Augmented Reality Games: Place-based Digital Learning

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Abstract: Educational augmented reality (AR) games engage users as participants in a motivating experience with technology in the real world. Carrying handheld computers, players move from place to place in real space to interact with virtual information that has been programmed to help them learn about topics of the game designer's choice. In this symposium, four researchers and practitioners with a combined more than two decades of experience with AR games will examine issues to be considered for implementation of augmented reality games for learning and the future directions for the research field. Among others, these issues will include assessing claims of learning through AR games, the value of such games as a tool for place-based education, the value of authoring vs. simply playing AR games, and the claim that using handheld computers for an AR game building experience benefits, rather than distracts participating students.

Introduction

Players of augmented reality (AR) games use handheld computers, often common smartphones, to interact with virtual information that is connected to real-world spaces. For example, players of TimeLab2100, a game built using the MIT Augmented Reality (MITAR) platform, travel the MIT campus armed with GPS enabled smartphones that enable them to interact with virtual guides. These guides help the players to experience the campus as it might be nearly 100 years in the future. As they move across campus with the guides, the GPS in the phones tracks the player's location on the map. The players see icons that represent themselves move across a map shown on the screen of the smartphone.

As they walk through the play-space, players also observe other, stationary icons on the map. When they move close enough to one of these other icons, information that is some combination of text, images, audio or video is triggered on the phone. At each location, the virtual guides, fictional MIT graduate students in the related fields of political science and climatology, engage the players in dialog about the possible consequences global climate change might have on the campus. With this information, the players consider which laws could be passed now to ameliorate either the causes or the symptoms of global climate change years from now with the goal of learning about causes and consequences of climate change, as well as what we can do about it.

Each of the three educationally focused augmented reality game technologies used by the panelists for this symposium, MITAR, developed at the MIT Scheller Teacher Education Program in partnership with the Missouri Botanical Garden; ARIS, developed at the University of Wisconsin-Madison; and ROAR, developed at Radford University, share similar technical features, however each has its own unique affordances, developed to best serve the learning goals of their target audiences and the research agendas of the teams building the software. Of course, the software is a means to an end, and is most interesting in what it allows its users, whether those users are playing games or both building and playing the games, to do. Similarly, the actions that one takes in the games, and the way they are designed are based on slightly different takes on theories of engagement and learning.

In his book, *Augmented Learning*, Klopfer (2008), the moderator for this symposium, details some of the considerations that led to the design of Outdoor Augmented Reality software from MIT, an early and formative example of AR games software and a precursor to MITAR. In this symposium, he will use his experience leading one of the early and ongoing educational AR games programs to probe differences between implementations of educational augmented reality games by the panelists. Issues to be considered include: building tools that afford student authorship of games to foster constructionist learning; what qualities teachers and other practitioners must possess to implement an AR games curriculum successfully; AR games as part of a place-based education model; claims that using handheld computers for AR game authorship and playing enhance learning activities rather than provide distractions; and perhaps most important for any educational technology intervention, how to assess claims of disciplinary learning during the play of AR games. Each of the sections below represents a piece of the emerging research agenda around AR games and demonstrates the experience and thinking of the panelists with regard to augmented reality games. The issues mentioned below will serve as a starting place for panel discussion.

Forging Students' Connection to Place

Augmented reality games and simulations have great potential to forge a productive synergy between the documented benefits of students exploring their local community and the educational potential of handheld technology (Roschelle & Pea, 2002). This work also brings the added benefits of getting students out in the community through service learning projects, thereby addressing the pressing need to engage students in opportunities to build their identities around citizenship and stewardship.

As an educational approach, place-based education immerses students in their immediate community, using this local angle as the context and motivation for student inquiry. Thus, instead of studying water quality as an abstract idea, or learning about a great river system hundreds or thousands of miles away, students in a place-based approach use their local creek as the basis for learning core academic concepts. From this basis in real-world investigation, students extend their understanding, scaffolded by the conceptual structures they built in their community. Drawing on a decade of research, the Place-based Education Evaluation Collaborative (2010) has documented a range of educational benefits, including increased levels of students' academic achievement, community involvement, and stewardship, as well as enhanced teacher motivation, school culture change, and increased school-community partnerships.

Augmented Reality (AR) games and simulations extend the benefits of a place-based educational approach, as they provide opportunities for students to build relevant STEM-related skills both directly through their innovative use of hand-held technologies and game design software, and indirectly through the use of on-screen simulations to model aspects of scientific or historic research that would not be possible outside of the AR environment. Imagine that students are investigating a water quality mystery and need to conduct sophisticated monitoring that is too expensive for a school budget. This process can be simulated "in place" with the student scientists conducting a test when they reach the appropriate site along the creek banks. Similarly, students investigating local history can "conduct" interviews with people ordinarily not available but who can appear in a video via the handheld units. Emerging research is helping to discern and document the optimal balance of authentic first-hand experience and simulated experiences made possible in an AR environment. (Coulter et al., in press)

A third program leg being developed by the LIONS and CSI programs (jointly run by the Missouri Botanical Garden and MIT) is the promotion of service learning opportunities emerging from the AR simulations. With the increased interest and understanding generated through the game environment, students are better motivated and able to engage in community action projects that serve to improve their community. In turn, students' experiences with these projects extend their understanding to create a virtuous learning cycle. Both short-term (Duffin, Murphy, and Johnson, 2008) and long-term research research (Beane, 1981) has documented the benefits of service learning. In the Duffin study, projects that had a service learning component anchored in the needs of the community were compared to activity-based projects without such a focus, with greater environmental improvements found in the service learning focused projects. The Beane study compared adults who attended a high school where random assignment 30 years ago gave some a course with service learning and others a more traditional academic course. Throughout their adult lives, the students with a base in service learning went on to significantly more (and higher levels of) community involvement.

In sum, a triad of place-based education, augmented reality, and service learning creates a powerful new paradigm of education, leveraging emerging technologies to foster student collaboration while building on proven educational approaches.

What is clear, however, is that this approach cannot just happen. Research to date (e.g. Coulter, 2010) shows that certain teacher attributes are needed for effective program leadership, including a strong understanding of relevant content, comfort with data and model based reasoning, ability to guide students in exploring questions, and personal curiosity and passion to learn more. While each teacher will vary somewhat in these attributes, it is abundantly clear that teachers need some capacity in these areas – and a willingness to continue growing – for complex program implementation. More generally, work undertaken by the Garden/MIT collaboration is developing a theoretical model further articulating the capacities teachers need to lead effective, AR-enhanced projects. A certain level of personal agency is required, built on the teacher's growing pedagogic vision and skill, capacity to forge partnerships within the school and community, and ability to make optimal use of emerging technologies and other resources. This model and a proposed teacher growth trajectory will be shared as part of the symposium.

Changing Social Dynamics in Learning with AR Game Authorship

As an increasing number of youth bring mobile media devices to school with them, educators are wrestling with whether to encourage their use, integrate them into instruction, or ban them entirely (Klopfer, 2008; Squire, 2009). As Roschelle and Pea (2002) argue, the sheer presence of broadband enabled, mobile multi-media computers that users can tailor according to their own interests (downloading audio, video, text or interactive media) and that they can consume with privacy raises questions about how to maintain a central focus to learning activities while also support learners in pursuing their own trajectories. Indeed, with constant access to information and social networks, mobile media challenge our very notions of place, as participants' attention can be divided among classrooms, online forums, and their own media. Learning is amplified through mobile media, as participants extend their interest in new areas, participation in social networks, and experience increased power to influence the world.

Over the last two years, the Augmented Reality and Interactive Storytelling Group at the University of Wisconsin-Madison (ARIS) has been investigating how to create a platform for educators to design mobile learning experiences that leverage these capacities. As an outgrowth of the MIT Augmented Reality team led by Klopfer (2008), it seeks to provide ordinary people tools to author mobile media enabled learning experiences. These range from students designing games about social issues in their neighborhoods to informal science educators creating interactive games about watersheds or forests.

Early research has shown that using smartphones as tools for media creation and AR game authorship can have a transformative effect on students' learning experiences. In this symposium, we will examine claims stemming from a formative case study in which 12 at-risk youth designed mobile media learning experiences about their neighborhoods using the ARIS software platform and other tools. The design work occurred as part of a semester long local games course which, based on the studio model, integrated ecology, citizenship, social history, and media production within one course. Students' design work leveraged a variety of tools, including cameras, applications downloaded from iTunes, and ARIS, the platform used for publishing these games. Each student had access to mobile media devices such as iPhones with full data services for the duration of the course. Researchers observed home, school, and work interactions, collected and analyzed data from time logs, and interviewed parents, students, teachers, and administrators to triangulate findings.

The case study reveals challenges and opportunities for using mobile media within a design workshop, including these four claims:

1) Mobile media devices caused few, if any disruptions in students' home, work, or school lives, and instead, amplified interest, success, and capability for participants in these three spheres. Instructionally, iPhones were useful, although participants most often made use of a variety of tools in context-appropriate ways. Specialized tools such as high-resolution cameras, digital audio recorders, and phones were deployed.

2) Scaffolding local game design through playing games, structured design exercises, and open-ended collaborative design succeeded in engaging youth, teaching particular design practices and enacting their identities as designers. The first classroom sessions were marked by confusion, as students struggled with the basics of game design and how to take ownership over the experience.

3) Curricula that fully integrate mobile media reduce the physical and social barriers to the classroom, enabling participants to more fully engage in civic planning, science, or media design. Participants were constantly in and out of the classroom as they collected physical data, interviewed stakeholders, analyzed the world and used the classroom for conducting meetings, analyzing documents, and producing media.

4) Producing local games about their lives led participants to challenge existing knowledge and beliefs as they were forced to integrate the perspectives of different stakeholders in their games. Participants ended the class with more sophisticated understandings of civic planning and democratic processes, as well as increased self-efficacy in citizenship.

Strategies to Assess Learning in Place-Based AR games

Assessing learning outcomes is crucial to any educational technology intervention, and AR games are no different. The Radford Outdoor Augmented Reality (ROAR) project at Radford University is conducting a proof-of-concept project documenting the feasibility of using augmented reality to effectively teach science to rural middle school students. To show this feasibility, the team needs to assess learning that happens as part of student experiences with AR, and show that it is on par with or better than learning that takes place through other instructional methods.

Radford University is developing and studying elementary, middle, and high school curricula that use augmented reality to create mobile games requiring critical thinking, communication, and collaborative problem solving skills. The story-based, mobile AR games developed by the ROAR team are played on handheld computers. The student players work collaboratively on problem solving challenges based on narrative, navigation, and collaboration cues. (Dunleavy, Dede, & Mitchell, 2009; Klopfer, 2008; Squire & Jan, 2007).

While many areas of AR assessment overlap with other computer-based learning fields, there are specific assessment opportunities and challenges presented to researchers and evaluators (Dunleavy & Simmons, 2011). There are three particular areas related to AR learning, which provide unique assessment opportunities: 1. Identity; 2. Collaborative problem solving and knowledge building; and 3. Data collection and analysis patterns. In addition, the outdoor, dispersed, social and physical nature of AR learning presents unique qualitative data collection challenges.

Role-based AR learning environments provide unique opportunities to assess identity and domain-specific self-efficacy. For example, in an epidemiology game designed by the ROAR team, the students were assigned roles (i.e., entomologist, zoologist, botanist), which required them to collect relevant digital flora and fauna specimens from their school grounds to create an antidote for a deadly disease. Depending upon his or her role, each student saw and interacted with unique and incomplete pieces of data, which needed to be interpreted and combined with his or her teammates' data to gain a full understanding of the problem. Due to the role-based design, each student had a specific area of specialty adding unique value to the team. The use of scientifically based roles is a direct attempt to cultivate a sense of projective identity that could serve as a mediation between the students' real world identity and their game identity (Gee, 2003). In other words, if a student adopts the role of a scientist in a game and finds the role-based activities satisfying and self-affirming, their game-identity could theoretically influence their real-world identity and their related self-efficacy. Although domain-specific self-efficacy has been researched within the virtual gaming environment (Ketelhut, 2005), this is a relatively emergent field and AR provides a rich assessment opportunity to explore the possible interplay among place, situated learning, and identity.

Most AR learning environments provide a ubiquitous or one-to-one computing environment, which affords evaluators and researchers the opportunity to assess the students' ability to collaboratively problem solve using knowledge building and jigsawing techniques (Scardamalia and Bereiter, 1991; Brown and Campione, 1996). As discussed above, a design strategy used to facilitate collaborative learning (Johnson, Johnson, & Holubec, 1994) is to create interdependent roles, which the students adopt within the AR experience. To successfully navigate the AR learning environment, the teams must work together to share and synthesize their respective pieces of data requiring each member to successfully collect, interpret, and communicate his or her unique information. This is a direct attempt to approximate authentic team-based inquiry and is a design strategy used in role-based video games as well as AR games (Jakobson & Taylor, 2003; Klopfer, 2008; Steinkuehler, 2006).

Continuing the epidemiology example provided above, the students need to individually collect their respective specimens, compare how effective it might be in an antidote relative to their teammates, evaluate the best choices and then make a team decision as to which specimens would be most advantageous within the antidote. Using qualitative methods (e.g., observation and player reports) at each step of this process, researchers can assess the skill of the individual student and the larger team based upon their performance on specific observed tasks as well as their overall performance during the experience.

Related to collaborative problem solving is the opportunity to assess the process, logic and pattern of data collection and analysis within AR games. As each student uses a GPS-enabled handheld within the experience, researchers are able to incorporate log files, which can record the students' physical movement and the length of time spent at each location. In addition, these log files can also record responses to embedded assessments, handheld communication, Internet research activity (e.g., websites visited, duration of visit), access to hint screens or tutorials, and other data points. This log file data could provide researchers with a 'cognitive audit trail' for a more thorough analysis of game play and learning than could accomplished outside of an AR environment (Dunleavy and Simmons, 2011; Montola, Stenros, & Waern, 2009; Dede, 2009).

In addition to the assessment opportunities found within specific areas of learning, AR also provides more general methodological assessment challenges (Dunleavy and Simmons, 2011). For example, the outdoor, dispersed, social and physical nature of AR learning makes observations more complex than a typical classroom observation. During a typical AR implementation, there are approximately ten student teams of three members each spread out over a physical area the size of a football field. Through trial and error, the research team concluded that shadowing groups of students using a given sampling technique (i.e., maximum variation, convenience) while holding a clipboard to fill out an observation protocol was difficult and problematic. The most significant challenge was the inability of the written observation protocol to accurately document the complexity, nuance, and totality of all the various interactions the students experienced during an AR game. The solution was to shadow as many teams as possible with mobile video cameras to capture the interactions. These videos were then coded and analyzed to reveal any patterns in behavior and movement directly related to the research questions (Dunleavy and Simmons, 2011).

While emerging technologies such as AR will continue to present researchers with unique assessment environments, the lack of valid and reliable instruments aligned with collaborative problem solving and scientific inquiry poses a greater challenges to the implementation of serious, inquiry-based gaming tools such as AR (Dede, 2009). This challenge needs to be addressed by policy makers at the federal, state, and district level as well as academics if augmented reality and other emerging tools are going to be meaningfully adopted by professional educators.

Speaker Biographies

Eric Klopfer, moderator, is the Director of the MIT Scheller Teacher Education Program and the Scheller Career Development Professor of Science Education and Educational Technology at MIT. The Scheller Teacher Education Program prepares MIT undergraduates to become math and science teachers. Klopfer's research focuses on the development and use of computer games and simulations for building understanding of science and complex systems. His research explores simulations and games on desktop computers as well as handhelds. On handhelds, Klopfer's work includes Participatory Simulations, which embed users inside of complex systems, and Augmented Reality simulations, which create a hybrid virtual/real space for exploring intricate scenarios in real time.

He is the co-director of The Education Arcade, which is advancing the development and use of games in K-12 education. Klopfer's work combines the construction of new software tools with research and development of new pedagogical supports that support the use of these tools in the classroom. He is the author of "Augmented Learning", on the research and design of mobile educational games (Klopfer, 2008).

Bob Coulter is the director of the Litzsinger Road Ecology Center, managed by the Missouri Botanical Garden, and PI / PD for two NSF-funded research and development projects focusing on linking teachers and students to their community through place-based education, augmented reality technology, and service learning. He has also published and presented extensively on educational applications of geospatial technologies, and is a lead member of the Place-based Education Evaluation Collaborative. Prior to this work, he was an award-winning elementary school teacher in public and private schools for 12 years.

Matt Dunleavy is an Assistant Professor in Instructional Technology at Radford University in Virginia. From 2006 to 2007, he was a postdoctoral fellow in learning technologies at the Harvard Graduate School of Education and the director of the Handheld Augmented Reality Project (HARP). Dr. Dunleavy received his Ph.D. in Educational Research, Statistics, and Evaluation at the University of Virginia, where he focused on the impact of ubiquitous computing on student learning and the classroom environment. Prior to completing his formal education, he lived overseas teaching English as a Second Language in Cameroon, Central Africa as a Peace Corps volunteer and then independently in Taiwan, Republic of China. He is currently the principal investigator on a National Science Foundation grant and a Virginia Department of Education grant (http://gameslab.radford.edu/), both of which explore how mobile technology and augmented reality can be used to improve academic and socio-cultural skills for K-16 school students.

R. Benjamin Shapiro is a Postdoctoral Research Associate of the Morgridge Institute for Research at the University of Wisconsin, Madison. He specializes in the design of technologies to make schools more interesting, challenging, fun, and caring, and the study of processes through which technologies are adapted to fit local contexts.

He is currently leading the design, development, and study of educational video games to teach about, and engage the public in, cutting-edge science, including biomedical imaging, ecological conservation, and stem cell biology. One such game will teach about anatomy and cancer by enabling a crowdsourced public to assist doctors in making more accurate cancer diagnoses from CT scans and MRIs.

He has previously designed a range of social and educational technologies, including pioneering mobile tools for finding nearby places, events, and friends, socially networked collaboration and assessment tools used to mentor urban youth into artistic and journalistic communities, data visualizations to help teachers to understand students' thinking, and agent-based computational modeling tools to assist children and scientists alike in studying and understanding complex, emergent scientific phenomena.

Ben received his PhD in the Learning Sciences from Northwestern University, and has a BA from University of California, San Diego, where he studied Computer Science and Cognitive Science.

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