Using Augmented Reality Games to Teach 21st Century Skills

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Abstract

Augmented Reality (AR) games can potentially teach 21st century skills, such as interpretation, multimodal thinking, problem-solving, information management, teamwork, flexibility, civic engagement, and the acceptance of diverse perspectives. To explore this, I designed Reliving the Revolution (RtR) as a novel model for evaluating educational AR games. RtR takes place in Lexington, Massachusetts, the site of the Battle of Lexington. Participants interact with virtual historic figures and items, which are triggered by GPS to appear on their PDA (personal digital assistant) depending on where they are standing in Lexington. Game participants receive differing evidence, as appropriate for their role in the game (Minuteman soldier, Loyalist, African American soldier, or British soldier), and use this information to decide who fired the first shot at the Battle. Results of initial trials of RtR suggest that AR games, when properly designed for pedagogical purposes, can motivate the authentic practice of 21st century skills.

Keywords: 21st century skills, augmented reality, critical thinking, educational games, history education, wireless handheld devices

1 Introduction

How can we teach the skills necessary for an increasingly global digital economy and a democratically involved citizenship? Many educators are searching for ways to creatively integrate these 21st century skills into K-12 pedagogy with innovative, effective, and appropriate activities. In this paper, I evaluate the potential of Augmented Reality (AR) games as engaging and authentic environments for learning, activating, and practicing these skills. To do this, I examine in detail a novel AR game, Reliving the Revolution (RtR), in regard to nine different categories of skills, such as media fluency, critical thinking, and community awareness. This is based on a framework developed by The Partnership for 21st Century Skills, an advocacy organization that promotes the education and assessment of 21st century skills (Figure 1) [2003].

In particular, The Partnership recommends that the preparation of these skills should emphasize content areas including global awareness; financial, economic and business literacy; and civic literacy. In other words, students should learn about diverse cultures and global issues, understand how economic and political principles interact with other disciplines, consider ways to effectively participate in a democracy, and think about the consequences and historic implications of one's decisions. The Partnership argues that such skills, coupled with these content areas, can provide students with the conceptual tools and breadth of perspective to contribute the critical dialogue and informed actions necessary to create a stronger world. Therefore, activities should not only support learning 21st century skills, but they should emphasize and illustrate these content areas.

In this paper, I first briefly introduce pedagogical foundations for AR games, and describe previous educational AR games. I then provide an overview of the RtR gameplay and my testing methodology. Finally, I use the 21st century skills framework to assess the results of RtR game trials, and to examine more generally the use of AR games in education.

Figure 1: The 21st Century Skills Framework.

2 Background

Augmented reality (AR) games are gaming environments that embed virtual, location-specific and contextual information into a physical site. These games require mobile or ubiquitous computing devices, such as handheld computers or cellular phones, to enable game participants to access this virtual information. Instead of putting people in an artificial world, these games augment the physical world by embedding them with digital data, networking and communication abilities, and enhanced properties [Mackay 1996]. For example, designers of AR games might program "hot spots" of digital information to appear in specific physical locations that can only be retrieved by using a PDA (personal digital assistant) or by reading an RFID (radio frequency ID) tag. Game participants are encouraged to detect and access these hot spots and use the embedded data–in conjunction with real world objects–to play the game.

Support for using AR games to teach comes from a confluence of factors. One, the growing penetration of mobile devices in edu-

cational settings: wireless handheld devices such as PDAs and mobile phones are becoming more ubiquitous in classrooms because of their relatively low cost, accessibility, flexibility, networking capabilities, and portability [Klopfer et al. 2003; Dede 2004; Dieterle 2005]. Simultaneously, video games and other types of games are gaining increased acceptance as potential learning environments and as supplements to classroom curricula, in part because they support engagement, curiosity and motivation, social interaction, new semiotic systems, and identity reconfiguration [Gee 2003; Squire and Barab ; Jenkins III, H. 2002]. AR game's particular potential as an educational medium is sustained by a few pedagogical frameworks, including Constructivism and Situated Cognition, as described in Klopfer, et al. [2003]. For example, in Constructivism, learners actively construct their own knowledge, instead of passively receiving information from a teacher or guide. They learn cooperatively and socially, and upon reflection on their own learning process. In the Situated Cognition approach, context and learning, knowing and doing, are seen as interdependent [Dede et al. 2002]. Cognition is wedded to a specific situation and the students environment is essential to learning; an environment can alter, enhance, and scaffold certain types of performances, approaches to problems, or learning activities. Putting these together, AR games can be an authentic practice field—it can establish scenarios and provide resources so that students can effectively work together to solve meaningful problems and construct their own solutions, narratives, and connections, in the environment where they would typically occur.

MIT's Teacher Education Laboratory has developed and tested a suite of AR games, each of which enables students to work collaboratively on problems from within a real world location. In Environmental Detectives (2003), an outdoor game, participants work in groups to analyze a virtual oil spill that occurred on the actual MIT campus. The participants navigate a physical location and use handheld and GPS devices to gather information from virtual game characters and take virtual toxicity analyses at specific GPS coordinates.

Similarly, in River City AR (2004), based on Dede's multi-user virtual environment (MUVE), Charles River City, participants investigate a potential simulated biological epidemic in an outdoor portion of MIT's campus. In this game, a team of participants, each with unique roles and responsibilities, must work together to divide resources, gather information, and take virtual measurements and medical examinations to solve the epidemiological mystery. (For more information, see http://education.mit.edu/ar/).

Initial findings from these AR games, such as Klopfer, et al. [2002], suggest that they encourage teamwork, scientific inquiry, and resource management, and potentially teach 21st century skills, further motivating my creation of RtR.

3 Overview of Reliving the Revolution (RTR)

Building on this research, I designed a new AR game, Reliving the Revolution (RtR), as a potentially effective and engaging activity for teaching and motivating 21st century skills, and infusing civic literacy and historical content into middle and high school curricula.

RtR takes place in Lexington, Massachusetts, the site of the Battle of Lexington of the American Revolution. The goal of the game is for participants to "relive" the events of April 19, 1775, and decide who they think fired the first shot at the Battle of Lexington, which remains a mystery today (Figure 2). To do this, game participants explore the present-day Lexington Common and inspect the physical buildings and structures that were involved in the Battle of Lexington. They also use a GPS-enabled personal digital assis-

tant (PDA) to help navigate the physical environment and access and store virtual information pre-programmed to appear at specific GPS coordinates (Figure 3). Participants can (a) "talk" to a historic figure such as Paul Revere or Captain John Parker (these are called non-playing characters or NPCs); and (b) inspect a game item or real building (such as a musket or Buckman Tavern). For example, when a participant gets closer to the Old Belfry, a photo and description of the item is triggered to appear on the PDA (Figure 4). Or, when a participant approaches the northeast corner of Lexington Common, an NPC such as Minuteman soldier Nathan Munroe is triggered. The participant can then read his version of the events at Lexington, which appears in the form of a concise written testimonial. NPCs will often also provide to the participant a graphical document or image, which are typically copies or recreations of actual documents from the Revolutionary War period, such as diary entries, letters, newspaper articles, maps or sketches; or photographic images of physical buildings and signs around Lexington (Figure 5).

The testimonials and other multimodal media provided: (1) subjective versions of what happened at Lexington and who fired the first shot, that could be used to refute or corroborate other evidence; (2) contextual information that could help the participant understand more about the social, economic, geographic and political forces shaping the Battle and Revolutionary War; (3) detail that would provide the flavor and tone of the time period; (4) clues as to whom to speak to or where to inspect next; and/or (5) inducement for the participant to look closer at physical or virtual objects in the game environment.

Overview of RtR	
Locative technology	GPS
Mobile device	PocketPC handheld computer
Game infrastructure	XML/.NET (RiverCityAR Engine)
Goals	Primary goal: Who fired the first shot at the Battle of Lexington?; two additional role-specific mini-objectives
Action	Search for location-based virtual historic figures (NPCs) and game items triggered by GPS
Linearity?	Nonlinear with constraints
# of time periods	Two (before and after the Battle of Lexington)
Roles	One of four historic roles (Minuteman soldier, Loyalist, British soldier, African American slave); play roles as a pair
Game completion	Participants debate and collectively decide who fired the first shot.

Figure 2: Overview of the major game elements in RtR.

The participants play the game in pairs and in one of four roles, based on actual historic figures from the Revolutionary War period: Prince Estabrook (African-American slave/Minuteman soldier); John Robbins (free/Minuteman soldier); Ann Hulton (Loyalist/townsperson); or Philip Howe (Regular (British) soldier). Moreover, participants collect distinct evidence based on their role in

the game; for example, an NPC such as John Pitcairn, the major of the British regulars, provides very different evidence to a Minuteman soldier than to the female townsperson or fellow British soldier roles. The game is structured into two 30-minute time periods: Time 1 in the game simulates the moment before the Battle of Lexington has begun and the first shot has been fired, and Time 2 recreates the moment immediately after the Battle ends. NPCs provide different testimonials and documents in Time 1 and Time 2. Participants gather and analyze as much information as they can in Times 1 and 2; following this, they come together and collectively compare their role-specific evidence, share hypotheses, and debate who they think fired the first shot.
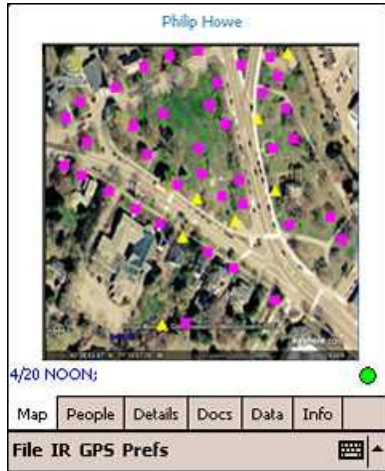

Figure 3: This map of Lexington Common appears on the participants' handhelds, along with colored dots that indicate "hot spots" of information: the historic figures (NPCs) and game items.

In addition to the primary goal of deciding who fired the first shot, each pair of participants can also solve two role-specific mini-objectives or "secret missions." These missions help guide, direct, and check one's progress in the game. They also help the participant tackle and compartmentalize the more complex historic question, because they highlight different hypotheses as to who fired the first shot. In other words, while playing RtR, participants can focus on smaller specific subtasks, rather than just the larger, unwieldy goal; and by completing these mini-objectives, they can have a better grasp of their progress in the game and a larger picture of what happened in Lexington.

Although I designed RtR for middle and high school students, it is flexible enough to engage and challenge college students, while still being accessible to younger participants. I created RtR by adapting and modifying the game system used for MIT's River City AR. I researched, devised and designed all of the content and gameplay. There were approximately 40 NPCs and 10 game items in RtR, each of which provided differing information to each role and within each time period. I based the game's content on extensive research on the Battle of Lexington and the American Revolution, and built in 16 distinct historically-based hypotheses as to who fired the first shot.

4 Testing

In June 2005, I tested RtR with three separate groups of students; the first two consisted of college and post-graduate school students, the third consisted of local middle and high school students. Measurements included: (1) pre- and post-game survey instruments on game play and history concepts; (2) videotaped and in-person observations of the participants' game play; and (3) a content analysis of the debate, game interactions, and participants' notes. Participants also provided oral feedback on their subjective experience of the game and what they learned. In this paper's evaluation of RtR, I specifically look at how AR game elements such as collaboration, role-playing, mobility, and narrative influenced or supported aspects of 21st century learning.

5 Results

In general, RtR enabled participants to simulate the activities of a historian—investigate a historic problem, collect and compare evidence, test and debate hypotheses, and draw conclusions—all in the place where this evidence was originally generated. Although participants could not relive the past, they could access it from within a living, breathing site. Likewise, participants felt that they were deeply and meaningfully exploring a historic moment and site, and comprehending the context for what occurred in Lexington. They immensely enjoyed reading the personal accounts of the Battle, playing the game with peers, inhabiting a role, and controlling the game's navigation and outcome. They seemed enthusiastic, motivated, and appropriately challenged. They took their tasks seriously—they embraced its challenges and critically immersed themselves in the game—in part because they felt that the game environment, content, objectives, and issues were authentic, and also because they felt they had a unique responsibility and agency over the game's outcomes. Accordingly, participants collectively constructed novel narratives of the past after engaging in a detailed, information-rich debate on the collected evidence. During this process, they seemed to become more open to diverse opinions, while also reflecting and critiquing their own interpretations. In turn, they considered more deeply their own personal biases and preconceived notions, and even articulated the necessity for applying multiple perspectives to current global and community issues.

In the following subsections, I describe in detail the results of my game trials, which suggest that many of the game's elements, tasks, and actions in RtR enabled and enhanced the practice and learning of 21st century skills.

Figure 4: Participants can access virtual information about buildings and other structures around Lexington Common.

5.1 Information Management Skills

RtR seemed to encourage participants to practice information management, critical evaluation, and comparison skills, because it required participants to access, navigate, and manipulate a rich virtual historical database mapped to a physical environment. Since there was no clear linear or established path through the game, to successfully play it, the participants needed to construct their own unique course through the content. Thus, participants began the game by interacting with any NPC or game item of their choosing, and then based on the information they received, decided their next move. Each time the participants reached a new "hot spot," they stopped, read the testimonial or inspected the item aloud, interpreted the information, and considered its relationship to other collected data. For example, in one pair's exchange, two participants interacted with a Minuteman soldier (NPC). One participant read aloud the essential parts of the testimonial, "Nathan Munroe was also fighting and went to the tavern," and then said to her partner, "We need to get to the tavern, that's where all our guys are." She then looked at the handheld to find the approximate location of the tavern, pointed to it in the real world, and the pair walked together across the Lexington Common toward it.

While the abundance of information was initially overwhelming, once oriented, it seemed that the openness, depth, and detail of RtR encouraged participants to plan geographic and intellectual routes through the information, discover novel relationships among evidence, manage their resources, and integrate information from multiple sources. Because participants were continually finding new puzzle pieces of information, they needed to keep reshaping their hypotheses and reorganizing their data. In other words, RtR gave the participants a taste of managing a large archive of diverse historical sources, mimicking the work of a social scientist.

Moreover, in addition to navigating a large amount of information, participants needed to divide, delegate, and share limited resources, such as maps, notes, handheld, GPS devices, and manpower. And, since participants only had thirty minutes to gather evidence before, and then after, the Battle, they quickly had to begin experimenting with strategies on how best to traverse Lexington and the game. Thus, when designed with an accessible, authentic, and navigable information database, and appropriate parameters, an AR game can challenge and support necessary information management skills.
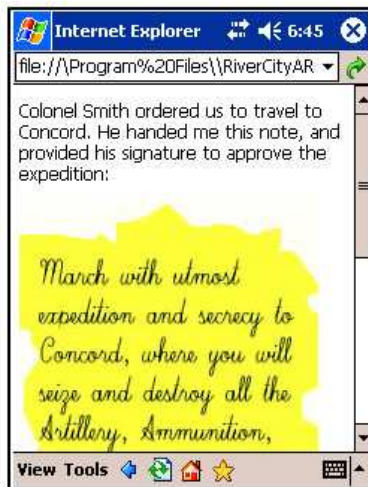

Figure 5: An example of a document that might be provided by a virtual historic figure (NPC).

5.2 Media Fluency Skills

In RtR, the participants fluidly integrated textual, graphical and physical information, and then articulated the connections using multimodal formats. They compared written testimonials, real world objects, and images of documents; they inspected them closely, interpreted their meanings, determined their connections, and figured out which evidence to trust in light of contradictions or discrepancies. They continually shared and supported interpretations of evidence by speaking to other participants, presenting their visual data on their handheld, showing or pointing out physical objects, or writing notes that summarized connections among data. Participants seemed not only to easily transition from textual to graphical formats, but RtR also compelled them to look closer at the built environment and found physical objects, its words and meanings, and find connections between the real and virtual worlds. Moreover, it motivated participants to look more deeply at the evidence, and analyze closely not only the text, but the visual and contextual elements of game images, structures, and objects. For example, one participant said that "this [game] makes you actually look at stuff. Like 'oh, that house over there was lived in by that famous [person].'" In another instance, participants received a testimonial, and judged it as more authentic when they saw the same words etched into a physical monument on Lexington Common (Figure 6). Furthermore, participants would judge images based on their source or perceived historical authenticity, privileging diary pages or old letters over photographic evidence. This suggests that the incorporation of multiple media formats in AR games can support the practice of media fluency skills, but also stimulate critical thinking, creative problem solving, and stronger communication.

5.3 Communication Skills

RtR seemed to further the practice of communication skills in a variety of ways, including its collaborative-intensive gameplay and physical environment, which enabled both serendipitous exchanges and the motivated sharing of information. First, since the participants played the games in pairs, they needed to constantly articulate to each other their interpretations of the evidence they gathered, explore hypotheses aloud or on paper, and share testimonials and documents accessed on the handheld to support their beliefs. For example, typically after retrieving a testimonial or inspection of a game item, participants would take turns reading it aloud, discuss what it meant, and how it connected to other information they had gathered. They would also jointly decide where to travel next, by showing each other places on the map on the handheld, and pointing to sites in the real world.

The role-specific mini-objectives ("secret missions") also encouraged participant pairs to share information with other pairs, since they often needed information from others to complete their objectives. Each role received distinct information, so they relied on other roles to fill in gaps, corroborate findings, or expose discrepancies in NPC stories. Moreover, for each of the game trials, participants communicated extensively throughout the debate, using the data, observations, and experiences they gathered from the one hour of evidence collection and interpretation. The participants arguments were well-supported by research and their use of material was both insightful and innovative. Since they were able to communicate their detailed analyses to others, it further suggests that they had each gathered, interpreted, and digested a vast amount of material.

For example, the following is an exchange from the debate period of a game trial.

Minuteman 1: What is interesting is that you are a loyalist woman. Who did you get to talk to?

Loyalist 1: Essentially loyalists, soldiers in the King's troops, and the drummer William Diamond. They were all blaming it on

the rebels or the Minuteman.

British Soldier 1: Did any of you talk to Margaret Winship?

Slave 1: Yes, we did. In the first part she said, "Stay away from me slave, she was mean to us."

Loyalist 1: We talked to her in the beginning, and she had seen Daniel Murray talking with the members of the Kings regiments by the schoolhouse.

British Soldier 1: You are a loyalist? How was she described to you? Oh, [Margaret Winship] said it was probably some drunken Lexington townsmen and shot at.

Minuteman 1: Daniel Murray said that Sylvanus Woods was a spy for the King, and that Paul Revere is not trustworthy. That confirms what we found with what [British Soldier 1] found.

British Soldier 1: It was Daniel Murray who said that it was hard to tell who fired the first shot because there were two shots at once.

Minuteman 1: He is also suspiciously hanging out with the King's Regiment.

Thus, during the debate, participants were freely verbally communicating their views, presenting their evidence, and listening to other's ideas. AR games can provide opportunity for collaborative exchanges or debates, where participants can trade theories and reflect on their own conclusions, which can further ensure the practice of critical communication skills.

5.4 Critical Thinking and Problem Solving Skills

In RtR, participants collected evidence (by walking around Lexington and retrieving data using the GPS-enabled handheld device), analyzed information (discussed and interpreted the evidence with a partner, categorized it on the notes sheet), decided next steps (chose how to navigate the game environment), selected other participants to ask for information, made hypotheses (offered mini-conjectures as they collected evidence), collaborated with others to formulate bigger hypotheses, and drew informed conclusions. In other words, they didn't just collect data; they also interpreted it and related it to other data. Said one participant, comparing it to what she normally does in her middle school history class: "A history class is like data, but this was like data and then you had to interpret or analyze it on top of it."

To solve the game's objectives, participants needed to be critical thinkers; they had to identify biases in the evidence, question authorial intent, relate information to other data, and respect the limitations of their interpretations. Moreover, they had to be problem solvers: they needed to frame the game's objectives, pull apart the problem into smaller issues, identify and evaluate potential solutions, and decide how to tackle novel challenges.

For example, in the following exchange in a debate of a game trial, two paired participants reflect on the thought process that led to their current hypothesis. Then, another participant offers a corroborating piece of evidence, but the first participant uses her role's perspective to explain the biases in the other's evidence, even though it would further support her beliefs:

Participant 1 (British soldier): There wasn't one piece, but it was the mentioning of one name over and over again. Like, you can never really trust one firsthand account, because of course they are going to be biased by their side. But if you get like four or five people mentioning Edward Mitchell. It kinda leads you to believe that he did something...

Participant 3 (British soldier): We found a hat that had been marched on. So that probably means that... the British were in pursuit, that they probably came here looking for a fight, they were willing to pursue it.

Participant 2 (Slave): Like whenever we found a British person, they were too busy to talk to people, they were only busy looking for something and doing something.

Participant 1 (British soldier): Well that could have been you. You are a slave and a Minuteman, so I don't think they would have talked to you anyways, *(looks for evidence on the handheld)* because a lot of British people talked to us because we were British. This guy said, "Those Lexington Minuteman asked for it. The Minuteman were out for revenge. They should surrender."

RtR enabled participants to analyze realistic evidence, and solve an actual question from within a historical, social and geographical context. This encouraged participants not only to practice critical thinking and problem solving skills, but to view their actions as authentic, thereby motivating them further and strengthening their ability to apply these tasks and conceptual frameworks to other situations. AR games, when based on authentic data and using realistic questions and tasks, can possibly support critical, analysis, and problem solving skills.

Figure 6: Two participants look at a monument on Lexington Common, with Minuteman Captain John Parker's words, "Stand your ground. Don't fire unless fired upon."

5.5 Enthusiasm, Creativity, and Curiosity

RtR seemed to encourage engagement in the gameplay and enthusiasm for history and historical thinking. It even inspired creativity; participants devised novel narratives or innovative connections among data, many that I had not planned or predicted. Participants seemed very motivated to seek out new information and even help each other learn. They excitedly shared their findings and interpretations of evidence with others, and were particularly curious after the game ended to find out who actually fired the first shot. A few elements of RtR may have supported this:

First, the open-endedness of the game enabled participants to uncover and develop their own game narrative and solution. Participants enjoyed feeling agency over the game. Related to this, the "history mystery" aspect of the primary objective motivated participants to figure out who fired the first shot. Said one participant, "Once you got that first testimonial, you just want to keep on going to find out who it actually is."

Second, retrieving information using a handheld device and continually finding new "hot spots" lent novelty to the game and, said one participant, "mimicked the process of discovery." Another participant noted that, "the thing we had the most fun with on our team was 'oh were getting closer, oh we found one,' the wandering and finding" of the hot spots.

Exploring a physical location also motivated participants to learn more, and engaged them further in the game. For instance, one participant noted that the walking around made the game "more engaging and more interactive," and another said that the best part of the game was "getting to know a physical site.... [was] the excitement of the game." Many others also commented on how the ability to

walk around Lexington was the most important distinguishing feature of RtR as opposed to playing, for example, a virtual Lexington game at their desktop. Said one participant, "It helped me get a better sense of the historical site itself by actually being there. Students could get a sense of the historical site itself by walking around and seeing the places and imagining where these things took place. It is still better than the substitute of a virtual game." Similarly, the participants especially enjoyed being able to actively walk around and learn, rather than sitting passively in a classroom.

Participant 1: Yeah, if we sat in a classroom and did this and I would walk away and be like "Yeah, okay."

Participant 2: But when you are actually moving around to do it.... I think it's definitely more interesting to do it this way than to sit in the classroom.

Inhabiting a role also motivated participants, not only because other participants relied on them, but also because it made them curious about what information other roles were receiving. One participant noted that when she met virtual historic figures who were slaves, she thought, "oh, I wonder how [our evidence] is different from what the slave role is getting ... I wonder how she is talking to me is different from how she is talking to them" (Figure 7).

And finally, the AR game increased enthusiasm by enabling more social interactivity and collaboration among participants. Said one participant, "I think that the social aspect of being here together in Lexington ... made it much more enjoyable." Participants were excited to share their hypotheses with others and bounce ideas off their peers. They looked forward to collaboratively uncovering the overall mystery by comparing evidence and re-evaluating their own beliefs with others' perspectives. An AR game may be particularly suited to supporting these elements, and therefore, may be able to encourage the enthusiastic practice of 21st century skills.

5.6 Consideration of Multiple Perspectives

While collecting evidence in RtR, the participants experience the Battle of Lexington and interact with the virtual historic figures and items from unique, distinct historic roles or lenses. Then, during the debate, the participants share, compare, and evaluate their own and others' perspectives to devise the best hypothesis for what happened at Lexington. Therefore, the game play, such as the inclusion of roles, the collective debate, and the role-specific information, all support the participants' consideration of alternate views on the Battle of Lexington. Moreover, by using an open game environment with simultaneously accessible diverse views, rather than textbooks or other traditional pedagogical methods, to express the various perspectives and information, RtR encouraged critiques and revisions of master narratives of the past, making participants more open to new ones.

The trials suggested that participants more aware and accepting of others opinions and viewpoints. For example, said one participant, "I learned about all the different sides. Normally you would just think of the American soldiers and the British soldiers, slaves, the wives, the Minutemen, there are people frustrated here for personal reasons, patriotic reasons, You get a sense of the different roles of that time period." Another participant noted that reading the diverse historic figures' testimonials, "gives you a larger point of view about what happened." Echoing this, a participant commented in the focus group that, "In the [pre-game survey] you are asked who fought in the Revolutionary War, well its the British vs. the Americans. Then you realize it's not just the British and the Americans, it's the British army against the rebels, slaves, and everyone has their own agenda." After the game, it seemed that the participants began to have a more complex, nuanced understanding of the various points of view of the historic moment of the Battle of Lexington. They did not just interpret the tensions involved in the Battle as a simple dichotomy, but as a more multi-dimensional
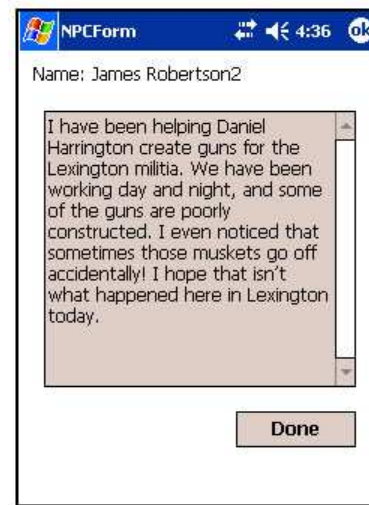

Figure 7: An example of a testimonial of a virtual historic figure or NPC. In this testimonial, James Robertson, a slave in the town of Lexington, is speaking to the slave role in RtR.

issue with many factors involved. Furthermore, AR can express a variety of views by emphasizing or suppressing certain roles, suggesting that it can be used as a powerful tool for exploring, simulating, and teaching multiple perspectives and the acceptance of alternative views.

5.7 Teamwork and Collaboration Skills

In RtR, there are many opportunities for participants to practice interpersonal and teaming skills, such as the sharing of resources, the communication of expectations and opinions, division of labor, leadership, and role-playing. The physical nature of RtR may increase the game's collaborative potential—sharing a location-based game environment encouraged participants to interact socially—but the game play also seemed to strongly support the practice of these skills. First, the participants can play the game in pairs and share information with other pairs. And, the participants interact frequently during the debate period. As a result, throughout the game, participants experimented with different collaboration styles, traded off responsibilities, and took turns as the leader. Said one participant, "It was fun to play with others, one, to have someone to help with the handheld/taking notes, and two, just to have someone to bounce ideas/theories off," while another enjoyed being able to "exchange ideas, notes, plan what to do next" with a partner. Because the game play necessitated dialogue and sharing of evidence, the participants needed to continually share their views and interpretations, debate hypotheses, and agree on next steps. The interdependence of roles in terms of distinct evidence led to broader group collaboration and a non-competitive spirit. For instance, often participants would ask other pairs questions such as, "Did anyone else get to Paul Revere?" or "Did you hear anything about the trunk?"

The playing of a role also helped participants adapt to and empathize with others' views, while helping them more closely bond to their game partner. Because participants were playing the role in pairs, they immediately formed a connection since they inhabited a shared identity. Moreover, collaboration encouraged participants to try out new ideas and identities, and digest and retain the information more deeply. This suggests that AR games can be designed to weave in multiple scenarios that reinforce the practice of collaborative and teamwork skills.

5.8 Self-Direction, Responsibility, and Reflective Learning Skills

In RtR, there were no pre-established game endings or narratives; instead, participants made their own hypotheses and discoveries, monitored their own learning, set personal goals, and controlled the pace of their play. Empowering participants with a sense of responsibility and setting appropriate and flexible boundaries helped motivate the game participants. RtR places participants in a safe game environment where they can more easily break apart these narratives and play with their own theories. Said one participant, "I liked the sense of control over the learning experience that one has, you had the ability to take your own pace and navigate through [the game and Lexington], thinking 'oh, I forgot about this, let me go back and check that out.'" This encouraged the participants not only to collect evidence, but then to question and reflect on their interpretations, and creatively back up their novel claims about the past. They began to see themselves as valid interpreters and conveyers of a past moment.

For one participant, through a self-directed construction of her learning and a possibly new sense of entitlement, she was able to delve more deeply into the historic moment, as well as the game itself. She said, "in [this game] you had to put it together, you had to research and then figure something out for yourself. It wasn't like a set [answer] like 'you have to click on this conclusion now.' You have to come up with whatever."

The debate also helped encourage group and individual reflection on the learning process through, for example, peers' queries into each other's interpretations. By helping to frame questions and pose questions at appropriate points during the debate, I was also able to encourage participants to further reflect on the game's issues. This further supports the idea that AR games do not replace teachers; instead, they are necessary to ensure that learning objectives are met and to add yet another perspective to the mix. On the other hand, while it is imperative to properly scaffold the gameplay and learning, it is also essential to let participants make mistakes, be self-reliant, solve snags, transgress boundaries, and experiment with ideas. AR games, through a balance of freedom and constraints, can provide agency to the participant, and possibly strengthen self-directed learning and reflection skills.

5.9 Social, Global, and Community Awareness

RtR encouraged the participants to reflect on their reconstruction of the Battle, and also to think more deeply about their preconceived notions and myths of the Revolutionary War, and history in general. Participants became more aware of diverse viewpoints, the involvements of different historic figures, the interrelation of economics, geography and politics, and the spectrum of agendas for the various townspeople and soldiers. Participants began to consider what textbooks offer as opposed to original sources, as well as the perspectives missing from dialogue on global issues. For example, in the following exchange, one participant expounds on the problems of bias in the testimonials of the NPCs in the game, and relates it to an international issue:

Participant 1: The textbooks always focus on one side, and with this you got both sides of the story.

Participant 2: In America, we have American textbooks and they are written by Americans, so of course you always get that portrayal of the British as being the bad guys and I'm sure the British kids when they learn about this, it's completely different. It's either that the Americans are the bad guys, and like of course it's going to be different depending on what side your country is on. The same with Iraq, people are going to in years to come when we read about that in textbooks it is going to be different.... Everything is controlled by some higher powers so of course it's going to be biased.

In RtR, participants take their more multifaceted understanding of the Battle of Lexington historic moment, and start to relate to other situations and even global social problems and complexities. AR games can present multiple dimensions of an issue in an authentic and compelling way, which can potentially motivate participants to apply this to other problems and disciplines.

6 Conclusion and Next Steps

In this paper, I explored a potential activity for teaching 21st century skills that could be part of a broader social studies curriculum. The results of my initial tests suggest that an AR game such as RtR can engage learners in an authentic practice of critical 21st century skills, if designed and implemented properly. In this unique game environment, participants were able to manage and navigate vast amounts of data, fluidly analyze and communicate among multiple modes of media, apply visual analyses to images and objects, try out various leadership and collaborative styles, identify biases in evidence, refute others' claims using found data, reflect on one's learning process, construct one's own narratives and hypotheses, adapt, play, and experiment. Moreover, participants took this learning and applied it to other situations, and began to consider multiple perspectives or alternative viewpoints in their interpretation of issues. Most importantly, RtR seemed to motivate an enthusiastic and engaged practice of these skills, and perhaps, helped the participants recall and apply them more easily.

Further, these results suggest that AR games can be motivating, fun, and engaging environments for learning 21st century skills. AR games seem to have the potential to make large amounts of information more navigable, intriguing, and memorable by mapping it to specific geographic locations. It provides an authentic learning field where participants can work on realistic problems while interacting with other participants, the physical environment, and actual data. It seems to support collaborative styles, self-determined constructions and evaluations of knowledge, reflection, creativity, curiosity, novelty, and discovery.

My hope is that researchers, game designers, and educators will experiment with AR games and other pedagogical approaches to find engaging ways to support 21st century skills. We need more research conducted on AR games in other locations and environments, concerning other types of problems, and using a variety of content. We must consider how best to incorporate AR games into more traditional pedagogy, and how to support AR with teachers, mentors, and guides. Finally, we need to invite students to design these games alongside educators. By encouraging them to be media creators, we can help students participate in and feel responsible for their own educational processes; and hopefully, to contribute critically to their local and greater global communities.

Acknowledgements

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