Ensuring Mobile Devices Deliver Mobile Support: Are We There Yet?

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Estimates show that knowledge workers perform approximately 50 percent of their workplace tasks while they are on the go. Mobile workers frequently require access to task-relevant instruction or knowledge in remote work environments where desktop or even laptop computers are impractical. Recently there has been a convergence of enabling technologies and an increased interest in the use of mobile devices, such as Smart Phones and Personal Digital Assistants (PDAs), to support worker learning and performance. This is evidenced by the popularity of Web sites (e.g., mLearnopedia.com) and journals (e.g., International Journal of Interactive Mobile Technologies) dedicated to mobile learning (mLearning) and mobile performance support (mSupport). Most of this interest has been focused on mLearning rather than mSupport, and there is a tendency to assume that what works in practice for mLeaning will work for mSupport. This assumption may not be tenable. Therefore, there is a need for the educational community to better understand mLearning and mSupport, as well as the characteristics of mobile devices, their users, and their operational environments, to maximize the educational value of mobile devices for mSupport. We provide a discussion of mLearning and mSupport that focuses on six user-centered issues likely to determine mobile device effectiveness and user acceptance for mSupport: 1) device characteristics, 2) form factor, 3) user interaction styles, 4) task characteristics, 5) content management, and 6) context awareness. We examine these issues and discuss potential solutions. In addition we provide real-world context via a hypothetical scenario from the hazardous materials transportation domain.

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Nina is a Principal Consultant in the Learning and Human Capital Business Unit of Serco, Inc. She has 14 years experience designing and developing learning solutions for clients in academia, industry, and government. At Serco, Nina is the Outreach Task Lead for the Advanced Distributed Learning (ADL) Initiative, and she evaluates and designs instruction and supports the knowledge management efforts of the Defense Ammunition Center (DAC). From 2000 to 2006, Nina was part of the Learning Systems Architecture Lab (LSAL) at Carnegie Mellon University where she co-authored the several SCORM related publications including the "SCORM Best Practices Guide for Content Developers." .She designed and co-led a successful series of workshops to assist content developers and programmers implementing SCORM-conformant instructional materials. Nina served as a senior instructional designer on the Boeing C-17 Aircrew Training System designing and developing computer, instructor, and simulator-based training for pilots and loadmasters for four years. She earned an M.A. from Abilene Christian University, an M.A.S. from Embry-Riddle Aeronautical University, and a B.A. from Grove City College.

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INTRODUCTION

A Hypothetical Scenario

Rhonda Smith is a certified hazardous materials (HAZMAT) shipper who works at a large Midwestern United States ammunition depot. Like all certified shippers, Ms Smith is very familiar with the standard HAZMAT reference: Transportation of Hazardous Materials, Code of Federal Regulations Part 49 (a.k.a., 49 CFR), and has used a printed version regularly for the last two years. One day, she received a request to transfer 100 kg of ammunition propellant along with 20 free-fall bombs to a Navy installation on the East Coast. Leveraging her 15 years of experience in shipping HAZMAT, she prepares the routine shipment.

*Rather than using her somewhat dated printed version of 49 CFR, Ms Smith powers up her trusty handheld HAZMAT Mobile Support Device, an electronic hand-held touch screen mobile performance support tool, fondly known by her fellow shippers as the HazMoSuDe (pronounced "haz-**MO**-su-die"). The HaMoSuDe has a continuously-on wireless connection to the HAZMAT database located on a server at the Defense Ammunition Center (DAC) in McAlester, Oklahoma. The HAZMAT documents on the server are updated weekly based on the latest doctrine and field experience following data base maintenance best practices.*

She points to the 49 CFR icon on the touch screen which brings up the most recent electronic version of the 49 CFR. She types in a search term using the soft keyboard to locate the 250-lb free-fall bombs within the Joint Hazard Classification System (JHCS) and uses the single-figure touch feature to scroll to the appropriate section of the JHCS on packaging requirements. Finally, she zooms in on the relevant data using the two-finger flicking method and cross-references the information to the appropriate proper shipping name (PSN) and United Nation Identification Number (UN/ID). This provides her with the information she needs to determine the most up-to-date approved packaging and security requirements, as well as any segregation required between the bombs and the ammunition propellant.

Background

Like Rhonda Smith, knowledge workers are individuals who are valued for their ability to work with, interpret, and apply information and knowledge within a specific subject area. Estimates show that knowledge workers perform approximately 50 percent of their workplace tasks while they are on the go (Singh, 2009). Mobile workers (e.g., HAZMAT shippers, military ammunition quality control inspectors, business sales representatives, insurance adjustors) frequently require quick, accurate, and timely access to task-relevant instruction or knowledge to complete time-critical tasks in remote work environments that are impractical for desktop or laptop/notebook computers.

Recently there has been a convergence of enabling technologies as well as a marked increase of interest in, and enthusiasm about the use of mobile devices, such as Smart Phones and Personal Digital Assistants (PDAs), to support workplace learning and task performance (Brown, 2009). This is evidenced by the popularity and success of Web sites like mLearnopedia.com and moblelearn.com, as well as journals like the International Journal of Interactive Mobile Technologies dedicated to mobile learning (mLearning) as well as mobile performance support (mSupport).

Judy Brown, a Mobile Technology Analyst and former head of the Advanced Distributed Learning Academic Co-Lab at the University of Wisconsin and presently coordinator of mlearnopedia.com, recently commented online about the rapid and extensive changes that have taken place in the use of mobile devices for mLearning and mSupport:

> We began with standalone devices (personal data assistants or PDAs) that could be connected to a single computer for a single person. Once these devices were combined with a cell phone, communication opened up. With today's capabilities to seamlessly move from cellular to Wi-Fi, collaboration opens many more doors. Location-based context and tagging, sensors and feedback, recognition and specialized apps now open up our imaginations and provide powerful

learning opportunities not even available on a desktop (Brown, 2009).

This interest and enthusiasm seems to have been focused more on mLearning and less on mSupport. In addition, there appears to be a tendency to assume that what works in practice for mLeaning will work for mSupport. This assumption may not be tenable and needs to be re-examined if progress is to be made in utilizing mobile devices for learning and performance support to their fullest potential.

Accordingly, there is a need for the educational and job performance communities to better understand mLearning and mSupport, as well as the characteristics of mobile devices, their users, and their operational environments, in order to maximize the educational value of mobile devices for mSupport.

Purpose and Scope

Our purpose in this paper is to provide a review and analysis of the mLearning and mSupport domains that focuses on user-centered issues likely to determine mobile device effectiveness and user acceptance. We intend for the findings of our work to be useful to mLearning and mSupport academics and practitioners, and hope that the findings stimulate further research and development.

Early in our work we realized the literature on mobile devices, mLearning, and mSupport was vast and continuously growing, and that a comprehensive review of these areas and their synergistic interaction was beyond the scope of this paper. Instead, we focused on examining critical issues and their implications for mobile delivery of content.

Among the reports and papers cited in the Reference Section are three recent reviews that provide integrative, substantial, and practical coverage of mobile devices, mLearning, and mSupport: Lewis et al., (2009), Herrington et al., (2009), and Ryu and Parsons (2009). Our intent in this paper is to discuss issues from a vender- and product-neutral perspective, although we make occasional reference to a specific product or service to illustrate key points.

Organization of the Paper

In subsequent sections we list the research questions that guided our effort, describe our approach, provide working definitions of key concepts and examples of existing systems, examine critical issues, and discuss supplementary technologies. Finally, we state our conclusions and suggest directions for future work.

RESEARCH QUESTIONS

Our effort was guided by four research questions:

- What are the key attributes of mobile learning and mobile performance that impact the effectiveness and usability of mobile devices?
- What critical issues need to be addressed to promote the best use of mobile devices for mLearning and mSupport?
- What are the challenges to optimizing mobile devices for mLearning and mSupport, and how might they be solved?
- What complementary technologies exist that might enhance the effectiveness of mobile devices?

APPROACH

We reviewed the literature on mobile devices, mobile learning, and mobile performance support, including authoritative textbooks, scientific and technical papers, professional journals, and Web site postings. The resources we drew from for this paper are listed in the Reference Section. In addition, we conducted informal discussions with mobile device users to obtain a flavor of their real-world experiences.

MOBILE LEARNING AND MOBILE PERFORMANCE SUPPORT

Working Definitions

Learning can be defined as a process of action, reflection, and modified action. Learning is how people get where they need to be so as to perform in ways they could not previously perform. *Performance* can be defined as applying what has been learned to real world situations. Learning promotes performance by discovering and inventing new ways to respond that improves performance. More often that not, performance support has been considered a subset of learning and training rather than a separate and integral process. For example, we found little agreement among theorists and practitioners about when just-in-time learning/training leaves off and performance support begins, or even how learning sets the stage for performance (Edmondson, 2009).

Mobile learning (mLearning) happens when one is not at a fixed, predetermined location or takes advantage of learning opportunities offered by mobile technologies. Mobile learning can assist learners by using media like audio (e.g., audio podcasts), video (e.g., video podcasts), flashcards, quizzes and assessments, slideshow presentations, and glossaries. Detailed presentations on the state of the art in mobile learning can be found in Herrington et al., (2009) and Ryu and Parsons (2009). In comparison, *mobile performance support* (mSupport) is a process that provides a worker with access to a systematic repository of information, processes, and perspectives that inform and guide the worker's planning and action. An mSupport system can incorporate job aiding as well as mobile knowledge management. A detailed presentation on mobile performance support can be found in Gery (1991), Cichelli (2003), and Rossett and Shafer (2007).

A mobile performance support system has many potential benefits (Rossett and Shafer, 2007). Specifically, it can:

- Deliver up-to-date support or step-by-step procedures to mobile devices that enable already trained workers to perform faster and more effectively
- Provide a high degree of scalability to distribute updates in both content and features
- Provide a known baseline of competencies, allow non-experts to perform closer to the level of experts, and enable individuals to perform with a similar pace and limited error rates
- Enhance the competence of an employee beyond the level of his or her training

Cichelli (2003) noted that situations which could benefit from the development of an electronic performance support system (EPSS) are characterized by:

- Complex, infrequently performed decision-making and problem solving tasks at remote locations that change frequently
- Work environments characterized by a need for consistency across practitioners, little time for training, and frequent staff turnover
- The need to have immediate and timely access to reference information

Performance support for human tasks has existed since early man. Initially performance support was accomplished through personal contact or by using printed materials. More recently, more and more performance support is delivered by electronic means, such as an electronic performance support system (EPSS). An EPSS as an electronic device, such as a laptop, tablet PC, or PDA, that provides support information like technical documentation, learning content, and expert advice at the point of need to enable a person to achieve the desired level of performance in the fastest possible time with the least intervention from others (Cichelli, 2003, Jarvis and Swift, 2005; Joyce and Cichelli, 2002).

Recent Mobile Performance Support Examples

In the following paragraphs, we discuss two examples of recently developed mobile performance support tools to provide context for readers who may have only a passing familiarity with this area. We considered these examples to be noteworthy instances of mobile performance support systems that contained both learning and performance support elements.

British Army Vehicle Recovery EPSS

In a 2005 I/ITSEC paper, Crome and Charles (2005) reported that the British Army was trying to achieve a cultural change in training which moves away from residential-based courses to work-based learning, with e-Learning identified as a key enabling technology. In a follow-on I/ITSEC paper, Jarvis and Swift (2006), described the results of a study for the British Army to explore the role of mobile technology in delivering an effective dual mode (i.e., learning and performance support) mobile solution to support military vehicle recovery operations. A screen shot from the Vehicle Recovery EPSS, showing screens from both the Support and Learning Modes, is presented in Figure 1. Additional details about the development and usability testing of the Vehicle Recovery EPSS can be found in Jarvis and Swift (2006).

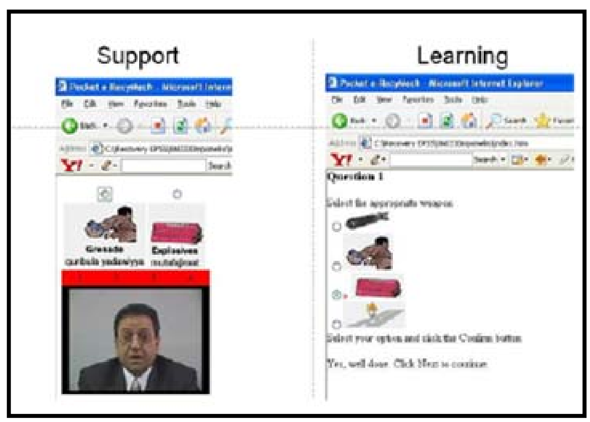

Figure 1. Screen shots from the British Army Vehicle Recovery Mobile EPSS

US Coast Guard Vessel Boarding Officer EPSS

The second example of a mobile EPSS is the US Coast Guard (USCG) Vessel Boading Officer Tool (D. Hardin, personal communion, June 25, 2009; Rossett and Shafer, 2007). Prior to using the tool, USCG boarding officers were required to attend a one-week course on the intricacies of enforcing hundreds of pages of federal regulations for fishing vessel safety.

The laws were quite complex and applied to many types of boats and situations. This often resulted in inconsistent or inaccurate enforcement action choices by boarding officers. The PDA-based EPSS eliminated the need for much of the memorization of legal requirements.

The USCG EPSS presents a series of questions about the vessel (type of vessel, type of engine, etc.) to the boarding officers at the point of performance during the onboard inspection. Based on answers to these questions, the EPSS generates a customized checklist of safety requirements for firefighting, lifesaving, and bridge equipment appropriate to each vessel for the boarding officer to complete (see Figure 2).

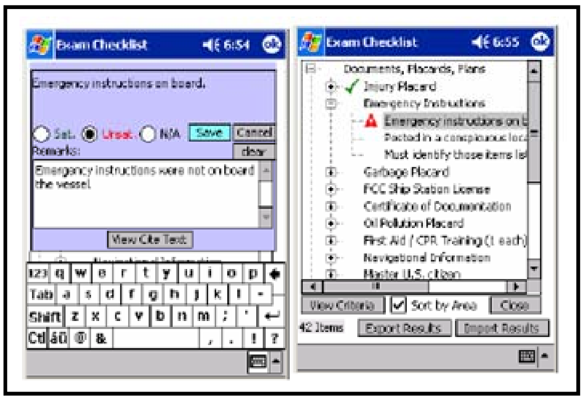

Figure 2. Screenshots from the USCG Vessel Boarding Mobile EPSS

Thus, rather than spending an inordinate amount of time determining the number of required life jackets or types of buoyant devices, the boarding officers were able to devote more of their limited time and attention to safety-critical inspection points, such as the adequacy of life raft construction.

MOBILE DEVICE ISSUES

Our review suggested six critical issues that affect the utility and acceptability of mobile devices for mLearning and mSupport (see Table 1).

Table 1. Mobile Device Issues for mLearning and mSupport

1. Device Characteristics
2. Form Factor
3. User Interaction Styles
4. Task Characteristics
5. Content Management
6. Context Awareness

We discuss these issues in the following paragraphs and provide context with illustrative examples. It should be noted that, although we discuss the issues separately, they frequently interact and often need be traded off in the final design to achieve optimal system performance.

Device Characteristics

Like we human beings, mobile devices come in a variety of shapes and sizes. Some examples are personal digital assistants (PDAs), like the "HP IPAQ" and the "Dell Axim," smart phones, like the "Apple iPhone" (see Figure 3) and the "Blackberry Storm," media players, like the "Apple iPod Touch and "Zune," tablet PCs, and electronic document readers, like the "Amazon Kindle 2" (see Figure 4) (and more recently the "Amazon Kindle DX") and the "Sony eBook Reader Digital Book."

Figure 3. Apple iPhone Smart Phone

These devices have inherent design characteristics (both capabilities and limitations) that are determined by current technology, manufacturers' design and marketing goals, user interests and preferences, and cost. These device characteristics can have a profound effect on the effectiveness and usability of mobile devices for mLearning and mSupport.

Among the most relevant characteristics are the display dimensions and resolution, user interface features (e.g., touch screen, hard/soft keyboard, tilt sensing mechanism), on-board and add-on memory, processor speed, navigation controls, connection protocols and speed, photo capture, video capture and playback capability, and battery life. A detailed discussion of these characteristics is beyond the scope of this paper (see Lewis et al., 2008). Here we briefly address selected characteristics judged to be the most pertinent to mLearning and mSupport.

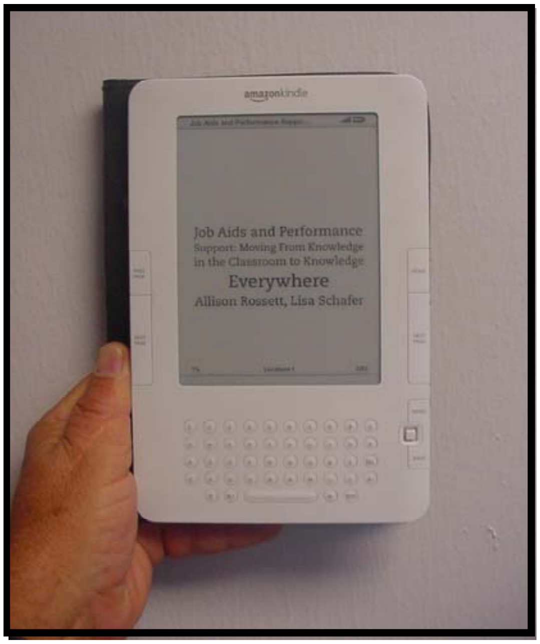

Figure 4. Amazon Kindle 2 eBook Reader

The physical size of the device’s visual display is arguably one of the most influential factors affecting the utility and usability of mobile devices for both mLearning and mSupport. The display size of many basic cell phones is only slightly larger than a postage stamp, whereas the display size of many smart phones is similar to that of a standard business card.

The optimal display size, as well as the display type (i.e., a backlit display like the iPhone or reflective display like the Kindle 2) for an mLearning/mSupport mobile device will depend on several factors. These include, but are not limited to: 1) the nature of the learning or performance task, 2) the ability to zoom in and zoom out the display, 3) whether the device is set on a surface, handheld or body-worn, as on the wrist or arm (see the next section on form factor), and 4) characteristics of the user’s indoor or outdoor environment, such as the intensity and color quality of the ambient light.

Informal user feedback and casual observation suggests that the postage-stamp size displays of most basic cell phones are most likely too small to enable essential mobile learning or performance support functions. In comparison, the larger business card size displays of smart phones, such as the “Apple iPhone” (see Figure 3) and the “Blackberry Storm” represent a reasonable tradeoff between screen size and an acceptable form factor, as discussed in the following subsection. This is clearly an area that has important implications for mobile device effectiveness and usability, and thus warrants further investigation.

A factor closely related to the mobile device's display size is the protocol (e.g., Wi-Fi, 3G) and quality of the available network connection. This is primarily because available bandwidth sets an upper limit on the file sizes to be transferred to and from the device. This, in turn, will impact the functions the device can support. For example, low available bandwidth may require that pictures be highly compressed or simplified before transfer or mean that full motion video is not practical. Furthermore, the efficiency of mechanisms that learners and performers use to interact with the mobile device (e.g., stylus, trackball, touch screen) depends on connections with high and reliable bandwidth (Lewis et al., 2008).

Form Factor

We define form factor as the physical platform that comprises the mobile device. It is an indication of how well a device matches human anthropometric characteristics, such as hand dimensions, thumb and finger dexterity (Lewis et al., 2008), and how consistent the device is with user expectations and past experience. Thus, the device’s form factor is a key consideration for ensuring its usability and ultimate user acceptance for mLearning and mSupport. Such a mobile device might adopt the form factor of hand held, wrist worn, or head worn.

An example of how selecting the correct form factor can positively affect the effectiveness and user acceptance of a candidate device was reported in an I/ITSEC paper by Ruffner, Labbe, and Hoyt (2006). The investigators developed an air traffic tower controller head-up display (HUD) for the US. Air Force that adopted the form factor of a handheld set of binoculars.

Tower controllers at commercial airports and military airfields are responsible for aircraft in the terminal approach area and for the safe and efficient movement of aircraft and ground equipment on the airport surface. The controllers in a tower cab use binoculars on a regular basis to check critical items like whether an approaching aircraft’s landing gear has been lowered or if there is adequate separation between a taxiing aircraft and a fuel truck. Since the handheld binoculars form factor was already familiar to the controllers, the team’s decision to develop the HUD as a “virtual binocular” greatly facilitated user acceptance.

An example of contrasting form factors in mobile devices is the soft display/control form factor (characteristic of the “Apple iPhone” and the “Blackberry Storm”) and the dedicated screen/separate mechanical keyboard screen form factor (characteristic of the classic Blackberry models and the “Palm Pre”). Given similar overall device dimensions, there is a tradeoff between having a dedicated hard mechanical keyboard and having a soft keyboard with the potential for a larger display area.

Thus, it is important those responsible for selecting or implementing mobile devices for both mLearning and mSupport consider how well the devices optimize the form factor to match human anthropometry without hindering essential operations, such as data input and information conveyance (Lewis et al, 2008).

User Interaction Styles

As Lewis et al. (2008) note, mobile device interactions take place with users learning or working in a wide variety of environments and circumstances. In addition, as noted in a previous section, mobile devices have different characteristics, such as small screen size and different types of input mechanisms, than do laptop and desktop PCs. These characteristics often result in constrained interaction styles compared to stationary systems.

Given the ubiquitous nature of mobile devices, users often engage in other tasks while operating the devices, like writing notes on a piece of paper. This makes one-handed use a highly desirable option. Karlson, Bederson, and Conteras-Vidal (2006) reported that most phone and PDA users prefer to use a single hand.

To accommodate this type of interaction, the device form factor must enable users to hold the device while operating the device keys and/or touching the screen with the same hand that holds the device. In addition, much of the software designed for devices that incorporate a touch screen requires the manipulation of on-screen objects with fingers and/or thumbs. Lewis et al. (2008) note that the on-screen objects must be in a location that accommodates a range of hand sizes and digital flexibility, and that the objects must be large enough and appropriately spaced to allow accurate selection. The authors provide recommendations for key size and separation distance, acknowledging there is a trade-off between user performance and preference on one hand and salvaging screen real estate for the display of additional learning or job performance content on the other hand (Lewis et al., 2008).

Because of limited screen space and resolution, displays on mobile devices can effectively present only a small amount of content at one time. Accordingly, methods that improve access to additional viewable content, such as one finger touch scrolling and paging and two-finger touch zooming, become extremely important for mLearning and mSupport.

Menus on mobile devices provide learners and performers with access to an increasing variety of features, options, and commands now available through mobile devices. Thus it is important to optimize menu design to allow users to find and use the options efficiently (see Tang, 2001). Likewise, searching, browsing, and viewing digital images and digital video are important mobile device capabilities, as are the discovery and retrieval of mobile content for mLearning and mSupport. These are discussed further in the later sections on content management and mobile device enhancement.

In addition, several prominent members of the eLearning and mSupport communities (i.e., Clark, 2009, Rossett and Shafer, 2007) have emphasized the importance of taking into account individual difference variables, like prior knowledge, preferred learning style, and working memory capability as key parameters that will affect the mobile device effectiveness for both mLearning and mSupport.

Task Characteristics

Another important element to consider for mLearning and mSupport mobile devices is the nature and requirements of the task to be learned or to be performed. Many of the content and context implementations, described in the following sections, are fairly widespread and can be used for most types of tasks. However elements specific to the task may need to be adjusted for each task type.

To effectively support mobile performance a mobile learning or performance *system* (including the user, the device, the connection protocol, server, and knowledge base) must have the ability to access the right content at the right time for the right person for the right task. An example of such a system is provided by Thiele et al. (2006). These investigators developed a semantic XML description format that can be used to semantically express what knowledge should be retrieved from which database to support task performance based on the nature of the task.

What is needed, but not yet implemented, is a taxonomy of learning and performance tasks to guide mobile device designers and content developers. The classic text on human performance taxonomies by Fleisman and Quaintence (1984) provides an excellent starting point to achieve this. Two important considerations in this regard are: 1) whether to use an object oriented taxonomy or an action-oriented taskonomy (see Chicelli and Shimip, 2007) and 2) whether to use a Windows-like file/folder browser or a graphic hyperbolic browser for visualizing, discovering, and retrieving learning and performance task information (see Ruffner et al., 2009).

Content Management

How well content is designed, developed, organized, made discoverable, and delivered has a significant impact on the effectiveness and usability of mobile devices. Mobile device characteristics such as small display size, limited memory, and constraints on the type of input mechanisms accentuate the need to design content as smaller bits or nuggets of information for both mLearning and mSupport (Lewis et al., 2008).

In a previous I/ITSEC paper (Ruffner and Deibler, 2008), we stressed the importance of learning and knowledge management (KM) practitioners gaining a better understanding of learning objects (LOs) and knowledge objects (KOs), in terms of their basic characteristics, similarities and differences, as well the implications for learning and performance support system development and implementation. Similarly, it is important to understand the basic characteristics of, and similarities and differences between, mobile learning objects (mLOs) and mobile knowledge objects (mKOs) for effective mLearning and mSupport. Dzartevska (2009) provided several useful recommendations for creating and using mLOs and mKOs that are applicable here. Specifically, mLOs/mKOs should be:

- limited in size
- available on demand
- presented in a sequence of slides or screens
- highly cohesive but also logically connected with other mLOs/KOs
- created with content split across multiple mLOs/mKOs
- incorporated into the learner's/worker's day-to-day workflow
- structured to use media wisely to compensate for the limited amount of continuous text used

To enable single-source authoring and content maintenance assuring access to the most current content objects, we also suggested (Ruffner and Deibler, 2008) that learning and knowledge management (KM) practitioners author KOs and LOs using a standard XML content schema such as DITA (Darwin Information Typing Architecture) or S1000D. This enables practitioners to author their content once, maintain it in a single location, and move it over to mLearning and mSupport devices in a variety of formats including html, PDF, Flash, and plain text. Storing these objects in an object-oriented repository that enables dynamic assembly at the time of need to meet the user's precise platform requirements for mLearning and mSupport will enhance the end-user experience and speed adoption of mLearning and mSupport initiatives.

Likewise, we recommended the following activities to facilitate the discoverability, usability, reusability, and conversion of KOs and LOs that are relevant to mLOs and mKOs (Ruffner and Deibler, 2008):

- Development of standard metadata schema based on the IEEE Learning Object Model (LOM) and a standard metadata vocabulary
- Registration of LOs and KOs in the ADL Registry
- Storage of LOs and KOs in a central, web-based repository

Context Awareness

Neither learning nor performance take place in a vacuum, but are affected by the situation or context. We define *context* as a collection of semantic situational information that characterizes the entity's internal features or operations and external relations under a specific situation. Accordingly, mobile devices need to be "aware" of the context in which learning or task performance take place, such as location, task requirements, and the relevant characteristics and preferences of the user, to deliver the right content to the right person at the right place and time.

Context can be based on active (e.g., sensed information from visual codes or natural scene image processing) or passive (e.g., information from a data base on role, job title, or length of service) information. An example of an innovative technology for attaining context awareness is the Contextualizer developed by Thiele et al (2006). The Contextualizer is a middleware software component that serves as a mediator between the human agent, the task, the situation, and existing knowledge bases. It addresses communication with the knowledge base (knowledge storage and retrieval) as well as linking the server and client side device according to the context.

Knowledge-intensive tasks are often ones in which the performers are faced with some degree of uncertainty and are required to bring together and apply their experience, training, expertise, and judgment for the quick resolution to a problem (Heravizadeh and Edmond, 2008). However, most current workflow technology does not support such tasks, as it deals almost exclusively with predictable and easily automated decision making tasks. In particular, it fails to deliver the right information to the user at the right time based on the context.

Context-aware workflows are a way to overcome the shortcomings of workflow management systems. For example, Heravizadeh and Edmond (2009) proposed an approach that dynamically integrates knowledge and workflow processes by offering appropriate support for the real-time handling of the both the current context of a process as well as its intended execution path.

ENHANCING MOBILE LEARNING AND MOBILE PERFORMANCE SUPPORT

Our literature review revealed several innovative technologies that have potential for substantially enhancing the effectiveness of mobile devices for mLearning and mSupport. They include thin sheet wrist-worn displays, behavioral-based learning using sensors and accelerometers, mobile content development, games and simulations, mobile collaboration, and speech recognition. These technologies should be monitored closely for possible adoption. We discuss three technologies here: 1) augmented reality (AR), 2) Rapid Serial Visual Presentation (RSVP), and 3) the Hyperbolic Browser.

Augmented Reality

Augmented reality (AR) is a computer graphics technology that can help mobile device users increase their understanding of complex visual scenes in real-time. AR accomplishes this by superimposing on the real world scene supplementary information relevant to the task at hand and referenced to the real world. AR display enhancements that support mobile device user tasks include overlaid textual or graphical information and cueing information that serves to guide the user's attention to key elements in the visual scene. The development of an AR system to provide real-time performance support for air traffic control tower personnel is described in Ruffner, Labbe, and Hoyt (2006) (see the visual display shown in Figure 3).

More pertinent to mobile devices are AR applications for mLearning and mSupport. An example is the Wikitude Augmented Reality Travel Guide (see Figure 5) in which text and graphics are overlayed on a tourist attraction in real time to enhance the learning experience. This learning and performance sport system is currently implemented on the "T-Mobile Android G1" phone (Mobilizy, 2009). Work is underway to develop mobile AR capabilities for other mobile devices such as the "Nokia Smart Phone" and the "Apple iPhone."

Rapid Serial Visual Presentation (RSVP)

Rapid serial visual presentation (RSVP) is a technology for displaying information rapidly and sequentially on a limited display space (Lewis et al., 2009). The goal of RSVP is to increase information processing efficiency and conserve limited display space by minimizing user eye movements in reading text and viewing graphics and pictures.

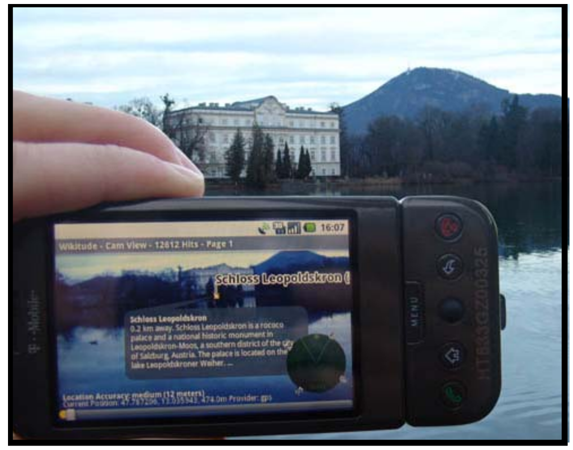

Figure 5. Augmented Reality implemented on a mobile performance support device

RSVP has great potential both as a method for searching for images on mobile devices as well as for displaying dynamic text adjacent to a static mage. RSVP technology would seem to be particularly useful on smaller mobile devices, such as the Apple iPod Nano shown in Figure 6 or a flip phone, where display space is at a premium

Figure 6. Mobile Rapid Serial Visual Présentation (RSVP) concept

Hyperbolic Browser

The hyperbolic browser (theBrain Technologies, 2009) is a technique for representing large amounts of inter-related hierarchical and associative information in either a static or dynamic format using a relatively small display space (Pirolli et al., 2001).

Concepts are shown as "nodes" which can be connected in a hierarchical (e.g., parent-child, narrower than, broader than) or associative (e.g., child-child, related to, equivalent to) manner. The lines linking the nodes may or may not be labeled, depending on the purpose of the display. Figure 7 show a hypothetical hyperbolic display for an ammunition logistics taxonomy that could be implemented on a mobile device (see Ruffner et al., 2009). A demonstration of the hyperbolic browser can be viewed at theBrain.com.

Figure 7. Mobile hyperbolic browser concept

CONCLUSIONS AND FUTURE WORK

In this paper we considered the nature of mLearning and mSupport and the capabilities and limitations of mobile devices for delivering learning and performance support content. This includes providing the required degree of reliable connections and interactivity to fully support both mLearning and mSupport.

We conclude that many of the issues we discussed (e.g., display size, connection speed) apply to mobile devices used for both mLearning and mSupport, although to somewhat different degrees. Hanley (2009) judged that currently available mobile devices work better as electronic performance support tools than as learning tools. This is because they allow quick access to pertinent information that can be provided directly at the point of need to pre-trained users needing specific forms of assistance, but are less efficient in allowing the richness of feedback and two-way interactivity required for effective mLearning.

Wagner (2009) noted that the success of mLearning and mSupport to enhance the mobility of knowledge workers will depend on finding common ground among learning designers, information technology managers, stakeholders, and end-users. He contends that learning and performance support designers and practitioners must balance their goals of connecting people with information, ideas, and each other regardless of physical location, time of day, or choice of digital transmissions and reception, with the realities of what it really takes to support the needs of mobile learners and workers. The degree to which an enterprise is willing to support its mobile worker needs will be a significant factor in determining whether or not mLearning and mSupport provide a viable solution for meeting distributed performance support as well as professional learning and development needs.

Our findings suggest that the mLearning, mSupport, and mobile device communities have made great strides in identifying needs and requirements, establishing goals, and developing paradigms for the effective use of mobile devices for delivering content. However, regarding our journey of understanding suggested by the title of this paper, we contend that our traveling party has yet to arrive at the final destination. Additional work is needed to better understand the disparate aspects of mLearning and mSupport, the nature of their relationship and boundary conditions, the role of context and situational variables, and the applicability of current and emerging mLearning, mSupport, and auxiliary technologies. We need to understand how these technologies can mutually support each other in a synergistic relationship to achieve the desired learning or performance objectives.

Accordingly, with regard to our goal of ensuring that mobile devices deliver mobile learning and support at the right time to the right individuals, we conclude that we are on the right road, are in plain sight of the ultimate solution, but have not quite entered the exit ramp yet.

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