British Journal of Educational Technology *Vol 43 No 4 2012* 561–575
doi:10.1111/j.1467-8535.2011.01214.x

Message design for mobile learning: Learning theories, human cognition and design principles

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Abstract

The demands of an increasingly knowledge-based society and the dramatic advances in mobile phone technology are combining to spur the growth of mobile learning (mLearning). However, for mLearning to attain its full potential, it is essential to develop pedagogy and instructional design tailored to the needs of this new learning environment. At present, there is a lack of research on message design for mLearning. Towards these ends, this paper explores the principles and processes of message design for mLearning, including the influence of learning and cognitive theories, human–computer interaction principles, devices and methodologies. And it presents a number of practical guidelines for designing instructional messages for mLearning.

Practitioner Notes

What is already known about this topic

- Message design is the way that information is presented to the learner.
- Instructional message design is "the manipulation and planning of signs and symbols that can be produced for the purpose of modifying the cognitive, affective or psychomotor behavior of one or more persons" (Lohr, 2011, p. 1).
- With the increasing use of technologies in teaching, message design also involves applying a variety of theories (perception, learning, communication and systems) to the design and evaluation of instructional media (Lohr, 2011).
- Although Mayer's message design principles (Mayer & Moreno, 2005) are widely used for instructional design in complex online learning programs and computer-based learning, they have not been tested for mobile learning (mLearning). There is still a dearth of research on message design principles for mLearning.

What this paper adds

- A focus on a number of key mLearning message design issues (eg, the use of different mobile devices, learner mobility and the use of multimedia elements).

- Concepts and heuristics for practitioners to consider and deploy.
- The cultural dimensions that need further exploration.

Implications for practice

- It is important for instructional designers to master the skills required "to design multimedia messages that promote meaningful learning" (Mayer & Moreno, 2002, p. 107).
- Design learning based on the learning environment (formal vs. informal).
- Design content that can be used on different devices based on the typology and the activities these devices can support.
- Design for learner mobility (use of audio, captions, icons, color and symbols).
- Use captioning to provide adaptable messages for differing contexts and provide guidelines on both fonts and placement.
- Use color as an example of cultural considerations in designing for mLearning.

Introduction

The existence of nearly 2.7 billion active mobile phones worldwide dramatically illustrates the huge potential for the mobile learning (mLearning) market (Ahonen, 2007). mLearning enables the delivery of instructional content to a student when the need, relevance and value of the lesson are highest. mLearning is at an early stage, but it is already drawing a great deal of attention in the US, Europe and Asia. In some contexts, it is replacing aspects of traditional teaching and learning (eg, the use of mobile courseware in an online college in Shanghai), and is exploring new learning models (eg, mobile on-demand learning). However, instructional designers and developers who plan to incorporate mLearning into their educational experiences will need guidelines for effectively designing materials and activities for mLearning.

This paper synthesizes research and development in the design of mLearning, with a focus on message design. We aim to provide specific, practical recommendations for designing teaching and learning content for mLearning. To achieve these goals, we address the principles and processes of mLearning message design from the following aspects: (1) design for different devices, (2) design for learner mobility and (3) design for better accessibility, usability and learning.

Theories and paradigms underlying message design for mLearning

The development of modern mobile communication equipment introduces new learning media and tools that, when combined with earlier theories and paradigms, accelerate the change of learning concepts that provide new modes of interactive learning. This section addresses the major learning and cognitive theories that are relevant to mLearning and illuminate them with exemplary applications.

Dual coding theory

The dual-coding theory presented by Allan Paivio (1986) was the first systematic objective measurement on the effects of imagery on learning. The theory recognizes two cognitive subsystems: one processes nonverbal objects or events, such as images, and the other one processes verbal language and audio. A given task may require one or both kinds of mental processing, and the interconnectedness of these cognitive systems facilitates a better interpretation of the overall environment. Human cognition is unique. It accommodates linguistic input and output such as speech or writing, while simultaneously manages nonverbal objects, events and behaviors (Paivio, 1986). Verbal and nonverbal cues have a profound impact on memory, recall and cognition and, together, can have an additive effect on learning.

Dual coding conditions exist in mLearning as they do in all instructional media. Therefore, these constraints on the modes of information that learners can consume at a given time should be taken into account in mLearning. Some content is better suited for images while other content is best conveyed through text or audio presentation. Some content would be most effectively transmitted with a multimedia display that carefully combines audio and visual content. Effective learning components design should first conform to the principles of cognitive load theory (Chandler & Sweller, 1991), which states that learner's cognitive load is affected by intrinsic (complexity of the content), germane (building new complex schema) or extraneous demands (techniques in presenting the information). Reducing the levels of extraneous cognitive load through redesigning instructional materials, for instance, may enhance learning outcomes. In addition, design that abides by cognitive load theory will place images, spoken language and printed words in appropriate combinations to maximize the instructional effectiveness.

In addition, many environmental factors affect how mLearning content will be received, including ambient noise, mobility of learners, bandwidth and connection capabilities. Research by Teng, Bonk, Bonk, Lin and Michko (2009) found that YouTube videos shown in class illustrated that participants preferred videos that had multiple media elements, such as text, pictures and voiceovers. The media-rich videos were deemed to be more creative and engaging by most of the 113 students involved in the study. Further, the study found that the richness of online media influences viewer's perceptions and their motivation to watch videos, in addition to how well they learned the content. Participants rated the videos with a combination of text, pictures and voicing as more engaging than the text-only videos, which were seen as informative but dull. Ultimately, the form of the video should depend on learner needs, subject matter and timing within the course (Teng *et al*., 2009).

Formal and informal mLearning

Learning environments can be classified as one of two types: formal and informal. Formal learning occurs under management of a teacher (and generally in a purposefully built environment), whereas informal learning occurs under self-management of the learner and in ad hoc environments. In formal learning environments, the convenience provided by mobile technologies strengthens the link between learner and the content which, in behaviorism terms, is described as "stimulus and response." It also enhances the interaction between learners and teachers. If instructional designers improve the optimization of time, sequence and technology, learning content can be pushed to the learners' mobile terminals in ways that promote improved feedback and learning autonomy.

By way of some examples of mobile technology in a formal learning setting, the MobiSkoolz Project 2001 in Singapore illustrates such an instant information feedback system. The project used the date and time of students' responses to prompt teachers to provide real-time advice to the students. In this case, the learning content was displayed on mobile devices and the responses from the learners' behavior formed a "stimulus and response" loop. At the same time, the mLearning system facilitated the reinforcement that behaviorism believes is a basic element of learning. Another project in Japan, the Basic Support for Ubiquitous Learning Environment (BSULE), shows how mobile technology works to enhance interactivity in a knowledge transfer and feedback system (Saito, Ogata, Paredes, Yano & Martin, 2005). At the environment's core is a smart classroom that can support traditional classroom activities based on the use of computer and mobile technology. In particular, it included an instant information feedback system so that the teacher could change and adjust teaching strategies according to the diagnosis and remedial instruction provided by the system. Students in the environment thought that the interactive learning in BSULE was interesting and instructive, while experts thought that the use and participation of this learning environment was suitable and appropriate for the learning activities.

Content-based pushing services are also a solution to the interactivity of mLearning design, especially in formal learning cases. According to the MOBILearn Project's Final Report, a WAP (Wireless Application Protocol)-based environment called UniWap allowed students and teachers to access a shared database of learning resources anytime, anywhere by mobile phone WAP (IST, 2006). It also provided test review options, notes, study guides, and additional information for the students participating in this project. Similarly, there were other successful stories in Europe's "From E-learning to M-learning" project and the "SNS-based English Learning System" from the University of Westminster in the UK. Instructional designers should take advantage of the new tools and means provided by mobile technology to promote the interactivity in traditional education system. The examples given above illustrate innovative practices for mobile interactivity.

In contrast to formal learning, informal learning takes place accidentally, sporadically and unconsciously in association with certain occasions. It is rather problem-related and well-focused from the changing practical requirements (Andreatos, 2007). However, it can be difficult for designers to organize learning content systematically in subjects because the learning activity occurs outside the curricula of formal educational institutions (Livingstone, 2001). Therefore, a self-directed learning platform related to professional practice sounds suitable for mLearning.

Another good way to promote learning in an informal learning environment is through social interaction and cooperative learning. Using mobile technology, instructors can provide efficient collaboration enabling portable devices to support creative ideas for interactive learning. Situated learning theory provides mobile technology with a unique opportunity to promote interactivity in social and informal learning environments. By carrying mobile devices, learners can acquire knowledge to make decisions and to solve problems in real situational contexts. Knowledge and environments are interrelated, which means there are abundant learning resources in social networks, resources and physical environments. Knowledge is the product of interaction between people and the environment. It is the best choice for learners to get knowledge and skills via activities in real environments.

The following examples illustrate the potential of mLearning in informal learning settings. For instance, podcasting is representative of content-based mLearning development. A good use of it is the BoilerCast Project at Purdue University. At its core is a podcasting website to allow instructors to share recordings of their courses with students by downloading into portable mLearning devices. Personal broadcasting services are also very popular in Stanford, Duke and a few other universities. Stanford University provides users with a free, comprehensive course on software development for the iPhone operating system. This program of study is offered through Apple's iTunes storefront and provides free, high-quality instructional videos to a wide audience. It also includes exercises, application examples and lectures. Several anecdotal stories on the Internet describe learners' production of applications after watching the videos.

Considering communalization of knowledge, Liverpool John Moores University designed an educational system using Personal Digital Assistant (PDAs) for breast cancer patients. After 3 years of design, development and implementation, their experiences on supporting handheld technologies in a medical school curriculum provided a lesson on interactivity for problem-based learning paradigms. Patients communicated via short message service (SMS) and shared valuable experiences and understanding of breast cancer that provided encouragement for fighting their cancer.

mLearning projects in Europe have developed a system for mobile devices with a client program named "MediaBoard." Users can access the MediaBoard system via mobile devices to share information, text and pictures. The MyArtSpace platform from the University of Nottingham described a similar idea for designing interactivity within mobile and informal learning environments. These types of applications can be viewed as being similar to Twitter or MicroBlog, which have demonstrated their ability to impact society.

In relation to independent learning in community contexts, the ubiquitous learning system for the Japanese polite expressions in the University of Tokushima and the tour guide system for mLearning in museums from National Central University in Taiwan illustrate how mobile technoloy works in the context-aware learning paradigm. The design of collaborative social interaction can maximize the interactivity in situational learning so that the learner can get a better learning experience. In addition, the LOCH (Language-learning Outside the Classroom with Handhelds) project in the University of Tokushima (Paredes, Ogata, Nobuji, Oishi & Ueda, 2005) show how to support informal language learning outside the classroom with handhelds, while the Mobile Butterfly-Watching Learning System from National Central University in Taiwan provides solutions for independent learning based on a case-based learning paradigm (Chen, Kao, Yu & Sheu, 2004).

Informal learning emphasizes the autonomy of deepening awareness, asking learners to combine study with some research and exploration in order to build a better understanding of what they are learning. The main purpose of using mobile equipment and technology in this type of learning was to promote retrieval, collection and exchange of information to enable instructors to focus on the design of collaborative tasks and communicative interactivity. In terms of location-based services, researchers at the University of Tokyo use USB cameras and GPS (Global Positioning System) locator to help pupils to share their research findings outside the class. With the help of mobile technology and software named SketchMap, a system supporting outdoor collaborative learning and enhancing the ability of information and knowledge-sharing, this project provides a useful insight into designing interactivity for cooperative learning.

The C-notes project of Växjö University in Sweden exemplifies the design of a mobile wireless application to support collaborative knowledge building (Milrad, Perez & Hoppe, 2002). It demonstrates how to construct collaborative knowledge via mobile systems. Meanwhile, the Pocket Pico Map project in the University of Michigan extends learner-centered design to the development of handheld educational software (Luchini, Bobrowsky, Curtis, Quintana & Soloway, 2002). It promoted interactivity by supporting learning in context and by sharing a concept map with those who participated in the collaborative learning.

Devices and design concepts for message design

At present, many challenges in the design of mLearning content stem from the variety of mobile devices used in formal and informal settings. The next generation of learners will be accustomed to sophisticated communication devices. Future educational initiatives will deploy mLearning content via devices that can be used at home, in the workplace, during transportation periods and during leisure activities. Students across the globe now have access to powerful, portable computing technologies that are capable of supporting learning in novel ways. Looi, Wong, So and Seow (2009) observe that "… the affordances of mobile learning support (1) multiple entry points and learning pathways, (2) multi-modality, (3) in-situ student improvisation and (4) the sharing and creation of student artifacts on the move" (p. 217). These affordances provide substantial opportunities for educators, especially given the widespread acceptance of mobile technologies. Learners now view mobile media devices as a first point of reference for information access. To realize these opportunities, instructional designers will need to develop a basic understanding of the information delivery capabilities of these devices, as well as the appropriateness of each type for different environments and content.

The following segment of the paper examines emerging trends and metaphors in the development of mobile devices. It will also illustrate the implications of central trends for the instructional design of mobile education. The result includes some tips and a typology of information delivery devices that practicing instructional designers can use to shape their mLearning delivery decisions.

General trends and challenges

Internet-based eLearning services and programs have evolved into a high degree of interactivity over the past two decades. Advances in computing power and bandwidth availability allow eLearning designers to deliver synchronous aural, visual and interactive experiences to students in real time. Performance support software, such as Adobe Captivate and Camtasia, allows experts to package their knowledge for asynchronous distribution. Educators of all types use these synchronous and asynchronous technologies to create broad repositories of knowledge. Multimedia performance support and educational content often require significant bandwidth to deliver and significant computing power to receive. These technologies are extremely valuable to educators, especially as instructional design researchers learn more about the optimal ways of conducting online classes and designing eLearning.

Therefore, the mobile devices will be a major delivery vehicle for multimedia learning content in the coming decades. Improvements in the fields of integrated circuits, cellular transmission and human–computer interface design have yielded systems that can provide a broad range of services. With these devices, learners can interact with the thousands of content objects available on the Internet. Further, mobile devices enable learners to build virtual communities around media sharing applications, social networks and Web 2.0 applications. However, as mobile devices become more available, researchers and practitioners in instructional design will need to develop greater insight into the best ways of using mLearning and Web 2.0 technologies in tandem.

mLearning must overcome some core challenges in order to have a significant impact on the global educational environment. Fortunately, current trends in network technologies, human–computer interfaces and information distribution will provide opportunities to understand and improve mLearning practices as the mobile medium grows in use. These trends are most visible in the 3G femtocell, the smart phone and more varied information delivery methods.

In addition to the use of static Internet computers, mLearning experiments around the world have shown the value of emerging 3G networks to educators and students. These high-speed cellular data networks allow learners to access broadband services through laptops, netbooks, smart phones and other online devices. The most valuable property of the technology is that 3G networks allow the simultaneous use of speech and data services. This allows instructional designers and teachers to build multiple modalities into their courses. The technology also provides students with multiple ways of interacting with content and with one another, resulting in a high degree of user satisfaction (Wang, Shen, Novak & Pan, 2009). However, 3G networks are expensive to build and maintain, and services are, at the time of writing, not widely available outside of urban environments.

Types of information exchange

Mobile devices come in increasingly varied forms, but fall into four general categories of information exchange (ie, stand-alone, network-centered, mobile computers and web portal). Instructional designers should give thought to the kind of devices that they plan to leverage for their content, as not all devices provide the same services. Table 1 presents four basic types of mobile devices differentiated by their core modes of information delivery and transmission.

Principles of designing for different devices

mLearning practices need to make the best use of the increasing connectivity, power and variety of mobile devices. In relation to designing mLearning curriculum, 3G technologies will enable users to manage their time better. The added functionality will facilitate greater use of a wider

Table 1: Mobile devices and activities supported

Info. delivery type	*Definition*	*Example devices*	*Types of activities*
Stand-alone devices	Devices where all content must be loaded to the learner's unit from an originating computer.	iPods and mobile media players, e-books, laptops	Learners who do not have consistent wireless Internet access can still bring information with them to the field through take-away devices. Useful for podcasts and instructional guides.
Network-centered devices	Devices that primarily use Internet and ad hoc networks for communication during educational experiences.	iPhones, smartphones, the One Laptop Per Child Project's XO, 3G enabled tablets	Network-centered devices harness the Internet to promote collaborative learning experiences. Some of these machines can create localized computer networks on the fly. This quality can be used to allow sharing of content among dispersed learners.
Mobile computers	Portable devices that can connect to a network but are also fully functional without Internet access.	Laptops, netbooks, Smartbooks	Mobile computers are machines that can retain full local functionality even without Internet access. These computers have larger hard drives and longer battery lives than many handheld devices. This is valuable for downloading portable, interactive multimedia learning content.
Web portal	Simplified devices that leverage Internet-based applications and data over wireless networks.	Google's ChromeOS, Palm Pre, PDAs, Microsoft Courier, iPad	Web computers are thin clients that allow learners to interact via web portals with powerful, feature-rich data services that exist online. For example, a phone that provides learners with word processing services via GoogleDocs, or video blogging using YouTube. This segment will grow in utility as more applications move online.

range of devices with features such as always-on connectivity, better video displays, speech recognition attributes and scientific calculators while also providing increased capacity and coverage. More applications will be available to more users, and devices will have increased battery life and memory resources. Interoperable devices supporting interactivity will be typical characteristics expected by consumers and stakeholders. mLearning designers will have a wider array of tools, models, capacities and standards to work with in developing new applications.

However, these improvements in technology do not provide clear design principles in and of themselves. In the following we suggest four principles of message design for different devices.

Principle 1: design for the least common denominator

Compared with the smart phones, the functions of simple mobile phones are even more sterile. Learning content needs to be chunked and packed into multimedia messaging services or SMS so that they can work on a variety of mobile phones. A survey on 3000 participants from the Online College of Shanghai Jiaotong University shows that students prefer video-based mLearning materials, and each video should be less than 5 minutes (Shen, Wang, Gao, Novak & Tang, 2009). In addition, students anticipate learning guides, help for exams and other technical support services.

Principle 2: design for eLearning, adapt for mLearning

Among all the mobile devices, a PDA can be an excellent tool for mLearning. It can provide a pleasant learning environment and resolve several of the possible issues associated with small screens. All types of learning content can be coded in HTML and read with a PDA Reader (Wang, Li & Zhang, 2009). For instance, Microsoft developed a piece of software (Reader) to provide a better user experience of e-books. The software also supports other learning activities such as Bookmark, Notes, Highlight and so on. With the Microsoft Reader, learners can study an entire course on a PDA.

Designing for PDA devices can be guided by several of the theories and models that are considered effective for eLearning, such as the ADDIE (analysis, design, development, implementation, and evaluation) process (Chan & Robbins, 2006), steps in motivation design (Balaban-Sali, 2008) and successive approximation (Allen, 2003). The newest and most successful eLearning instructional design method in use today is probably successive approximation as shown in Figure 1 (Allen, 2003). This iterative design approach is evolutionary, rapid and allows instructional designers to move quickly through the initial phases of design to a rapid prototype ready for testing.

Principle 3: design short and "condensed" materials for smart phones

The smart phone's form factor is a key limitation for many users. For example, older learners with diminished eyesight and dexterity may have difficulty interacting with a smart phone's small keyboard and screen. Developments in light emitting diode (LED) projector and touch screen technology offer a number of ways to transcend these limitations. Motorola, Nikon and a number of other manufacturers are currently refining a technology known as "pico-projectors." This technology uses tiny LED and digital light projection arrays built into mobile media devices to project visuals onto nearby surfaces. Preliminary studies on learner interaction with projected maps have found that pico-projector technology "provides clear evidence of several distinct advantages, such as improved task completion time, reduced number of errors and higher user satisfaction" (Hang, Rukzio & Greaves, 2008, p. 215). Hang and his colleagues attribute the positive gains in user performance over smart phone screens to the increase in available onscreen data enabled by the higher resolution projectors.

In addition, many scholars believe that mobile phone screens are too small to provide a comfortable learning environment. Therefore, they argue that it is not feasible to develop an entire course for smart phones. Instead, designers can focus on providing brief key points or the summary of courses. Study guides, progress test reviews, notes, simple questions and answers, and other written content with pictures are also good choices.

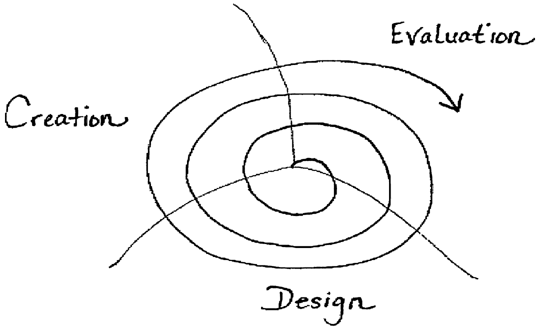

Figure 1: Successive approximation (Allen, 2003)

Principle 4: be creative when designing for mobile devices with 3G and 4G technologies

The arrival of 3G and 4G wireless technologies accelerate the development of mLearning. In particular, "a 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smart phones, and other mobile devices" (http://en.wikipedia.org/wiki/4G). These new wireless technologies offer a different way for users to connect with the public by phone. It also enables live video connections and makes higher capacity data transmission possible. The more powerful processors allow more sophisticated programs that could previously only run on computers to run on 3G and 4G phones. Thanks to 3G and 4G technologies, instructional designers can create a greater variety of learning content for mobile devices, which include videos and audios. Learners can also use web browsers in their phones to start e-learning coursers via mLearning means.

Message design principles for mLearning

Message design is analogous to the use of building blocks, with the whole picture being composed of smaller but well specified elements such as language, images, signs and symbols. The goal of message design is to coordinate these elements so that they work together in our brains to provide better accessibility, usability and learning. With a deep understanding of how people learn and how cognition works in realistic settings, designers can appropriately organize different kinds of learning messages by integrating pieces of knowledge into a course or learning content to fit the needs of human cognitive features.

Mayer's theory of multimedia message design is probably the most widely cited approach. Drawing on the quintessence of dual-coding theory, model of working memory, cognitive load theory, generative theory and the SOI (selecting, organization, integrating) model of meaningful learning (Mayer, 1996), Mayer and Moreno (2005) suggest a theory of multimedia learning that generates principles for overcoming common types of cognitive overload by building coherence, providing learning cues, creating spatial and temporal contiguity, and reducing redundancy. The following are the details:

- Coherence: eliminate extraneous content to promote coherence.
- Signaling: cue the learner on how to process information.
- Spatial contiguity: align printed words near graphics.
- Cognitive redundancy: avoid using the same stream for printed and spoken words.
- Temporal contiguity: present narration, keyword labels and animation together.

Some of Mayer's message design principles might be applicable to message design in mLearning. For example, the Multiple Modality principle, which advocates presenting an explanation in pictures with annotated graphics and related audio, is a good guideline for designing mobile content. In addition, multimedia explanations should include key, need-to-know information, rather than many extraneous facts and nice-to-know information. In addition, words should be presented as auditory narration rather than as on-screen text (Mayer & Moreno, 2005).

Location of the learner is another important consideration in the design of learning messages and, recently, definitions of mLearning have shifted their focus from the mobility of technology to the mobility of the learner. Placing emphasis on the mobile learner's perspective requires studying: ". . . how the mobility of learners augmented by personal and public technology can contribute to the process of gaining new knowledge, skills and experience" (Sharples, Milrad, Sánchez & Vavoula, 2009, p. 3). Here we will discuss the importance of learning mobility and how to better design learning content to cater the specificities of learner mobility.

The European Erasmus programme demonstrated how mobility can bring about the set of linked benefits—benefits to the human capital of participants, the creation of personal links across borders, language learning and breaking down institutional barriers. In all the forms of mobility, learning and personal development are the essential factors. According to the report of Eurostat, about half a million European university students undertake their studies abroad each year. The European forum on mobility even suggested that "Learning mobility should be a natural feature of being European, promoting competitiveness and openness to the world and a deeper and more tangible European citizenship" (Rodrigues *et al*, 2008, p. 17).

As mentioned earlier in this paper, in connection with the mobility of learning or learner mobility, learning environments can be classified as formal and informal. Examples of formal environments include university-based facilities such as the Shanghai Jiaotong University system that uses mLearning as part of a large blended classroom (Shen, Wang & Pan, 2008; Wang, Shen, Novak & Pan, 2009), whereas examples of informal environments include field-based education such as the SketchMap project of the University of Tokyo and the Mobile Butterfly-Watching Learning System from National Central University in Taiwan. In addition, the I-Guides project of Exploratorium in the US and the Gidder project in Norway provide typical cases for the application of mobile technology in public education, which we use to inform our design for learner mobility.

According to the projects mentioned earlier, it is clear that the locations where learners use mobile content are very important and should be considered in instructional design. Although it will be hard to predict where learners will be using the mLearning content, we still can extend our catogorisation of environment by adding the descriptors "noisy and quiet." Table 2 presents four typical locations for learner mobility, related learning preferences, and different styles of information delivery that instructional designers should pay more attention to when designing for mobile learners.

The types of design (Table 2) are based on theories of learning styles, such as visual (*learning through seeing*), auditory (*learning through hearing*), tactile or kinesthetic (*learning through experiencing/doing*) (Dunn, Dunn & Price, 1989). Researchers and practitioners seem to agree that learning styles can affect learner performance and learning outcomes (Cassidy, 2004). Even though there are many models and inventories as related to learning styles, we found the categorization mentioned earlier being most applicable to mLearning. Therefore, designers should give thought not only to the environmental factors but also to learners' preferences and use different design components to meet the needs of distinctive learners in diverse situations.

Thus, from this discussion, it is evident that the design of mLearning systems is a complex area involving factors ranging from content, through media to location. In the following discussion we review the main tools at the disposal of the mobile message designer, emphasizing areas that hold particular potential for mobile message design, such as the use of captions that are suitable for almost all users, at any time or place.

Use of audio in mLearning message design

mLearning travels with learners as they move about their lives. Because of the variety of possible conditions that learners may encounter, it is possible that some of the audio components of mLearning curriculum will not be available to the learners in noisy environments. The lack of

Table 2: Learner locations and design components

Environment	*Type of design*	*Example*
Subway & bus	Visual numerical	Short article, strong pictures
Home	Auditory-visual-kinesthetic combination	Music, oral content, instructional videos, sports videos
Office	Written expressive	PPT, e-books
Café	Auditory, visual, and linguistic	Music, oral content, instructional videos

audio components or their poor usability can be compared to attributes of deaf learners and the findings of studies involving images and language in relation to cognitive processes. When the intended users are not using audio, the corresponding images and text on the screen are all that is available to stimulate learning. Therefore, multimedia mobile content should be carefully chosen to cover all the possible circumstances of the learner.

In addition to audio output, designers should consider audio as an input mechanism. The application of speech recognition, using either automated or human interfaces, is an essential element of mLearning design that warrants further study. Whether the learner uses the feature for inputting content or applying commands, the difficulty of using miniature keyboards can be minimized. Automated speech recognition (ASR) can help to avoid tiresome repetitive manual input on standard size keyboards (Koester, 2004). Koester's study found that ASR users mainly appreciated the reduced fatigue associated with manual input methods. Speed was a secondary benefit of using speech recognition as an input method. These prior studies using full-sized keyboards can serve as a model for mobile devices and are all considerations to be taken into account in design of new mLearning content.

Captions in mLearning message design

The attempt to link text to sound and image dates back to the earliest days of filmmaking. The endeavor continues today with the latest handheld devices (Downey, 2008). Whether one labels it captioning or streaming text, the use of words on the mobile device to facilitate learning is positively an enhancement to the other audio and visual content. Captions render audio components in an available format suitable for almost all users at any time or place. Captions may also serve as a system to provide emergency information, a tool to teach English literacy, as well as a vehicle for underserved communities to enjoy full cultural citizenship (Downey, 2008). By synchronizing media clips with audio tracks and text, the multimedia database becomes more powerful and searchable. With the use of this textual media, learners can cheaply, quickly and accurately retrieve any portion of audiovisual media on a variety of devices. Captioning has gone from being a specialized accommodation for a minority viewing audience to a multipurpose amenity for all to use (Downey, 2008). In our view, captioning is one of the most versatile mechanisms available to mobile message designer, allowing for designs to cater for a variety of unknown contexts that typify mobile usage.

The Captioned Media Program funded by the US Department of Education established guidelines and standards for captioning in educational environments. The most important of those guidelines are that captions should be (1) synchronized and appear at approximately the same time as the audio is delivered; (2) equivalent and equal in content to that of the audio, including speaker identification and sound effects and (3) accessible and readily available to those who need or want them (http://www.captioningkey.org/). Captioning engages and facilitates use of the dual-coding learning theory while simultaneously applying principles for the universal design of instruction (Burgstahler, 2011), which mainly include equitable use, flexibility in use, simple and intuitive use, perceptible information and tolerance for error. Text may be used by learners in a variety of ways, from reinforcing images to enabling the captions to substituting for audio components in noisy environments.

An important design issue to consider is the placement of captions. In broadcast television, most captions are placed on the bottom two lines. Generally, it is important to ensure that placement does not interfere with existing images, such as maps, illustrations, names of countries, job titles or the names, faces or mouths of speakers. Should interference occur, captions should be placed at the top of the screen. If placing captions at the top of the screen also interferes with visuals or other graphics, then captions should be placed elsewhere on the screen where they do not interfere.

Some other guidelines that are worthy of consideration for mobile devices are as follows. When captioning media with one off-screen narrator and no pre-existing graphics, captions should be left aligned at centre screen on the bottom two lines. Single-line captions should be centered on the bottom line. Three- or four-line captions are occasionally acceptable if a one- or two-line caption would interfere with pre-existing graphics or be confusing with regard to speaker identification. Finally, we present the following guidelines that are drawn from font captioning standards used in educational broadcast television captioning. We believe they are valuable recommendations based on best practices from the field and will provide instructional designers with a starting place for the development of standards for captioning in mLearning.

- Characters need to be a font similar to Helvetica medium.
- Characters must be sans serif, have a drop or rim shadow and be proportionally spaced.
- The weight must support a 32-character line.
- The font must include upper and lower case letters with descenders that drop below the baseline. Pick a font and spacing technique that does not allow overlap with other characters, ascenders or descenders.
- Consistency throughout the media is extremely important.
- The use of a translucent box is preferred so that the text will be clearer, especially on light backgrounds (Source: http://www.captioningkey.org/).

The research findings cited earlier, as well as many other studies, demonstrate that the use of captioned content can lead to significant improvements in reading comprehension, listening comprehension, vocabulary acquisition, word recognition, decoding skills and overall motivation to learn. In addition, captioning provides the flexibility that is essential for mobile messages to be received in a variety of changing contexts (eg, noisy environments).

Icons in mobile message design

When designing images and icons for mLearning, several considerations must be taken into account. For example, color, size, illumination, position of visuals, as well as connection or download speeds and many other device attributes, are all important elements of each individual image, symbol or other graphic illustration of educational content. Dimensions, style, weight, resolution, color as well as design consideration for interfacing with many devices are other important factors to keep in mind.

Use of color in mobile message design

The advent of color display monitors now means that color is used almost universally in the creation of instructional content. Pett and Wilson (1996) address the use of color as related to instructional technology from three categories: color as seen—physiological; color as seen—psychological, and color and learning. They also emphasize the significance of the context in which a color is viewed. For example, human eyes have adapted to see and determine color in three ways: general, local, and lateral. "General adaptation occurs when a person moves from a light room to a dark room or vice versa. . . . Local adaptation is demonstrated by afterimages. . . . Lateral adaptation refers to the effects that are created when two colors are viewed simultaneously" (Pett & Wilson, 1996, p. 20). Considering learners' mobility in mLearning, content design should take general adaptation into consideration. For instance, use colors that can remain consistent in different environments, whether the user is out on a street in broad daylight or at a subway station lit by neon lights.

The use of color in design also varies a great deal from culture to culture. Color often has cultural connotations and it can arouse different emotions from different people. Nevertheless, common rules apply to all cultures when it comes to emotional arousal and legibility. In general, colors at the end of the spectrum (eg, red and violet) have greater arousal effects than the ones in the middle (green and cyan) (Pett & Wilson, 1996). The following background colors are ranked from best to worst in legibility: white, yellow, green, red and blue (Snowberg in Pett & Wilson, 1996). Some studies have found that red and yellow can result in higher anxiety in the readers than other colors (Pett & Wilson, 1996). In addition, a neutral background is often more legible than colored backgrounds. Also, increasing hue and value contrast can help people with color deficiency.

However, not all researchers agree on the value of color in learning content design. Even though the use of color in instructional content does not necessarily result in increased learning (Pett & Wilson, 1996), the appropriate use of color does affect attention, search tasks, retention and other measures (Dwyer, 1971). As Levie (in Pett &Wilson) discovered, "Color can facilitate learning when it focuses attention on cues that might otherwise not be noticed" (p. 26). When it comes to information search, color can also help grouping information. There is some evidence that careful coordination of words and image colors can increase retention. Color is of value to cognitive learning "when it emphasizes relevant cues, is used as a coding device or when it is a part of the content to be learned" (Pett & Wilson, 1996, p. 27).

Finally, in terms of the use of colors we offer the following guidelines to designers of content for mLearning:

- Use color to discriminate between elements of a visual.
- Use color to focus attention on relevant cues.
- Use colors to code and link logically related elements.
- Be consistent in general color choices throughout content.
- From psychological perspective, choose colors that are consistent with the instructional message and that are appropriate for the intended audience.
- Use highly saturated colors such as red and violet to attract attention and to create an emotional response, and in content intended for young children.

As to the use of symbols, three rules to follow are:

- Use black background with high brightness color.
- Use white background with a low brightness color.
- Use moderate to high brightness contrast between symbols and background.

When discussing message design, we avoided platform constrained discussion, preferring to address more generic issues. It is clear that mobile technology, such as cell phones, is evolving rapidly and the challenges and opportunities for mobile message design will change in sympathy with the ongoing advances. This also means that message design for mLearning will be an area of ongoing research for some time.

Conclusions

This paper explores the principles and processes of message design for mLearning, including content, devices, and methodologies. In doing this we review the cognitive, instructional and usability aspects of mLearning.

Our exploration of learning theories and design principles for mLearning generated advice for practitioners, which we presented as sets of guidelines. In addition, we also raised many questions for future research. In particular our studies suggest that researchers need to explore possible solutions for some of the following pressing issues:

- How will learning theories influence the development of instructional design strategies for mobile devices, and vice versa?
- How can instructional designers leverage existing captioning standards into standards that fit the specificities of mobile devices?

- How will development in network access, device design and information exchange extend the experiential possibilities of mLearning?
- How will context (including cultural, environment and device) effect the specification of future mLearning systems?

The answers to these questions would help instructional designers form a baseline degree of knowledge that can guide future data collection. Equally, they will lead to design and development criteria that will improve mLearning courseware and products. With this greater store of knowledge, educators would be able to design more satisfying mobile instructional experiences for more people. This is a need that will increase as the world heads to a more knowledge-driven era, where education will become an increasingly ongoing, in situ, lifelong process facilitated by mLearning.

Acknowledgements

We sincerely thank Xiaoyi Chen and Daniel Novak for their contribution to some of the design principles and Dr Victor Callaghan for his editorial assistance.

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