Using Mobile Devices to Support Formal, Informal and Semi-formal Learning

Uses and Implications for Teaching & Learning

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Abstract Mobile devices are ubiquitous. They are often invisible to accomplish our everyday tasks and learning goals. This chapter explains how individuals learn using mobile devices during their daily lives—within K-12 schools, higher education, and outside of educational institutions altogether—with specific attention to STEAM disciplines. First, brief definitions of mobile devices and mobile learning are presented, then types of learning, i.e. formal, informal, and semiformal, are discussed. Next, seven categories describe how mobile devices have been used for teaching and learning with examples as appropriate from STEAM disciplines: (a) increasing access to student information and campus resources, (b) increasing interaction with learning contents, (c) creating representations of knowledge, (d) augmenting face-to-face instruction, (e) supporting performance and decision-making, (f) enabling personalized learning, and (g) deploying instruction. Finally, five implications for employing mobile devices for teaching and learning are discussed.

Keywords Mobile learning · Formal learning · Informal learning · Semi-formal learning · Social media

Introduction

Mobile devices continue to grow in their numbers, as well as permeate our everyday lives. It is no surprise that these devices are also considered part of our educational landscape. In 2013, the Horizon Report for K-12 (Johnson et al., 2013b) and the Horizon Report for Higher Education (Johnson et al., 2013a) listed mobile learning with smartphones and tablets and tablet computing, respectively, as significant impacts within 1 year or less. Similarly, the annual EDUCAUSE Center for Analysis and Research (ECAR) Study of Undergraduate Students and Information Technology (Dahlstrom, Walker, & Dziuban, 2013) reported that it was equally common for undergraduate students in the U.S. to own two, three, four, or more Internet-capable

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X. Ge et al. (eds.), *Emerging Technologies for STEAM Education,*
Educational Communications and Technology: Issues and Innovations,
DOI 10.1007/978-3-319-02573-5_9

devices, including laptop computers, smartphones, tablets, and e-readers. Most recently, the 2014 Horizon Report for Higher Education (Johnson, Adams Becker, Estrada, & Freeman, 2014) identified social media for learning as an accelerating trend along with mobile apps, tablet computing, mobile learning, personal learning environments, and location-based services as key emerging technologies.

In parallel, the integration of mobile devices in education also dovetails with the broad goals of STEM (science, technology, engineering, mathematics) education and the more recent STEAM education, which includes the visual and performing arts (Ostler, 2012). The novelty of mobile devices (Ciampa, 2014) and their ubiquitous uses for "communication, collaboration, gathering, and sharing" (Lai, Khaddage, & Knezek, 2013b, p. 2) in and outside of schooling may increase interest in STEM careers and postsecondary study. Plus, there is some evidence to suggest that the use of mobile technologies with appropriate pedagogies can aid retention in postsecondary STEM majors (e.g., Romney, 2011). To the second goal, mobile devices may "improve the proficiency of all students in STEM" (Thomasian, 2011, p. 12) when used meaningfully with teaching and learning. However, there is little empirical evidence of the STEAM interdisciplinarity advocated by Ostler (2012).

The purpose of this practical chapter is to describe how individuals learn during their daily lives—both within school and outside of educational institutions—and how mobile devices are being used to engender this learning, particularly within STEAM disciplines. First, I briefly define mobile computing devices and mobile learning, then types of learning and the purposes for which they occur. Next, I present how mobile devices have been used for teaching and learning, and I offer selected examples of how mobile devices are or could be used, highlighting STEAM disciplines where most appropriate. Finally, implications for employing mobile devices for teaching and learning are discussed.

Mobile Devices and Mobile Learning

Learning with mobile devices has been described and defined in myriad ways. Mobile devices themselves have included technologies that broadly operationalize mobility and transportability, such as cellphones, smartphones, tablet computers, laptop computers, and netbooks (Valk, Rashid, & Elder, 2010). Keegan (2005), however, recognized that mobile learning should focus on the actual mobility of the device, recognizing that some devices in fact are more mobile than others, primarily predicated on their sizes. Therefore, mobile learning should be "restricted to learning on devices which a lady can carry in her handbag or a gentleman can carry in his pocket" (Keegan, 2005, p. 33). Moreover, Traxler (2007) described devices that learners are accustomed to "carrying everywhere with them" and that they "regard as friendly and personal" (p. 129). Some of the definitions for mobile learning found in the literature focus specifically on the technology; others focus on the learner; still others attempt some combination. Most recently, Crompton (2013) as an extension of Sharples' (Sharples, Taylor, & Vavoula, 2007) definition stated that mobile learning is "learning across multiple contexts, through social and content interactions, using personal electronic devices" (p. 4).

Because the field of mobile learning and the technologies of mobile devices are both still rapidly evolving, it seems prudent to offer some compromise to defining mobile learning that respects and reflects the litany of previous work with an eye to future advances and changes. Therefore, in this chapter, mobile teaching and learning is operationalized as (a) learning that is more than delivered and supported by handheld, mobile computing devices (Keegan, 2005; Mobile Learning Network (MoLeNET), 2009) but (b) learning that can be both formal and informal (Quinn, 2000; Sharples et al., 2007; Traxler, 2007, 2010) or learning that incorporates elements of both formal and informal learning, and (c) learning that is context dependent across different settings and authentic for the learner (Sharples et al., 2007; Traxler, 2005, 2007, 2010).

Types of Learning

Barron (2006) describes a learning ecology in terms of contexts for physical and virtual spaces. Lai et al. (2013b) interpreted this to mean that "learning in a physical environment in a classroom setting and can be classified as formal" and virtual learning "occurs outside a formal classroom setting … and can be classified as informal" (p. 2). Hull and Schultz (2001) and Eshach (2006) emphasizes, however, that using physical environment characteristics may be insufficient to distinguish between formal and informal learning environments. Moreover, with the increased uses of online learning and mobile learning, classifying formal learning within a physical space is inadequate. Instead, it is more advantageous and forward thinking to consider types of learning along a continuum (c.f., Lai, Khaddage, & Knezek, 2013a) with respect to their origins and learner motivations. More details are explained below for formal, informal, and semi-formal learning.

Formal Learning

In this chapter, formal learning is considered where learners are engaged with materials developed by a teacher, trainer, or faculty member to be used during a program of instruction in an educational environment (Colley, Hodkinson, & Malcom, 2003; Halliday-Wynes & Beddie, 2009). These are often initiated, led, and evaluated by an instructor and associated with credentials (Jubas, 2010). Certainly courses, coursework, and required activities in K-12 schools and higher education are considered formal learning. Eshach (2006) also depicts formal learning as structured and prearranged in which learners are extrinsically motivated. Within this definition, if a teacher were to require learners to collect or create examples outside of class to be analyzed, reviewed, reflected upon, or evaluated, then this would still be deemed formal learning.

With regard to mobile devices, Zhang et al. (2010) describe elementary-aged students building KWL (i.e., What you know, What you want to know, What you want to learn) charts on mobile devices to document their prior knowledge and learning progress with science content as part of a required science curriculum on fungi. In higher education, Isabwe, Reichert, Carlsen, and Lian (2014) created a computer tablet-based mathematical assessment application. In the application, peers provided formative feedback on mathematical tasks.

Informal Learning

At the other end of the spectrum, Hrimech (2005) describes informal learning as learning “which people do on their own” (p. 310). Informal learning is motivated and initiated by an individual. Activities, such as reading and Internet searches; visiting community resources, such as libraries, museums, nature centers, and zoos; attending local events; gaining expertise in avocational hobbies; and learning on-the-job (e.g., Hull & Schultz, 2001) are considered informal learning activities. This type of learning is sometimes “unanticipated, unorganized, and often unacknowledged, even by the learner” (Jubas, 2010, p. 229). This type of learning can also be referred to as free-choice learning or incidental learning. Barron (2006) acknowledges compulsory formal learning can sometimes lead to informal learning, where an individual’s interests are piqued for further investigations.

Much educational research with informal learning has been focused around (a) science education and science centers, such as museums and nature centers (e.g., Yoon & Wang, 2014); (b) out-of-school mathematical experiences (e.g., White, Booker, Ching, & Martin, 2012; White & Martin, 2014); and (c) literacies (e.g., Hull & Schultz, 2001). However, there is considerable interest in leveraging much more informal contexts with learning. Informal learning opportunities can also include what Caron and Caronia (2007) refer to as “non-places” and “non-times” (p. 38), such as waiting in line at a grocery, crossing a street, or waiting at a bus stop. Grant and Hsu (2014) identify mobile devices being used informally for “communications, searching, creation, sharing, curation, and aggregation” (p. 33).

With mobile learning, Cui and Roto (2008) describe how individuals used mobile devices for fact-finding to seek out a specific piece of information and for information gathering, where they collected information from multiple sources to compare or aggregate the information in order to make a decision. These tasks are completed as part of the individuals’ daily routines and are not required as part of a curriculum. In addition, Balasubramanian, Thamizoli, Umar, and Kanwar (2010) describe the use of mobile phones by women in rural India to become business women for goat rearing. The women were encouraged to use the phones as tools for discussion among the 320 participants to converse on topics such as business, technologies, and goat rearing, as well as emergent cultural and legal issues.

Semi-Formal Learning

As mentioned previously, many authors (e.g., Impedovo, 2011; Koole, 2009; Roschelle, Patton, & Tatar, 2007) contend that mobile learning blurs the lines of formal and informal learning, or at the very least, links informal learning to formal learning. Along a continuum, this type of learning is referred to here as semi-formal learning to indicate that this type of learning shares characteristics with both formal and informal learning. These contexts and opportunities for learning are also sometimes referred to as non-formal learning (e.g., Colley, Hodkinson, & Malcolm, 2002; Thompson, 2012). White et al. (2012) lament that "few examples exist of school-based attempts to fully integrate formal and informal learning" (p. 8).

Two examples of semi-formal learning in science and medicine are provided below. GeoJourney (see BGSU Monitor, 2007; http://www.geojourney.org) is an undergraduate field-based geography course at Bowling Green State University. In this course, students travel across the United States to geophysically and historically significant geographical sites. Students prepare between stops with iPods packed with slides, videos, and documentaries designed and organized by the faculty member. In addition, Pimmer et al. (2014) describe how nurses and nurse educators in South Africa connect workplace learning with their formal educational experiences. In these rural settings, they mention the use of mobile phones and a Facebook group to share and reflect on on-the-job practice within their formal education coursework. These types of instruction and learning reflect both formal learning and informal learning elements. So, the distinctions between the two types of learning are blurred, and in some instances, the lines among semi-formal, informal, and formal learning may be blurred. Admittedly, it is quite possible for an individual to move among these fluidly, such as through multitasking or personal interests.

Uses of Mobile Devices for Teaching and Learning

Having examined the types of learning that can occur with mobile devices, this section will offer a broad taxonomy for understanding how mobile devices have been used with these types of learning. Specifically, there are seven primary ways in which mobile devices have been used to support teaching and learning. These are to (a) increase access to student information and campus resources, (b) increase interaction with learning contents, (c) create representations of knowledge, (d) augment face-to-face instruction, (e) support performance & decision-making, (f) enable personalized learning, and (g) deploy instruction. These groups are not mutually exclusive, and they are summarized in Table 1. Select examples of these uses are also provided, focusing on STEAM disciplines where most relevant.

Table 1 Uses of mobile devices for teaching and learning

Use	Example
Increase access to student information and campus resources	Students use university app to access library databases (Bushhousen et al., 2013)
Increase interaction with learning contents	Students use commercial or school-specific app to practice engineering vocabulary (Redd, 2011)
Create representations of knowledge	Students create short videos of mathematical concepts (White & Martin, 2014).
Augment face-to-face instruction	Teachers/faculty members encourage students to pose questions using social media during large class lectures (Rankin, 2009)
Support performance & decision-making	Medical practitioners use app to help compare, analyze, and prepare report of diagnosis (Lower, 2010)
Enable personalized learning	Medical students use social media, social networks, and mobile devices to participate in a medical education community Facebook page (Pimmer et al., 2014)
Deploy instruction	Students access interactive content on nuclear science (Chang, Wu, & Hsu, 2013)

Increase Access to Student Information and Campus Resources

As an initial entry, many universities are accommodating mobile devices with dissemination of university information. Universities such as Stanford (http://mobile.stanford.edu), Duke (http://m.duke.edu/), Vanderbilt (http://vanderbilt.edu/apps/), Missouri State (http://missouristate.edu/mobile/), and Texas A&M (http://tamu.edu/mobile/apps/) have developed specific applications for students to access information about campus transportation, athletic events, course directories for registration, university related events and even university resources such as the library database (e.g., Keller, 2011; O'Neill, 2013). For example, at the University of Florida, the Health Science Center Libraries (Bushhousen et al., 2013) used survey data to form a mobile technology committee in order to support and propagate information and resources specific to their patrons with mobile devices. Likewise, there have been a number of these needs analyses and subsequent implementations in higher education, such as the University of Nebraska at Omaha (Wright, 2011), GB Pant University of Agriculture and Technology in India (Goria, 2012), and the Himmelfarb Library at George Washington University's School of Medicine and Health Sciences (Gomes & Abate, 2012). These approaches do not typically have direct impact to learning as it relates to accessing and interacting with course content, fellow students, and instructors. However, the access to resources and information is valuable to students in and outside of class. So, this is a common initial method to implement and integrate the mobile devices that learners are already bringing to campus.

Increase Interaction with Learning Contents

Another way in which mobile devices have been used to support learning is to increase the interactions individuals have with instructional content. From a cognitivist perspective, repetition and practice with new knowledge and skills are successful in improving learning (Cavus & Ibrahim, 2009; Driscoll, 2005). For example in formal learning, an app was developed for a Statistics I course at Abilene Christian University that featured touch screen simulations for experiential and interactive learning, calculators that graphed bell curves for student experimentation, and decision making flowcharts for conceptual understanding (Nihalani & Mayrath, 2010). The students felt they learned more being able to access the software more often on both tablet and smartphone devices. Similarly, the University of North Carolina's Project Numina offered students the opportunity to actively engage in mathematical and science concepts using mobile devices (Heath et al., 2005). Students engaged with charts and graphs, and the results were displayed publicly.

Abrams (2013) presents a number of mobile app games that support engineering concepts. These games are most likely used by individuals to support informal learning, such as Tinkerbox by Autodesk. However, the engineering concepts and content built into Schnittkraftmeister and Fourbar are sophisticated enough to integrate with curricula in higher education for formal and semi-formal learning. The use of games and digital game-based learning can support increased interactions with content, such as through practice and review (Redd, 2011).

Create Representations of Knowledge

Many of the built-in features to mobile devices, such as photo capture, video recording, audio recording, and SMS text messaging, in addition to installed apps, allow the creation of representations of learners' knowledge. These artifacts represent the learner, the learning, and the context in which the learning has occurred (Grant, 2011; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Marx, Blumenfeld, Krajcik, & Soloway, 1997). Impedovo (2011) suggests that mobility in learning and the use of personal mobile devices allows autonomy for learners to produce multimedia artifacts as needed. So, learners can use devices they have on hand, during the stream of their daily lives and across different contexts.

For example, at the University of Reading (UK) (France, Whalley, & Mauchline, 2013), microbiology students conducted fieldwork with tablet computers in Iceland that meshes formal learning and semi-formal learning charateristics. They collected GPS data, photos, videos, and field notes to be aggregated into research presentations and video reflections. In K-12, Soloway and Norris (e.g., Project Tomorrow, 2010; Zhang et al., 2010) have been working with schools with the GoKnow Mobile Learning Environment. Small applications, such as PicoMap for concept mapping and Sketchy for drawing or animations, allow students to create artifacts that reflect their learning. Similarly, students in Scotland made videos to showcase their country, and other students used an "iPad at home to capture and edit their own multimedia compositions, such as short movie trailers, biographical videos of family members" (Burden, Hopkins, Male, Martin, & Trala, 2012, p. 70). So, many built-in functions and downloadable applications make mobile devices powerful tools for learners to generate evidence of their knowledge.

Augment Face-to-Face Instruction

Teachers and university faculty members can also use mobile devices to enhance their face-to-face formal instruction. Rankin (2009) provides a well-known and publicized example of using Twitter in her large class for discussions and backchanneling, which is posting questions and comments during a lecture or event. Havelka (2013), however, has implemented face-to-face courses on information literacy with students using smartphones and tablet computers exclusively. In my own teacher professional development, I have used the web service PollEverywhere.com with mobile devices to demonstrate in-class polling options. With PollEverywhere.com for example, teachers and faculty members can use SMS text messaging or a web page to submit responses for quick knowledge checks with mathematics (see Fig. 1) and to spark discussions with open-ended reactions (see Fig. 2). In these instances, the formal learning may look less like mobile learning. Instead, the learning with mobile computing devices may be a replacement technology, replicating existing or previous practice (White & Martin, 2014). Mobile devices in these cases are smaller and more convenient as compared to larger laptop or desktop computers and classroom response systems (i.e., clickers).

Support Performance & Decision-Making

Instead of relying completely on memory, digital performance supports and decision supports can help individuals at the times of need, particularly indicative of informal learning. These technologies can be used to improve productivity and efficiency delivering information and support just-in-time (Nyugen, 2012). Rossett (2010) describes performance and decision supports as "external resources that can be referred to as they are needed, when they are needed" ("Table 1: Mobile

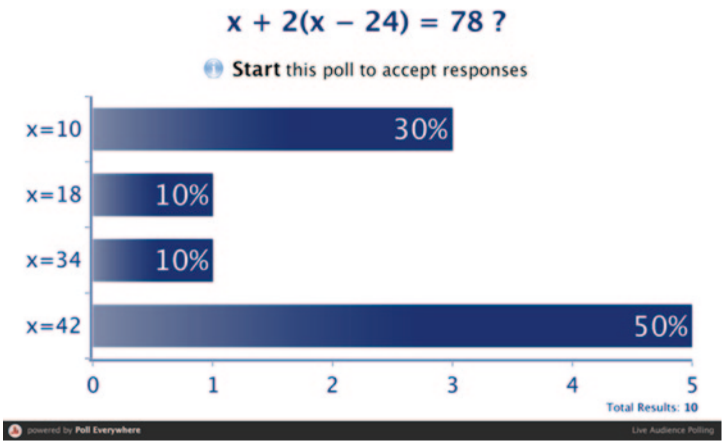


Fig. 1 Using PollEverywhere.com for a quick knowledge check in math class

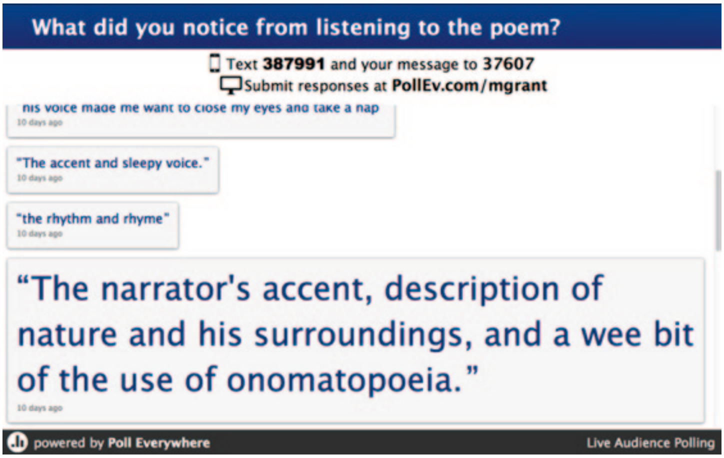
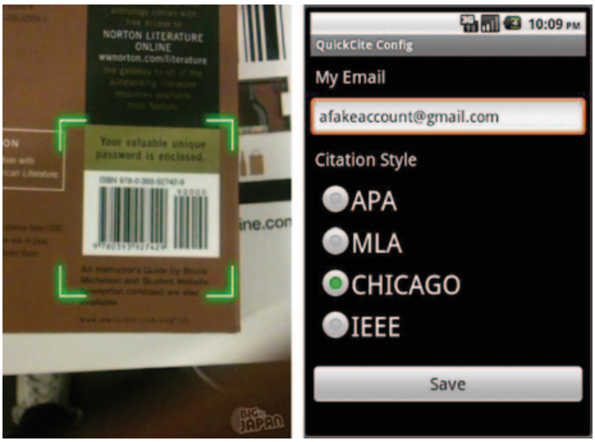


Fig. 2 Using PollEverywhere.com for an open-ended response to an audio reading of a poem

Learning and Mobile Performance Support Compared"). Because mobile devices are often easily accessible, individuals may not need to "break from the work context entirely" in order to use a performance support (Nyugen, 2012, p. 153). Instead, digital performance supports on mobile devices may resemble what Nyugen (2012) identifies as extrinsic and even intrinsic supports, which are more integrated into work systems and user interfaces. One example of a common mobile performance support is QuickCite. QuickCite is a mobile app that allows an individual to scan the bar code from a book, and then the application will email the reference citation in APA or MLA form (see Fig. 3). The individual does not have to remember the formatting rules for a book citation, and an individual does not have to write down the reference information for a book while searching. In both instances, QuickCites helps at the time of need.

Fig. 3 Screen shots of Quick Cite app for reference citation capture. Used with permission QuickCite



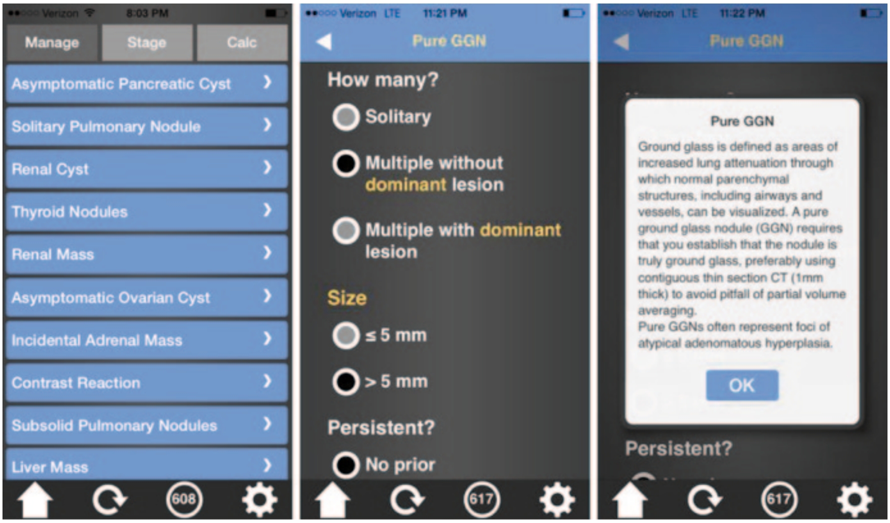


Fig. 4 Screen shots from RadsBest, a clinical decision support app for radiologists. Used with permission RadsBest

In terms of decision support, much has been done in the health and medicine fields. Martínez-Pérez et al. (2014) describe clinical decision support systems as a connection between “health observations with health knowledge to influence health choices by clinicians for improved health care” (Martínez-Pérez et al., 2014, p. 2). For example, RadsBest (see Fig. 4) is a decision support tool, deployed as a mobile app, to aid radiologists. While radiologists have been extensively trained and continue professional education, it can be challenging to be aware and use the most recent medical research and standards. The app integrates “algorithms from published standards into a user-friendly series of questions” (Lower, 2010, para. 3) in order to help radiologists analyze patient data. The app also helps radiologists interpret their findings and make appropriate recommendations to referring physicians for patient care.

Enable Personalized Learning

Informal mobile learning also affords continuous learning and personalized learning. Attwell (2007) depicted the needs of personal learning and, subsequently, personal learning environments. He recognized that (a) an individual identifies his or her learning needs, which extend across informal learning, workplace learning, and formal learning; (b) learning takes place in various circumstances and conditions; and (c) all learning needs cannot be addressed through one program of study or environment. Networked personal learning leverages a collection of devices (e.g., computers, smartphones, tablet computers), software/applications (e.g., mobile applications), and web services/learning resources/objects (e.g., SMS text messaging, video tutorials) that together serve an individual's learning needs (Attwell, 2007; Dabbagh & Kitsantas, 2012; France et al., 2013; Martindale & Dowdy, 2010). For example, personal digital magazines, such as Flipboard, present relevant information or resources based on a learner's previous preferences.

Personalized learning is initiated by an individual. Learning opportunities, such as "unintentional discoveries, events, and various experiences" (Lai et al., 2013b, p. 2), may be opportunistic or spontaneous. In the visual arts, Philadelphia's Museum Without Walls is a city-wide collection of outdoor art, sculptures, and statues (Brady, 2014). Through a cellphone call or smartphone app, individuals can listen to various voices describing the cultural or historical significance of the works. Because the works are public and outside, an individual must be motivated to pursue the learning. But, there continues to be little research on the motivations for individuals to use mobile devices (c.f., Ciampa, 2014).

Personalized learning can also take the form of continuous professional development with personal learning networks and professional learning networks. For example, Pimmer et al. (Pimmer, Linxen, & Gröhbiel, 2012; Pimmer et al., 2014) describe the uses of social networking sites, like Facebook, for individuals to solve problems with their peers while on-the-job. This personalized learning is especially beneficial when individuals are "working in professional isolation," such as in rural settings (Pimmer et al., 2014, p. 1402). Medical professionals use searches on their mobile devices *in situ* to look up unfamiliar terms and cases, as well as provide examples to peers on social networks of unusual or rare cases. Experts within personal learning networks and professional learning networks can tweet or retweet relevant information, resources, and links to their followers. Even for an individual mobile learner, all of these data can be selectively saved into social bookmarking systems (e.g., Diigo, Pinterest) or personal note-taking applications (e.g., Evernote) with relevant metadata (i.e., tags with bookmarking sites, specific boards for Pinterest or Learn.ist) for later retrieval.

Deploy Instruction

Some authors (e.g., Georgiev, Georgieva, & Smrikarov, 2004; Motiwalla, 2007; Quinn, 2000) have related mobile learning to extensions of distance education and elearning. As such, it is possible to use mobile devices to deploy complete formal units of instruction and learning activities. For example, Grant and Barbour (2013) describe a small study with an online advanced placement (AP) European History course. Two of the 26 units in the course were completed through a mobile application *Mobl21*. In my own graduate courses, I have also piloted the deployment of complete units with this mobile application. One online course in graduate teacher education (see Fig. 5) integrated texts, graphics, and videos into the *Mobl21* application delivered by iOS devices or a computer desktop application using Adobe AIR. Another course was a senior-level graduate course in developing interactive

Fig. 5 Screen shots of course unit on mobile learning for a graduate teacher education course built with *Mobl21*

instruction for instructional design majors. Again, texts, graphics, and videos on rapid prototyping and rapid elearning were chunked into small modules.

In science education, Chang et al. (2013) describe the use of augmented reality that superimposed virtual environmental elements, such as radiation levels, indoor conditions, and indoor construction materials, onto geographical locations. Ninth grade students in Taiwan considered nuclear energy and radiation in a simulation of the Fukushima Daiichi Nuclear Power Plant accident in Japan. The students were positive toward the mobile implementation, and there was initial evidence that the instructional strategy was effective. Similarly, Zimmerman and Land (2014) describe the creation of augmented reality elements to accompany an arboretum, where fourth graders and the public "could observe trees like a botanist— understanding the important ecological and biological concepts relevant in their own community" (p. 80). A mobile website and QR codes allowed access to tree-specific scientific information.

Implications for Employing Mobile Devices with Teaching and Learning

Using mobile devices to support teaching and learning within STEAM disciplines is not simple. In the previous section, I presented seven uses for mobile devices to support teaching and learning. Planning formal, informal, and semi-formal learning environments that leverage mobile devices, however, requires attention to pedagogical, technological, content, and contextual characteristics. This section discusses implications for employing mobile devices with teaching and learning. Five broad themes are presented: (a) situatedness and learning mobilely, (b) distinctions between mobile devices and mobile services, (c) mediating interactions in physical and networked environments, (d) mobile learner characteristics to evaluate resources and information, and (e) teaching and learning with mobile devices versus mobile learning.

Situatedness and Learning Mobile-ly

An implication of using mobile devices with teaching and learning is the complexities of ubiquity and situated learning. Because of mobile devices, social media, social networks, and pervasive access to the Internet, individuals are "always on" (Northcliffe, & Middleton, 2013, p. 200). Learning is a social endeavor situated in particular contexts and embedded within a certain environment (Bereiter & Scardamalia, 1985; Lave & Wenger, 1991). Applications on mobile computing devices allow learners to create video/audio, take photographs, geotag, microblog, receive or send SMS text messages, and access social networking sites for communication with classmates, their instructor, and even experts. By using the applications available on mobile devices, a personalized, authentic learning experience can be created by learners and for learners during the course of their everyday lives. Within the STEAM discipline of mathematics, White and Martin (White & Martin, 2014; White et al., 2012) have researched and discussed this in terms of "making the personal mathematical and … making mathematics personal" (p. 9). This meaning making is an important component of semi-formal and informal learning.

Mobile semi-formal and informal learning may, however, be difficult to achieve. Caron and Caronia (2007) explain that mobile devices can afford active learning during "non-times" and "non-places" (p. 38). Learning in places and times with little meaning may produce fragmented knowledge (Traxler, 2010). While learning *in situ* and across multiple networked communities, there is justifiable concern that this isolated and disconnected knowledge will become inert (Bereiter & Scardamalia, 1985), unable to be generalized or integrated into existing schemata. Knowledge and context-dependent skills must be encouraged to transfer across disciplines or domains. Unfortunately, not all contexts or times are significant, so we must be explicit in emphasizing, or encouraging individual learners to emphasize, when context matters.

Moreover, learning in small episodes of time may make retention problematic. Designing learning contents or encouraging learning that can tolerate disruptions and episodes of discontinuity may be very difficult to achieve. Disconnected pieces of information must be integrated and internalized before they can be considered knowledge (Tella, 2003).

Distinctions Between Mobile Devices and Mobile Services

Little attention has been given to the distinctions between using mobile devices and using mobile services with mobile devices. For example, many mobile devices have cameras that allow photo and video capture. However, to use the text messaging features on mobile devices, subscription to a data plan is required. Admittedly, for many individuals these differences may go unnoticed. Many examples of mobile teaching and learning depict the integration of mobile devices and mobile services (e.g., Ducate & Lomicka, 2013; Herrington, 2009; Northcliffe & Middleton, 2013; Pimmer et al., 2012). However, how the devices and the services are used for mobile learning is significant because many mobile services, such as data plans that afford persistent network access, allow learners to enact characteristics of mobile learning. This includes many of the examples of informal learning with networked communities and access to information and resources.

In addition, the costs associated with mobile devices and data plans should not be dismissed. In some recent research with K-12 online learners (Grant & Barbour, 2013), there were a number of secondary students who did not have access to devices or who chose not to use their devices to the fullest extent because of barriers such as cellular coverage or data plan rates. This differentiation in functionality highlights a concern for the costs associated with data plans and the lack of widespread coverage of cellular networks.

Mediating Interactions in Physical and Networked Environments

Another implication for using mobile devices is recognizing mediated interactions. Based in Activity Theory, human activity is mediated through the use of an artifact, such as mobile computing devices (Impedovo, 2011). Moreover, learners act as agents in their learning environments, transforming them as needed to achieve their individual goals. Human agency is directly linked to the relationship between the learner and the artifacts, or tools he uses. So mobile computing devices and mobile services both mediate the interactions for learning and the interactions with others, bridging the transactional distance between individuals and translating the interactions with the learning environment (Looi & Toh, 2014; Park, 2011). So, the mediation by the mobile devices helps to overcome the distance between networked learners and the course content.

In K-12 mathematics, White and Martin (2014) researched how seventh, eighth, and ninth grade students captured photographs and video of algebraic concepts, and these examples were then anayzed in class. Ryu and Parsons (2012) describe how dyads collaboratively explored a simulated training program with mobile text messaging communications to share observations, photos, and questions. Similarly, France et al. (2013) recount uses of social media by higher education students for reflection of scientific fieldwork. So, the mobile devices mediate, or help interpret, the human activity.

In another example, Pimmer et al. (2012) describe the use of a social networking site with mobile phones to support professional medical education in emerging countries. The "Medical Profession, wow I Love it" Facebook page is an informal learning environment, where participants can choose when and to what extent they will engage. Pimmer et al. suggest that through the discussions and responses to the moderator's questions and posts, practicing professionals and students were grounded in a specialized context. So, in this case, the learner may be mobile but still rooted in a meaningful professional learning network.

Mobile Learner Characteristics to Evaluate Resources & Information

Learning in a variety of places and times requires critical thinking for reflection, monitoring, and metacognition as part of learning autonomously. Tella (2003) and Traxler (2010) warn that learning across various places and in small chunks of time require that a learner combine and internalize small pieces of knowledge together into existing cognitive structures (e.g., assimilation, accommodation, accretion, tuning). For learners to succeed in personalized learning, Dabbagh and Kitsanstas (2012) argue that learners must engage first with personal information management, then social interaction and collaboration, and finally, information aggregation and management. As Sha, Looi, Chen, and Zhang (2012) explain, learners must be willing and capable to determine the "right things … right time … right place …and …right strategies" (p. 367).

However, mobile learners may be ill prepared for this evaluation of resources and information. Mobile learners may need to distinguish between information and knowledge. While there are not universal definitions discriminating information from knowledge, Wiig (1999) characterizes the generally accepted proposition that information represents facts or data that is situated to a particular context while knowledge embodies an individual's beliefs and has been incorporated into his schemata. So, mobile learners may have autonomy and self-direction for specific learning goals, but they may need increased levels of scaffolding for self-regulation to solve information problems and integrate knowledge (Shih, Chen, Chang, & Kao, 2010).

Distinctions between experts and novice mobile learners may also impact problem solving. Naïve information problem solvers, like mobile learners attempting to search for a solution to a domain-specific problem, are often reactive in information seeking, having difficulties in identifying both what they know and do not know (Hill, 1999; Yang, 1997). They may use random actions with little evaluation and information problem-solving strategies are limited to browsing and exploration. Knowledgeable learners are most self-directed with a higher level of understanding for the problem domain and they tend to use more advanced strategies for problem-solving. The more knowledgeable learners have a well-developed schema in order to integrate new or missing knowledge.

Teaching & Learning with Mobile Devices v. Mobile Learning

As described above, mobile devices have been used to augment formal face-to-face instruction in classroom settings and increase interactions with curricular content. However, it is significant to note that these examples of using mobile devices with teaching and learning may not depict wholly mobile learning. In an earlier section of this chapter, I indicated that mobile learning was more than instruction and learning delivered and supported by handheld, mobile computing devices (e.g., Keegan, 2005; Mobile Learning Network (MoLeNET), 2009). Mobile learning should also be authentic and context dependent (Sharples et al., 2007; Traxler, 2005, 2007, 2010). In some instances of teaching and learning with mobile devices, the learner and the device may neither be mobile. For example, some schools are experimenting with classroom sets of mobile devices, where the teacher determines when the devices will be used and the students are unable to take the devices home or use them with autonomy (e.g., Grant et al., in press; Greenberg, 2010). Kiger (2012) describes the use of iPod Touch devices and math software applications for third grade multiplication practice. The students practiced on the devices with specific applications during class and did not take the devices home. In addition, Rankin's (2009) use of Twitter in class for backchanneling may be limited as mobile learning. In these instances, the formal learning may look less like mobile learning. Instead, learning with mobile devices may be using a technology that is simply smaller, more convenient, or supplied by the student.

Conclusion

In this chapter, I have provided categories for understanding how mobile devices have been used with teaching and learning in K-12 schools, higher education institutions, and even everyday circumstances as they relate to STEAM disciplines. Of particular interest is the lack of empirical research to document and describe the use of mobile devices in technology supported informal learning (Jones, Scanlon, & Clough, 2013). Connecting formal learning and informal learning continues to be a challenge (White et al., 2012) while leveraging the ubiquity of mobile devices so individuals can learn at differing times and spaces (Sha et al., 2012). This, of course, is related to the challenges in capturing meaningful data and measuring learning at potentially non-times and non-places (c.f., Boticki & So, 2010), as well as in instances when learners may be unaware they are even learning (Jubas, 2010). The type of research by Cui and Roto (2008) with extensive data collection into how, where, and under what conditions learners are conducting searches is a beginning to understand informal learning with mobile devices. Additional research with large data sets may help us to understand more about how mobile devices are integrated with everyday lives and how learning is segmented, or chunked, in between events in our everyday lives.

In addition, I presented five broad implications for integrating mobile devices within teaching and learning. These implications highlight the complexities in designing formal, informal, and semi-formal learning environments that exploit mobile devices and mobile learners. Pedagogically, teachers and higher education faculty should consider when mobile devices will be used for practice with specific learning contents and when mobile devices may be used in authentic contexts to interact with peers, experts, or environments. These decisions directly reflect whether learning with mobile devices authentically depicts mobile learning or whether mobile devices are replacement technologies (Traxler, 2007). The examples presented in this chapter that are most authentic, meaning those instances that are most reflective of real world practices (e.g., Balasubramanian et al., 2010; Cui & Roto, 2008; France et al., 2013; Pimmer et al., 2014, 2012; White & Martin, 2014), are also the most representative of mobile learning as defined at the beginning of this chapter.

The potential of teaching and learning with mobile devices in STEAM disciplines is promising. In order to employ this potential, we must recognize the inherent characteristics of formal, informal, and semi-formal learning environments, as well as the affordances and opportunity costs to mobile devices. These include the on-board features of mobile devices in addition to data and network services, social media, social networks, and installed applications.

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