Augmented Reality Games in Education

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Abstract: Augmented reality technology is a powerful tool for student learning that is made even more effective through the interactivity of games. This paper compares six case studies that exemplify the medium's educational strengths, each representing a different method of interacting with augmented reality technology. Best practices for using augmented reality games to teach abstract concepts (by visualizing arithmetic), scientific inquiry skills (by diagnosing a failing ecosystem), design thinking (by planning a city), and creativity (by creating a game) are also discussed. However, inadequate research, limited teacher training, and the challenge of obtaining funding for new equipment pose challenges to implementing this new technology in schools. Until augmented reality becomes more commonplace outside of schools, its impact on formal education will be limited.

Introduction

Augmented reality allows teachers to create lessons that cross the gap between abstract concepts and real life. It can demonstrate impossible things and still situate them within the context of a classroom or field trip. Teachers can use augmented reality to simulate a conversation with a historic figure, the effects of a toxic chemical spill, or motion in a frictionless environment. In the author's experience, teachers' responses to demonstrations of educational augmented reality have been highly positive. They immediately get excited about the possibilities for using this new technology to demonstrate difficult concepts like gravity or scientific inquiry. The fact that the virtual images are contextualized means that they are very accessible and invite both teachers and students to "come play!" Augmented reality is only going to get more sophisticated and ubiquitous, and teachers should be able to harness these developments to help their students learn in fun and engaging ways.

However, when an augmented reality app isn't interactive, it's little more than a video. For example, *Aurasma*, an augmented reality application that is becoming popular with teachers, features on its website images that will trigger video responses on a handheld device (Aurasma, 2012). However, since the original image is already on a computer screen, it actually would be easier to just put a "play" button on the image to start the video. Whereas there is some potential for application if the images were a hard copy (at a museum, for instance) the real power of augmented reality comes when students begin interacting with both the virtual and real worlds. Video games can provide that interactivity, as well as provide a structure for learning.

The unique way augmented reality combines the real and the virtual creates an immersive experience for the player, enhancing the gaming experience and increasing student engagement. James Paul Gee (2007) has identified 16 characteristics of video games that make for excellent educational experiences. Many augmented reality games have some or all of these characteristics, but the unique medium enables them especially to excel in situated meanings: the ability to relate academic concepts to real-life understanding. Textbooks and other traditional tools have trouble with this since they are isolated from real contexts. Video games do better in that they relate meaning to in-game situations. However, augmented reality games can relate meaning directly into the real situations students are dealing with – whether it's a pond, a historic marker, or their own school.

According to the New Media Consortium (2012), augmented reality is four to five years away from widespread adoption in schools. This paper looks forward to some of the technological advancements that will make it much easier for teachers to create augmented reality lessons, and even create their own games. There is much potential for using this exciting new technology to improve education, and this paper provides a broad look at the options that are currently available. Both benefits and drawbacks of the technology are discussed, and educators are encouraged to consider how the unique affordances of augmented reality technology can complement their current curriculum.

Benefits of Augmented Reality Games

Augmented realities facilitate the visualization of abstract concepts.

Fetch! Lunch Rush is an arithmetic game from PBS, available to parents and kids in the iPhone and iPad app store. It provides students with 3D visualizations of math problems as they go through the game. This game is based on fiduciary markers that show up as 3D sushi within the app. *Fetch! Lunch Rush* helps kids prepare for

algebra by strengthening the connection between real objects and abstract symbols (PBS Kids, 2011b).

Another example of this visualization aid is *SciMorph*, a 3D character who teaches elementary school students about science concepts like gravity, sound, and germs. Students print out a fiduciary marker, hold it up to the webcam, and view both themselves and SciMorph on the screen. Through augmented reality, students are able to manipulate physical forces in ways that are impossible in real life. Students can use *SciMorph* to investigate the effects of different levels of gravity and sound in ways that would be challenging to simulate even in a physics lab. (United Kingdom Department for Education, 2010).

Although everything SciMorph does, like jumping up and down or sneezing, can be expressed in a 2D video, the interactivity and non-linear structure of the game increases student engagement in the material. According to the International Center for Leadership in Education (2008), active learning strategies that require interactivity are significantly more engaging than videos and other traditional media. They recommend that teachers vary their instructional methods to incorporate many types of interactive media.

Augmented realities are uniquely suited to teaching scientific inquiry and problem-solving.

EcoMobile, an augmented-reality project at the Harvard Graduate School of Education, addresses the challenge of teaching scientific inquiry, not just scientific facts. Students are presented with an ecology problem during a field trip to a local pond environment, and are tasked with finding the cause and proposing a solution. As students explore the pond, they encounter "hotspots" where virtual information is available via fiduciary marker. They can use their handheld devices to take water quality measurements, interact with fictional characters, or explore microscopic processes. Students interview virtual characters, gather data, review documents, and ultimately form and test a hypothesis. However, there is no one right answer – students are assessed on their process and reasoning, and create a video to share their findings (Dede, Grotzer, Metcalf, & Kamarainen, 2011). According to the National Academy of Education (2010), these sorts of open-ended questions encourage the kind of complex thinking that adolescents need to develop their inquiry skills. They warn that if students are given problem-solving tasks that are too simple, they will not develop necessary complex thinking skills or an appreciation for science. Although students are unfamiliar with these kinds of open-ended problems, they tend to enjoy those discussions more. According to a high school engagement survey, 65% of students agreed that they "like discussions in which there are no clear answers" (Indiana University - Bloomington School of Education, 2010).

Teachers have been very supportive of the *EcoMobile* project, reporting higher student interaction and collaboration, as well as a deeper understanding of ecological principles, than seen on typical field trips (Kamarainen, et al., 2012). As one sixth grade teacher said, "I felt like it gave them a different ownership over the experience than if there had been just one teacher voice and a crowd of kids…My students were psyched about molecules, too… all that world unseen, all that new stuff is making them feel much more like this is real science or adult science. A bunch of my students are hooking into science in a way that they report that they never have before. I can't help but think that the high-powered technology helps" (Dede & Grotzer, 2012).

Augmented realities encourage open-ended play and design thinking.

Augmented reality games allow students to explore relationships of objects and situations that aren't easily accessible to them in the real world. A great example of this is the *Star Wars: Where Science Meets Imagination* travelling museum exhibit. The exhibit is a Star Wars-themed urban planning puzzle game. Players are given puzzle pieces printed with fiduciary markers. When placed on the game board, the puzzle piece appears as a 3D building on the display screen. As players move the pieces around, they can rearrange the configuration on the screen. The game introduces principles of urban planning in a familiar and fun environment (Rodley, 2008).

By eliminating the constraints of reality, students are able to experiment with their own designs and quickly discover the results. Moreover, this game also provided students with a tactile connection to the systems they were building, allowing them to manipulate the virtual elements in the same way as they would real objects.

Google's *Field Trip* app is a great example of how this technology can be used for more ubiquitous informal learning outside of museums. This smartphone app runs in the background as users go about their day. When they pass by something interesting, the app alerts them to what's nearby and provides information about it (Niantic Labs @ Google, 2012).

The free-play nature of both *SciMorph* and *Field Trip* allow students to move at their own pace, draw connections, and learn through experiencing different perspectives. Although the two programs are very different in content, medium, and audience, they both provide students with the freedom to explore topics in ways that would be impossible in a traditional classroom setting (United Kingdom Department for Education, 2010; Niantic Labs @ Google, 2012). All three of these examples embody constructivist principles of allowing students the time and freedom to

discover and create meaning for themselves.

Augmented realities facilitate active learning through creativity.

Mansel Primary School in Northeast Sheffield, UK addressed the challenge of teaching creativity and design by having students not only play augmented reality games, but create one of their own. The *Imaginary Worlds* project started by having students play *inviZimals*, a commercial augmented reality game for PSP, to introduce them to augmented reality. Afterward, students created their own games by designing virtual locations, linking them to fiduciary markers, and placing those markers at locations around their school. Then, fellow students could go on quests to these locations using camera-equipped PSP devices (Fletcher, 2011).

The *Imaginary Worlds* project engaged students in active learning by emphasizing the process of generating new knowledge rather than facts or even understanding. By focusing on the process of creation, students were encouraged to take active control over their own learning and create links with past experiences. One student displayed this sort of deep thinking about the project when he reported thinking through what his imaginary world would smell like so he could choose images that would evoke the same feeling (Phillips, 2010). Although active learning can take place in many venues, studies have shown that the act of creating their own video games and other media can result in improved student outcomes (Farrell, 2009).

Augmented reality games are fun!

According to Raph Koster, fun is defined as “the feedback the brain gives us when we are absorbing patterns for learning purposes.” The challenge in designing learning games is to keep the patterns just difficult enough that the players remain interested (as cited in Kirkley & Kirkley, 2005). Many commercial video games are already designed with this in mind – levels get progressively harder, and players can purchase or find items in the game to make challenges easier when necessary. In this way, video games are set up to keep the player constantly within their own Zone of Proximal Development, at least as it relates to their gaming skills (Puentedura, 2010). In fact, in interviews students report specifically seeking out video games that are challenging, and enjoying repeating levels until they were mastered (Gumulak & Webber, 2011). Designers are harnessing this power when creating video games that provide “just-in-time” help and scaffold instruction in the various levels of the game (Gee, 2007).

Barriers to the use of augmented reality games in school

Teacher professional development

Although technologies like augmented reality can spark excitement about its potential, they can also incite worries about implementation. A major barrier to widespread adoption is that many teachers are hesitant to change their teaching style to include any kind of technology, but especially games, in their classrooms (Dunn, 2012). Since there is so little up-to-date research on educational video games, teachers can be skeptical about using games in their classrooms (Online College Courses, 2012). The research on augmented reality games in education is currently very weak because the games being studied are mostly unavailable to the general public. The games that teachers easy access to, such as those being sold in app stores or those being offered through education companies, have very little research demonstrating their efficacy. More research is needed to evaluate commercially available augmented reality games.

Teachers are also concerned about the transfer of skills from video games to real life (Online College Courses, 2012). However, using augmented reality in educational games can help bridge that gap by placing the game in context within the real world. Teacher Karen Schrier accomplished this with her game *Reliving the Revolution*, a location-based history RPG about the Battle of Lexington. The game was set at the actual battlefield, and her students played roles as period-accurate characters as they attempted to solve the real-life mystery of who fired the first shot. Schrier reported that the experience was positive and more effective than a typical field trip to the battlefield, and she encourages other teachers to try similar games with their classes (Schrier, 2006).

Classroom management is always an issue for teachers, and they especially have difficulty monitoring students as they go through video games at their own pace (Online College Courses, 2012). However, many games address this issue by allowing students to repeat sections, ask for help, or skip through to a harder level. In addition, when students are engaged in a learning game, the off-task behaviors that require constant monitoring are typically diminished. Continued training can help teachers develop a new classroom management style that accommodates the presence of video games in the classroom.

Many teachers are unaware of the augmented reality games that are currently available, and aren't prepared to use them effectively in their classrooms. More professional development is needed to provide teachers with the support they need to effectively use augmented reality games.

mplementation issues

The cost of the technology is major barrier for many schools - 50% of teachers say this is the top reason they choose not to use video games in their lessons (Online College Courses, 2012). This is especially challenging for augmented reality games. Because handheld technology is developing so rapidly, the devices schools purchase will become obsolete in a few years. Until video games have solidly established their educational efficacy, many schools will continue to prioritize other expenses.

Additionally, implementing augmented reality games in a school environment can be very labor-intensive. Often two or three facilitators are required to set up the game, make sure the devices work properly, and address any problems that arise. The games also often rely on the expertise of a skilled teacher to help students make connections to previously leaned material (Dunleavy & Dede, n.d.).

Finally, many schools that regularly use handheld devices for learning do so as part of a "Bring Your Own Device" (BYOD) program. However, this means that students' devices will have varying age, type, and operating system. Since most augmented reality games are not available on all platforms, even schools that are already using handheld devices will have difficulty implementing these games as part of the curriculum (New Media Consortium, 2012).

Unfortunately, there is no clear-cut solution to the problems of funding in education. However, many schools have been able to overcome these difficulties and successfully implement a mobile learning program. The Consortium for School Networking provides some recommendations to schools that are starting a mobile learning program, which can help ease some of these implementation pressures. They recommend a variety of creative professional development opportunities, robust wireless internet connection throughout the school, and a focus on improving teaching and learning through the technology. Schools that apply these recommendations will be in a much better position to use the augmented reality technology that is available now, as well as set themselves up to take advantage of future developments (Gray, 2011). More and more schools are investing in technology as studies continue to show increased achievement in math, literacy, and reading when teachers integrate technology into their lessons (Common Sense Media, 2010).

Conclusion

The augmented reality games presented here were chosen as examples of six different ways of using the technology. There are many more quality games available to teachers and researchers, but they will typically fit one of these six broad types. The games generally fall into two categories based on how they combine real and virtual information. One type consists of small, simple games that can be used anywhere on a smartphone or other handheld device. These games use fiduciary markers or GPS location to provide players with the virtual images (see Table 1). However, this type of game is limited in its scope and its ability to create an immersive environment. Examples include *SciMorph* and *Fetch! Lunch Rush!* (United Kingdom Department for Education, 2010; PBS Kids, 2011b).

The second type is large, event-based games that require extensive setup. These are often created using handheld devices like a smartphone or PSP (see Table 1). Players are restricted to a designated play area that is specially prepared for the game using markers or GPS coordinates. The extensive setup makes it difficult or impossible to play these games in another location (Broll, et al 2008). *EcoMobile* is a great example of this type because it requires the setup of hotspots at a local pond (Kamarainen, et al., 2012). Other games are restricted to one specific physical location, either by GPS coordinates within the game, or, as is the case with *Star Wars: Where Science Meets Imagination*, because it is housed within a museum exhibit.

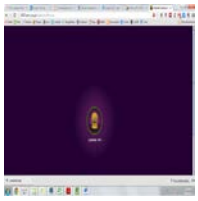
	Webcam	Handheld & Markers	Handheld & GPS
Ubiquitous	 SciMorph	 Fetch! Lunch Rush	 Field Trip
Event-based	 Where Science Meets Imagination	 EcoMobile	 Aurasma

Table 1: Types of Augmented Reality Games

(United Kingdom Department for Education, 2010; PBS Kids, 2011a; Niantic Labs @ Google, 2012; Discovery Science Center, 2011; Dede, C. & Grotzer, T., 2012; Aurasma, 2010)

The small, simple augmented reality games like *Lunch Rush, SciMorph,* and *Field Trip* have the potential to have a transformational impact on education in the future, when augmented reality technology is more commonplace. As the technology improves, and as wearable devices become more user-friendly, augmented reality as a whole will become ubiquitous in areas with the infrastructure to support it. Increasing dependence on augmented reality and other technological advances are likely to have a transformative effect because teachers will have to give up some measure of control in their teaching styles. In structured lectures, where teachers are the only authority in the room, they don't have to have a complete understanding of the topic – they only have to understand what's in the lesson. Augmented reality and other tools that allow students to explore beyond the confines of a structured lesson will lead students to ask questions beyond the scope of a teacher's preparation. Because of this, teachers will have to shift from *having* all the answers to the role of a guide helping students *find* all the answers (Dede, 2012).

However, the impact of all augmented reality gaming will be limited until augmented reality technology becomes commonplace outside of school. There is not much evidence that schools will be early adopters of this technology, and there is little incentive for developers to create entire curricula around augmented reality games (New Media Consortium, 2012).

Finally, in the future we will see more and more teachers like Karen Schrier designing and creating their own augmented reality games. As the technology improves, so do the tools for creation. Right now, teachers are using *Aurasma* to create their own learning experiences for their students (Aurasma, n.d.). *Aurasma* is a platform similar to the popular augmented reality web browser *Layar* in that it provides location-based information using GPS. However, it is unique in that users can create their own "Auras" and share them with others. These auras can then be viewed by any smartphone that has the *Aurasma* app installed (Aurasma, 2012). *Aurasma* is highly versatile and customizable, and innovative teachers have found it to be useful in creating their own immersive environments or scavenger hunt games on their school's campus. For this reason, I've included it as an event-based game, although there are certainly other ways to use this app. (Aurasma, n.d.). In addition, since *Aurasma* is free and easy to use, teachers are also using it to help students build their own augmented reality projects (Noonoo, 2012).

The use of *Aurasma* as a creative tool points us toward the future of augmented reality – when designers and teachers hand off the creation process to students so that they can learn not only as consumers of the technology, but also as designers. We teach students to read, but then we also teach them to write. We teach them to appreciate art, and also to paint. Students are already starting to use augmented reality on their smartphones and video game devices – now it's time to teach them how to create exciting new games using this technology.

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