The growth of m-learning and the growth of mobile computing: parallel developments

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ABSTRACT. M-learning is made possible by the existence and application of mobile hardware and networking technology. By exploring the capabilities of these technologies, it is possible to construct a picture of how different components of m-learning can be implemented. This paper will explore the major technologies currently in use: Portable Digital Assistants (PDAs), Short Message Service (SMS) messaging via mobile phone, and podcasts via MP3 players.

KEYWORDS: *M-learning, Mobile technology, Podcast, Portable Digital Assistants (PDAs), Short Message Service (SMS)*

Online learning and blended instruction, both utilizing technology to convey educational content, are shifting from a model working only with e-learning to encompassing mobile learning (m-learning). This shift in learning locations and learner access to information has been driven both by demand and by advances in technology, that make mobile technology access a practical option for the average person. In examining the growth of these technologies, it is possible to see the growth to date, and possibly the future direction of, m-learning.

Introduction

M-learning is broadly defined as the delivery of learning content to learners utilizing mobile computing devices (Parsons, Ryu, 2006). Kambourakis and colleagues defined it as: "The point at which mobile computing and e-learning intersect to produce an anytime, anywhere learning experience" (Kambourakis et al., 2004, p. 1). The advantages of learning anytime and anywhere have long been near the top of the benefits listed by proponents of online education, but until the advent of m-learning technologies, it was not really an anytime, anyplace environment. The demand for a learner to be physically at a computer, and physically connected via some kind of cable to a network meant that learning locations were constrained. With constraints in place on the available learning locations, time constraints existed as well: someone

taking classes using their computer at work might not have access to that resource at midnight or on Sunday afternoon (Petrova, 2005). Mobile learning is exactly that: mobile. M-learning as an educational method is new and more flexible than previous e-learning applications. Learners can have the opportunity to review course materials, or correspond with instructors or colleagues, while sitting in a restaurant or waiting for a bus; they are not made immobile by the restrictions of desktop computer technology (Georgiev et al., 2006).

Because m-learning is such a new field, the research is still in a stage where different categories of m-learning pedagogy are being developed, identified, and researched (Frohberg, 2006). With this developmental stage in mind, the very existence of m-learning, not to mention its growing application, is directly tied to the growth of mobile technology. This fact is why it is so important for researchers and practitioners to be familiar with mobile technology applicable to m-learning. It simply is not possible for someone to log onto a Learning Management System (LMS) wirelessly from a Personal Digital Assistant (PDA), if wireless networks do not exist or if PDAs do not support wireless connectivity.

Hardware advances are one of two key components to the emergence of m-learning, the other being networking. To be mobile technology, hardware had to advance to a point at which people would carry and access the device, on a regular basis. It is generally accepted that devices like mobile phones, PDAs, and MP3 players fit into the category of mobile devices (Mellow, 2005; Andronico et al., 2003). Sources disagree on the status of laptop and notebook computers as mobile devices: while they are capable of working without plugging into a power source, and can utilize wireless networks, they are not devices that people can carry everywhere, and quickly access at any time, due to their size, configuration, and the time required to boot up and shut down. For the purposes of this paper, mobile technology will be described as a device that can fit in the average shirt or jacket pocket, and be carried on a daily basis.

Wireless networking is the second technological component contributing to m-learning success. While some m-learning resources can be utilized in a non-networked, offline environment, many depend on access to the Internet to exchange information and access up-to-date information. To serve this need, mobile

devices needed a way to access network resources, without plugging into a landline connection. Currently, the leading candidate for this technology is the IEEE 802.11 wireless communication standard, commonly called *Wi-Fi*. Also gaining ground in the market are wireless phone broadband connections and, to a lesser extent, the IEEE 802.15.1 wireless communication standard, commonly called *Bluetooth*. While *Bluetooth* is more frequently used as a device-to-device data transfer technology, its use as a network system is possible. Regardless of which standard is in use, wireless networking provides learners with the opportunity to connect with colleagues and instructors via online resources, from a much broader variety of places than are accessible via traditional wired connections. An in-depth review of the technology will be explored in a later section, but it is important to recognize just how important this technology is in facilitating m-learning environments.

Defining m-learning

There is much debate as to whether m-learning is the next progressive step from e-learning, or simply an advanced tool that integrates with e-learning. In either case, m-learning is a new and unique component of distance learning. Georgiev and colleagues define it as: "…a new stage of the development of e-learning" (Georgiev et al., 2006, p. 1). To understand the distinctions, it is necessary to look at what e-learning really is, followed by the emerging definitions of m-learning.

Laouris and Eteokleous cite Pinkwart and colleagues in defining e-learning as: "…learning supported by digital 'electronic' tools and media" (Laouris, Eteokleous, 2005; Pinkwart et al., 2003). Ramshirish and Singh open by defining e-learning as "…essentially education via electronic network in which content is transferred via the Internet, intranet, extranet, audio/video tapes, satellite television, and CD-ROMs" (Ramshirish, Singh, 2006, p. 2). It is important to recognize that definitions of e-learning almost always specify that there is indeed learning taking place in an environment, and that the environment happens to utilize electronic means of communication to convey the learning experience. While it may be difficult to precisely define what e-learning is, and what it is not, dependent on the amount of electronic integration into the course, it is probably fair to say that any educational environment which utilizes any electronic media tools as a part

of the instruction is utilizing e-learning, even if it is not a hundred percent e-learning environment. As an example, a face-to-face class viewing information on an archaeological dig on DVD would be utilizing e-learning as a component of their experience, while an asynchronous online course, where all activities take place in the confines of a CMS, would be a dedicated e-learning class.
Given that e-learning is learning incorporating electronic media, what defines m-learning? This paper will define m-learning as any e-learning application delivered on-demand via mobile digital device. As a relatively new term, however, there are many other definitions in use. Kambourakis and colleagues define m-learning as being "the point at which mobile computing and e-learning intersect to produce an anytime, anywhere learning experience" (Kambourakis et al., 2004, p. 1). Colazzo and colleagues state that: "A mobile learning educational process can be considered as any learning and teaching activity that is possible through mobile tools, or in settings where mobile equipment is available" (Colazzo et al., 2003). Laouris and Eteokleous cite multiple sources for definitions of m-learning (Laouris, Eteokleous, 2005, p. 2), including:

- Pinkwart et. al. (2003), who define m-learning as "e-learning that uses mobile devices and wireless transmission".
- Polsani (2003), who defines m-learning as "a form of education whose site of production, circulation and consumption is the network".
- Traxler (2005), who defines m-learning as "any educational provision where the sole or dominant technologies are handheld or palmtop devices".
- Sharples (2005), who defines m-learning as "a process of coming to know, by which learners, in co-operation with their peers and teachers, construct transiently stable interpretations of their world".

The common thread of all these definitions above as cited by Laouris and Eteokleous is that they incorporate the use of mobile technology to facilitate the transfer and acquisition of knowledge, the learning process (Laouris, Eteokleous, 2005, p. 2). Again, like e-learning, m-learning can be utilized on different scales. One environment may utilize m-learning as a single component of a single topic, while another environment may be dedicated to

using m-learning as the only means for learning. In either case, the technology applied will be mobile.

With both e-learning and m-learning defined, it is possible to see many similarities between the two processes. Most obviously, learning is a key component of both: the goal of the application, regardless of the technology utilized, is to engender the acquisition of knowledge by a learner. Also obvious is that electronic technology is used in both systems. Granted, there are differences in the types of devices, and the types of media used, but e-learning and m-learning are really studies in technology integration into educational environments. Clearly, the theories behind these two different forms of instruction are the same: the integration of technology can improve the learning experience. With such common goals and methods, then, why is it necessary to delineate m-learning from e-learning? The answer to that is in the very real differences between the two.

Kambourakis and colleagues' definition of m-learning is a good start to identifying the differences from e-learning: m-learning is, to an extent, e-learning, but e-learning is not necessarily m-learning (Kambourakis et al., 2004). What this means is that while, by definition, learning through mobile computing devices utilizes electronic media, and therefore meets the definition of e-learning, e-learning may or may not incorporate mobile devices, and, as such, may or may not meet the definition of m-learning. Georgiev and colleagues state this concept as: "The main difference between e-learning and m-learning is in the technologies used for educational content supply" (Georgiev et al., 2006, pp. 2-3). In many ways, m-learning acts as a partner to e-learning, providing learners with the opportunity to maintain involvement in their learning environment, while not accessible via static technological devices, such as desktop computers (Charmonman, Chorpothong, 2005). It is this unique connection that defines the difference between the two. M-Learning is a dedicated, special-purpose component of the e-learning world, that provides expanded opportunities and abilities to learners. As a special component, m-learning warrants its own definition and dedicated study into its creation and application, to provide the best facility to mobile learners.

Given that m-learning is a discipline unto itself, there are certain advantages provided in an m-learning environment that are not present in other kinds of e-learning. The primary advantage

of m-learning is to provide truly anytime, anyplace learning (Kambourakis, et. al., 2004; Ramshirish, Singh, 2006). What this means to the learners is that they are no longer constrained by static resources. A desktop computer, no matter how powerful or user-friendly, will always be limited by size, weight, and the need for power and network connections, via cables plugged into sockets, and ports that are not mobile.

In addition to being able to access resources from anywhere with a mobile device, this ease of transport has other advantages. Perhaps most notably, mobile devices provide users with an interface to their content that is both personalized and secure (Petrova, 2005). In the computing environments of many educational institutions or corporations, personalization is simply not a viable option for computer systems. Indeed, convenience is one of the identified benefits of m-learning technology (Parsons, Ryu, 2006). Because there are multiple users for each public machine, individuals are often unable to set up personal profiles for things as simple as *Post Office Protocol* (POP) or *Internet Message Access Protocol* (IMAP), access to e-mail accounts or bookmarks in browsers. While this may seem to be a minor inconvenience, it can quickly add up to large quantities of wasted time. The time required logging in, and finding specific pages, or accessing e-mail through a Web interface may even reduce the frequency of a person's access to the learning environment. Lack of access can adversely influence learners' experience in the environment. With mobile devices, these issues are eliminated. By carrying a personalized device, the user has media access tailored to best fit their personal preferences. This being the case, the user can quickly and easily access the resources they need, which may result in a higher frequency of access. Complimenting this advantage is the ability of m-learning to deliver, via these media sources, a personalized learning experience (Türker et al., 2006). Taken as a whole, m-learning delivers to the learner a flexible, easy-to-access learning resource, that can be tailored to their specific needs.

The advantages of m-learning can be summarized as being advantages of access. Whether it is a question of time, place, or simply convenience, ease of access streamlines the learning process for the learner. From an efficiency perspective, the less time spent managing resource access, the more time is available to capitalize on the value of those resources. These advantages do come at

a price, however. There are unique demands for designing and administering m-learning environments.

Because of the multiple technologies involved in m-learning, designing instructional content for this medium can be very challenging. The first demand for a successful application of m-learning is one of scale: without a saturation of the technology in the target audience, the system will fail (Viteli, 2000). The need for learners to have equal access to the technology is not significantly different from access issues for other teaching methods. A class Web-site is not helpful, if none of the students has Internet access, just as course notes distributed on CD are not helpful, if students do not have access to computers to access the CD. While the hardware and networking technologies of m-learning will be covered in a later section, the best *Short Message Service* (SMS) system or podcasting platform is useless, if learners do not have access to SMS-capable mobile phones or devices to play MP3 files. Thus, in planning m-learning integration, some difficult decisions have to be made. It is very dangerous to assume that all learners will have access to a certain type of technology, while at the same time mandating the purchase and use of what can be very expensive hardware can be a challenge as well. These issues have to be addressed in every individual environment, and addressed early, so that the m-learning environment can be properly planned and implemented. Closely connected to the issue of access is the issue of capability. While all users may possess a certain type of hardware, different models may have different capacities in terms of processing power, network access, or other features. Thus, when designing an m-learning environment, it is necessary to consider the content and format of the information being delivered, taking into account the users' locations, and the limitations of their devices (Lonsdale et al., 2003).

One of the possibly unexpected, but very real, demands of designing m-learning environments is to maintain the proper focus during the design phase. As the point of m-learning is to facilitate the acquisition of knowledge, it is critical to focus on the learner, rather than the technology, when working with m-learning pedagogy (Lonsdale et al., 2003). With such an intense focus on the capabilities of the new technology available to integrate into a learning environment, it is far too easy for a designer or instructor to put all of their time into the technical aspects of an environment. Similar to the issue

of access to the devices themselves, the best system ever devised is of no use to the students, if it is too complicated for them to use. Therefore, the technical acumen of the intended consumers of the information must be considered, along with the technology access of the group. More and more, the degree to which this consideration matters is changing, in relation to the intended audience. Current traditional undergraduate students are coming in, as what are referred to as digital natives, who can seamlessly integrate technology into their daily practice, while older students, referred to as digital immigrants, cannot (Cobcroft et al., 2006). Two good rules of thumb are that users are rarely at the same level as designers, and that just because something can be done, this does not necessarily mean that it should be done.

M-learning technology

With these design requirements in mind, the available m-learning technologies can be explored. The broad categories include PDAs, mobile phones, and MP3 players. The start of this discussion involves defining what m-learning devices are. The *Hardware* section will explore details of each device, but what categorization defines these devices? Generally, mobile devices can be defined as electronic devices that are small enough to fit in a shirt or jacket pocket. Mellow states that: "This would include such devices as mobile phones, *Portable Digital Assistants* (PDAs) and *iPods*. It would not include laptops, as, while they are portable, they are not mobile. Mobile devices should fit in your pocket" (Mellow, 2005, p. 1). In relation to the widespread availability of these devices, Petrova says that: "In the near future, mobile communication devices will exceed the number of personal computers" (Petrova, 2005, p. 1). Finally, Trifonova and Ronchetti define mobile devices as follows: "By mobile device we mean PDA and digital cell phone, but more generally we might think of any device that is small, autonomous and unobtrusive enough to accompany us in every moment of our every-day life, and that can be used for some form of learning" (Trifonova, Ronchetti, 2003, p. 1).

It is interesting to note that these definitions, by default, eliminate notebook computers from classification as mobile devices. As Mellow stated, there is a distinct difference between portable and mobile (Mellow, 2005). The prime characteristic of mobile devices is that they are carried on a regular, if not constant basis.

The old routine of picking up car keys and wallet every morning has for most people expanded to include, at least, a cell phone, if not a PDA and MP3 player as well. It is this constant access to the devices that drives m-learning as a viable delivery system.

In order to be different from other forms of distance learning, and in order to function at all, mobile learning has to be exactly that: mobile. Mellow quotes Oblinger as saying that today's learners are "digitally literate, always on, mobile, experimental, and community-oriented" (Mellow, 2005, p.2; Oblinger, 2004). The mobility of m-learning takes advantage of an entire population that maintains their connectivity through digital devices; they are involved with it all day, every day, and are comfortable with its use (Charmonman, Chorpothong, 2005). This cultural phenomenon leads to what Woukeu and colleagues identify as the goal of m-learning: "The ultimate objective being for learning to become an integrated part of our daily life, that is no longer recognized as learning at all" (Woukeu et al., 2005, p. 2). It is mobility that drives m-learning as a product. Because learners are connected to digital media devices at all times of their day, and are comfortable accessing information through these devices, they no longer require a particular location or environment to review educational material. Learners not only do not need a classroom, they do not even need a table to set up their notebook computer, or enough elbow room on a train or bus, to get into a comfortable typing position; their thumbs or a stylus have supplanted the need to type on a traditional keyboard. Working hand-in-hand with the physical mobility of the devices is the virtual mobility of networking. No device, no matter how powerful or portable, can deliver educational material, if it does not have access to that material. Thus, mobile networking is a key component of the m-learning environment. The connectivity allowed by mobile networking gives learners not only access to static instructional materials, but to dynamic discussion environments, and updated information from an instructor. Taken to the farthest extreme, anytime, anyplace learning becomes all-the-time, everywhere learning. With these parameters of mobility defined, it is time to examine the mobile devices themselves in detail.

Mobile hardware

Probably, the first device that comes to mind, when mobile hardware is discussed, is the PDA. These devices offer many of

the features of a full-size laptop computer, but in a package that fits in a pocket. As discussed, mobility is a primary component of m-learning hardware, and few devices offer the combination of mobility and features that the PDA does.
From the start, the PDA experience lends itself to being ideal for the m-learning environment. Whether a *Palm* or *PocketPC* operating system, a PDA will start up almost instantly, as opposed to the boot process that is required for a larger computer. This advantage by itself is a significant one: if a learner wants to check e-mail, or reply to a message board, while in-between appointments, the time spent booting up and shutting down a traditional computer platform is a very real deterrent, the PDA interface eliminates that wasted time.
Once the PDA is active, it provides a wide variety of applications that in the past were not available on mobile devices. Andronico and colleagues investigate three areas of applications using PDAs in the m-learning environment (Andronico et al., 2003, p. 3):

1. The use of PDA as an enhanced organizer, by uploading/downloading data with the central system, in order to align, periodically or on-demand, the agenda of the user (teacher, student, or other actors of the system) with all the academic appointments. This will imply the integration of the data schema of the agenda software of the portable device with the data coming from the central system.
2. The browsing of newsgroups managed by the central Learning Management System (LMS) on the PDA screen, in case the user has no keyboard attached to the portable device, or the full interaction with the newsgroup, in the other case.
3. The browsing of the LMS Web pages, where it is possible to download the educational material, and consult it with specific viewers (at the moment, those related with the Office suite and with Acrobat PDF format).

The first area, used as an enhanced organizer, speaks to the origins of PDAs as electronic date books and rolodexes. Prior to networking technology, the PDA was primarily a mobile data storage system, maintaining calendars, phone numbers, and other personal and business information for the user. With networking capability and shared calendars, the PDA can

apply this use to the m-learning environment, by facilitating the schedules of multiple people, with the goal of achieving a learning objective. As anyone who has been through a post-secondary degree, and particularly a graduate degree, knows, scheduling time to meet with a busy professor, or to assemble a project team, to work on a class assignment, can be difficult at best, and, at times, it borders on the impossible. By providing a live-update, shared calendar environment, the networked PDA can facilitate arranging these meetings that are so critical to learning. Like many of the things seen in m-learning, and with technology in general, meetings are not a new or unique tool, but the technology improves the efficiency of arranging the meeting, therefore saving time for the individuals, and sparing that time for some other purpose.

Andronico and colleagues' second case, the engagement of a Learning Management System (LMS), connects directly not only to m-learning, but e-learning as well. As a digitally delivered instructional media, the LMS is well established as a component of distance or blended instruction. What takes the LMS from e-learning to m-learning is the application of mobile technology, in this case, the PDA. With a mobile network connection, the user can access the LMS in live time, and view updates, assignments or discussions. While it is true that the lack of an attached keyboard may inhibit full participation, devices are improving to a level where, even when using the stylus as an input tool, it is possible to compose messages with practice. For a more user-friendly data entry environment, many manufacturers are also offering thumbpads, small keyboards designed to be used by a user's two thumbs, while the device is held in the hands, that will dock with PDAs that do not have such an entry device included in their construction. In either case, a learner has the ability to participate in discussions from virtually any location, at any time, and the educational environment is maintained as a dynamic, active exchange of ideas (Andronico et al., 2003).

The final of Andronico and colleagues' three points relates to the downloading and accessing of course materials (Andronico et al., 2003). Again, this type of function was not long ago limited to only computers, but the PDA platform has become much more capable. Once linked into wireless networks, PDAs can now read and even edit traditional Office and PDF files (Savill-Smith, 2005). With this level of functionality, a user can truly access all of the resources

that would be available to their computer-bound colleagues. It will likely not be long, before the mobile device is simply another computing platform, without a clear distinction between the desktop or laptop, and the palmtop (Qingyang, 2003).

The only potential drawback to the use of PDAs is their lack of processing power, relative to a laptop or desktop computer. Baek and colleagues say that: "Mobile devices have the shortcomings of small screens, low processing speed, and limited storage, while they can provide very specific learning materials for an individual learner, with mobility at any time" (Baek et al., 2004, p. 2). While this is true, the technology is changing at a rapid rate. To put the current state of PDA power in perspective, the author completed the first year of business school in the year 2000, with a laptop computer that had a 166Mhz processor. The author's current PDA, not the most powerful on the market, has a 312Mhz processor. While laptops will almost always hold the advantage in processing power, it is important to remember just how little power is really required to use common applications like word processors and document viewers. Also, memory capacity is changing rapidly, as most PDAs accept *Secure Digital* (SD) or other memory cards, and the capacity of these cards is constantly improving. Where the power and capacities of mobile devices are really being seen as issues is at the design stage of m-learning media. Because there are so many differences among different mobile devices, it is critical for m-learning media designers to know what kind of hardware platforms their intended audiences are working on (Georgiev et al., 2006).

Outside of the PDA realm, another mobile technology finding success in m-learning is the use of SMS messaging on mobile phones. SMS allows learners to access text information, and exchange messages and information, via their mobile phones. This provides the learner with access to the learning environment anywhere they can receive a mobile phone signal, and utilizes a device that they will likely be carrying every day, even in the absence of an m-learning requirement to do so. Mellow cited the advantages to SMS as being "…true flexibility to control the time, place and pace of their learning, specificity of content, tutor-constructed study aids, designed for those areas that are 'challenge-to-learn' concepts, using technology that is engaging and totally comfortable for the student, non-threatening, private availability of on-demand

study support" (Mellow, 2005, p. 5).

There are three possible models of information exchange via SMS: one that involves the educational institution sending out information on their schedule; one in which the student requests information as they need it; and a third where the student is involved interactively with the environment (Mellow, 2005). The most immediate difference that is apparent between the SMS model and that of an LMS is that there is not a set of available information resident on a server for students to access on-demand: a process must be initiated to transmit the information to a recipient. While this may not be the ideal model for some applications, for others it is a very good fit. Messages regarding class changes, reminders of upcoming deadlines, or questions and responses involving specific course material could all be excellent uses of SMS. Because of the constant presence of a mobile phone, all individuals involved in the system are likely to receive and respond to SMS messages more quickly, and possibly more reliably, than they are to e-mail. Again, the application of technology to the m-learning environment is facilitating all the time, everywhere learning.

The third and final unique hardware category to consider is the MP3 player. These devices store and play digital audio files that, in the case of m-learning applications, are commonly referred to as podcasts. The 'podcast' term comes from the popular Apple MP3 player, the *iPod*. The term itself is somewhat of a misnomer, however. Any device that can play MP3 files can be used to listen to podcasts, not just the *iPod* device.

Most podcasts consist of an audio file that conveys information on a given topic. In many ways, this is simply a recorded lecture that is made available on-demand to learners, and in some cases, it actually is a recording of a lecture that was originally delivered live. Recently, however, podcasts have begun to evolve in response to improved MP3 players. Many of these devices now offer the option of displaying a slideshow of static digital image files, or even playing digital video. Using this technology, podcasts can include traditional slides to accompany a lecture, or even a video file of the lecture, where sample problems or other information can be viewed, as it is written out to accompany the audio of the lecture. In a dramatically short time, podcasts have advanced from simply theory to a fully-developed instructional tool, utilizing not only audio, but also image and video files. For users, podcasts have

become much more popular as a tool to download audio files of lectures and tutorials (Oloruntoba, 2006).
Having examined the individual devices that are prevalent in m-learning, it is important to note that single-use devices are not necessarily a reality anymore. While dedicated PDAs, mobile phones and MP3 players can certainly be purchased, there is an increasing cross-over of functionality between them.
More common than anything else is the inclusion of an MP3 player in another device. Very few new PDAs lack a headphone jack and MP3 playing capability, and an increasing number of mobile phones are embedding this functionality in their devices as well. In application, this indicates that incorporating m-learning technologies in the form of podcasts, particularly audio-only podcasts, may capitalize on the greatest saturation of available technology in the population. Also, if an organization plans to utilize m-learning technologies that require a PDA, it is helpful to recognize that with virtually any current PDA having the capability to play podcasts, the use of any PDA-based m-learning technology can be coupled with podcasting, thereby delivering multiple media streams, via a single piece of hardware.
The other increasingly common combination of mobile devices is that of the PDA phone. Several mobile phones currently integrate a PDA platform into the handset, thus providing the user not only with a mobile phone, but also a mobile computing platform. With these devices, it is possible to combine not only PDA and MP3 functions, but SMS messaging applications as well. In an environment, where users can be required to purchase a given device, a PDA phone can incorporate all the aspects of m-learning into a single hardware package. Pedagogy of each organization will determine if it is reasonable to require such capacity, but the technological capability does exist, if it appears useful in the proper situation.

Mobile networking

For mobile hardware to engage in the mobile learning environment, it is necessary for these devices to have access to m-learning content, often located on a network resource. If the mobile device was limited to working at a location, where a network cable could be plugged in, then its use would no longer be mobile, regardless of how small the device itself is. The second half of technology

mobility has been the rise in mobile networks. The combination of mobile hardware with mobile technology is what allows this phenomenon to progress.

Perhaps the most prevalent and most widely recognized mobile networking technology is the IEEE 802.11 specification, commonly called *Wi-Fi*. *Wi-Fi* works by using a series of access points, which are transmitter/receiver stations, that wireless devices can connect to, via their own *Wi-Fi* networking card. Initially seen as external cards, that were used in a *Personal Computer Memory Card International Association* (PCMCIA) slot on laptops, *Wi-Fi* networking devices are now being integrated into standard-size PDAs, and even smaller platforms, such as mobile gaming devices. If a mobile device does not have a built-in *Wi-Fi* card, there is a wide variety of add-on cards available, some small enough to fit into the SD slots on handheld devices. Thus, many devices not originally configured to access wireless networks can be converted to do so. There are two widely used standards: 802.11b (b), which transmits at 11 Megabits per second (Mbps), and 802.11g (g), which transmits at 54 Mbps. Both of these common standards are interoperable, meaning that a g device can operate at a slower speed on a b network, and a b device can access a g network. Most devices today that include built-in *Wi-Fi* connectivity are using either the g or b standard, as are most publicly accessible *Wi-Fi* access points, which are referred to as hotspots.

The hotspot phenomenon has rapidly expanded to provide coverage to many public places (Balachandran et al., 2003). This gives m-learning students and instructors the freedom not only to work at a wide variety of locations, but also to deliberately choose comfortable locations, such as a favourite coffee shop, from which to work. Thus, m-learning participants cannot only work on the move, but they can also work from a good environment, that may not be available to someone tied to a desktop or landline networked laptop. The other side of the *Wi-Fi* connectivity issue is the possibility for groups to meet and connect to each other, via what is referred to as an *ad-hoc* wireless network. This does not require an access point, as it does not necessarily connect users to the Internet - it just allows users to connect to each other via *Wi-Fi*. In the event that participants in an m-learning course meet, in a physical location, to work on a group project or just to discuss the course content, they can avoid the need to print notes on paper

or e-mail documents ahead of the meeting, even if they are at a location that does not have an accessible hotspot. Once together, they can create an *ad-hoc* network, and exchange electronic documents wirelessly, even without a service provider.

The question of device-to-device networking brings up a second wireless networking standard, this one being IEEE 802.11.1, commonly called *Bluetooth*. Commonly seen as a networking technology, *Bluetooth* connects hardware devices to each other. Perhaps the most commonly witnessed application of the technology today is the *Bluetooth* headset, which wirelessly connects a headphone and microphone to a mobile phone. While in wide use for this purpose, *Bluetooth* can also be used to transfer data between devices, synch PDAs and mobile phones with other devices for data backup, and even access *Bluetooth* network portals to the Internet. *Bluetooth* is a much shorter-ranged technology than *Wi-Fi*, and because of that it is rarely used for hotspots, but it is very useful for device-to-device communication. In the m-learning environment, this would be useful for sharing data between devices. As an example, an m-learning system utilizing SMS messaging would transmit messages to a learner's mobile phone. With a *Bluetooth*-enabled phone and PDA, the learners could transfer that message from their phone to their PDA wirelessly, and store and access the information from that device, at a later time. Because of its relatively new presence in the market of mobile technology, *Bluetooth* probably does not have a fully-developed application set at the time of this writing, and it bears watching to see what new uses may be beneficial to the m-learning environment.

The final two mobile networking technologies are connected to mobile phones: SMS and cellular broadband. SMS is a data transmission option, that allows the sending and receiving of short messages via mobile phone. This does require a mobile phone to use, but has the advantage of not being tied to hotspots like *Wi-Fi* technology, and the messaging is accessible anywhere the user has a mobile phone signal.

Also seen most often on mobile phones, but far more fully featured, is the cellular broadband network. Cellular broadband provides full Internet access to a mobile device, most frequently a mobile phone, via wireless cellular network. Coverage at the time of this writing is still more limited than cellular phone coverage, but it is

growing daily, and encompasses most urban areas in the United States. First seen on mobile phones, it is now possible to access a cellular broadband network via a variety of devices, through the appropriate expansion cards. Basically, this technology provides the user with *Wi-Fi* capabilities, without the need to access a hotspot. Its applications in m-learning are much the same: it provides Internet access on mobile devices. In the future, it will be interesting to see if cellular broadband builds a customer base to rival *Wi-Fi* for mobile networking applications.

Conclusions

Mobile technology, both hardware and networking applications, is a necessary component for the existence of m-learning. As instructors and designers, practitioners of m-learning need to be fluent in the use of these technologies, and cognizant of what technologies their learner population has access to. Application of specific pedagogical theories is directly connected to the technologies in use in an m-learning system, and as such, design of m-learning environments demands a system approach, where development accounts for all aspects of the environment. As technology continues to improve and innovate, the options open to m-learning will expand; the key is to focus on the fact that the goal of m-learning is to facilitate learning, no matter what form the delivery may take.

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Sintesi

La formazione online e quella di tipo blended stanno attraversando una fase di cambiamento, che all'impiego esclusivo dell'e-learning vede associato quello del mobile learning (m-learning). Questo mutamento nell'accesso alle informazioni da parte dei discenti è stato provocato sia dalla domanda che dall'evoluzione tecnologica. Le attrezzature di mobile technology, di cui vengono passate in rassegna numerose definizioni, sono qui semplicemente descritte come apparecchiature che si possono portare, ogni giorno, normalmente con sé. Esaminando la crescita di questa modalità tecnologica, è possibile valutarne lo stato attuale e, in parte, supporne la futura direzione.

Due sono le componenti chiave alla base del successo del m-learning: i progressi dell'hardware e il networking. Per diventare mobile, l'hardware si è evoluto a tal punto da supportare apparecchiature portatili immediatamente accessibili, tra cui rientrano comunemente cellulari, Personal Digital Assistants (o PDAs) e lettori MP3. Il wireless networking consente di accedere alle risorse del network, senza bisogno di alcuna connessione, qualità che ne costituisce la caratteristica innovativa. Al momento, il principale candidato per questo tipo di tecnologia è lo standard di comunicazione wireless IEEE 802.11, comunemente noto come Wi-Fi. Altre apparecchiature che stanno guadagnando terreno sul mercato sono le connessioni telefoniche wireless a banda larga e, in misura minore, lo standard di comunicazione wireless IEEE 802.15.1, universalmente conosciuto come Bluetooth. Anche se Bluetooth viene usato con maggiore frequenza come tecnologia per il

trasferimento di dati da un'apparecchiatura all'altra, è possibile utilizzarlo anche come sistema di rete. A prescindere dallo standard in uso, il wireless networking dà ai discenti la possibilità di connettersi con colleghi e insegnanti, sfruttando le risorse della rete, da una varietà di luoghi molto più ampia, rispetto a quanto sarebbe possibile con le tradizionali connessioni via cavo. Tra i diversi tipi di tecnologia che rendono facilmente accessibili ambienti m-learning, vengono esaminate le principali categorie tecnologiche di tipo mobile, che comprendono appunto i PDAs, i telefoni cellulari e i lettori MP3.

La mobile technology, sia nelle applicazioni networking che hardware, è una componente necessaria per l'esistenza stessa dell'm-learning. Come insegnanti e progettisti, i professionisti dell'm-learning devono avere familiarità con l'utilizzo di queste tecnologie e sapere quali siano accessibili dalla propria utenza di discenti.

L'applicazione di specifiche teorie pedagogiche è direttamente connessa alle tecnologie in uso all'interno di un sistema m-learning; il design di ambienti m-learning richiede dunque un approccio sistemico, il cui sviluppo tenga conto di tutti gli aspetti dell'ambiente stesso. Mentre la tecnologia continuerà a migliorare, con l'apporto di innovazioni e aggiornamenti, le possibilità dell'm-learning aumenteranno di pari passo; la chiave sta nel concentrarsi sul fatto che l'obiettivo dell'm-learning è, in ogni caso, quello di facilitare l'apprendimento, a prescindere dalla forma di erogazione.