Editor's Notes

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Synthesizing Perspectives on Augmented Reality and Mobile Learning

This special issue focuses on connections between research, design, and scalability of augmented reality and mobile learning environments. This issue explores how perspectives on learning with and from everyday settings can be integrated with mobile devices or mixed forms of media. Our rationale for the issue is to present theoretical and design frameworks for mobile computing and augmented reality in education to support on-going efforts to create learner-centered environments. We highlight efforts by scholars whose work connects learners both to their everyday experiences and to disciplinary practices. A central theme that unites these papers is the emphasis on learning with and from everyday experiences, in formal or informal spaces. We categorize the work presented in this issue, along with other current research and design efforts in AR and mobile learning, into three primary themes:

1) Developing and Scaling Mobile Games for Learning
2) Studying how Museum Exhibits and Everyday Experiences foster Learning Interactions
3) Designing for Place-based Learning in the Outdoors

Developing and Scaling Mobile Games for Learning

Early work in mobile games involved the development of augmented reality games and simulations for handheld devices. Squire and Klopfer (2007) developed the AR game *Environmental Detectives* for environmental science students. As users moved about a university campus, they determined the location and severity of a chemical spill by taking virtual sample readings of the chemical composition of groundwater, calling upon videos of experts to explain the data and get local geographical information. By playing the game in a real location, users connected scientific content to a specific setting (Squire & Klopfer). The *Outbreak @ the Institute* (Rosenbaum, Klopfer, & Perry, 2007) and *Outbreak at Radford University* simulated an avian flu outbreak on a university campus. As participants moved about campus buildings, information, different characters and health status updates were displayed on their handheld devices, based on whether they had been exposed to the virus. The Handheld Augmented Reality Project developed *Alien Contact!* for middle school students to learn math and language arts through AR (Dunleavy et al., 2009; O'Shea, Mitchell, Johnston, & Dede, 2009). *Alien Contact!* used students' GPS location to trigger the display of virtual characters and clues via video, audio and text to determine why aliens have landed on Earth. Like other AR environments, students were given roles (e.g., chemist, computer hacker, FBI agent) that requires students to collaborate to understand the complete picture of the problem.

For those considering how to design AR games, our issue offers design support from three sets of authors. First, Matt Dunleavy (this issue) offers three key design principles from his own work and others' empirical studies to support AR gaming: (1) enable and then challenge the learner, (2) drive by the gamified

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story, and (3) see the unseen through AR. Next, John Martin, Seann Dikkers, Kurt Squire, and David Gagnon (this issue) present a participatory model of scaling AR and mobile technology innovations by involving key stakeholders groups (students, teachers, researchers, administrators). They demonstrate participatory scaling through various cases of ARIS (arisgames.org), an open-source tool to create and disseminate mobile AR learning experiences. Chris Holden (this issue) addresses issues of adopting new innovations such as AR through presenting multiple game-based learning examples that were initiated or inspired through a grassroots design and implementation effort called Local Games Lab ABQ at the University of New Mexico.

Studying how Museum Exhibits and Everyday Experiences foster Learning Interactions

Informal learning institutions have been early adopters of mobile technologies, and research on mobile computers in museums is a productive line of research (e.g., Frohberg, Göth, & Schwabe, 2009; Phipps, Rowe, & Cone, 2008; Sung, Hou, Liu, & Chang, 2010; Wishart, & Triggs, 2010). Recently, museums and related informal institutions have adopted different kinds of location-specific AR tools as a means to educate visitors and to enhance their visitors' experiences. Many informal education sites—including gardens, aquaria and zoos, science centers, and museums—are using image-based tags, RFID tags, and barcodes to supplement on-site signage with targeted information. In addition, over the past decade mobile computers have been infiltrating everyday life (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sanchez, & Vavoula, 2009; Pachler, Bachmair, & Cook, 2010) and designs for education that leverage these everyday experiences have emerged.

Early work in this area (Hsi & Fait, 2005) examined the use of RFID tags within a science center to personalize the visitors' experiences. Yoon, Elinich, Wang, Steinmeier, and Tucker (2012) worked with a large science center in the Northeastern United States to understand how visualization and scaffolds could support museum visitors' STEM learning in regard to electricity knowledge outcomes. By working with 119 students in four experimental conditions on a AR program integrated with an exhibit on electrical circuits, Yoon and colleagues concluded that digital augmentations, without scaffolds, were successful in supporting young people's conceptual knowledge gain around electricity topics, but that scaffolds plus augmentations were needed to enhance student engagement in higher level thinking.

A challenge for those in our field is how to assess learning in such informal institutions or in everyday life, given the complexity of these places. Our issue offers three research examples: two examples from scholars of how they assessed learning in complex environments and a third example of how to use mobile computers to bridge community learning to the formal schooling. First, Susan Yoon and Joyce Wang (this issue) present a study that analyzed learners' critical thinking when learning science in an AR museum exhibit on magnets. Next, Michael Tscholl and Robb Lindgren (this issue) studied how to assess learning interactions and conversations when family audiences engaged with digital mixed reality physical sciences content in a science center exhibit. Third, Tobin White and Lee Martin (this issue) designed a study where learners took digital video and photographs in their communities that they believed to be related to mathematics. The learners' everyday experiences in their communities and their informal technological practices were leveraged for successful mathematical learning in the classroom.

Designing for Place-based Learning in the Outdoors

Given the portability of mobile devices, outdoor learning settings have utilized handheld devices to provide users the ability to access information, record field observations, or search databases onsite to identify plant and animal species present in natural settings (Chen Kao, & Sheu, 2003, 2005; Rogers et al., 2004). Most outdoor learning settings rely on docents or volunteer enthusiasts to provide tours of the natural environment. In absence of docents or other experts, mobile devices have augmented information for visitors via text, video, or photographs through a wireless network or a database residing on a tablet device (Liu et al., 2009). Such "nomadic" computing environments (Hsi, 2003; Rieger & Gay, 1997) potentially transform an outdoor space into a learning laboratory. For instance, the Sundial project (Halpern et al., 2011) developed an iPhone app for use in the outdoor spaces of a science museum. Families recorded field observations using photos, videos, and field notes through responding to questions generated by the application. In one activity, users were guided to take photographs of shadows from a large sundial and asked questions about the role of seasons on the shadows. One goal of augmenting is to provoke reflection and discussion by users about their surroundings (Rogers et al., 2004).

Outdoor learning centers have also utilized mobile technologies to store image repositories that can be searched and accessed on demand. For instance, Chen, Kao, and Sheu (2003; 2005) developed a mobile image-retrieval system to support bird watching and butterfly watching, so that visitors observed and identified species outdoors. Likewise, Liu et al., (2009) used Tablet-PC devices in Taiwan to guide students' science learning of aquatic plants using illustrations and photos. These retrieval systems provided natural history and ecological data about the species being observed.

Scholars have also used mobile technologies to enable users to capture and share information for outdoor fieldwork tasks and to coordinate with classroom activities (Huang et al., 2010; Hwang & Tsai, 2011). For instance, Tan et al. (2007) developed a mobile learning infrastructure for the Guandu Nature Park in Taiwan. Learners used the system to receive messages from teachers, record videos from the park for later classroom annotation, and share notes that were compiled into a team report.

Given the challenge for designing for outdoor spaces, we present two articles to support design work in outdoor learning settings. First, Brian Smith (this issue) presents the concept of bodystorming — a manner by which designers leave their office to physically conduct design work in learning spaces. Smith presents two case studies, including one of an outdoor exploration of historic places. We, Heather Zimmerman and Susan Land (this issue), present a design framework to bring together science education's perspectives on place-based education with mobile computers' location awareness features. We illustrate our three design principles and related strategies with a case study of an outdoor learning project at the Arboretum at Penn State.

Conclusion

In sum, this special issue is a basis for informing empirically-based guidelines for design and research of AR and mobile learning environments. When developing learner-centered technologically-enhanced environments, complex issues related to design perspectives, scaling, and research methodology emerge. This issue presents a compilation of strategies and findings to address the emerging complexity in augmented reality and mobile computing environments for learning.

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