Educational Stages and Interactive Learning:

From Kindergarten to Workplace Training

Jiyou Jia
Peking University, China

Information Science
REFERENCE

Managing Director:	Lindsay Johnston
Senior Editorial Director:	Heather Probst
Book Production Manager:	Sean Woznicki
Development Manager:	Joel Gamon
Development Editor:	Hannah Abelbeck
Acquisitions Editor:	Erika Gallagher
Typesetters:	Lisandro Gonzalez, Russell Spangler
Cover Design:	Nick Newcomer, Lisandro Gonzalez

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Educational stages and interactive learning: from kindergarten to workplace training / Jiyou Jia, editor.
p. cm.
Includes bibliographical references and index.
Summary: "This book provides a record of current research and practical applications in interactive learning, reviewing all aspects of interactive learning and investigating the history, status, and future trends of interactive learning"--Provided by publisher.
ISBN 978-1-4666-0137-6 (hardcover) -- ISBN 978-1-4666-0138-3 (ebook) -- ISBN 978-1-4666-0139-0 (print & perpetual access) 1. Computer-assisted instruction. 2. Virtual reality in education. 3. Student-centered learning. 4. Human-computer interaction. I. Jia, Jiyou, 1969-
LB1028.5.E336 2012
371.33'4--dc23

2011042031

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Chapter 6
Looking In, Looking Out:
A Discussion of the Educational Affordances of Current Mobile Augmented Reality Technologies

Daniel Novak
The University of Washington – Seattle, USA

Minjuan Wang
San Diego State University, USA

Victor Callaghan
Essex University, UK

ABSTRACT

This chapter explores the format of Augmented Reality (AR) and its use in mobile learning. It first addresses precedents and theories of mLearning that inform the discussion of AR and Virtual Reality (VR), explores the "virtuality continuum" and the concept of mixed reality, and discusses some of the technologies in the mobile-AR ecosystem. It then describes the potential uses of AR in mobile education. At the end, the authors present potential applications of mobile-AR to curation activities and provide ideas for future areas of exploration in AR-based mLearning.

MOBILE LEARNING (MLEARNING) AND AUGMENTED REALITY

Mobile devices allow on-the-go people to access a world of digital information via the Internet from any location. Mobile learners, who are marked by a high degree of physical mobility, frequently use these devices to find just-in-time information about their environment. This constant connection to computer-mediated information about products, stores, buildings, or the natural world allows physically mobile learners to locate information and answer questions about their surroundings in novel and, sometimes, surprising ways. In recent years, the intersections of virtual and physical 'realities' have lead to a provocative new technology

DOI: 10.4018/978-1-4666-0137-6.ch006

called "Augmented Reality," or AR, which might have profound implications for mobile education.

Even more, these systems provide an environment that supports opportunities for higher quality human interaction across the digital and physical worlds. Cawood and Fiala (2007), two AR designers, made a statement in 2007 about "the ambitious goal of AR," as creating the sensation of virtual objects being present in the real world. Pribneau and Iordache (2010) describe AR as a technology that "can bridge the gap between the theoretical knowledge acquired through analytical activities (such as reading textbooks and listening to lectures) and the practical experience learned from constructive activities" (p. 247). And, indeed, empirical experiments in static AR by Chen and Wang (2008) indicate that the realization of this goal can improve student performance in open-ended creative tasks. In their primary experiment, Chen and Wang (2008) asked urban design students to develop an urban space using physical wooden blocks to represent buildings and roads. Students were also able to share the workspace through an augmented reality environment, where they used the system to visualize the actual design structures and to create a shared design workplace for multiple learners. In this case, AR helped to simplify and to facilitate the overall design process.

Before we examine mobile-AR learning technologies, it is important to note that mLearning and AR are only technological contrivances; they have specific constraints and affordance. Fisher and Baird (2007) see the mobile environment as merely another platform for interaction, collaboration, and knowledge transfer to occur. From their perspective, mobile technology provides opportunities for the social exchange of information and instruction. In addition, mobile technology enables students to "reconcile their authentic use of technology in a learning context," (p.8) which in turn can motivate them to actively engage in the learning process. From this perspective, the same principles of human learning should apply in all realities and modalities, mobile, virtual, or augmented.

Fisher and Baird also provide a number of useful qualities and values that mobile-AR designers should keep in mind. These include designing for interactivity, learner centrality, authenticity, collaboration, and on-demand service. In foregrounding these design guidelines and teaching characteristics, instructional designers working on mobile platforms can create novel and innovative learning experiences for students on the move. As noted by Callaghan, Shen, Gardner, Shen, and Wang (2010) and Davies, Callaghan, and Gardner (2008), a significant feature of augmented reality is its ability to help visualize abstract concepts and to bring a sense of community to otherwise isolated learners. However, the real promise of AR-supported mLearning comes from its ability to integrate mLearning teaching methods into an immersive experience that creates authentic learning situations. As Liu, Tan, and Chu (2010) note, Augmented Reality (AR) has the potential to enrich the learning outcomes and educational experience if integrated effectively into a mobile environment.

Improved mobile technology now puts Cawood and Fiala's "ambitious goal" within reach from a hardware perspective. SmartPhones and other devices now have the necessary battery power, processing power, Internet connectivity, multimedia capabilities, and location-based services to make Augmented Reality practical for use in education. However, recent studies of large-scale mobile learning programs (e.g., Shen, Wang, Gao, Novak, & Tang, 2009; Wang, Novak, & Shen, 2008; Wang, Shen, Novak, & Pan, 2009) found that mobile devices are limited by two major factors: small input interfaces and small displays. As a result, students tended not to tune into the live course on their cell phones. Instead, they downloaded the recordings and watched them on-the-go. These problems are compounded in current SmartPhones with touch-screen keypads, where the display space is also used for input.

This chapter will explore three hardware solutions for the problem of small display areas on mobile devices. First, we see the practical uses of QR Codes and cellular cameras as a means of bridging the worlds of physical and virtual artifacts and reducing the need for user input. Second, we examine Head-Mounted Display (HMD) units and mobile displays as a means of providing users with the ability to look into the virtual world while functioning in the physical world, and the role of Smart Phones in reducing the need for expensive HMD AR technologies. Finally, we compare HMD technologies with personal projectors, which allow the user to project virtual or digital information onto the real world. The affordances of HMDs and projectors provide an interesting cognitive contrast, with one allowing the user to "look in" to an augmented world, and the other allowing the user to "look out" onto a data-enriched environment.

AUGMENTED REALITY (AR) AND VIRTUAL REALITY (VR): CRUCIAL DISTINCTIONS

Before discussing the relevant AR technologies, we must point out the differences between AR and the more familiar Virtual Reality (VR) technologies. In AR systems, the user's perception of the world is altered through the overlaid experiences of virtual and physical phenomena. This differs from virtual reality systems, where the user perceives only virtual or digital stimuli. This difference is most distinct in the treatment of spatial and location-based services, where researchers (e.g., Biocca, Owen, Tang, & Bohill, 2007; Cawood & Fiala, 2007) note that the display of computer-generated information to guide the user to specific locations is one of the most promising applications of AR. These locations can include buildings, tools, packages, and other assets tracked by online database systems. Thus, AR can be understood as a technology that creates new experiences and opportunities from the synthesis of physical and virtual information. Mobile platforms are ideal hosts for AR applications, as mobile technologies (particularly Smart Phones) possess the necessary processing power, battery life, Internet connectivity, and multimedia capabilities necessary to render AR objects.

Pribneau and Iordache (2010) and Chen and Wang (2008) also developed interesting 'seated' (non-mobile) AR technologies that allow learners in laboratories and design studios to use AR overlays displayed on monitors to better understand their work and better collaborate. However, these displays make use of high-resolution screens and desktop processing power, and mobile device-based AR tools may not provide this degree of resolution at an affordable price for some time. Also, as instructional designers and teachers acquire these technologies, they should be aware of several design constraints. Kiyokawa (2007) describes a number of eye-brain issues associated with the visual displays of HMDs, including poor depth perception, occlusion, and depth of field concerns. These visual limitations may affect learners' vision or cognition, and require further testing as the technologies evolve.

In contrast, the virtual environments created through VR technologies immerse participants in detailed digital environments, which are created entirely by advanced computer systems. For example, the fields of military, transportation, and medical training have incorporated VR training systems since the late 1990s (Christou, 2010), and have discovered many fascinating educational affordances provided by the technology, including improved user motivation and satisfaction. A number of universities have built Cave Automatic Virtual Environments (CAVEs) to create immersive virtual experiences and simulations (first described in Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). However, CAVEs are room-sized, high resolution virtual reality environments that require substantial technological expertise and expenditures. Mobile virtual reality environments will require smaller form factors and low power consumption. However, many existing mobile programs (such as Dragon NaturallySpeaking and Google's voice search) have circumvented limitations in mobile CPU power by offloading processing tasks to servers. In the case of Dragon NaturallySpeaking (available on the iOS and Android platforms), the SmartPhone's microphone records the user's voice and uploads the information to Dragon's processing server, and downloads the transcribed text. This allows the SmartPhone to make use of high-capacity servers by capitalizing on the presence of high-speed mobile networks.

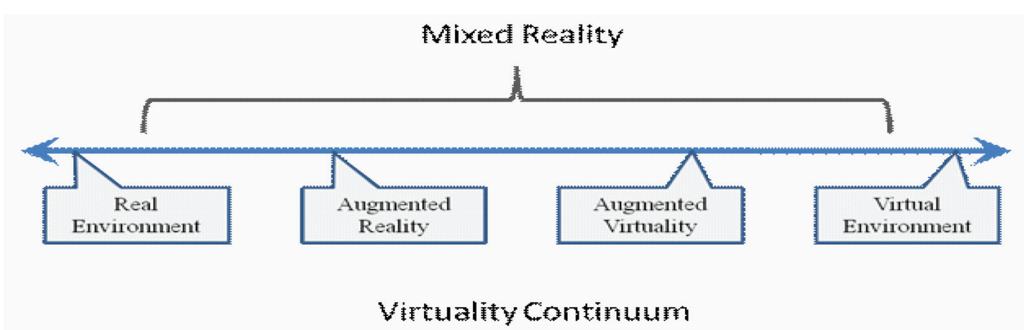
MIXED REALITY: A SPECTRAL APPROACH TO AR AND VR

Though the distinctions between the virtual overlay of information on physical environments (AR) and the creation of wholly virtual environments (VR) seem fairly distinct, a number of authors (including Davies, et al., 2008; Hughes, Stapleton, & O'Connor, 2007; Klopfer, 2008; Milgram & Kisinho, 1994) have muddied the waters with the idea of 'Mixed Reality' (MR). Klopfer, an educational game designer at MIT, expands on Milgram and Kisinho's idea that augmented and virtual reality represent part of a continuum, with various levels of virtuality mixed together with information from the real world.

The MR model (reproduced below, based on Klopfer, 2008, p.92) complicates our earlier definitions of AR and VR, but in exchange offers educators the opportunity to think about the integration of physical and virtual environments in finer degrees. For example, an educational program that uses location-based GPS services to inform students of nearby points of interest (i.e. Google Maps, as available on Android and iOS) might fall on the AR side of the spectrum. However, as Klopfer (2008) notes, the existence of Augmented Reality on the Virtuality Continuum immediately posits the existence of the idea of Augmented Virtuality.

Augmented Virtuality, in contrast with Augmented Reality, uses physical-world information to inform activities in the virtual world. This might also include integrating elements from reality (i.e. people, objects, buildings) into a virtual space. While these technologies are not easy to picture, several examples already exist. More widely known examples include Facebook and Four Square (available on most platforms in the United States) which have integrated location-based services into their software to allow users to update their profiles with information about their present activities and locations in the physical world. The virtual communities formed online (through Facebook's mobile app, for example) are augmented by the influx of data from users in the physical world (see Figure 1).

Figure 1. Virtuality continuum (adapted from Klopfer, 2008, p.92)



As more mobile learners maintain simultaneous virtual and physical presences (e.g. the use of mobile social networking tools with location-based services), mLearning designers may have the opportunity to create learning experiences that capitalize on both modalities. For example, future developments in Massively Multi-User Games (MMUGs) like SecondLife and World of Warcraft (virtual environments) may prove scalable to mobile devices by offloading more complicated processing routines to powerful servers via high-speed connections. Callaghan et al. (2010) described a pair of projects that emerged along these lines as a result of collaboration between learning organizations in the UK, China, and the United States. They describe the development of a "mixed reality teaching & learning environment" (MiRTLE) that allows students and teachers to communicate using avatars in a MMUG.

In the MiRTLE model, instructors simultaneously teach students in a physical classroom, a synchronous online classroom, through a mobile-device based audio/video feed, and via a specially designed virtual classroom environment where students and teachers take the form of avatars. Students in the virtual environments (i.e. the eLearning, mLearning, and MMUG-based students) can see and hear the instructor through audio/video feeds from the physical classroom, and can see the instructor's PowerPoint presentation and digital blackboard. Equally, the instructor can see student avatars displayed on a computer monitor at the back of the room, and students can ask questions through a spatially-realistic voice bridge (a telephone or Internet-based audio transmission protocol) built into the system. Both environments are synchronized so changes in one environment are mirrored in the other (Davies, et al., 2008). Systems such as MiRTLE bring together several developing teaching media into a unified mixed reality learning environment, illustrating the potential utility of these technologies to instructional designers. Callaghan et al. (2010) outlined an interesting, if somewhat speculative, vision for how mixed reality might be augmented with artificial intelligence to enhance the teaching capabilities of such systems.

REDUCING USER-INPUT: QR CODES AND INFORMATION CACHING

One of the core technologies that educators and designers can employ in the development of AR learning systems are Quick Response (QR) codes. QR codes are a type of multi-level 'symbology barcode' that can contain more data than the standard product barcodes. Unlike the single layer of data that a product barcode contains, one QR code can include contact information, GPS coordinates, and the URLs of web-based objects. The technology integrates smoothly with mobile devices, as most SmartPhones can read these codes using built-in cameras and commercially available applications (Osawa, Noda, Tsukagoshi, Noma, Ando, Shibuya, & Kondo, 2007). The application of this technology to mobile learning has the potential to significantly reduce user-input for mobile devices. In the example below (Figure 2), found in Tokyo, a company paid to place a QR code onto a video

Figure 2. A QR code used on a promotional video billboard in Tokyo

billboard to allow mobile customers to navigate to their site without manually typing a URL.

The extra information density afforded by QR codes presents an opportunity for mLearning designers to tag and coordinate physical objects with virtual information and virtual learning objects. Osawa et al. (2007) describe the application of QR codes for that purpose in a mobile-AR learning experience that they developed for an agricultural class in Japan. The students in this class were frequently in the field examining plants and farming tools, with limited access to computers and support systems. The course's developers placed QR codes around the farm, and provided students with a mobile device that they could use to decrypt the codes. When students took photos of the QR tag with the device, a server would supply brief messages about the plants and locations that corresponded to the tag. The authors found that students enjoyed the context-sensitive information and made periodic use of the additional information supplied by the device. Though they find that QR codes are a suitable technology for integrating technological support into outdoor education, the authors also note that some students had difficulty locating the QR codes in the field.

Liu, Tan, and Chu (2010) describe a similar use of QR codes in a mobile-AR English language learning system that puts QR code technology to effective use in authentic learning situations. In this experiment, learners used an augmented reality application on their mobile device to find locations on their campus where English language interactions might take place. When they arrive at these specific locations on the map (i.e. the campus library), they could use the camera function on their mobile device to decrypt a QR code posted at the location. When the user takes a photo of the QR code through the specialized application, the mobile device uploads the photo of the QR code to a server for decryption. The server then routes the application to an Internet location that contains a short, interactive English lesson with a virtual conversation agent (a librarian) that takes place in the student's physical location. Students also have the option of completing spoken English dialogs at these locations that are recorded by the AR app and transmitted to the instructor for evaluation. Student responses to a post-experiment surveys indicated that the students enjoyed the overall AR experience, especially as a post-class extension exercise. In this experiment, the QR code allowed the student to access lessons on the go with minimal input, thus removing text entry as a barrier for mobile learners.

Mobile devices that can read QR codes and are equipped with digital projectors or mobile video displays (which we discuss in the next two sections) can also allow students to read and project encoded information onto physical artifacts. In the example below, the handheld projector is displaying information gathered from the QR code onto the image. This keeps the wall relatively free of visual clutter, but still provides information to learners who are motivated to find out more. This practice of hiding information until it is needed ("information caching") may help to reduce demands on learner's focus and improve attention management (Biocca et al., 2007). The next section of the chapter explores some of the display modalities that make the display of QR coded information possible and practical (see Figure 3).

LOOKING IN: HEAD-MOUNTED DISPLAYS (HMDS) AND MOBILE DEVICE DISPLAYS

Head-Mounted Displays are complex technological devices that allow a learner to see computer-generated images overlaid onto the real world via a digitally enhanced viewfinder. Since the 1960s, engineers have been working on these technologies in areas from medicine to the military to improve interaction between the user, their information stream, and their physical environment (Christou, 2010; Haller, Billinghurst, & Thomas, 2007).

Several studies have described the introduction of high-resolution AR HMD technologies into medical processes involving laparoscopic surgery. As Kiyokawa (2007) notes, augmented 3D visualization HMDs reduce the need for surgeons to look back and forth between the patient's body and images of the small camera inside the body during laparoscopic and endoscopic procedures. The ability to reference patient vitals, videos, and live video feeds from the digital environment while operating on a person in the physical world has the potential to reduce cognitive load and to provide surgeons with the ability to make better decisions without looking away from their work.

The utility of these HMD devices is equally applicable in education, where geo-spatial recognition programs and tags can help students identify information, locations, pathways, objects, and resources as they look around their physical environment. Klopfer (2008) asserts that "heavily augmented" technologies (using HMD devices or displayed via goggles or helmets) provide a more immersive experience that allows users to make rapid decisions based on the stream of digital information displayed on the HMD. He notes that this is most valuable when learners need to respond quickly and remain aware of their environments (to avoid colliding with walls or falling into ditches) during activities.

Figures 3. A mock-up of a mobile-AR projection

AR developers have learned a number of valuable design principles from the use of seated and head mounted AR displays, and mobile phones now provide the necessary processing power, wireless bandwidth, and display size to allow mLearning designers to proceed without these additional, expensive technological devices. Designers for mobile learning can also consider more "lightly augmented" approaches to AR-based mLearning. Smart Phones and other portable devices that are equipped with cameras can now display virtual overlays of digital information. Smart Phones have become a new form of portable AR display that can bring AR-based mLearning to a much broader audience. However, Klopfer (2008) warns that displays that are in the learner's field of view might be accessed more frequently than a handheld or mobile display. But as he notes, this concern can be overcome at the design phase, as it is possible to design a handheld game that requires the learner to look at the screen quite frequently, or a head-mounted display that provides only event-based information to a learner.

It is potentially dangerous to distract a learner as they navigate the physical world. Kiyokawa identifies this potential constraint, and notes that AR applications may need to display minimal information in the visual overlay. Still, this hazard is present in any situation where the learner's attention is distracted from their environment. Safety concerns aside, the full consequences of the cognitive act of looking through a head-mounted display are not as well documented in the area of augmented reality as in the field of virtual reality. Therefore, researchers should focus on exactly how activities are best supported through HMDs, and how the effect of looking through glasses or a mobile device display at an augmented world changes learners' perceptions. However, as researchers such as Clarke (2010) observed, wearing AR HMD's, no matter how unobtrusive they become, is not without drawbacks and so there remains a strong incentive to find alternative ways of presenting equivalent information via alternative means.

In the example shown in Figure 4 (rendered in the Acrossair Browser, on the iOS platform), GPS coordinates, contact information, and other publicly available forms of information are drawn from existing Internet databases (like Google, Wikipedia, Yelp, and Bing in the United States) and overlaid onto the Smart Phone's camera display. This could reduce the likelihood of injury by reducing the demand on the participant's field of vision, and improve the authenticity of the experience by eliminating a cumbersome piece of equipment. In the next section we examine another option for wide field of view mobile augmented reality display: microprojectors.

LOOKING OUT: SMART BOARDS AND PERSONAL PROJECTORS

In recent years, projection-based augmented reality has emerged as a viable commercial tool for classrooms. New SMART board technologies, now in use in US school, universities, and businesses, combine digital projectors with sensors that allow teachers to draw directly onto their PowerPoint slides and in other virtual spaces with specialized pens. These systems also feature integrated interactive software that allow students to submit their answers, polled opinions, or comments directly to the board-space. Equally, it allows teachers to create annotated lectures that they can save and refer to in the future (Pierce, 2009).

The application of AR projection technology to extend the input functions of mobile devices emerged as early as 1999, with several companies producing prototypes for sale in 2003. Tomasi, Rafii, and Torunoglu (2003) designed a small projection-based keyboard system that uses infrared beams and projected light to discern user's

Figure 4. Screenshot of the Acrossair AR application in iOS

interaction with the keyboard on a flat surface. According to the designers, the device senses the interruption of the projected keyboard image, and infers finger positioning from the position of the infrared disruption in the device's field of view. The camera's sensors do not need user calibration or modification, as they are fixed in production. Though this projection-based augmented reality keyboard (Figure 5) did not achieve commercial success, one can imagine that similar technologies may emerge in the future. These projected AR technologies offer significant advantages over other kinds of mobile device interaction, including the potential to enlarge keyboards for those with limited eyesight or dexterity. These devices may be able to serve several cultures through the projection of language-specific keyboards. However, for the time being, projection-based input technology's relative scarcity and high price point may make this option to expensive and complicated for most users.

However, the application of projector technology in augmented reality educational experiences goes beyond SMART boards and projection keyboards. Motorola, Nikon, and a number of other manufacturers are currently refining a technology known as 'microprojectors.' This technology uses tiny LED (Light Emitting Diode) and DLP (Digital Light Processing) arrays built into mobile media devices to project visuals onto nearby surfaces. The availability of built-in projectors can help to mitigate a key problem in current mLearning design. Smart Phone's small screen size is a key limitation for many users, especially when screens must perform as both display space and input space. This directly impacts the utility of mLearning for certain groups. For example, older learners with reduced eyesight and dexterity may have difficulty interacting with a Smart Phone's small keyboard and screen.

Figure 5. An augmented reality project keyboard

Preliminary studies on learner interaction with projected maps found that personal projector technology "provides clear evidence of several distinct advantages, such as improved task completion time, reduced number of errors and higher user satisfaction" (Hang, Rukzio, & Greaves, 2008, p. 215). Hang and colleagues attribute the positive gains in user performance over SmartPhone screens to the increase in available onscreen data enabled by the higher resolution projectors. They note that map labels and icons can are clearer, larger, and easier to read than similar icons on mobile phone interfaces.

In terms of their utility as an AR tool, Bimber (2007) also asserts that some of the limitations of mobile devices (including low resolution, small field of view, focus constraints, and ergonomic issues) might be ameliorated through the application of personal projector technology. This is especially true now that personal projector technology can "achieve consistent occlusion...and illumination... effects between real artifacts and optically overlaid graphics" (p.65-66). As Bimber examines in his chapter, personal projectors can now create the experience of "seeing" a virtual object projected onto a non-flat surface. In the future, users may be able to project maps onto spheres (for a more accurate understanding of distance), or merge digital projections with photographs that are present in the real world.

Mobile-AR projection technologies including SMART boards, virtual projection keyboards, and handheld projectors present significant potential for improving user interaction and providing on-demand information. Though the technologies are in nascent forms, they demonstrate that projection-based augmented reality has a place in the sphere of mobile learning technologies. However, mLearning designers should be aware of the high costs associated with these technologies during this stage of their development.

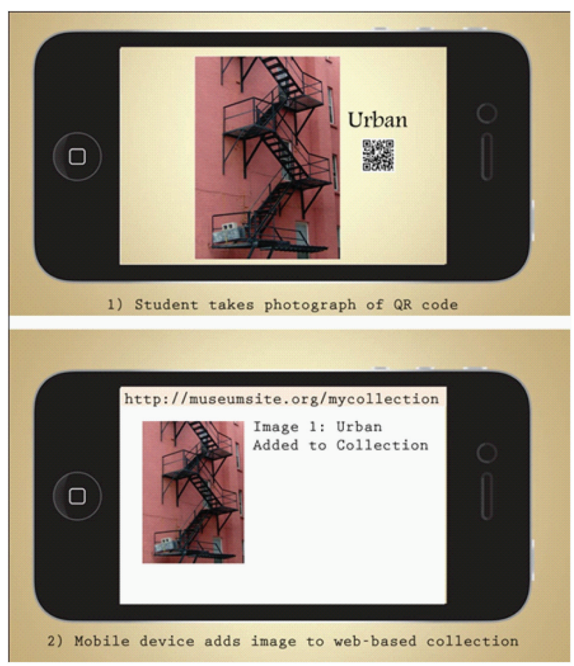
BRINGING THINGS TOGETHER: CURATION AND MOBILE-AR

This chapter will conclude with a rationale and design for a mobile augmented reality educational experience that implements the major technological themes discussed thus far. In this case, we describe an AR museum experience that integrates QR codes and the mobile device display of virtual objects to give learners the opportunity to engage in the creative act of curation.

Art and science museums are frequently at the forefront of technological integration and education, and are prime spaces for informal learning experiences. At present, most major museums provide the opportunity to rent handheld audio and multimedia tours of their collection (Tallon & Walker, 2008), and several now allow visitors to call specific telephone numbers for audio information about the piece, and download podcasts or applications to their Smart Phones (including the San Francisco Museum of Modern Art and the Seattle Art Museum). The New York Metropolitan Museum of Art has also allowed Google to create a virtual tour of the museum that learners can access from their mobile phones. These technologies can enrich the experience of visitors to these museums, and provide multimedia information that can make the museum's knowledge more accessible to visitors. Further, they can help to orient visitors to the physical and virtual aspects of the space.

This section of the chapter presents several possible ways to integrate mobile augmented reality technologies into museum education experiences. In the first and most obvious opportunity for integration of mobile-AR with existing museum systems (illustrated in Figure 6), a student could use their mobile device to take a photo of a QR code that corresponds with a piece of art or an exhibit that interests them. A web-based application could then decode the QR symbol and add this image to a student's personal collection, perhaps associated with an account or built into a Smart Phone application. A system that uses this technique could extend the museum experience beyond the walls of the institution, and create the opportunity for students to carry their own pared-down version of the collection with them. These virtual assets, collected at physical locations, could then be reused and remixed by students in other projects.

Figure 6. Personal galleries created through mobile-AR



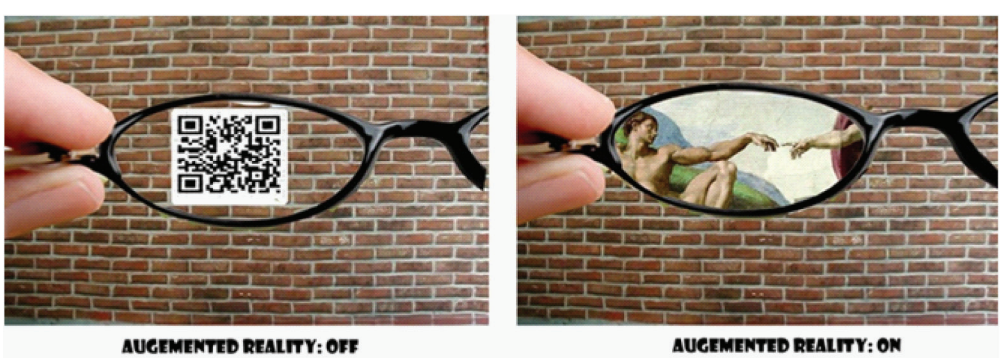
Our next example mock-up (Figure 7) illustrates one use of an augmented reality headset as a display medium for an image from the Sistine Chapel. The placement of this image in a learner's context is important, as the vast majority of art students from the United States cannot afford an extended field trip to view the fresco in person. Art historians also have difficulty conveying the wonder of the space, and mostly use two-dimensional representations (slides, plans, images, video) in teaching about the paintings. Augmented reality presents museum curators with the opportunity to display artistic and scientific works on more realistic surfaces, and potentially at life size. Beyond this use of the extant technologies, the use of AR shows promise as a medium for the activity of artifact curation.

Curators and other designers use museum spaces to create critical relationships amongst objects, to promote discussions of the deeper themes of those objects by assembling them into one space, and to create a social space for that discussion. In this design, we will advocate the use of curation as a technologically-supported constructivist activity that empowers students to collect virtual objects, analyze them, and generate a critical argument about the relationships of those objects (Harvey, 2010). As we proceed, it should be noted that curation, as a mode of instructional design, requires further research and a more formal body of literature in the field of education. There are volumes of writings on the subject of curation by art critics, museum curators, and archivists, but relatively few resources regarding the use of curation as an educational activity.

However, Rosenbaum (2011) has taken a step towards a more formal educational definition of curation as a twenty-first century activity in his book titled *Curation Nation*. As Rosenbaum describes, people are surrounded by vast amounts of information in digital and physical forms that they must evaluate, search for, and sort. Unlike selection algorithms used by sites like Amazon.com, humans add value to the selection and assembly of materials through the application of qualitative judgments. The kinds of 'amateur curation' behaviors described by Rosenbaum have become popular through websites like Facebook (where participants select people, places, and things that interest them), and are notable for the enthusiasm and intrinsic motivation that they inspire. Researcher must now work to understand how those qualitative judgments, cultivated through the activity of curation, can help students better understand their own interests. Equally, researchers should examine the potential of curation as tool for generating motivation.

Figure 8 provides some preliminary guidance for the use of curation as an educational process. It begins with instructing students in the development of a theme that will guide their selection of artifacts and resources. This process is akin

Figures 7. An augmented overlay of an image onto an HMD lens



to developing a thesis in an essay. After students have developed a theme for their curated experience, they should use that theme to guide artifact selection. In this way, artifacts serve as evidence that supports the thesis. Then, students should work to understand deeper relationships between these artifacts, and come up with arguments and thematic organizations that use these artifacts in meaningful ways. This part of the process may require added instructor intervention and discussion. Finally, the students should display their work, and be encouraged to discuss the selections with their peers. Though this process will need extensive testing, it provides adequate room for students to explore while remaining working through a number of cognitive processes.

A learner-centered way to use mobile-AR devices to promote curation activities is to provide students with web-based QR encoders, printers, and mobile decoding applications. When students identify web-based objects that they would like to include in their curated experience, they could encode this information into a QR code, print it, and hang it on a wall. This would allow students to create unique juxtapositions of artifacts that other students could easily see using a mobile AR decoder. In the simplified mock-up below, a student has encoded the URLs of images of urban and rural life into QR codes using an available web-based encoder, and posted them on a wall. When another student activates their AR display, the decoder displays the web-based images side by side. Instructors can then work to facilitate a dialog about students' artifact selection and thought processes. The discussion phase of the activity may help to spur creative thinking and deeper explorations of thematic ideas. As instructional designers continue to refine this technique, they should focus on developing a qualitative discussion around the selection of objects (see Figure 9).

Figure 8. Potential model for the design of mobile-AR curation exercises

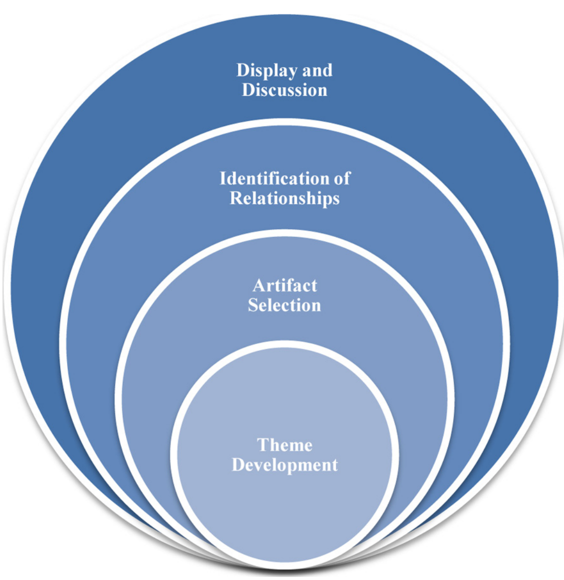


Figure 9. A mock-up of a student curated augmented reality display space

Table 1. Constraints and affordances of mobile-AR technologies

QR Codes	● Reduces required user input by tagging physical locations and artifacts ● Allows for the encoding and decoding of information ● Easy to print and display ● Requires wireless network access
Head-Mounted Displays and Mobile Display Devices	● Allows learners to look in on virtual artifacts related to their physical environments ● Information-environment treasure hunts ● Geo-tagging and geo-caching ● Enhanced museum experiences ● On-demand performance support for job tasks ● Integration with expert-systems for real-time feedback
Personal Projectors and Projection-Based AR	● Allows Learners to project data onto physical environments ● Map-projection ● Allows learner to display self-produced digital artifacts onto physical surfaces ● Ability to interact with projected information ● Project information onto existing images ● Camera-Projector artistic activities ● Currently expensive

CONCLUSION

Augmented Reality technologies such as QR Codes, Head-Mounted Displays, and Personal Projectors give instructional designers a number of new opportunities for creating educational experiences. AR can help provide learners with endless new experiences and information environments, as well as seamlessly integrate learning into the learner's daily activities. In this article, we explored the format of AR and its use in mobile learning. Current research shows that AR can support just-in-time, context-based learning, and can help to build knowledge-rich environments. There are great potentials of using AR in mobile teaching and learning, especially in the area of student-led curation exercises. The new medium of mobile augmented reality learning, supported by an ecosystem of integrated technologies, has the potential to enrich the lives of students, wherever or whenever they may learn.

However, the instructional and cognitive implications of these new technologies and ways of seeing are in need of continued research, development, and testing. Researchers should continue to study the cognitive properties and constraints of these devices, as well as their effects on learner performance in authentic circumstances. Equally, this chapter has revealed the need for a more in-depth investigation of the instructional uses of curation as a mLearning activity.

Table 1 summarizes some of the potential new affordances available to instructional designers and teachers through emerging mobile AR technologies.

REFERENCES

Bimber, O. (2007). Projector-based augmentation. In Haller, M., Billinghurst, M., & Thomas, B. (Eds.), *Emerging Technologies of Augmented Reality* (pp. 64–89). Hershey, PA: IGI Global.

Biocca, F., Owen, C., Tang, A., & Bohil, C. (2007). Attention issues in spatial information systems: Directing mobile users' visual attention using augmented reality. *Journal of Management Information Systems*, *23*(4), 163–184. doi:10.2753/MIS0742-1222230408

Callaghan, V. (2010). Tales from a pod. In *Ambient Intelligence and Smart Environments*. Kuala Lumpur, Malaysia: IOS Press Books.

Callaghan, V., Shen, L., Gardner, S. R., & Wang, M. J. (2010). A mixed reality approach to hybrid learning in mixed culture environments. In Fong, J., Kwan, R., & Wang, F. L. (Eds.), *Handbook of Research on Hybrid Learning Models: Advanced Tools, Technologies, and Application* (pp. 260–283). Hershey, PA: IGI Global. doi:10.4018/978-1-60566-380-7.ch016

Cawood, S., & Fiala, M. (2007). *Augmented reality: A practical guide*. Dallas, TX: The Pragmatic Bookshelf.

Chen, R., & Wang, X. (2008). An empirical study on tangible augmented reality learning space for design skill transfer. *Tsinghua Science and Technology*, *13*(S1), 13–18. doi:10.1016/S1007-0214(08)70120-2

Christou, C. (2010). Virtual reality in education. In Tzanavari, A., & Tsapatsoulis, N. (Eds.), *Affective, Interactive and Cognitive Methods for e-Learning Design: Creating an Optimal Educational Experience* (pp. 228–243). Hershey, PA: IGI Global. doi:10.4018/978-1-60566-940-3.ch012

Churchill, D., & Hedberg, J. (2008). Learning object design considerations for small-screen handheld devices. *Computers & Education*, *50*, 881–893. doi:10.1016/j.compedu.2006.09.004

Clarke, G., & Lear, M. (2010). We all wear dark glasses now. In *Ambient Intelligence and Smart Environments*. Kuala Lumpur, Malaysia: IOS Press Books.

Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The CAVE: audio visual experience automatic virtual environment. *Communications of the ACM*, *35*(6), 64. doi:10.1145/129888.129892

Davies, M., Callaghan, V., & Gardner, M. (2008). *Towards a mixed reality intelligent campus*. Paper presented at the IET International Conference on Intelligent Environments 2008. Seattle, WA.

Dieker, L., Hyneq, M., & Hughes, C. (2008). Implications of mixed reality and simulation technologies on special education and teacher preparation. *Focus on Exceptional Children*, *40*(6), 1–21.

Fisher, M., & Baird, D. E. (2007). Making mLearning work: Utilizing mobile technology for active exploration, collaboration, assessment, and reflection in higher education. *Educational Technology*, *35*(1), 3–30.

Haller, M., Billinghurst, M., & Thomas, B. (Eds.). (2007). *Emerging technologies of augmented reality: Interfaces and design*. Hershey, PA: IGI Global.

Hang, A., Rukzio, E., & Greaves, A. (2008). Projector phone: A study of using mobile phones with integrated projector for interaction with maps. In *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services,* (pp. 527-530). New York: ACM.

Harvey, D. R. (2010). *Digital curation: A how-to-do it manual*. New York: Neal-Schuman Publishers.

Hughes, C. E., Stapleton, C. B., & O'Connor, M. R. (2007). The evolution of a framework for mixed reality experiences. In Haller, M., Billinghurst, M., & Thomas, B. (Eds.), *Emerging Technologies of Augmented Reality* (pp. 198–216). Hershey, PA: IGI Global. doi:10.4018/9781599040660.ch010

Kiyokawa, K. (2007). An introduction to head mounted displays for augmented reality. In Haller, M., Billinghurst, M., & Thomas, B. (Eds.), *Emerging Technologies of Augmented Reality* (pp. 43–63). Hershey, PA: IGI Global. doi:10.4018/9781599040660.ch003

Klopfer, E. (2008). *Augmented learning*. Cambridge, MA: MIT Press.

Lampton, D. R., & US Army Research Institute for the Behavioral and Social Sciences. (2001). *Instructional strategies for training teams in virtual environments*. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Liu, T.-Y., Tan, T.-H., & Chu, Y.-L. (2010). QR code and augmented reality-supported mobile English learning system. *Lecture Notes in Computer Science*, *5960*, 37–52. doi:10.1007/978-3-642-12349-8_3

Milgram, P., & Kisinho, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, *77*(12), 1321–1329.

Pierce, A. (2009). Turning whiteboards in smartboards and standard notebook computers in tablet PC's. *Tech Directions*, *69*(1), 10–11.

Pribeanu, C., & Iordache, D. D. (2010). From usability to user experience: Evaluating the educational and motivational value of an augmented reality scenario. In Tzanavari, A., & Tsapatsoulis, N. (Eds.), *Affective, Interactive and Cognitive Methods for E-Learning Design: Creating an Optimal Educational Experience* (pp. 244–258). Hershey, PA: IGI Global. doi:10.4018/978-1-60566-940-3.ch013

Rosenbaum, S. (2011). *Curation nation: How to win in a world where consumers are creators*. New York: McGraw-Hill.

Shen, R., Wang, M., Gao, W., Novak, D., & Tang, L. (2009). Mobile learning in a large blended computer science classroom: System function, pedagogies, and their impact on learning. *IEEE Transactions on Education*, *52*(4), 538–546. doi:10.1109/TE.2008.930794

Tallon, L., & Walker, K. (2008). *Digital technologies and the museum experience: Handheld guides and other media*. Lanham, MD: AltaMira Press.

Tomasi, C., Rafii, A., & Torunoglu, I. (2003). Full-size projection keyboard for handheld devices. *Communications of the ACM*, *46*(7), 70–75. doi:10.1145/792704.792732

Wang, M., Novak, D., & Shen, R. (2008). Assessing the effectiveness of mobile learning in large hyrbid/blended classrooms. *Lecture Notes in Computer Science*, *5169*, 304–315. doi:10.1007/978-3-540-85170-7_27

Wang, M., Shen, R., Novak, D., & Pan, X. (2009). The impact of mobile learning on students' learning behaviors and performance: Report from a large blended classroom. *British Journal of Educational Technology*, *40*(4), 673–695. doi:10.1111/j.1467-8535.2008.00846.x

KEY TERMS AND DEFINITIONS

Augmented Reality: The overlay of digital information onto the physical world.

Curation: The deliberate selection and display of objects (physical or virtual) in a way that illustrates a complex relationship. Curation has potential applications as a mobile augmented reality teaching technique.

Head-Mounted Displays (HMDs): Helmets or other head-mounted devices that allow viewers to see digital information overlaid onto physical space.

Mixed Reality: A combination of digital and physical information that provides the learner with sustentative information about the physical and digital properties of their environment. This includes augmented reality, virtual reality, and augmented virtuality.

mLearning: Mobile Learning. Past studies of mobile learning focused on mobile and cellular technologies, but has recently begun to focus on learner mobility and the effects of ubiquitous cellular Internet access.

Quick Response (QR) Code: A type of barcode technology that allows users to embed digital information into a decodable glyph that can be read by cell phones. This technology has the potential to reduce user input into mobile devices with Internet connectivity.

Virtual Reality: A digital environment wherein all sensory information is computer generated.

Virtuality Continuum: The continuum between 'real' environments and virtual environments that includes mixed reality environments such as augmented reality and augmented virtuality.