to choose how many questions the user would like to test, results in HTML format, define timer settings, and special set of algorithms that randomize questions.

Monkey Preschool Lunchbox is an app that also supports iOS and provides six exciting educational games. It teach kids ages 2 to 5 about colors, letters, counting, shapes, differences, and matching. The learning process is supported by rich, simple, but dynamic interfaces full of animations.

English in a Month is an app that will teach users the English language in a simple and intuitive way within half a year. The app is divided into four main sections: learn basic phrases—without tedious study and repetition; begin hearing and understanding native speakers—every word is narrated by two narrators (male and female) who pronounce words in various intonations and speeds; overcome barriers—testing the knowledge acquired; and learn how to study—methods and directions to a simple but effective study method. The learning process is done using a simple and intuitive UI.

U.S. Presidents, as the name suggests, is an educational app that teaches about the U.S presidents. It provides a clean and intuitive interface for the learning process. Diverse information regarding each president is presented, such as years in office, birthplace, trivia party, vice presidents, and more. It provides special characteristics such as trivia quizzes, search for specific information, and even a parade.

MapMaster is an educational geography app game where the mission is to pinpoint capitals, state capitals, and famous places in countries around the world. This app supports up to 10 players competing by themselves on the same device. It is based on GPS coordinates and offers the exact distance between the target and where the user is. It features the following: eight levels with three levels each, high-definition on-line maps, 350 places including continent capitals, Wikipedia integration, and online high scores.

Kids Numbers and Math is an educational app for kids to learn numbers and build basic math skills. The app presents numbers to the user in several languages (English, French, German, Spanish, Russian), and through a simple and intuitive UI the user can learn them and also learn the basic math operations. It features the following activities: learning numbers, choosing the maximum and minimum number, math operations—addition and subtraction, and advanced exercises.

Kids Shapes in an educational app that enables users to learn shapes in an enjoyable way. It provides two main activities: learning shapes using real-life objects and recognizing shapes in their real-life settings. The following shapes are supported: circle, rectangle, triangle, square, rhombus, and oval. It features a clean, intuitive, and dynamic UI, since it is designed for young kids.

Physics Formula Calculator is an app focused toward teachers and students doing homework and grading papers quickly and accurately. This app has over 70 formulas that allow the user to solve for not one, but all of the variables in each formula. It comes complete with a full list of solvable physics formulas, trigonometric functions, the Pythagorean theorem, and important constants needed in physics. It features several topics such as Newtonian Mechanics, Electricity and Magnetism, Fluid Mechanics, Thermal Physics, Atomic and Nuclear Physics, and Waves and Optics.

Med Surg I Nursing in a Flash is an educational medical app that reviews vital nursing concepts across 30 modules. The app's authors converted more than 4,500 study questions and imported them into the app, providing nursing students with an easy, efficient tool to learn vital nursing content on the go. This app contains no multiple-choice questions, only question-and-answer flash cards for test preparation. Review content is categorized by major body systems and then further broken down into disease states to allow the user to review content pertinent to his or her education.

The questions are geared toward providing the needed information to ace nursing exams and to build a solid knowledge foundation for the future.

Student's Pet is a compact application meant to maximize the productivity of any student. One way this is accomplished is through the elimination of replication. Redundancy can be annoying and this app tries to scale it back while still being informative. The authors do this by the use of assignment types. An assignment type is a user-defined type that holds a name and a value. This is great for sequential assignments (Quiz 1, Quiz 2, Quiz 3, etc.) where the name and point value are reused. The user can define Quiz as being worth 20 points and then reuse it wherever necessary. The built-in calendar is an important tool that allows events to be added as well as reminders. The application will sync due dates with the user's personal calendar, allowing him or her to see due dates from anywhere.

The previously described applications from the online stores address specific characteristics of the educational area. They all share a common number of features. The nature of mobile applications depicts some interesting characteristics because they focus on a specific theme or area. Normally the app cannot understand if the user is really acquiring the contents or if the learning process is the correct one. There is no competition between the users that use the same app. Some apps have an online score, but that is not a fully competitive scenario, nor the best way to metric the learning evolution process. The main disadvantage of these apps lies in the learning evolution process. All of the aforementioned applications were created to transmit learning content. However, such process is somehow limited since the application does not normally evolve with the user. Namely, the user knowledge is dynamic while the application contents are static and do not offer a true form of knowledge monitoring.

4. DISCUSSION AND OPEN ISSUES

This article reviewed and analyzed the most relevant proposals and projects available in the related literature focusing on m-learning technology. From the literature, several heuristics and insights were gathered, providing important information about the available solutions for further works. Most research available falls into the category of best practices for m-learning and does not focus on a specific technology or approach.

Currently, both users and developers have access to a wide range of mobile device technologies and applications that offer a new way to achieve a new level of m-learning. The most relevant characteristics were collected and their advantages and disadvantages are presented below.

—*Obsolete mobile OS.* The operating system is the base for applications and their development. So, its specifications and characteristics compromise the performance of applications running over it. The majority of the OS reviews point to the Symbian OS as the most used OS. As discussed earlier, the Symbian OS is decreasing both in terms of market share and users, and it is lacking some specifications compared to the newest Android and iOS.
—*Obsolete mobile device.* Similar to OSs, the mobile devices used in most applications were outdated. Usually, the available proposals use Symbian-based phones with small screens, low battery life, and various limitations in terms of connectivity, multimedia content, portability, CPU, and memory.
—*Small screen size and resolution.* Due to the nature of the used devices, their screen size and resolution are very limited. Usually, they used a resolution of about 240 × 320 PX, and they are limited for dynamic, rich, and multimedia content.
—*Multimedia contents.* Nowadays, almost all the information transmitted and distributed to mobile devices is multimedia enabled. Therefore, using obsolete devices restricts the user's access to this type of content.

—*Low battery life.* Once again, due to the aforementioned characteristics of the devices, their battery life is very low. In an m-learning scenario, where the user needs to access the information (especially multimedia format) anytime and anywhere, he or she needs a device with, at least, fi5 hours of battery life.
—*Limited connection.* Most of the studied proposals have devices with limited connection support. Most projects focus on only one type of connection. This is a device-related problem since (once again) its characteristics are connectionless. Normally, the used connection is General Packet Radio Service (GPRS). In some projects, Wi-Fi and 3G connectivity are also considered.
—*Nondynamic interfaces.* The interfaces provided by such devices, including their OSs, lack the dynamic features to display information. Usually, the user interface (UI) is static, presenting many sections of text with some coupled pictures.
—*Only focus on specific problem.* In addition to the frameworks, the rest of the available approaches focus on their development to cover a single problem. Despite being m-learning systems, they are only oriented to a single problem and corresponding solution.
—*Poor contents.* Considering the used devices and OSs, the contents are limited since most of it includes text, some images, and only focuses on a single subject.
—*Not focused on the student.* This is probably the most relevant feature that is lacking in all deployed projects. All the approaches focus on the subject of study and not on the student itself. For a better learning curve, the contents of study must be adaptable and controlled by each student, considering also personal learning approaches.

The characteristics presented do not reflect the standalone applications from both the App Store and Google Play, since they are not cataloged as a truly m-learning system, but rather mobile standalone applications. Most of the characteristics and limitations provided are hardware and device associated. Technology is evolving rapidly and the technology used 3 years ago cannot compete with that used at the current development stage.

4.1. Forthcoming Technologies and Approaches

Considering the set of features and limitations presented earlier, the authors identify several approaches that can be useful to overcome those limitations and evolve the m-learning system a step further, improving the learning process. Such improvement can be achieved using various technologies, such as introducing real mobility solutions, using new tablet computer technologies, introducing dynamic elements to the system, and focusing the learning process on the student.

Some characteristics and restrictions available on the aforementioned devices can be easily overcome in a neutral way by the currently available technologies, namely, by tablet PCs. Thus, the following directions to improve m-learning mechanisms are presented:

—Tablet computers: A tablet offers a new world of opportunities for both users and developers. Its characteristics easily overcome the performance at different levels compared with previously used mobile devices. First, it offers a larger screen size and resolution (starting at 600×1024 px), providing much more organized information. Second, with a faster CPU and more available memory, applications can handle and use newer technologies. Third, the battery of these devices can handle more than 12 hours using highly demanding CPU applications. Fourth, they are equipped with several connectivity technologies, such as Wi-Fi, 3G, GPS, and Bluetooth.
—Dynamic content: The contents should be dynamic and changing, taking into account the user's system, location, and even context characteristics [Clough 2010].

—Intelligent learning environment: Proposal of a specific intelligent environment that supports the learning process. It will be able to automatically generate a variety of problems and exercises, have the capacity to explain the teaching contents, and automatically solve and generate understandable answers to the teaching contents.
—Evolutionary learning environments: Proposal of an evolutionary mobile learning environment system capable of classifying students in order to predict their "type." Such classifications will provide a way to cluster students per group and treat each group individually.
—Contents focused on students: Based on the aforementioned classifications, the system allocates resources autonomously and adapts it for them. Each user has particular characteristics and those characteristics will be taken into consideration when the contents are delivered [Berge 2011].
—Allocation of personalized contents: Based on the previous classifications, the system will automatically redirect specific content to each user or to a group of users. Thus, each group is able to learn using its own characteristics and metrics. Each user or group is considered as a whole and the learning process is personalized [Aljohani et al. 2012].
—Evolution monitoring: The system is able to follow its users and their learning process evolution constantly. If any user has a specific problem or difficulty, the system can adapt and help him or her to overcome it. The system will act and react accordingly to the several situations (e.g., if a user has some learning difficulties, the prinft function, regarding the C programming language, the system is able to explain it in another way other than the traditional one).
—Mobile applications: Construction of custom mobile client applications for teaching and learning with friendly, rich, and dynamic small-screen interface design for tablet PCs.

Mobile learning is constantly evolving the way of traditional education, since it introduces a new learning environment and contents. Most of the research available falls into the category of best practices for m-learning, and currently, most of the contents are not directed to the various classes of students using the environment. Through the proposed set of research directions a new personal learning environment for mobile learning can emerge. Such an environment should be able to classify students in order to predict their group or "type." Then, after an initial classification, it can allocate personalized contents for students based on previous classifications. It will constantly monitor and track the user learning process and support it accordingly. Finally, the student will access information anytime and anywhere, using a rich and dynamic UI supported by a range of connectivity options.

5. CONCLUSIONS

This article presented a synthesis of the main achievements of mobile learning technologies and pointed to several directions for future work. The main objective of this survey was the discussion of a critical analysis and extensive literature review considering the related literature and mobile learning projects published till 2012.

Initially, mobile computing and the main mobile OSs and their main features were introduced. Next, the authors emphasized the architecture of the two major mobile OSs in terms of market share. Then, four categories of learning systems technologies (generic tools and applications, web and quiz environments, frameworks, and mobile applications) were considered where each one contains specific contributions to mobile learning. The available approaches are diverse and yield a spectrum of results.

This review summarized the characteristics and technologies of the mobile learning activity and discussed the advantages and disadvantages of those approaches.

Specific mobile application approaches created to run as standalone applications on mobile devices (i.e., applications from the online stores) have been discussed, as well as nonspecific mobile approaches. Specific mobile applications, for both Android OS and Apple iOS approaches, were discussed considering their similarities, differences, and applications.

From the aforementioned reviews some conclusions were achieved. The nature of mobile devices, with their small screens, low connectivity, and poor input capabilities, leads to the assumption that they cannot replace standard desktop computers or laptops. The mobile learning process shares some constraints with the areas of e-learning, including isolation issues, technical support problems, and lack of contact between students and teachers.

With the introduction of tablet computer technologies, a new world of opportunity emerged. Such hardware provides single characteristics to users, such as large screen size, high resolution, diverse connectivity options, and rich and dynamic user interfaces. Together with tablets, new types of applications arise, true mobile applications for those devices that focus on specific subjects such as mobile learning. The available online stores have more than 5,000 mobile learning apps, all with specific features aimed at specific users. Such stores are always available to users, providing an anytime and anywhere learning scenario. Furthermore, the current environment for mobile learning is significantly different from the scenario of the last 5 years. The devices and technologies have evolved, providing users with technology that can take the learning process a step further. The future direction of research is obviously encouraged and dictated by applications, although without the specific hardware requirements, such applications cannot fulfill their objectives. As mentioned above, tablet computers will have an important role in the development of mobile learning. Tablets have a larger screen size and resolution, providing a vast UI space. Their CPU and internal memory can carry heavy tasks, such as multimedia streaming. Their battery life is increased and in extreme conditions can hold up to 12 hours of massive computation. The GPS system can be used to pinpoint their location and thus provide specific content [Shen et al. 2009]. The tablet OS is modular, providing thousands of tools for users to create even more rich and dynamic applications.

Nevertheless, there are a number of other innovative approaches that can be explored. Such an approach is the creation of meta-data or meta-language for content classification (i.e., the system can classify the content and adapt with the user the creation of new content based on the aforementioned classification) [del Jesus et al. 2011; Ciurea 2011]; intelligent customization of contents (i.e., the system can customize contents focusing on each student) [Liu et al. 2010]; each user is unique with his or her own characteristics (i.e., the system can classify the user by a type) [Organero et al. 2010]; focused learning in detriment of general learning (i.e., each user learns at his or her own pace) [Passey 2010]; and introduction of a true mobile learning scenario (i.e., the user has the tools to access the system anytime, anywhere without any constraints) [Simoni 2011].

Mobility should offer the ability to guide and support students and teachers in new learning situations when and where it is necessary. The dependency of the content can be relative to location context (i.e., the system knows the location where the learner resides and adjusts to it), temporal context (i.e., the system is aware of time-dependent data), behavioral context (i.e., the system monitors the activities performed by the learner and answers to them, adjusting its behavior), and specific interest context (i.e., the system modifies its behavior according to the user's preferences).

It seems inevitable that m-learning technology and applications will be an essential extension or even a complete replacement of e-learning soon, although this transition will occur gradually [Sung et al. 2005; Corlett et al. 2005]. The promise of instant access to anytime, anywhere learning mechanisms is an enormous benefit, but it will remain limited until the wireless software technology and users adapt to an appropriate set of rules, pedagogies, and specifications.

In short, on the issue of "What is possible in m-learning using recent technologies?" the answer is direct and evident. Current technologies offer brand new possibilities for users to learn in a new and totally innovative way, with full customization in terms of personal preferences or learning specifications.

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