

## Collaborative Learning through Augmented Reality Role Playing

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**Abstract.** This research investigates the potential of Augmented Reality (AR) technologies, specifically handheld computers, to create an emotionally compelling, rich context for collaborative learning. Building on work in collaborative learning, we sought to design games requiring positive interdependence, promotive interaction, individual accountability, interpersonal and small group skills, and group processing. While the collaboration within groups was strong and successful in the first generation AR games, the collaboration between groups was limited or non-existent. Several new game play elements added to a new engine created a more dynamic game play experience. These features included time dependence, cascading events and distinct player roles. In subsequent iterations of AR games, we have found these new features to be effective at fostering collaboration, which in turn scaffolds a more authentic investigation process

**Keywords:** Handhelds, games, simulations, role play, PDA

### INTRODUCTION

Handheld computers make possible new kinds of field investigations where learners collect data, access authentic tools and resources, and participate in collaborative learning practices while in the field (Roschelle & Pea, 2002; Soloway et al., 2001). Whereas traditional desktop VR applications or 3D gaming technologies such as MUVes (e.g. Dede et al. 2004) burden the developer and computer with representing 3D, augmented realities exploit the “3D” characteristics of the real world, and instead provide users with layers of data that augment their experience of reality. As a result, simulations are untethered from the desktop and learners can physically and actively participate in technology-enhanced investigations, location-based games, or participatory simulations. Because players are free to move throughout the world, novel opportunities exist for learners to interact with the physical environment, literally reading the landscape as they conduct environmental investigations or historical studies. This also frees up students to communicate and collaborate in natural ways. Students can talk and communicate with body language as they do everyday, rather than investing effort in developing communication skills relevant only within a purely virtual world. In sum, by integrating more of the real world, handhelds can create experiences that differ in significant ways from more traditional desktop computer based environments.

Leveraging design techniques from role playing games (c.f. Gee, 2003), we believe that opportunities exist for immersive gaming environments to recruit players into assuming new identities as environmental investigators, scientists, and environmental activists, thereby encouraging them to adopt epistemic frames that might be ideal preparation for future learning (c.f. Schwartz & Bransford, 1999; Shaffer, 2004). This research is investigating the potential of Augmented Reality (AR) technologies to create this kind of emotionally compelling, rich context. AR devices superimpose a virtual overlay of data and experiences onto a real world context. Early work on AR (Klopfer et al. 2002, Klopfer & Squire 2003, Falk, et al. 2001; Waltz 2002) indicates that AR simulations can be designed not only to support learning disciplinary content knowledge, but also to provide opportunities for students to develop critical 21<sup>st</sup> century IT skills including collaboration and information sharing, managing uncertainty, and analyzing complex systems (c.f. Beck & Wade, 2004). While initial trials of this technology are broadly discussed elsewhere (c.f. authors, in press), this study focuses on the design for social interactivity (or sociability), and how this is designed into the software and emerges during game play. When designed correctly, they can present authentic problems, give students access to investigative tools, and structure experiences to foster collaboration. Using a design narrative technique (c.f. Hoadley, 2002), this study seeks to provide an account of a research project over several design iterations that might illuminate the tensions behind designing for collaboration. Building on work in collaborative learning (e.g. Johnson, et al.

1994), we sought to design challenges (or games) requiring positive interdependence, promotive interaction, individual accountability, interpersonal and small group skills, and group processing (See Table 1)

<i>Positive interdependence</i>	Group members perceive that they are linked with each other so that one cannot succeed unless everyone succeeds.
<i>Promotive interaction</i>	Students promote each other's success by helping, assisting, supporting, encouraging, and praising each other's efforts to learn.
<i>Individual accountability</i>	Each individual student's performance is assessed and the results are given back to the group and the individual.
<i>Interpersonal and small group skills</i>	Interpersonal and small-group skills required to function as part of a team (teamwork)
<i>Group processing</i>	Group members discuss how well they are achieving their goals and maintaining effective working relationships



Figure 1. A screen shot of a handheld AR game (left) and 2 players conducting an AR investigation (right).

## GENERATION 1 – ENVIRONMENTAL DETECTIVES

Our first AR simulation, Environmental Detectives (ED) (Klopfer et al. 2002), engaged high school and university students in a real world environmental consulting scenario constructed to immerse players in the practices of environmental engineers, giving them a “virtual practicum” experience, similar to working on an environmental research team. Students role play as environmental scientists investigating a rash of health concerns on site linked to the release of toxins in the water supply, a scenario loosely based on actual historic situations. The main focus of the game was on planning an effective investigation that balanced quantitative and qualitative data.

Working in teams of two or three, players attempt to identify the contaminant, chart its path through the environment, and devise possible plans for remediation if necessary. As students physically move about campus, their handheld devices respond to their location and show their current location on a bird's eye view map, allowing them to collect simulated field data from the water and soil, interview virtual characters, and perform desktop research using mini-webs of data. At the end of the exercise, teams compile their data using peer-to-peer communication and synthesize their findings into case reports.

The problem space of ED is quite vast. By design, no one player can obtain all of the requisite information in the allotted time, and teams had to work with each other to collect data and come up with solutions. Each team had one Pocket PC, one walkie-talkie, a printed map and a notepad. Teams typically assign one player to the Pocket PC/map, and another player as notetaker and/or communicator. This promoted strong collaboration within teams – forcing players to work together effectively for navigation and planning. In most cases players were not specifically instructed to either collaborate or compete with the other teams in the game, but to use their judgment in order to devise the best solution and provide the strongest evidence. By creating this large physical space, which can easily be geographically subdivided, we were most strongly emphasizing positive interdependence. It should be noted that in ED, there is no “role” differentiation among players and, since all players are using the same software, they can potentially access the same information at the same time. Table 2 (below) depicts the components of Environmental Detectives designed to promote collaboration.

<i>Promotive interaction</i>	Moving in physical space, students working collaboratively can cover more ground and share information by looking at each other's screens. One group's information is often evaluated on the spot by other groups.
<i>Individual accountability</i>	Each pair of students is responsible for presenting their case to the class at the end of the experience. This is often supplemented by written arguments.
<i>Interpersonal and small group skills</i>	Groups of students communicated via walkie-talkie to share information or pool data.

<i>Group processing</i>	A classroom/lab space provides a shared location where students could plan next steps, assemble evidence and ultimately present their case to the class.
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Nearly a dozen classes have run through ED. Here we examine collaboration within and across teams, one an environmental science class from a suburban high school, and the other a chemistry class from a private all-girls high school, both in the Boston metropolitan area. Through these runs we have found that collaboration within the teams was quite strong. Both groups of students collected interviews and used sampling, though how much weight they gave to these qualitative (interviews) and quantitative (sampling) activities varied greatly.

*Suburban High School.* Looking at one team of three students towards the end of their investigation, they start to evaluate what they know, and they grow concerned that they do not have enough information to make a compelling case about the toxin. We pick up the discussion as they decide what to do next:

Louis: My socks are so wet.  
 Camera: We should head back soon.  
 Gina: Yeah, it is 12:50.  
 Louis: How far away is the thing [place they should return to]?  
 Gina: Where do we have to go again?  
 Stacey: Alan Morgan center? That is...  
 Louis: [Looking around]. Not around here.  
 Stacey: Right here [points at paper map].  
 Stacey: How are we supposed to make recommendations?  
 Gina: I don't know.  
 Louis: Just read off of the information that we got.  
 Gina: I thought we could dilly-dally but we actually did work.  
 Louis: For once.

One of the defining characteristics of the experience was a constant shifting of goals. Students were expected to manage their problem solving, reframe the problem as new information became available, and in short “work” toward finding a solution. Much of this work, however, emanated from an “acquisition” metaphor of knowledge. Perhaps influenced by the field trip nature of the experience, some students thought the goal was to acquire as much information as possible and then develop the right answer. Here, late in the experience, they begin to understand that developing an answer requires negotiating and synthesizing information. Although this group shared a lot of information and fluidly navigated multiple information spaces, much of their collaboration centered around game mechanics, and less around collaborating to work through scientific dilemmas.

Evidence of collaboration between teams of students is sparser. During this run, several groups tended to frame the activity as akin to a scavenger hunt, with little consideration as to the significance of the information contained within each of these interviews.

*Private Girls' School.* Another class with previous experience in collaborative problem solving divided the problem space and worked together to efficiently solve the problem. The facilitator began by asking students what they knew, what they needed to know, and asked them to make a plan. The groups went out and collected data, and, mid-game, decided to pool resources and see what they had learned so far.

Two girls stand at the board and add to the list of facts already started earlier in class. A map is passed around the room, and students add where they found their toxins. To those familiar with knowledge building communities (Scardamalia & Bereiter, 1991) or jigsawing (Brown & Campione, 1996), the scene was quite familiar. Each student was adding what she knew toward building a more holistic view of the problem. What was particularly noteworthy about this session is the way that the facilitator quickly receded into the background. While she drove much of the initial conversation, students quickly took ownership of the problem and coordinating the discussion. For evidence typical of this, one student, Miranda interrupted the conversation:

Miranda: Before we go back out, can we go through the names of all the interviews and make sure that everyone's hit one at least?

We highlight this case not only to show how the task, designed to be unsolvable by any one person, *could* elicit coordinated problem solving actions, but also to show how the game activity is not solely a property of the software or design, but an interaction between the software design and the existing classroom culture.

## GENERATION 2 – CHARLES RIVER CITY AND MAD CITY MURDER

While the collaboration *within* groups was strong and successful in the first generation AR games, the collaboration *between* groups was limited or non-existent, except in the last case, which showed that promoting collaboration at a larger scale requires providing additional scaffolding for collaborative learning. In order to promote greater collaboration between the teams, the core engine for our AR games was redesigned. From this redesigned engine two new games were created – Charles River City (CRC), which combines environmental science and epidemiology to create a large scale investigation, and Mad City Murder (MCM) which uses the

ED premise to create a mystery investigation. These games tap new features that were introduced into this engine including time dependence, cascading events and distinct player roles. The time dependence, which made the game change over time, and cascading events, which allow events to trigger other events, were added to provide a richer experience. Distinct roles were added to promote greater collaborative learning between teams.

Distinct roles added several key elements. First, players receive different information from virtual characters depending on what role they are playing. For example, a virtual character who is feeling sick might give a player in the role of "nurse" different information than she would give to the "detective". Second, roles have different data collection capabilities allowing them to collect unique types of samples or access unique kinds of data. For example, an environmental scientist might have access to water sampling equipment, whereas a medical doctor might be able to access medical records or get vital signs from virtual characters. Finally, since roles can access different information, players can use infrared beaming to exchange information between players. For example in CRC, a character reveals information to the "detective" about a student who has fallen ill. The "detective" must then beam that information to the "nurse", so that the "nurse" can interview the player and examine the specific symptoms and what might be causing them. Reconsidering the criteria for promoting collaborative learning, we see how these new game play elements have enhanced the potential for larger scale collaborative learning.

<i>Positive interdependence</i>	Each team's information is explicitly described to them as only a small piece of the puzzle, and they need information from other roles to solve the problem. This sharing is facilitated by the infrared beaming of information.
<i>Promotive interaction</i>	Students encourage players in the other roles to go out and get information that they know they need but cannot get themselves.
<i>Individual accountability</i>	Each role has access to unique information, necessary to solve the problem. Players know which role has access to the information that they need.
<i>Interpersonal and small group skills</i>	Sharing of information across teams via the infrared beaming becomes a point of instruction on how to share information and collaborate across teams.
<i>Group processing</i>	Groups could "divide and conquer" – with roles dispersing to find information and regrouping to exchange information at planned times or ad hoc, or move around in multi-role groups. Both strategies require getting together and planning how to move forward.

In subsequent iterations of AR games, we have found these new features to be effective at fostering collaboration, which in turn scaffolds a more authentic investigation process. The fact that sharing information could reveal new things encouraged frequent digital exchanges, which were accompanied by pertinent discussions of game progress. Here is a typical exchange of middle school students from an urban school in the Boston metropolitan area playing CRC. In this particular version, there are three roles – a doctor who can take people's vital signs and symptoms, an environmental scientist who can take samples from the water and air, and a department of public health expert who has access to hospital records and epidemiological data.

Manny: I got a document that says that says West Nile Virus has the most serious effects on people over 50.

Jane: So ... the doctor might be the one that wants to talk to Salvadore [previously identified older patient] since he can get his health information.

The doctor goes to the location where Salvadore is and takes physical exam. A player in another role (Department of Public Health official – DPH) also goes along.

Sal [Doctor]: I was right! He has all of the symptoms of WNV [West Nile Virus].

Tricia [DPH]: [Radios to whole group via walkie talkie] I found Salvadore!

Sal: [Via walkie talkie] He has all the symptoms that he carries for WNV.

This collaboration between groups continues on into the classroom where they are making their recommendations on what to do about the problem. Each one of them contributes information that they got on the topic specific to their role (Environmental Scientist – Env).

Dave [DPH]: I found that West Nile Virus can make you really sick.

Tricia [Env]: Mosquitoes are all over the world so it is dangerous.

Manny [Env]: Not right now. Since it is fall there aren't many mosquitoes out. Only in spring and summer.

Jose [DPH]: Julia [a character] said that an elderly man complained of swarms of mosquitoes.

Kim [Doctor]: We found the old man [Salvadore] that complained of symptoms that could be WNV.

Dave [DPH]: There might be enough mosquitoes where it could still be a problem.

Manny [Env]: So get rid of the ones that are there.

Dave [DPH]: Get rid of all of the water that is standing around like in old tires.

As seen in the above dialog, the different roles have different perspectives and different pieces of the puzzle. This encourages them to collaborate, which progresses into other forms of collaboration and discussion as they attempt to solve the problem at hand.

## FUTURE DIRECTIONS

One of the key design considerations for the different roles within the AR games is how much overlap there should be between the roles. Too much overlap between the roles will remove the positive interdependence and individual accountability that encourage collaboration. However, too little overlap does not give the students enough common ground to discuss the problem space. We have found that when students access the same information, it serves as a promotive interaction – reinforcing students that they have done well. It also gives them a point around which they can begin discussion. They start piecing the puzzle together around the common pieces and then work towards their own unique contributions. As in the CRC example, all of the students learned that West Nile Virus was a serious mosquito borne disease, but only certain roles were privy to the seasonality, the current levels, or the symptoms. In our next phases we will study how increasing and decreasing overlap can affect learning outcomes, and how role interdependence relates to both subject matter and student experience.

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## REFERENCES

- Beck, J. & M. Wade (2004) *Got Game: How the Gamer Generation Is Reshaping Business Forever*. Harvard Business School Press, Cambridge, MA.
- Brown, A.L., & Campione, J.C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289-325). Erlbaum, Mahwah, NJ.
- Dede, C., Nelson, B., Ketelhut, D.J., Clarke, J. & Bowman, C. (2004). *Design-based Research Strategies for Studying Situated Learning in a Multi-user Virtual Environment*. Paper presented at the International Conference on the Learning Sciences, Los Angeles, CA, June.
- Falk, J., Ljungstrand, P., Bjork, S., & Hansson R. (2001). Pirates: Proximity-triggered interaction in a multi-player game." *Extended abstracts of computer-human interaction (CHI)*, ACM Press: pp. 119-120.
- Gee, J. P. (2003). *What Video Games Have to Teach Us About Learning and Literacy*. Palgrave Macmillan.
- Hoadley, C. P. (2002). Creating context: Design-based research in creating and understanding CSCL. In G. Stahl (Ed.), *Computer Support for Collaborative Learning 2002* (pp. 453-462). Lawrence Erlbaum Associates, Mahwah, NJ.
- Johnson, D.; Johnson, R.; and E. Johnson Holubec. 1994. *The New Circles of Learning: Cooperation in the Classroom and School*. Alexandria, VA: ASCD.
- Klopfer, E. & Squire, K. (2003). Augmented reality on PDAs. Paper presented at the annual meeting of the *American Educational Research Association*, Chicago, IL, April.
- Klopfer, E., K. Squire and H. Jenkins. 2002. Environmental Detectives PDAs as a Window into a Virtual Simulated World. Paper presented at *International Workshop on Wireless and Mobile Technologies in Education*.
- Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change CSCL. *International Journal of Cognition and Technology*, **1**, 145-168.
- Scardamalia, M. and Bereiter, C. (1991). Higher Levels of Agency for Children in Knowledge Building: A Challenge for the Design of New Knowledge Media. *The Journal of the Learning Sciences*. **1**37-68.H
- Soloway, E., Norris, C., Blumenfeld, P., Fishman, B., Krajcik, J. & Marx, R. (2001, June). Log on education: Handheld devices are ready-at-hand. *Communications of the ACM*, **44**, pp. 15-20.
- Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of Research in Education*, **24**, 61-101. Washington DC: American Educational Research Association.
- Shaffer, DW (2004). Epistemic frames and islands of expertise: Learning from infusion experiences . In *Proceedings of the 2004 International Conference on the Learning Sciences (ICLS)*, Los Angeles.
- Walz, S. (2002). On the Move between Proximate Distance and Distant Proximity. Master's thesis published by the University Tuebingen, Germany, Dept. of Cultural Anthropology, and commissioned by the University for Art Media and Design Zurich. University Tuebingen, Germany.