Mobile Technologies for Teaching and Learning

45

Rajiv Ramnath and Ajay Kuriakose

Contents

Abstract

Mobile information technologies can unshackle learners from desks and classrooms and allow them to learn on the go. They can explore and consume information, record their learning, and collaborate with mentors and with each other at any time and in any place. A mobile device knows user location and identity, so learning can be location and situation based and personalized to the user. In this chapter, we describe current mobile computing technologies and their use in teaching and learning. We project how mobile technologies will evolve in

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the future and examine – using the various theories and processes of learning as a lens – how the growing affordances of these technologies may influence student learning and education in the future.

1 Introduction: How Mobile Technologies Can Support the Teaching and Learning

From blackboards to calculators to computers, technologies enable and enhance learning. Each new technology provides new and improved affordances that influence how we teach and how we consume educational material. However, when we explore how students *learned* by using technologies, it has become clear that naively applying technology is not enough, and we need frameworks for applying technologies. These frameworks come from learning theory. As Fischer and Scharff (1998) suggest, "New technologies and learning theories must together serve as catalysts for fundamentally rethinking what learning, working, and collaborating can be and should be in the next century." This idea is the foundation for this chapter that begins with a discussion of a selection of the seminal learning theories, styles, taxonomies, and processes. Next, reasons how and why popular mobile technologies can advance teaching and learning are illustrated. Lastly, future application of these technologies is projected, and examined, *through the lens of learning theory*, in relation to how capabilities and affordances of mobile technologies can enrich and improve learning outcomes.

2 Applying a Theory-Supported Approach to Mobile Learning

Before discussing how mobile technologies may effectively assist learners, it is important to understand how learners learn, how they experience teaching episodes, and how assessment shapes teaching and learning. To that end, some foundational elements of learning theory first deserve reflection, followed by a discussion on how mobile technologies may support. This debate applies learning theory, teaching methods, and learning processes as its argument.

2.1 Types of Learning and Learners and the Cognitive Processes of Learning

Learning has been broadly classified as follows:

- Learning-conscious or formalized learning (Rogers 2003): Formalized learning is "educative learning" rather than the accumulation of experience. Here, learning is a conscious process, with the intent that formalized knowledge will enhance and accelerate it.

Task-conscious or acquisition learning (Rogers 2003): Acquisition learning is seen as going on all the time. It is "concrete, immediate and confined to a specific activity; it is not concerned with general principles." Here, while the learners may not be conscious of learning, they are aware of the specific task in hand. Project-based courses, internships, and professional practice itself contribute to this kind of learning.

In addition to categorizing learning, considerable research in education has focused on categorizing the types of *learners* – from conceptual learners, who prefer to learn using abstractions, to hands-on learners, who prefer to learn by doing. One commonly referenced body of work is Kolb's Learning Style Inventory (LSI) (Kolb 1984). In this model, learners are categorized using two axes, namely, the active experimentation-reflective observation axis and the abstract conceptualization-concrete experience axis. Learners distribute to one of four quadrants, as follows:

- ***Convergers***, who believe in active experimentation as well as abstract conceptualization. For example, convergers may first think about things and then try out their ideas to see if they work in the real world or they could do the reverse, which is, experiment first and then generalize their experience into concepts. Convergers like to understand *how* things work. Convergers typically prefer to work by themselves, thinking carefully and acting independently. Computer-based learning tends to be effective with them.
- ***Accommodators*** learn by active experimentation and through direct interaction and concrete experiences. Accommodators do rather than think and like to ask "what if?" and "why not?" rather than "how?" Unlike assimilators (see below), they are likely to reject approaches to learning that are routine. Accommodators prefer to learn by themselves than with other people and like hands-on and practical learning rather than lectures.
- ***Divergers*** (reflective observation-concrete experience). Divergers take experiences, as well as instruction, and extrapolate and generalize learning in multiple directions. Divergers ask "why?" Divergers enjoy participating and working with others. While they like interactions with others, they like these to be calm and conversational and fret over conflicts.
- ***Assimilators*** learn by reflective observation and abstract conceptualization. Assimilators think rather than act. They task, "what is there I can know?" They prefer lectures for learning, with demonstrations where possible, and respect the knowledge of experts. They will also learn through conversations, guided by a logical and thoughtful approach. The best way to teach an assimilator is with lectures and reading material that start with high-level concepts and then work through the details.

Note that Kolb's model of learner types is considered useful as a description of learning types; however, its use to analyze situations and provide solutions is unproven (Hunsaker 1981).

An important aspect of all learning is "metacognition," i.e., the process of reflecting on and directing one's own thinking. Metacognition is the basis for two types of generalized learning, as follows:

- Double-loop learning (Argyris and Schön 1978): This form of learning involves the detection and correction of error. In single-loop learning, the response when something goes wrong is to look for another strategy that will address and work within the existing governing variables. In other words, given or chosen goals, values, plans, and rules become operationalized, and more efficient, rather than questioned. An alternative response is to question the governing variables themselves. This is double- loop learning. Such learning may then lead to an alteration in the governing variables and, thus, a shift in the way strategies and consequences become aligned.
- Reflective practice (Schon 1983, 1987): Reflective practice is a refinement of double-loop learning. The capacity to reflect on action to engage in a process of *continuous learning* is one of the defining characteristics of professional practice. The cultivation of the capacity to reflect *in* action (while doing something) and *on* action (after completion of the action) has become an important feature of professional training programs in many disciplines and encouraged as a particularly important aspect of educating the beginning professional.

When trying to develop students' metacognitive skills, making students' thinking visible to both their teachers and themselves is very important. "Thinking aloud" is a common practice suggested to learners, in order to have them reveal their thinking and thought processes. While thinking aloud is effective (Baumann et al. 1992), Ericsson and Simon (1980) point out that "verbalizing information is shown to affect cognitive processes only if the instructions require verbalization of information that would not otherwise be attended to." In other words, thinking aloud requirements need purposeful design.

2.2 Enabling Effective Learning

According to *How People Learn* (*HPL*) (Bransford et al. 2000), environments that best promote learning have all four of the interdependent characteristics described below:

1. They are *learner* centered: These learner-centered environments are those that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting. New knowledge extends existing knowledge, and therefore teachers need to uncover any incomplete understandings, false beliefs, and naïve concepts that students may have.
2. They are *knowledge* centered: Knowledge-centered environments present knowledge in a well- organized approach, in order to support understanding and adaptive expertise building. Teachers have clear learning goals that capture

exactly what knowledge students will be gaining and how they can use that knowledge. There is also emphasis put on developing a strong foundational structure of basic concepts on which to build further learning.
3. They are *assessment* centered: Assessment-centered environments provide frequent formal and informal opportunities for feedback focused on understanding and encourage and reward meaningful learning. In addition to grades on tests and essays that serve as *summative* assessments that occur at the end of projects, *formative* assessments provide students with opportunities to revise and improve the quality of their thinking and understanding.
4. They are *community* centered: Community-centered environments allow people to learn from one another, by collaboration, as well as by conflict.

The HPL framework also has several recommendations for enabling effective learning, as follows:

- Make thinking visible, of both students and experts, to enable metacognition. Thus, have students engage in activities that make visible the processes of their thinking, rather than merely the conclusions of their thinking. Model expert thinking to make explicit the strategies and techniques that are implicit in expert thinking.
- Benchmark the knowledge level of students. The knowledge (and misconceptions) that students enter the class with will affect their learning.
- Use contrasting cases as examples. Two examples whose differences highlight a particular point or set of points can illustrate particular points effectively. More so than novices, experts are likely to understand the contrast between two complex cases with many similarities. It is best, therefore, to start with simpler cases before moving to complexity as understanding deepens.

2.3 Assessing Teaching and Learning

As the HPL framework recommends, assessment is a key aspect of an effective learning environment. A well-known framework for assessment is Bloom's taxonomy. The revised and updated version of this taxonomy is (Anderson et al. 2001), which categorizes the levels of learning as the following:

- Remembering, that is, can the student recall or remember the information taught in (say) a class? Assessments for this level involve asking the learner to memorize and then define, duplicate, list, or even simply recall or repeat what was taught.
- Understanding, that is, assessing that the student can explain ideas or concepts. Here, the learner is asked to classify, describe, discuss, explain, identify, translate, or paraphrase what was taught.
- Applying, that is, assessing that the student can use the information. Here, the learner is asked to choose, employ, and demonstrate the use of the learning.

- Analyzing and evaluating, that is, can the student distinguish between the different parts by appraising, comparing and contrasting, examining, and critiquing the information taught, or can the learner justify a stand or decision?
- Creating, that is, assessing that the student can create a new information product or point of view.

While Bloom's taxonomy is intended to assess an individual's learning, Kirkpatrick's four levels of training (The Kirkpatrick Model 2015) are an orthogonal set of levels, primarily used for assessing knowledge delivery (i.e., the teaching or training). These four levels are as follows:

- Level 1: Reaction – To what degree participants reacted favorably to the training
- Level 2: Learning – To what degree trainees acquired the intended knowledge and skills from their participation in a training event
- Level 3: Behavior – To what degree trainees could apply on the job what they learned during training
- Level 4: Results – To what degree the appropriate outcomes (such as revenue growth, improved quality) occurred as a result of the training event

In a sense, Bloom's taxonomy is aimed at summative assessments (i.e., assessing the learner) as opposed to formative assessments (i.e., assessing the teaching or training), which is the target of Kirkpatrick's four levels.

2.4 Teaching Techniques

Terrell (2005) delivered a simple way to categorize activities as essential elements of a learning system: auditory, which includes listening and speaking; visual, which includes seeing and reading; and kinesthetic, which incorporates "doing" in the teaching and learning process. The use of hybrid activities within a mobile learning system is exemplified in Tan and Liu (2004), where words are learned through matching with pictures (kinesthetic plus visual) and having the tool read out words (auditory).

The "places" in which learning occurs is also a key characteristic of a learning system. Traditional lecture-based teaching typically takes place through lectures, interactions, and assessments in a specific room. Online systems remove constraints of location and distance. Thus, lectures stream as videos, assignments upload via email, and discussions may take place through online forums, such as chat rooms or wikis. Massive open online courses (MOOCs) are highly scaled up examples of online education systems. Hybrid systems consisting of place-based and online components deliver what is typically termed as blended learning (Meejaleurn et al. 2010). A (now) common example of blended education is done through what is known as a "flipped" or "inverted" classroom (Lage et al. 2000; Herold et al. 2012). The flipped classroom is widely regarded as an excellent approach to exploit affordances of online technologies to actively engage students and improve learning. Traditional lectures transform to online videos with class meetings being devoted to discussion and application of new ideas. The expectation is that this will help improve student achievement of course outcomes.

The granularity of learning (and teaching) has also been the subject of educational research. A learning object (Wiley 2000; Gerard 1967) is “a collection of content items, practice items, and assessment items that are combined based on a single learning objective.” The main idea behind learning objects is to break educational content into small chunks, reusable in various learning environments.

2.5 Learners and Technology

Prensky (2001) makes the claim that learners today are “digital natives” who “think and process information fundamentally differently” because of the way they use technology in their daily lives, texting constantly to stay in touch, holding parallel conversations, used to playing deeply immersive games, rather than reading, and skilled at integrating information quickly, rather than synthesizing it deeply. His claim (that has considerable anecdotal support but, truth be told, insufficient experimental validation) is that learners today must be taught differently, in ways that take advantage of their multitasking, nonlinear skills.

2.6 Implications for Applying Mobile Technology to Learning

The aforementioned theory and practice afford significant implications on how mobile technology integrates with teaching and learning, as follows:

- Support for task-conscious and learning-conscious learning: To begin with, mobile devices can support formalized, learning-conscious methods of teaching by presenting learning objects, or even just reading material, and streaming or podcasted audio and video lectures. Mobile devices can also support a wide and nuanced range of acquisition or task-based learning, for example, by having students take part in activities where they collect data in the field, and then analyze and present their findings.
- Personalization: As personal devices, smartphones and tablets can identify, store, and apply intimate knowledge about the user. Programming can specifically match knowledge to a user’s learning type. A digital native can use today’s devices to access knowledge in chunks, in parallel by multitasking, and through Trojan Horse means, such as in games like “Where in the World is Carmen Sandiego” (Bernstein 1991), where the learning about geography, mathematics, and cultures, among other subjects, was hidden inside the game.

- Support for single- and double-loop learning, reflection, metacognition, and learner visibility: At a micro level (selections, navigations, data entry, time of entry and exit, etc.), the smart device collects data as the user consumes educative material or practicing learned skills. This data can be mined and analyzed to provide detailed feedback to the user, so he can better apply what he has been taught (i.e., mobile technology can assist in single-loop learning). Further, mobile devices are programmed to identify lack of convergence toward a solution, compare one user's process with another's, perhaps someone who is an expert, and offer suggestions that direct the user toward double-loop learning as well. The device can facilitate active reflection; prompt the user to think aloud, to answer questions, and to probe engagement; as well as present quizzes or tests that assess learning and reveal problem-solving processes.
- Creating rich learning environments: A smart device is a conduit to an individual's learning environment. As mentioned previously, this environment may be learner centered through personalization, where the mobile device is collecting the data that enables this personalization. A smart mobile device can be programmed both to do explicit assessment (by presenting the learner with surveys and tests) and implicit or behind-the-scenes assessment, simply by observing the interactions between the user and the learning material. Finally, the mobile device serves as a means of connecting the learner with her learning community.
- Assessment: Nuanced assessment to measure the learner's level in accordance with Bloom's taxonomy or explore a program's quality with respect to Kirkpatrick's four levels uses explicit pop-up surveys and tests or implicit behind-the-scenes data analysis, with the mobile device serving as the data collection device.
- Support for auditory, visual, and kinesthetic models: The audio, video, and touch capabilities of the mobile device directly support these modalities, as well as hybrids of these modalities.

Certainly, other electronic and physical means (such as paper forms) may achieve the above as well! However, mobile technology allows the learner to acquire knowledge through various modalities and practice this knowledge while collaborating with others free from the tethers of time and location.

In the next section, then, we describe current mobile technologies and how these currently rich learning.

3 The Current State of Mobile Teaching and Learning Technologies and Applications

This section presents the current state of the computing technologies used in mobile teaching and learning applications and systems. This section then describes a selection of the teaching and learning applications and systems themselves. Applications for research and commercial applications are described.

3.1 Technologies

Types of devices: Mobile computing devices integrated into teaching and learning range include smartphones, tablets and laptops, as well as specialized devices. Most devices fall into following categories:

- iOS devices from Apple that include the various versions of the iPhone, the iPad, and the iPad mini. iOS devices have a share of approximately 33% of smartphone usage (Forbes 2017) while holding to approximately 15% of global market sales (IDC 2017).
- Devices powered by the Android operating system from Google that make up roughly two-thirds of smartphone usage (and about 85% of global market sales) (IDC 2017). These include smartphones and tablets from a variety of manufacturers, such as Samsung, Google, and HTC, as well as the Kindle Fire from Amazon (which has transformed from an e-book reader to a tablet that can run apps).
- Specialized devices such as the original Amazon Kindle Paperwhite, currently sold by Amazon, and the relatively new Amazon Alexa-based devices, namely, the Echo™ and the Dot™.

Most of the general-purpose devices (i.e., outside of the specialized devices) have high-density displays. Thus, all mobile devices can present documents (text and PDF are the common formats supported), and most can support high-density video presentation. Rich interactive graphics are displayable (such as games). All can run special-purpose “apps.”

Device capabilities: Apps on mobile devices can make use of a powerful set of built-in device capabilities. These include:

- Display and graphics: The presentation capabilities mentioned above but also rich interactive graphics capabilities through touchscreens.
- Storage: The ability to store increasingly large amounts of data – now up to multiple gigabytes (GB) for the more expensive and powerful devices (such as the Samsung Galaxy tablet, which has internal storage of up to 16GB) – with storage cards available that can store up to 128GB. Data can be stored as files as well in relational databases (such as SQLite [SQLite] that can run on the device).
- Computation: The newer mobile devices are high-powered computing devices with multicore processors that can do complex mathematical calculations and render rich high-quality graphics in real time.
- Sensing: These smart mobile devices come with a range of sensors that can sense magnetic fields, sound, light, and acceleration. A new sensor that is now found on many Android and iOS smartphones is a near field communication (or NFC) sensor. Together with the camera and audio recording capabilities, sensors are useful in creating active learning educational applications in which the device captures data in the field of physical phenomena.

- Location sensing: Location sensing allows the smart device to not just know its GPS location but also its location hierarchy (e.g., which country it is in and within that, which state, which city, which street address, and so on).
- Communication: A core feature of almost all mobile devices is the ability to communicate via the Internet through which apps can access information on the Web as well as send and receive emails and text messages, as well as communicate with each other. Devices also typically have a built-in *short-range* communications capability via a technology known as Bluetooth. This allows the device to connect to nearby devices such as displays and audio and video servers (like iTunes Plus that can stream content from the device to an audio system or the television).
- Interactivity: Most recent smartphones and tablets allow users to interact with them using touch (operating as mouse clicks) and gestures. With the advent of Siri™ and Google speech recognition technology in Android devices, speech recognition is now a mainstream and (almost) reliable capability; therefore, users can interact with applications with their voice.
- Built-in applications and app stores: Mobile devices come “factory installed” with several apps, such as a Web browser, a messaging app, a telephony app, a contacts app, and audio and video playback and recording apps. Thus, for example, an app that teaches biology has an experimental component where the learner in the field takes photos of various plants and uploads these as part of an assignment. A useful feature is that the services that these apps provide *are callable from other apps*. Thus, if a learning application needs to email results to a teacher for evaluation, it can simply use the built-in email app to send the email.

The apps on a device are not predetermined and fixed. New apps can also be downloaded and installed from the appropriate “app store,” thus Android apps [are] downloadable downloadable from the Google Play store and iOS apps from the Apple Store.

Software technologies: A large variety of software technologies build applications and systems for mobile devices, as follows:

- The standard set of Web technologies such as HTML, Cascading Style Sheets (CSS), and JavaScript build Web-based apps for mobile devices. The advantage of building Web applications is that they are cheaper to build (because of the availability of programmers familiar with Web applications) and easy to install (because no installation is needed!). Note that a Web app is driven by a software component on a server, which may be written in a scripting language (such as Ruby on Rails, PHP, or Python) or in Java™or .NET™. Such a server component will also typically use a commercial-quality relational database, such as mySQL™ or SQLServer™.
- Web applications have two disadvantages. They need to have constant and reliable access via the Internet to a server and (until recently) had limited capabilities with respect to a rich graphical user interface (or GUI). “Native”

applications, which are essentially desktop applications that run on the mobile device, do not have the disadvantages Web applications have. Native applications for iOS devices (i.e., the iPhone or the iPad) develop into Objective-C using a "framework" called the iOS Framework, on an interactive development environment (IDE) called Xcode. Applications for the Android platform are developed in Java using the Android Framework, on an IDE called Eclipse (a more usable IDE called Android Studio has recently been released by Google). Apps for the Windows phone use a version of the .NET™ platform from Microsoft on an IDE called Visual Studio.

- Cross-platform technologies: Native applications that need to run on more than one platform (i.e., iOS and Android) have to have a version developed for each platform. However, there are technologies that allow developers to develop an app once using one programming language and then have it automatically adapted by the IDE for all the platforms. Such technologies are called "cross-platform" technologies and include Sencha™, Titanium™, RhoMobile™, and Xamarin™.
- Other relevant technologies: A mobile app may call upon data storage technologies to preserve user data or on data mining algorithms to extract insights from the data that the user is supplying. Data is typically stored on the device in files (which are often encrypted for security) or in relational databases (such as SQLite™) that run on the device itself (as opposed to on a server). Several open-source data mining and machine learning technologies exist in open source (enabling free use), such as Weka™.

3.2 Software Development Methodologies

In addition to the technologies used for building mobile apps, it is also important to briefly describe "best- practice" methodologies (or the engineering processes) used to develop these apps and systems. When developing apps for teaching and learning, it is important to be able to evolve an app quickly to meet the needs of diverse target populations. The methodologies and techniques described below enable software developers to develop software in a flexible manner:

- Product line design: Product line design is an engineering design methodology used to develop a *set* of software-intensive systems that share a common, managed set of features. Typically, a *family* of systems satisfies the specific needs of a particular market segment or mission. These systems develop from a common set of reusable assets in a prescribed way. Using product line design greatly increases the efficiency and reduces the cost of developing apps that are all targeted for a specific domain (such as STEM teaching and learning).
- Agile development: Agile development is a management practice and a set of programming techniques for software development that allows software to adapt rapidly to changing needs identified during its development cycle.

3.3 State of the Research and Commercial Products for Mobile Learning

In this section, the "state of the art" in mobile teaching and learning first illustrates a selection of commercial products, followed by a selection of research projects in mobile teaching and learning.

3.3.1 Commercial Mobile Teaching and Learning Products

There are several commercial teaching and learning products available commercially. A short list of products from Scholastic – well-known vendor of products – targeted at K-12 is shown below:

- Read 180 (http://read180.scholastic.com): This is a reading intervention program from Scholastic that has a set of curriculum, instruction, assessment, and professional development programming. Read 180 has recently been made available on the iPad. Targeted at the Common Core State Standards. In the reading area, it provides reading comprehension material – articles and stories – integrated with embedded questions. Read 180 also provides writing assignments, which come with scaffolding material (such as bullet points outlining a suggested flow and content).
- Math 180 (http://teacher.scholastic.com/products/math180): Math 180 is a mathematics intervention program to help students struggling with algebra. Math 180 is organized into nine blocks of instruction, each of which not only presents a related set of algebraic concepts but also tries to present its mathematical theme in the context of application stories and potential careers.
- System 44 (http://system44.scholastic.com/): This is a reading program for reading-challenged readers in Grades 3–12+. It can be used as a standalone or as a supplement to Read 180. When combined with Read 180, System 44 is meant to bring students up to a level at which they can then use Read 180.
- Grolier Online (http://teacher.scholastic.com/products/grolier/): Unlike the three products above, Grolier Online is not targeted at a specific skill. Rather, it serves as a resource of information, designed to be usable for learners in Grades 3 and higher. Resources include videos, links to world newspapers, and clickable maps that give detailed information about the places (including current events).

Most commercially available products (like the above) simply use the ability of mobile devices to present and interact with information using native apps. The other capabilities of mobile devices – such as sensing, location, personalization, etc. – are not used. Commercial products will emerge that begin to use a richer set of mobile device capabilities. This prediction unfolds in Sect. 4.

3.3.2 State of the Research in Mobile Teaching and Learning

As is to be expected, research in mobile teaching and learning has focused on answering research questions in mobile teaching and learning. Research has primarily looked at

- The efficacy of specific learning modules when delivered on a mobile device (Yan et al. 2012; Tan and Liu 2004).
- The adaption of students to mobile and online environments (Luo and Huang 2012) when they are asked to migrate away from the traditional classroom. In particular, (Terrell 2005) examines the effect of learning styles with respect to adapting to online and mobile instruction.
- The combination, or blending, of mobile learning with traditional classroom learning, such as in (Meejaleurn et al. 2010).

Note that most research focuses on applications that follow an acquisition of knowledge metaphor (AM). The participation (in activities) metaphor (PM) is so far mostly unexplored in the research, at least in any rich level. Incorporating rich activities in applications will be an area of deeper exploration in the future. To that end, an example of the authors' research in mobile teaching and learning is presented.

GeoGame: The GeoGame project is an ongoing collaboration between researchers in geography, physics education, and computer science (and receives ongoing support from the National Science Foundation through an NSF-IIS Award #1320259).

The GeoGame project seeks to effect location-based learning (see Clough 2010) about the world through simulations built around online maps. Our first application (see Fig. 1) developed via this project, *GeoGame–Green Revolution*, turns digital world maps, similar to Google Earth and Bing maps, into a game board where any place in the world can be experienced firsthand through game-like simulations. The

Welcome swaroop84!

3/10

107 1.8 0

0 0 0

Free Land Left : 4.21 Acres

Work Capacity : 2 Acre

AREA 1 ACRES

SEED TYPE « Land Race »

FERTILIZER LEVEL « Low »

IRRIGATION LEVEL « 1 »

Fig. 1 Game play in GeoGame – Green Revolution online game combines satellite images, geographic information, and game play to give users a microexperience of what life is like in other places of the world. In the first 2 years of this project, the team has developed and tested a prototype game about the Green Revolution in India. The data collected from user studies in university geography classes will help the team and the learning technology community to understand

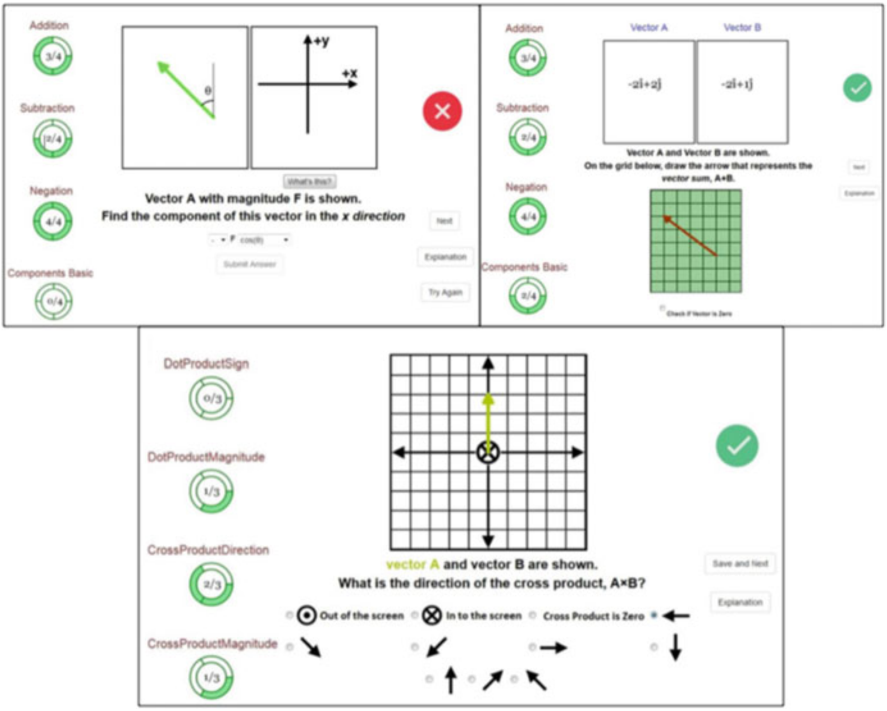
- What key components and functionality can help and guide others to develop similar learning technology
- How educators can naturally integrate an online social game activity into the classroom
- How a virtual microexperience can generate critical thinking and impact learning about a faraway place when the students can relate to what they experienced rather than what they have read

Our first results (Ahlqvist et al. 2013, 2014; Mikula et al. 2013) demonstrate that many students who play the game increase their understanding from simple explanations to an awareness of the complexity of agriculture in the developing world. Continued research will seek to determine how that awareness is developed and how the technology can be used to take the students one step further to formulate explanations of what happens in the game.

The technical innovations in GeoGame allow almost any type of board game played on top of a current or historic map of the world. In fact, the game can directly access and allow any known real-world information to affect the game play. Just imagine playing the popular game RISK with friends but in Google Earth on a current or historic map allowing real-world information on economy, population, and other conditions affect the game in real time or playing Farmville in a village close by or in a faraway Indian village, planting, buying supplies, fertilizing, irrigating, trading goods, and so on. The intent is for learners to have a lot of fun while learning about real-world facts and complex human-environment interactions. An edited book on geography-based games and learning (Ahlqvist and Schlieder, 2017) is scheduled to appear.

Vector Training Module: The vector training module is an ongoing collaboration among researchers in physics education and computer science and engineering (Heckler and Mikula 2016; Mikula and Heckler 2017). It is a Web- and tablet-based quiz application that presents learners with questions on vector algebra and allows them to answer using a touch-based interface. This project is aimed at removing mathematical misconceptions with respect to vectors from high school students and first-year students in the undergraduate program. The basic framework of the vector training module can be extended to build quizzes on various topics (Fig. 2).

Edgeo: The Edgeo application is another touch- and gesture-based Microsoft Windows application geared toward high school students learning geography. It is an application where teachers can present artifacts of geographic significance – such as the Three Gorges Dam – and present slides that provide various details about that



Vector A with magnitude F is shown.
Find the component of this vector in the *x direction*

Vector A and Vector B are shown.
On the grid below, draw the arrow that represents the vector sum, A+B.

vector A and vector B are shown.
What is the direction of the cross product, A×B?

○ ⊙ Out of the screen ○ ⊗ In to the screen ○ Cross Product is Zero ● ←
○ ↘ ○ ↙ ○ → ○ ↓
○ ↑ ○ ↗ ○ ↖

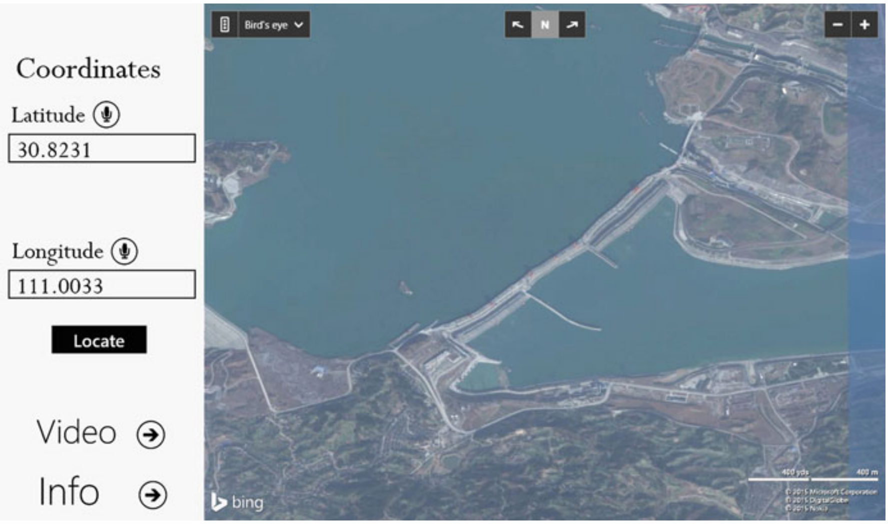
Fig. 2 Example problem in the vector training module

artifact, such as its dimensions, its capacity, its economic and social impact, and so on. Finally, instructors can then pose questions for discussion as well as quizzes for students to answer. Finally, the system provides analytics on how the students interacted with the system and how they performed (Fig. 3).

4 Future Directions

This section considers where mobile technologies will go and where they will take learners.

Mobile devices used by learners still suffer from several limitations – of high cost (the newest iPhone 7s costs upward of several hundred dollars), unreliable Internet connections and connections with low bandwidth, and limitations in screen size, storage, and raw computing power. In addition, market penetration of capable devices is slow. While the newer devices are much improved, not everyone has the latest iPhone, iPad, or Android tablet. In particular, the market with the highest need for mobile learning are students from underperforming schools, nontraditional students, and students in areas with poor information technology infrastructure.



Coordinates

Latitude 30.8231

Longitude 111.0033

Fig. 3 Interacting with Edgeo, a touch- and gesture-based geography instruction application

However, these learners are the same who might not have the economic wherewithal to purchase the latest devices.

However, as the cost of these powerful devices is diminishes, it is likely that sufficient market penetration will be achieved in 5–10 years. Thus, it is our belief that emerging research and commercial products should assume the wide availability to learners of powerful, well-connected devices. Given this, we now attempt to describe the future of mobile teaching and learning.

On demand learning: Technology will enable mobile learning to achieve its promise of on-demand, anytime-and-anywhere learning. Learners will be able to seamlessly start a lesson in school, continue the lesson on the bus, and complete the learning at home. Students will be able to initiate learning at any time and place as well. Finally, location and context capabilities of mobile device render learning ubiquitous and seamless with the environment of the learner. Imagine driving by a state or federal park and exploring rich, interactive information about its flora and fauna that is delivered on your smartphone!

Personalization: Since the mobile device will become the locus of all interaction between the user and the outside world, the device will have a rich awareness of context and a *centralized* and hence holistic and deep knowledge of the learner. Thus, mobile learning will adapt to the learning style of the learner. If the learner is an assimilator, the device will teach in an information-centric manner. If the learner likes to learn by doing, the device will suggest activities.

Richer activity-based learning: Lastly, sensing capabilities of the device will be utilized in mobile learning. For example, learning modules will offer information to teach about micro-weather patterns through experiences that allow the learner to measure wind velocity, identify the existence of eddies, and correlate wind patterns with the humidity and quality of the air around him or her.

A bright future lies ahead for mobile learning!

5 Cross-References

- ▶ Adoption of Mobile Technology in Higher Education: An Introduction
- ▶ Augmented Reality in Education
- ▶ SmartLab Technologies

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