From Information to Experience: Place-Based Augmented Reality Games as a Model for Learning in a Globally Networked Society

KURT SQUIRE

University of Wisconsin-Madison

Background/Context: *New information technologies make information available just-in-time and on demand and are reshaping how we interact with information, but schools remain in a print-based culture, and a growing number of students are disaffiliating from traditional school. New methods of instruction are needed that are suited to the digital age.*

Purpose/Objective/Research Question/Focus of Study: *The purpose of this study is to explore how curricula that are designed to capitalize on the affordances of mobile media might be employed in schools.*

Population/Participants/Subjects: *The study took place during a 2-week unit in a poor urban school district with roughly 50 at-risk middle school students. The partnering teacher adapted the model curriculum, which involved students investigating a rash of illnesses originating from a popular local beach. This qualitative case study, derived from field notes, videotapes, interviews, and document analyses, describes the practices that emerged and the strengths and limitations of the curriculum. From a classroom management perspective, the narrative elements of the unit enabled teachers to create a dramatically different classroom culture, one that was built around students performing as scientists. Students' performance was heavily dependent on the kinds of inscriptions that they made to organize data, suggesting the importance of designers developing tools to scaffold learning, but also suggesting trade-offs in having students struggle to organize information versus doing it for them. Most noteworthy to teachers was how the technology-enhanced*

Teachers College Record Volume 112, Number 10, October 2010, pp. 2565–2602

0161-4681

curriculum enacted students' identities as problem solvers and knowledge builders rather than as compliant consumers of information, reinforcing for them the schism between what is expected of students in school and how they interact outside of school. Teachers and students lamented the lack of opportunities to actually participate in community issues beyond the classroom, suggesting that the future of such curricula may reside in building community-school-home partnerships.

New information technologies have the potential to improve learning, but they also threaten the current order of schools. Students are bringing more and more digital technologies (such as iPhones) with them to school, creating disruptions between the social order of the digital world and the print-based one of schools. Recent news headlines tell of students using cameras to digitize tests and send them via e-mail, or using Internet-enabled cell phones to cheat in any number of ways (Clark, 2006). Outside of school, term papers are freely available online (or can be custom ordered), students divvy up homework assignments in chatrooms, and students use the Internet to exchange information. Meanwhile, in school, our reaction has been to ban these technologies or severely restrict their access. Librarians, educators, and parents acknowledge that they are two steps behind youth in understanding what is happening right now with these technologies, let alone understanding what *could* be done (Leander & Lovvorn, 2006; Levin & Arafeh, 2002). Ironically, we have invested millions of dollars outfitting classrooms with hardware, yet schools appear unprepared to handle the social upheaval that accompanies the new technologies (Cuban, 1986).

The potential educational benefits of such technologies, particularly communication technologies, are becoming well documented (Barab, Hay, & Duffy, 1999). Internet access connects students not only to information resources but also to online professional communities that can dramatically expand students' social networks (Steinkuehler & Williams, 2006). Cell phones and Web communication technologies could facilitate tele-apprenticeships, making possible the age-old dream of breaking the walls of the classroom (cf. Barab et al.; Squire & Johnson, 2000). Simulation technologies allow students to experience entire worlds otherwise unavailable (Squire, 2006). Indeed, as portable computing technologies such as the iPhone increase in popularity, educators face the reality that students will be coming to school with these technologies in their pockets, whether we like it or not. How will schools react to this disruptive technology? Will we continue to ban these technologies, or will we come up with pedagogical models that leverage students' constant connectivity?

From an information technology perspective, these technologies create at least two crucial disruptions: instantaneous access to information, and persistent access to distributed networks of expertise. First, most schooling is built on what Perkins (1992) labeled the "trivial pursuit" phenomena. Schools generally require and reward broad, superficial knowledge of facts (cf. Bransford, Brown, & Cocking, 1999). Digital communication technologies have made a mockery of such trivial pursuit tests, because anyone with a $200 Internet-enabled cell phone can locate almost any trivial pursuit-style question within seconds. Outside of school, when knowledge workers need information, they instant message, text message, or telephone someone with that expertise. In an age of instantaneous information access, what matters most is deep conceptual understandings that situate facts within a framework (and serve as a basis for evaluating information), enable participation in argumentation within different discourses, and support creative problem-solving (Gee, 2007; Hagel & Brown, 2005; Kuhn, 2005; Lemke, 1990).

Second, whereas today's technologies enable deep, multifaceted modes of collaboration, schools suffer from a fetishizing of what Bransford and Schwartz (1999) called "sequestered problem-solving": one's ability to solve problems while (usually) sitting alone, with a pencil and perhaps a piece of scratch paper (see also Brown, Campione, Webber, & McGilly, 1992). In most every other knowledge working sector, expertise is defined by one's ability to identify problems, mobilize resources to solve them, leverage social networks, communicate effectively, work over an extended period of time, and develop complex multimodal representations (Gee, Hull, & Lankshear, 1996; Reich, 1992). Today's digital technologies make this kind of problem-solving more accessible than ever. Students can access online databases of information to identify problems, leverage Web-based communities for knowledge, communicate via multiple modes, access groups inside and outside of school, and publish multimedia artifacts for public consumption—all on a hand-me-down laptop (and soon on a cell phone).

The disconnect between today's modern information technologies and the organization of schooling is striking, creating what Gee (2004) and others have called an indigenous critique of schooling (see also Bridgeland, DiIulio, & Morison, 2006; Games, Learning & Society Group, 2005/2007; Gates, 2005; Lemke, 1990). For the first time in history, a majority of high school students, even those succeeding in school, regard it as little more than accreditation. Meanwhile, the number of students dropping out of high school is reaching an all-time high, according to most reports, because "school is boring" (Baines & Stanley, 2002). Many educators fear that our school system is facing an impending crisis; in an increasingly globalized, networked world in which information *overload* is the problem, will students have the necessary problem-identification skills, technological expertise, underlying conceptual understanding, creativity, and ability to communicate via multiple forms of media that they need to stay globally competitive (Friedman, 2005; Partnership for 21st Century Skills, 2002; Shaffer & Gee, 2005)?

This article describes one instructional model, local augmented-reality games played on handheld computers, that explores what education for the interactive age should look like and suggests the new roles that communication technologies could play in this future. These games are played out in the world, in real space, centered on compelling, contemporary, and complex real-world problems; as such, they invite students to bring in what they know (and can find) about their worlds around them. Students use digital information technologies to access layers of simulated data and intrawebs of documents, suggesting how information technologies can be integrated into an environment rather than be in competition with classroom activities. This article is a case study of perhaps the first example of such a curriculum being integrated into classroom contexts with relatively little "researcher intervention" (cf. Squire & Jan, 2007). Drawing from observations, videotapes of classroom interactions, and interviews with teachers and students, it reveals some of the potentials and challenges of embracing video game-based learning as a model for education. The article concludes with implications for the changing role of information technologies in a digital era in which teachers and students may be creating, modifying, and maintaining curricular innovations via distributed communities of practice.

VIDEO GAME-BASED LEARNING IN THE INTERACTIVE AGE

Video game-based learning programs have emerged as a response to the demands of education in the interactive age. Video games are perhaps the clearest example of how digital technologies have ushered in what Lemke (2004) called an age of interactivity. Squire (in press) described this interactive age in terms of being built on technologies of simulation, being deeply participatory, and being based on the aesthetics of experience. Fundamentally, the computer affords the *simulation* of experiences (Baudrillard, 1994; Starr, 1994; Turkle, 2003); games are possible worlds that we explore (Squire, in press). These worlds elicit what Gee (2003) called projective identities—identities that are a melding of ourselves and our game identities, possible selves that the game invites us to inhabit. Second, digital media are deeply *participatory* (Jenkins, 2006). Digital tools have reduced barriers to media production (for example, Apple's

Garageband software is revolutionizing home music recording) and to media distribution (as in how the Web, compression, and iPods have revolutionized music distribution).

Finally, as an art form, digital media systems, especially games, are deeply *experiential*. They offer us the experience of leading a civilization, being a guitarist in the Ramones, or being the leader of a guild consisting of hundreds of players from all over the world. Designing learning environments based on these features could produce learning systems that better prepare students for future participation in the world.

Whereas literature, film, and television are generally thought of as storytelling media, games are perhaps better described as *worlds* (Squire, 2006).[1] Games consist of characters and narrative events tied together by underlying rule sets. These underlying rule sets, operating together with visual and audio representations, create systems of potential meanings for players. Because game rules enable and constrain actions, organizing the world in particular ways for players, games are ideological worlds, worlds that explore particular ideas or ways of being in the world.

As such, game play is a deeply *productive* act. Until recently, gamers have been depicted in popular media as either children or lone men in their basement, hunched over their keyboards.[2] These depictions overlook the profoundly social nature of game experiences. Whether it is on school buses or on Internet message boards, the meanings of games are deeply contested and negotiated socially. Consistent with sociocultural theories of learning, the meanings of particular games are legitimized through discourse groups (Squire, 2005, in press; Steinkuehler, 2006). Game companies of all sorts are paying increasing attention to these processes, designing features in games to serve as "fodder" for communities. With games like *The Sims*, in which players routinely create families and households that are shared with other players, the boundaries between the game and player community are blurred, with the game quite literally stretched across the player communities. As educators, a challenge is to develop forms of game play in which players' productive practices can align with curricular goals.

Although there is variance among game-playing communities and competing notions of what games are or should be, research is uncovering some common values underpinning gaming communities. In studying the video game *Lineage*, Steinkuehler (2005) found a meritocratic element in the culture, one that espouses equal access to resources but is quite comfortable with different outcomes. As part of this spirit, one's credentials, personal background, race, or ethnicity matters far less than one's ability to *perform*. Squire and Giovanetto (2008) described Apolyton University (an online community of *Civilization* players) as similarly meritocratic but constructed around a hybrid of (1) enculturation into a shared set of norms and practices and (2) a community of knowledge production in which players are expected to generate new knowledge and contribute to the shared knowledge base. Gee (2004), studying *Rise of Nations* groups, developed the notion of affinity spaces to describe such spaces as having a strong ethos of open access whereby people are encouraged to participate as fully as they wish regardless of personal background, credentials, or education.

INFORMATION RESOURCES IN VIDEO GAME-BASED ENVIRONMENTS

From an information-seeking and retrieval perspective, a game-based learning approach changes players' orientation to textual resources. Resources become tools that players mobilize in their pursuit of goals. This pragmatic, strategic orientation toward reading is one that literacy educators have sought to produce in schools, but unfortunately, the most strategic reading that students typically do involves reading for main points that will be covered on a test. In contrast, studies of game players have shown how players routinely use complex, technical texts in the service of game play in order to learn what they need. These texts include game manuals, in-game encyclopedias, game FAQs and walk-throughs, and complex texts embedded in games (Gee, 2003; Jenkins, 2006; Squire, 2005; Steinkuehler, 2007). Video games provide their players with situated experiences that they can draw on as they decipher complex texts. They can marry new vocabulary encountered in the process of game play to actions (Gee, 2007). Game contexts provide a purpose for reading and give readers an entry point into these texts. If games are helping students understand the nature of "strategic reading," they could also be valuable educational resources used to promote strategic reading in academic domains.

When viewed in the social context of gaming more broadly, gamers' consumption and production of texts is even more complex. In their pursuit of understanding game systems and traversal through a game, game players routinely produce and consume a variety of texts through both official and unofficial channels (Steinkuehler, 2005, 2007). One of the most intriguing developments in gaming is the ongoing symbiotic relationship between official, sanctioned developer-generated texts and those created by community members. Gamers facilely negotiate these channels, using each when appropriate (usually fan-generated texts are more thorough and up to date, although the nature of what information can be found on each is quite complex).

Many texts consumed and produced within game cultures are open source, or at least easily annotated and discussed by participants. The prototypical example at the moment is the array of information sites produced around the video game *World of Warcraft*. There is, for example, thottbot, a Web site that aggregates data uploaded from volunteers, which forms an online compendium of the *Warcraft* universe. Players annotate this information by clarifying ambiguous text or updating out-of-date or misleading information. Allakhazam and wowhead provide similar services. Finally, wowwiki, a wiki about *World of Warcraft*, is a more "traditional" wiki (online, user-contributed encyclopedia) that features over 40,000 articles about various *World of Warcraft* topics. Finally, there are literally thousands of posts made each day on a variety of official and unofficial forums. For example, popular forum posts on the official *World of Warcraft* might gather 300,000 views, with exceptional posts numbering close to 1 million (Steinkuehler & Duncan, 2009). Although it may seem counterintuitive to some, players invest in these forums "outside the game" because they are sites of collective intelligence; participating in and contributing to such sites allow them to know more collectively than anyone could individually (Jenkins, 2006).

The nature of discourse in these spaces is quite sophisticated, involving many advanced properties of scientific thinking (Steinkuehler & Duncan, 2009). For example, Steinkuehler and Duncan examined posts in the official *World of Warcraft* user forums and found that the overwhelming majority of activity was dedicated to social knowledge construction. Participants exhibited model-based reasoning, scientific use of evidence, and holding an evaluative epistemology (all goals of contemporary science educators; see Kuhn, 2005) at a much higher proportion than has been reported in either schools or in the American populace in general. These findings serve as further evidence that the level of discourse available to students outside of school in popular culture may be quickly eclipsing those available within schools. They also suggest opportunities for creating academic gaming out of the argumentation that naturally accompanies gaming.

Note that all these resources are "pro-am"—hybrid spaces that are neither professional nor amateur, but both, in that the underlying code and data-mining software are created by companies but rely on volunteers to actually gather the data. Players will genuinely go along with this, and even freely add thousands of pages of content that generate advertising revenue for the companies. Players make ethical judgments all the time about which of these for-profit databases they will support and which they will not. Consistent with the framework introduced here, the ethics of these decisions are frequently argued and debated within social groups (guilds or clans), with each group interpreting the ethics of these decisions a little differently.

Steinkuehler (2005, 2007, 2008) showed how at its advanced levels, game play literally becomes *producing* texts, with texts functioning as identity resources for their players. These texts might include fan stories, quest guides, or strategic documents. These same kinds of documents can also be found in first-person shooter clans, in competitive strategy games, and among single-player games through game FAQs. How to leverage this kind of productive text generation into academic gaming is a current challenge.

SOCIAL CONSEQUENCES OF GAMING

Research on people who self-identify as gamers suggests that prolonged participation in game cultures may lead to a more active, problem-solving orientation to learning. Beck and Wade (2004) surveyed 2,000 employees of large companies and found that gamers were more likely than nongamers to believe that challenges were solvable, were more driven to accomplish goals, were more confident in their abilities, cared more deeply about their organizations, preferred to be paid by performance rather than by title or salary, reported a greater need for human relationships, believed that connecting with the right people "got the job done more quickly," and preferred collaborative decision-making to independent problem-solving. Beck and Wade went on to argue that even if every member of the millennial generation is not a gamer (just as every baby boomer was not at Woodstock), these basic values are common to the generation and are among those that define them.

From both an educational and information technology perspective, the implications of Beck and Wade's (2004) findings are striking (see also Johnson, 2005, for a corroborating analysis); they suggest that the features and values of game-based learning communities articulated by Steinkuehler, Squire, and Gee are becoming, to some extent, adopted by their players and carried over into other endeavors. In contrast, as reviewed in the outset, schools are one of the last places in the knowledge economy where people must learn at the same pace, must take requirements before pursuing advanced topics, are not afforded opportunities to pursue their passions, have little access to any real experts within a domain, and must (usually) work alone. Perhaps it is little wonder that so many students see school as irrelevant to their lives (Baines & Stanley, 2002). In summary, changes in the media landscape appear to be an important factor influencing the disposition of a generation of students, and gaming technologies, when coupled with other digital technology, and media are changing how information technologies are produced and consumed (see Table 1).

Table 1. Learner Attributes and the Implications of Games for Information Resources

Learner Attributes[a]	**Information Implications**[b]
Believe challenges are solvable Goal-driven More confident Affiliate with organizations Prefer performance-based pay Value human relationships Value leveraging social networks Prefer collaborative problem-solving	Self-organizing learning Open source information Collective intelligence Redistributing power International Access to social affiliation Information resources used just-in-time and on-demand Negotiate official/unofficial Driven by personally meaningful goals Stems from interest or affinities Transmedia Knowledge makers

[a] See Beck & Wade (2004).
[b] See Squire & Steinkuehler (2005).

RESEARCH QUESTIONS

This comparative case study investigates the potential of local augmented-reality games played on handheld computers as a model for learning that leverages the engaging and educational features of video games. Previous research (Squire & Jan, 2007) suggested the potential of such games to engage students in scientific argumentation exercises, but little evidence suggests whether such technologies can be integrated into a typical academic curriculum. Thus, some questions remain: (1) Can such an augmented-reality game work within a school context? (2) What curricular experiences are effective in supporting game play? (3) What teaching practices are effective in supporting learning in this context? This study investigates students' and teachers' reactions to this unit, the kinds of understanding that emerged, and the challenges that exist in integrating such a curriculum into the school day.

RESEARCH METHODOLOGY

CONTEXT

This study was conducted as a subset of a broader study implementing this curricular unit in seven classrooms during the 2006–2007 school year (see Table 2). This particular school is a suburban-rural school consisting of mostly White (but mixed social class) students. One science teacher and one language arts teacher were paired to teach the unit, although they taught their classes independently.

Table 2. Participant Demographics

School	Teacher	Grade	No. students	Demographics
Olen	Ms. Jones, Mr. Simms	7	55	Predominantly Caucasian

A team of researchers collaborated with 5 teachers to implement a local augmented-reality game on handheld computers within a 2-week curriculum. The game, *Sick at South Beach,* designed by James Mathews, is a science mystery game in which a group of kids have fallen ill after a spending a day at the beach along Lake Michigan. Students role-play as water chemists, public health doctors, or wildlife ecologists working on the case, which requires them to investigate water quality issues common in Great Lakes cities. One day during the curriculum, students go "into the field" and investigate the site, examining key issues like storm water runoff, sewage overflows, and a well that the sick kids drank water from. While in the field, students use a personal digital assistant (PDA) equipped with a global satellite positioning receiver to gather data about the case. This PDA includes video, documents, and data related to the case, which are triggered as players approach geographic "hot spots" (see Figure 1). As students home in on the cause of the illnesses, they are able to order further tests that, if done correctly, reveal that the most likely cause of the illnesses was E. coli contracted from swimming in water contaminated by goose droppings, or perhaps by storm water waste runoff coming from rural farms. Both of these causes are based on actual E. coli outbreaks experienced at the beach.

Sick at South Beach meets state and national language and mathematics literacy goals by requiring students to interpret nonfiction academic texts (in social studies and science), draw inferences from multiple mathematical forms, draw conclusions from multiple representations of maps, and generate scientific arguments about the case (see Figure 2). The majority of the documents were gathered from professional texts (city or health documents) and were written at the eighth-grade level or higher. The teachers created a variety of scaffolding activities to assist students in comprehending the texts.

Figure 1. The Sick at South Beach interface

Figure 2. Sample data

Post-Rain Samples: Water Chemist

The water research boat is back at the marina after taking post-rain samples.

The water was really murky today. It must have something to do with the heavy rains. We collected some more samples for you. I think that you will find the results quite amazing.

The E. coli levels that were detected range from 1625 CFU to 55 CFU per 100/ml. The map shows the E. coli levels at various locations near the marina.

METHODS

Researchers employed multiple methods within a design-based research methodology (Barab & Squire, 2004; Cobb, Stephan, McClain, & Gravemeijer, 2001; Design-Based Research Collective, 2003). The logic of this design-based inquiry involves iteratively designing and researching curricular interventions and then theorizing learning based on changes to the curriculum.

DATA SOURCES

Researchers gathered observational, interview, and document data to better understand the nature of unfolding events (Guba & Lincoln, 1983). These multiple data sources enable the triangulation of assertions by seeking confirming or disconfirming evidence.

Observations. At least one researcher attended most class sessions during the 2-week unit. At least two researchers observed the "field based" game sessions and video-recorded each session. Field notes were posted to a database, where they could be searched and analyzed.

Interviews. Teachers were interviewed formally and informally throughout the summer program. Teachers and researchers exchanged multiple rounds of e-mails, phone calls, and Web forum communications during the unit planning. Researchers also conducted a formal structured interview following the curricular implementation to follow up on observations and better understand what issues teachers perceived as salient.

Documents. Researchers collected teachers' lesson plans and planning documents, reflection papers that explained teachers' design processes, online forum exchanges among participants, examples of students' work, inscriptions created by students during game play, videotapes of student presentations, and students' final papers.

DATA ANALYSIS

Data were analyzed in biweekly meetings in which researchers reviewed notes and developed themes. When appropriate, researchers shared these with teachers to gather their input and affect future decisions. An external project evaluator participated in these sessions and discussions, guiding the work.

Narrative/Case Analysis. The first analytic step was to develop a case narrative that highlighted key moments, data points, and themes that explained the unfolding events of the curriculum (Stake, 1995). Causal arguments were confirmed and disconfirmed with researchers, teachers, and students. These cases were assembled and shared with teachers for refinement.

Comparative Case Study Thematic Analysis. As the narrative cases were written, regularities and irregularities across cases were noted and themes generated. These themes were also shared with teachers' feedback and modification at biannual meetings.

LIMITATIONS

From a game-based learning perspective, there are several limitations to this study that inhibit researchers' ability to draw conclusions about the potential of game-based learning environments. In particular, the game was designed to fit within the normal school day and to be an easy-to-implement 2-week unit, and closely matched to current standards without drastically challenging the social organization of schooling. As a structured, in-school activity, students' ability to play the game was limited to in-class time. Although there were many examples of students working on the game at home and drawing on outside resources (such as searching for information on the Web or asking family members with a background in chemistry to help them), the bulk of the game activity was really limited to the class. Students could not access the simulation on their own PDAs or cell phones, and most materials were not designed to go home with them. Similarly, students all played with the same class members, as opposed to, say, playing in groups with more advanced learners.

A second limitation of this study for those seeking definitive answers about the role of such technology and media in education is the emerging nature of this technology and the exploratory nature of this research. The underlying technologies are increasingly stable, although the chances of 30 Pocket PCs, each equipped with a GPS device, running flawlessly is slim, and using these devices in a classroom context is exploring new territory. Further, partnering with multiple teachers opens us to working with teachers' own goals and contexts; thus, there was a constant tension between creating a polished, finished software product and providing enough flexibility so that the technology and curriculum could be used in a variety of settings. As such, standardized or controlled measures are not yet feasible.

RESULTS

Olen Middle School (OMS) is a public school located on the urban fringe of Milwaukee, Wisconsin. A team of 3 teachers attended our summer workshop and decided to implement *Sick at South Beach* in their classroom because the game (1) involved issues crucial to their local community, (2) used technology motivating to students, and (3) was connected to their curricular goals of teaching scientific thinking and the water cycle. We are currently working with these teachers to redesign the game to be set more directly in their community and to be about their own lakes.

CURRICULAR CONTEXT: TECHNICAL READING

Ms. Jones introduced the scenario of the girls becoming sick and asked students to brainstorm potential causes so as to trigger their prior knowledge. She then passed out medical briefs about various diseases, and students processed this information on "What do we know/What do I need to know/What questions do I have?" worksheets. Students were visibly engaged, with 95% of students contributing to the discussion during the observed periods. Students developed a range of initial hypotheses, which drew from information in the case ("It could have been the drinking water") and personal experience ("It could have been the cheese they ate"; one student had experience with food-borne illnesses with cheese). Ms. Jones explained her instructional goals:

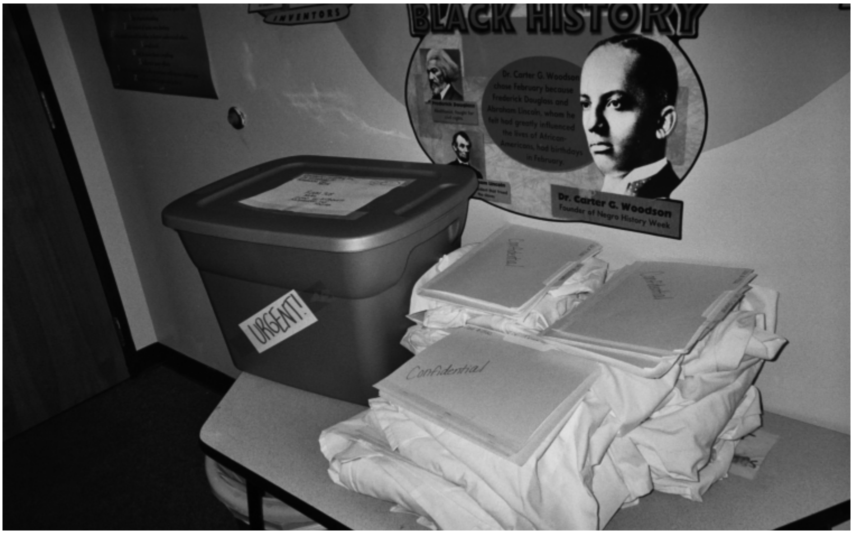
So the setup was, "How do you technically read in science? How do you pay attention to titles and headings and bold based words?" The introduction did a nice job. We talked about opening sentences and supporting details. They did great with that. So, I literally handed out the introduction and said, "We have a problem. Before you come back tomorrow you have to figure out what it is." So they come in the next day all fired up: "There are sick kids!" "And what are we going to do about it?"

On Day 2, students broke into roles. Building on an activity developed by another teacher (see Figure 3), Ms. Jones created "confidential information packets" for students, and each student completed a job application to apply for a role.

TEACHING PRACTICES IN GAMES

During these sessions, Ms. Jones acted as a "game manager," (1) observing student learning and adjusting activities on the fly, (2) reinforcing roles, (3) refocusing students to the guiding question, (4) reinforcing the

Figure 3. Materials, lab coats, and confidential folders



open-ended nature of the inquiry, and (5) modeling scientific thinking. Here is one such minilecture that occurred during the discussion on the second day:

> Today you will be introduced to the patients' symptoms—who became ill after visiting South Beach. You are going to receive confidential copies of their medical records. In your group, keep in the back of your mind your job, who you are. You are speaking as that person. You are looking for clues about these illnesses related to your *job*. But if you see something really obvious (not related to your job), point it to the group.
>
> Here's what you are going to do (next). I have a chart over here on the board and it talks about the patient's name, their symptoms, if they have a fever, vomiting, or diarrhea. You've got their medical records. You might even want to write a description and other red flags as you read through. There may some sort of implied meanings (in the readings)—it's not directly said, but based upon your *professional knowledge*, it would raise a red flag or a warning to you.

Students took to these roles quite readily. In postinterviews, students commented on their experiences.

Student 1: When I was a wildlife ecologist I learned a lot about what they actually do instead of “you’re a wildlife ecologist.” I didn’t know until I played it.
Student 2: Before we did the game, I had no clue what a water chemist was, and when I played the game, I kind a found out what they do. It’s a pretty interesting job. I had the job, and I was really doing what they do. It was kind of interesting.
Student 3: Same thing with the wildlife ecologist. I thought that they played with animals.

Here, Ms. Jones emphasizes strategic reading to the class, emphasizing the importance of reading for implied meanings in the text (implied causes), as opposed to simply scanning the text looking for answers. While reviewing the activity on video tape, Ms. Jones noted, “This [working within roles and then producing documents] has led to increased discussion and a greater analysis of what they are doing.”

As the curriculum progressed, Ms. Jones integrated these reflection prompts into the game play, introducing them within the game narrative. For example, on the third day, the students were given a memo from “the boss,” requiring them to synthesize the information gathered across various activities (see Figure 4). Although this activity may seem “worksheet heavy” (and quite structured), students were engaged, and it suggests how educators-as-game designers can use game conventions to “design experience” for students (cf. Squire, 2006).

Student discussion was generally problem directed, as opposed to being teacher directed (see Lemke, 1990). Here is one typical exchange:

Q: What information are we looking for?
A: Restating the problem
Q: How many kids got sick?
A: 4
Q: When were they sick?
A: 72 hours after the picnic.

Whereas most classroom discourse is noted for its “teacher-directedness,” this environment was characterized by the teacher presenting the game structure that students inhabited. The teacher did provide guidance, as in this day when she set the tone; however, students were responsible for working within that, consulting and reviewing resources and constructing cognitive tools (albeit relatively simple ones) to respond to the challenge. Focusing work toward the production of artifacts managed

Figure 4. Memo from the boss

Memo

To: Research Team
From: The Boss

You need to create a portfolio of the work you have completed so far. I will expect the following items collected in a portfolio by 8:25 today. This includes:

Portfolio items (in this order)

Introduction

Trifold paper with ideas

Job Descriptions
Water chemist
Ecologist
Public health doctor

Chart of patient names

Status report

students' work flow in a manner not unlike that of knowledge workers. Ms. Jones explained the function of these activity structures:

> It's a good thing we had those presentations [to drive their thinking]. Because after the kids went about filling in their graphic organizers, having those conversations, looking at the problem, forming their hypothesis, collecting—you know they collected the data. We had charts hanging around the room of here is what we think is the problem; here is how we are backing up those problems. All of a sudden they started identifying what *couldn't* be the cause of the problem.

Student-generated representations posted throughout the room functioned as a cognitive scaffolding to support their thinking through the problem space. This example suggests how games can respond to a critical challenge described by Kuhn (2005) and Kirschner, Sweller, and Clark (2006): How do we provide students sufficient scaffolding that they need to engage in effective inquiry, while still giving them some agency or sense of control over their actions?

Evidence from classroom interactions suggests that a "melding" of student interests and experiences and the roles and challenges of the game play occurred. When asked what she thought worked in the unit, Ms. Jones described the following:

> We had a huge discussion about processing cheese. One of my girls argued that Kraft actually kills the cheesiness of cheese by making it into powder, and wouldn't that kill any bacteria that could make you sick [from eating macaroni and cheese at the party]? And she was holding on to that point, and people were trying to talk her out of it. And she really didn't care if you added milk or not. Now again, those are funny stories that came out of it, but you're truly thinking as a scientist. If you think of all that she was doing with a problem, with a hypothesis, breaking it down, looking at it from a different way and then arguing her point in a strong intelligent way—that's when you know you're doing something great. When cheese can be great!

This was but one example of game play leading to scientific argumentation that engaged students' prior experience and evidence gathered in game. Situating the game as a fictionalized but hypothetically possible problem invited students to bring personal experiences into problem-solving.

Students' last task was to identify what information they needed to reach a conclusive diagnosis. Note that throughout these exchanges, the teacher was not guiding the discussion; rather, students were. In a postgame reflection, Mr. Simms commented on this changing of role as a major affordance of the game:

> Through this game, I feel that I have become more of a guide rather than a provider of information. When I witnessed the independence of the students, I quickly came to realize that they "did not need me" for several portions of the game. There were times when I could back off and other times when I did need to be more of a presence. This is something that I know, but need to be reminded of.

GOING TO SOUTH BEACH

Having developed more focused hypotheses about the causes of the illnesses, the class was ready to conduct fieldwork at the South Shore beach (the portion using handheld computers). The goal of this game piece was to provide students with a situated experience of the beach ecosystem, enabling them to connect ideas and concepts they read about (such as storm water runoff) with the actual physical space of the beach. Students interviewed virtual characters and took chemical samples from various locations along the beachfront.

During the game, students were primarily focused on information provided on the PDA. Few students investigated the environment itself for clues. On occasion, students literally walked through piles of goose droppings (almost stepping on live geese in the process) because they were so fixated on the PDAs. Our current implementations introduce less text in the field and focus students toward making and recording observations in the field in an effort to make the field experiences true "linking" experiences. Students were visibly excited during the game, most notably when they viewed a recent news clip from a local television station. The video, taken from the actual broadcast news Web site, describes an E. coli scare at the beach and explains how zebra mussels were "cleaning up" the mess. However (as many of these students knew), a thriving zebra mussel population is also a problem because they are an invasive species, killing off indigenous fish.

The game design includes an embedded reading strategy whereby students each have access to different information and then must work together to create a coherent picture of the problem. This technique combines interdependent roles (a game strategy) with jigsawing (a pedagogical strategy). Like previous design experiments (Squire & Jan, 2007), students read the text to themselves and then summarized their findings to one another. There was relatively little digging deeper to reason through their data on the fly; rather, the field experience was one of primarily uncovering information that was then examined back in the classrooms.

There were notable examples of students synthesizing information from the PDA with observations about the environment. One student commented that he had seen oil being spilled into the lake. Another, after viewing the video on E. coli and zebra mussels, ran to the teacher to tell her about a time when he was swimming and scraped his nose on zebra mussels. A few noted the amount of geese and speculated about their droppings. However, in general, we observed several missed opportunities to use the PDAs as a way of directing students to make observations about field conditions.

Reflecting on the role of the field work in the unit, Ms. Jones commented,

> Up to that point, they were researchers researching a problem. After that day, they were the people solving that problem. Their

> "I thinks" became "I know." I know that ___ . Their confidence in their learning, their thoughts, their beliefs changed. They went from I think, to I know. . . . It was meaningful to them. Sometimes we are so limited in a science lab about using all of your senses. They saw the geese and they saw the mess that they made. . . . They need to stand on a sandy beach, look out onto the water. Those things made this valuable.

For Ms. Jones, students conducting an investigation in the field more fully situated the investigation; students were literally put out in the field in the role of investigators, situating them both in the physicality of the space and in their roles as investigators.

DETERMINING THE CAUSE OF ILLNESSES AT SOUTH BEACH

Back in the classroom, Ms. Jones focused on helping students develop good presentations, particularly communicating professional presentation standards. Ms. Jones's exercises focused on techniques for processing information, and her partner teacher, Mr. Simms, provided instruction on their writing in his language arts class. Ms. Jones grouped and regrouped them both by class project and by profession. She explained this decision:

> We are learning about jobs and what they do, and talking about how different people will look through lenses differently depending on what their job is. That's how I often divided the kids. I would say, water people sit over there, doctors, sit over there. What are your observations? What are you thinking about? What inferences are you making? They would come up with a list as the doctors, the water people, the ecologists, and then they would go back to teams that I had put them in, where there was only one doctor, one ecologist, one water person—which was valuable because they knew that they had to learn within the group. They had to be prepared because they were the only doctor spokesperson. There was nobody else to carry the weight. Which really pushed some of my students who don't like to share or would not be as interested in sharing. When they were the only ones, there was no one else to fall back on.

This process allowed students to read and interpret texts in groups, encouraging them to examine data from their professional perspective and then synthesize findings in their groups. The water chemists, for example, did a webquest on water chemistry. Meanwhile, the doctors examined the symptom charts in light of their new data, and the wildlife ecologists examined data about goose droppings and E. coli, with each group aggregating their findings into a chart (see Table 3). As they received their findings, they read softly to themselves, sharing interpretations and potential causes as they found them. There was relatively little knowledge synthesis/construction in these groups; rather, the activity supported them in interpreting texts.

Table 3. Chart Scaffolding Students' Interpretation of Field Work

Who	What the person said	What it made you think	Questions that this idea leads to

Afterward, a group of students reflected on how their knowledge construction in groups unfolded, with one commenting:

> Student 1 I was playing the water chemist, so when I picked up the three water samples, they all tested very high with E. coli, so was pretty sure that it was E. coli. But, when I came back here to put together my poster, one of my partners found the guy in the shadows. When I read his description, it said that his friend—who was supplying food for the picnic—his refrigerator broke, and he just left the meat out so it could have gotten spoiled or something, and *that* could have been a big part of why they were sick.

The student described how his role (the water chemist) gave him access to particular data (E. coli levels) that generated alarm. His partner's information—that there was a broken refrigerator that could have caused food to spoil—changed his thinking. This discussion and synthesis across roles were typical.

Next, students ordered additional tests that would rule out unlikely causes and point toward more likely ones. Students had a limited budget to spend on tests, forcing them to prioritize what information they wanted, based on what information they anticipated receiving from tests. Most groups ordered additional tests on likely diseases: E. coli, cryptosporidium, and salmonella, whereas only two groups paid for spurious information.

As students homed in on finally identifying the causes, they were visibly more engaged. Whereas earlier games left the final cause relatively open-ended to prevent one "right" answer from circulating around the classroom, this implementation did have a "right" answer, but students could only obtain it through ordering the right tests and drawing inferences from results obtained across multiple data sources. Seeing students' motivation to find the "real" cause led us to consider similarly "definitive" solutions in future runs.

DEVELOPING OWNERSHIP OVER SOLUTIONS

By this point, most groups had decided on one of two solutions: (1) cryptosporidium, a conclusion drawn by comparing symptoms (meaning that it was led by the medical doctor), or (2) E. coli, a conclusion that was based on qualitative and quantitative data but that required participation from the water chemist. For example, a group of doctors described their diagnosis:

Doctor 1: It's cryptosporidiosis. That's what we think it is.
Teacher: Can you tell me why?
Doctor 1: Because they had diarrhea, [reading now from a chart] weight loss, cramps, fever, nausea. If it wasn't that, it would be Campylobacter jejuni, because this one had bloody diarrhea but the first one didn't say anything about it being bloody. It also has fever, nausea, and vomiting. And, it is the most common cause of bacterial infection.
Teacher: Those are some interesting ideas. I might go back and look at the health charts and compare some of the patients' symptoms.

The students smiled as they read this, showing signs of pleasure in being experts within this domain, particularly using technical vocabulary facilely.

The teachers were struck by the voracity of students' claims and how the game, particularly the roles, enabled them to argue positions—something they reported that students do infrequently. For a variety of reasons, ranging from social norms to self-confidence, she felt that her students rarely had contexts for arguing and debating ideas in class—something noted by Lemke (1990), Kuhn (2005), and others. Because students had access to differential information via roles, they were expected to argue scientifically as professionals. She described, "In fact, some of them made pretty strong cases for the wrong things. But, they made a strong case and they talked to one another. They would argue who was right and who was wrong. It was exciting."

Functioning in these roles also created *responsibility* for knowing particular pieces of information. Ms. Jones said,

> You don't have a choice when your group is going to say that you're the doctor, you have to answer all the doctor questions. "What do you mean you don't have the answers? You don't have the information? But, our group needs that." I chose groups, so they might have been with kids who they might not have been as comfortable saying "whatever."

Over the next 2 days, they read information packets, ruled out causes, and built an internal argument. The South Beach End of Unit Report (see the appendix) also structured their discussion. Students worked on whatever aspects of the problem they wanted during these 2 days. Some teams divided tasks and worked individually; others discussed their ideas and completed tasks as a group. There was no evidence of students withholding information or being concerned that other groups would "steal" information. Rather, the class resembled what Ms. Jones described as a "collaborative culture."

The class discussion was animated, to the point where the video cameras in the room where unable to reliably pick up students' comments. Students now were invested in particular theories and arguments. In this example, four girls huddled around a table, examining their documents. In this quick passage (the entire exchange took place in about 45 seconds), they each subscribe to a particular theory of how the disease was contracted and then think back to see if that potential disease is possible, given what they know about the kids' illnesses.

Girl 1:	It says right here *contaminated* water. What does that mean?
Girl 2:	I think it's crypto. And I'm not changing my mind.
Girl 3:	It's the food.
Girl 2:	Burned!
Girl 1:	(whispering) The teacher is right there.
Girl 2:	You always catch me in those moments (laughing).
Teacher:	You mean yelling "Burned!" to solve your argument? I'm trying to find you making your case.
Girl 1:	Wait, you guys (pointing to their compilation of symptoms). It's not giardiasis (mispronounces).
Girl 3:	It's not hepatitis A either.
Girl 1:	(consulting chart) It says here that it appears 1–2 weeks *after*.

Girl 2: (To teacher) Can we look at our interviews again?
Teacher: Yes—they are all in there.
Girl 1: (They all turn to chart). Listen, it can't be this one (pointing to giardiasis and crossing it off) because it says here that it appears 1–2 weeks *after*.
Girl 3: Yes, it can't be cryptotosis (as pronounced).
Girl 1: Yeah it can.
Girl 3: I think that it's salmonella.
Girl 1: It can't be hepatitis A either.

Their thinking process involves reciprocally reading and rereading texts and ruling out illnesses and circling potentially strong ones (such as Girl 2, arguing for a food-borne illness as a potential cause). The conversation is quick and heated, with the girls disagreeing directly over causes. The conversation itself contains relatively few examples of evidence being raised; they more frequently distribute their knowledge through their materials.

About 10 minutes later, the girls claim to have found the solution.

Girl 2: Look, it's *Campylobacter*. It happens 72 hours after, which is what it said on the sheet (the list of girls' symptoms). And it's comes from chicken, which they ate. And it mostly happens in the summer. And it's food borne. I think I just solved the case. (Putting pencil down)

Meanwhile, across the room, another girl is convinced that it is crypto.

Girl 1: There was a kid that had gotten lost and was thirsty, and it said that some of the symptoms here make you thirsty and none of the other diseases here have that. I looked through all of the other categories of diseases and symptoms too (pointing to materials), and it all fits.

Somewhat surprisingly, there was no consensus among the class about one correct answer. In fact, students argued their various positions so forcefully that the teachers had to reexamine the materials themselves to reaffirm the likely causes. We observed no examples of students eavesdropping on other groups to get the "right" answer; rather, the classroom culture was such that effectively arguing one's own position was much more highly valued than being "correct."

The final reports were primarily worked on in Mr. Simms's class. Mr. Simms began by introducing traits of good writing: conventions, vocabularies, and editing for particular traits. They began by writing the parts of the report that they could (describing the cause of the problem and important details) and edited the papers throughout the week. Students engaged in peer review, peer editing, and a number of exercises throughout the period. The biggest difference between this and other projects, Mr. Simms observed, was the amount of revising.

> The more that they want to revise . . . if I just have them write a letter for the sake of writing a letter, they don't get into it as much. That was something I've always done, but you forget it sometimes. You see this work and it reinforces it.

Mr. Simms attributed this extra interest in revising to the fact that students perceived it as authentic. "They felt that they were valued; they were important. It wasn't just a school task, [but] a real-life situation that needed to be taken care of."

The reports themselves were graded by the teachers according to a rubric. All the groups received exclusively 3s and 4s on a 4-point scale, with roughly one half receiving 3.5 or higher. Ms. Jones provided structure for the essays with an outline that included the following sections: (1) What is the problem? (2) What is causing the problem? (3) What are some issues that could have been the problem but are not? (4) What should be changed to avoid the problem from happening again? The essays were graded as being of consistently high quality; one third developed "correct" responses, attributing the illnesses to E. coli, incorporating a majority of relevant facts, and ruling out other diseases. Another third arrived at E. coli without a sound argument, and another third argued for crypto, based exclusively on symptoms.

Ms. Jones had her students conduct their final presentation before the school board. She wanted the board to hear about the project directly from students and in their own words. The students created a PowerPoint presentation that lasted about 5 minutes. It covered the need for 21st-century thinking skills, basic theories of situated cognition, the design and structure of the unit, and their major findings. Ms. Jones included the students because she wanted the school board to hear about the project from students "in a language that they are used to," showcasing what students can do with technology when sufficiently motivated. The school board voted to purchase a set of handheld computers for Ms. Jones, and she is currently working with a team of teachers designing a similar game around their local watershed. The class also planted a rain garden outside their school after learning about storm water runoff.

DISCUSSION

Analyzing students' activity, particularly as reflected in their artifacts, we identified patterns of thinking and activity that suggested the potential and challenges of this pedagogy. These findings are framed as assertions, the strongest statements available based on data that bear back on theories of learning and cognition in digitally mediated worlds, and theories of designing game-based learning environments. Consistent with a design-based approach, we also report these findings in terms of changes that we are making in our designs, and implications for theory.

1. Teachers emphasized the fictional elements of the game story as a way of creating context for students, inducing students into participating in the game system, and encouraging academic performance. Teachers' modifications to the curricula emphasized (1) the importance of students' *roles*, (2) the standards of the profession for behavioral conduct, and (3) the fictional context as a way to drive activity (particularly to encourage scientific thinking and writing). The first modification teachers made was to heighten students' identification with the roles through the use of physical props. Teachers marked information packets "confidential" and had students fill out job applications, which further induced them into roles. In current iterations, these teachers are integrating even more performative aspects of play, including distributing laboratory coats and other props (an idea developed by another teacher).

These curricular modifications highlight the potential for leveraging the intrinsically motivating aspects of role play to produce engaged learning. Because games are by definition associated with fantasy, many educators quickly move toward highly fictionalized contexts for producing games (e.g., *Number Munchers, Alga-Blaster*). These cases suggest, however, that the fantasy of being a scientist, wildlife ecologist, or even water chemist can be quite engaging for students when situated within those intrinsically motivating aspects of a career. As designers, we look for "what makes a profession, field, or idea for those who pursue that profession" and seek to design game experiences around them. Ms. Jones's instructional moves also pulled out the intrinsically motivating aspects of these professions, such as doctors obtaining confidential information or water chemists dealing with "gross" material, which is interesting to many middle school students.

The teachers also used roles and the fictional context as tools in classroom management. A few times per class session, Ms. Jones would remind students that they had to use the language of their profession in the classroom. She used the profession as a standard for student work; when students asked, "What should we include in the report?" she would redirect them to consider what would make the best case or help solve the problem, rather than abstract teacher-developed criteria. This approach led to increased engagement; Ms. Jones reported several incidents out of class in which she was stopped by students with questions about the case. We also observed several instances in which students wanted to know if the case was real.

Within the game play, the differentiated roles functioned much as they had in an earlier study (cf. Squire & Jan, 2007), although extending the curriculum over several weeks led students to have a greater sense of responsibility for their roles. Students in Ms. Jones's class identified even more strongly with their roles and argued more vehemently for particular diseases than observed in Squire and Jan (2007). Students reported that it was fun being "responsible" for their roles, and teachers reported that students were able to argue with one another in a manner they had not previously. We hypothesize that delving into such roles more deeply and extending and exchanging them over the course of a term may be a next step in creating learning environments more deeply immersed in game-based learning strategies. There are also possibilities for students to reflect on what counts as evidence within different professions and dig into deeper epistemic issues between fields.

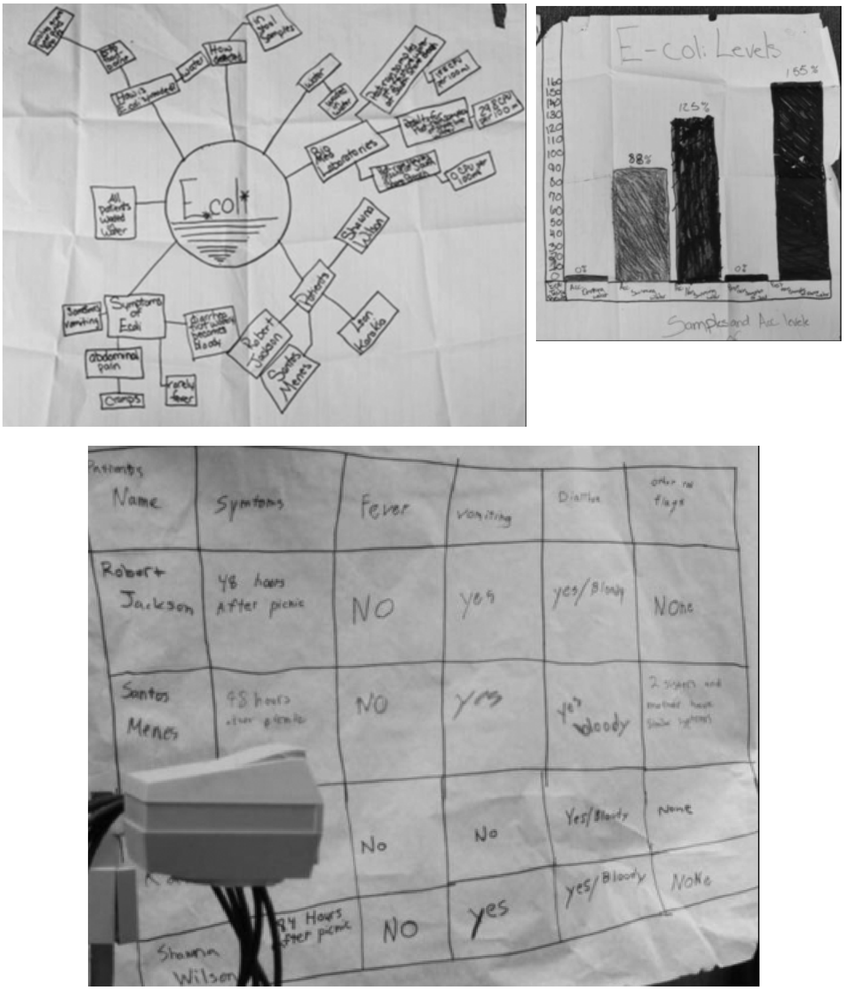
2. The type of representation students made to organize information correlated highly with their relative success in solving the problem. Successful groups created representations of their understanding of the problem that incorporated (1) information gathered across all three roles, (2) both quantitative and qualitative data sources, and (3) data from all phases of the project. Roughly one third of the groups developed such responses. All these groups created visual representations of their data similar to Figure 5. These representations combined multiple data sources coming from the entire group; they integrated signs and symptoms of illnesses (doctors' contributions), data from E. coli levels (water chemists' information), and observations about goose droppings (wildlife ecologists). Students with less accurate solutions created inscriptions with an overreliance on one form of data and focused on only one part of the problem (for example, the girls who created a chart of patients' symptoms and concluded that the disease was caused by cryptosporidiosis).

Successful students also gave the most specific instructions on how to avoid future outbreaks. One student who concluded that the kids contracted E. coli from the water wrote,

> We could avoid this from happening again by cleaning up the poop from the park, so it doesn't get washed in the water,

> sampling the water for safety, to see if it is safe to swim in, and if not they should shut it down so that only boats can be in there.

Figure 5. Examples of students' work



This analysis demonstrates at least a surface level her understanding of the beach as an ecosystem. She understood the causal mechanisms at play and developed an entirely reasonable solution. We found that this test item—asking what could be done to avoid future outbreaks—was a good one for eliciting responses that teased apart differences in students' understandings.

The importance of the *type* of representation in supporting cognition suggests that designing artifacts to scaffold students' thinking in play is a critical function when trying to guide students' thinking. The importance of such inscriptions in guiding students' thinking is recognized in problem-based and inquiry-based approaches to instruction (Roth, 1996; Savery & Duffy, 1996). In our current research, we examine the efficacy of embedding these structures in the game *directly*, in the form of periodic reports required by a fictional client, such as a fictional boss requiring a concept map of the problem after students return from the field. A question for future research is the efficacy of having teachers or designers dictating these structures, or whether to provide students coaching on how to create such inscriptions to guide their thinking.

3. Educators can design game features that serve as "choke points" for players, requiring them to confront difficult yet important deficiencies in their skills. Sick at South Beach requires students to transform data in order to interpret evidence across several measures. Students had difficulty with this activity, and several failed to develop interpretations based on their data. For example, several students misinterpreted the E. coli test (see Figure 6), failing to see the reading as an indication that the water was "dirty." In most cases in which this happened, the students simply saw the term *fecal* or *E. coli* and assumed that this was the cause of the kids' illnesses. One of these students claimed in his final report that lake water was bad even though he did not have actual data to support this claim.

Figure 6. E. coli test data

E. coli Test

High E. coli levels indicate that the water is contaminated with fecal matter and may contain disease-causing organisms.

Water Sample #3 Pre-Rain Water Sample	
Location	Beach Area
Indicator Type?	E. coli
EPA Safe Levels?	235 CFU / 100mL
Levels Detected?	28 CFU / 100mL

This example was also indicative of another broad pattern: Most students had difficulty using graphs, charts, and quantitative data to generate findings. Later, when students did receive tests indicating that E. coli levels were above legal limits, many failed to draw interpretations based on their evidence. This phenomenon was surprising to us given the relative simplicity of the task (reading numbers with units from a table) but relates to mathematics research showing the difficulty students have reasoning in complex, multistep mathematics problems (cf. Cognition and Technology Group at Vanderbilt, 1993; Kuhn, 2005).

There were also examples of the game design eliciting students' misconceptions about scientific concepts. Students had difficulty reasoning through how water flows through the ecosystem and how water purification systems work. For example, one student claimed that the illness was related to a water-borne illness contracted from the well water. He believed that the well water came *from* the lake (which is not true; the well water comes from the aquifer that flows *into* the lake). Our current work seeks to identify and predict such difficulties in students' understanding and then use them as "teachable moments" for just-in-time instruction (CGTV, 1993). Across all these examples, games as designed experiences *guide* students' thinking in ways less common to inquiry- and open- ended learning environments (Kirschner et al., 2006). Specifically, games can create *seductive failure states*, which are tied to areas that students struggle with or are designed to trigger students' misconceptions.

4. Triggering students' identities as problem solvers through technology-enhanced learning. In one of the more interesting, unanticipated findings, the teachers reported that a technology-driven unit in which technologies were in the hands of students elicited students' identities as *active problem solvers*; their role was to ask for help but to figure things out for themselves, as compared with the more passive type of consumer of information that they more commonly observed in their classes. It was as if learning via a game-based format triggered their out-of-school, media-using identities rather than their school-based identities, which Sizer (1984) described as one of docility. Ms. Jones explained how students oriented toward the unit:

> I think those global ideas of problem-solving and inquiry are so important—to look at the world and truly look at what scientists do. How many times have I gotten kids into a science lab, and they don't get what they expect to get for results. And you say to them, or they'll ask their partner, "Well what were we supposed to get?" "Well this is wrong, we must have done something wrong."

> Which is an interesting flip side with how they work with technology. The same kids that when they use the technology on the trip would say, "Well this isn't working, what's wrong with this machine?" or "Why isn't the computer doing what I want to do?' and they would try something else to fix it right away. They are natural problem solvers that way, but I put them in the science lab, and "Well I didn't get the right answer." "What did you get?" Not, "How did you get it?" or "What did you try?" but, "What did you get?" So, I think there is this natural correlation with okay, this is how we problem-solve, this is how a scientist problem-solves.

The link that the teacher makes here between students' active problem-solving with technology and the actual work of scientists is an intriguing one, one similar to the theory of learning posited by Johnson (2005) and others (cf. Gee, 2004), who argued that technology, media, and their associated literacies recruit more sophisticated thinking than school-based activities do.

Students confirmed this orientation, valuing the unit for how it positioned them as *active* learners. One student commented, "You're reading about it, but you can go out in person to learn." This student wanted more opportunities in which she could consult experts as resources to clarify understandings. A second student contrasted this experience of how the game worked with most of school:

> Student 2: I think it [the game] kind of helps because for me at least, it seems like because I learn a lot more when I actually care about something and I'm not bored out of my skull listening to some teacher yap about something.

In these comments, we see signs of the "indigenous critique" of schooling from a situated perspective argued by Gee (2004): Presented with more and more opportunities to learn by doing outside of school, these students were dissatisfied with their school-based learning experiences. Their statements of being "bored" in school echo those in the literature (see Baines & Stanley, 2002). This game-based curriculum (perhaps not surprisingly) stood in contrast to the more passive learning experienced in most of school. Curiously, both teachers and students saw this active, inquiry-driven learning as preferable to the status quo.

IMPLICATIONS FOR VIDEO GAME-BASED LEARNING IN INFORMATION TECHNOLOGY

These results suggest that game-based pedagogies can be integrated into schools in order to create personally meaningful learning tied to academic domains. These emerging pedagogies change the role of information and information technologies from that of the "content" to that of tools and resources that serve in the process of producing context for learning. In *Sick at South Beach*, the resources that students read about diseases served not as the basis of the experience, but as tools supporting the learning experience. In and of itself, this transformation of information and tools from students being the "center" of the learning experience to the periphery is not new; constructivist pedagogies such as problem-based or inquiry-based learning leveraged texts similarly as tools for student action (Bednar, Cunningham, Duffy, & Perry, 1991; Savery & Duffy, 1996).

TEACHERS MOBILIZING TEXTS TO DESIGN EXPERIENCE

Where game-based learning environments (perhaps) differ is in how they sculpt documents and resources to produce a "designed experience" of moment-to-moment unfolding interaction. Documents serve the function of piquing and sustaining students' emotional engagement, enlisting students' identities as problem solvers, confronting students' understandings, and prodding students to develop representations where they participate in the world (cf. Gaydos & Squire, in press). Although constructivist-based learning environments treat resources in a similar manner, game-based designs embody a *ludic* spirit, a spirit of playfulness, transgression, and fantasy that is emphasized less in constructivist environments. As a result, game designers spend considerable time making games *playable* (in game designer parlance). That is, they go through many cycles, polishing resources and tools to create the seamless, enjoyable experience expected by game players (cf. Davidson, 2005; Squire, 2005). This careful sculpting of resources suggests that the potential to categorize and reuse materials as learning objects within game-based environments may ultimately be limited because they need to be polished to work within contexts.

This polishing process also suggests that teachers, not just instructional designers, need considerable access to materials to tweak them for students' needs. Contemporary video games such as *The Sims* that have succeeded with mainstream audiences invest considerable time (on the order of years) researching player activity through a variety of user testing procedures, ranging from quick tests of thousands of players to live beta tests with millions (Laurel, 2004). This kind of development cycle is impossible for most educators. As a result, we have argued for flexibly adaptive curricula that allow teachers to modify and adapt materials based on their local needs and based on previous iterations. This case reflects the results of these ongoing experiments as teachers have taken out materials, modified them to meet their needs, and then shared them with other teachers who have done the same.

This vision of teachers continually modifying and publishing documents as an integral part of their professional practice suggests a radically different role for information technologists; it suggests that information technologists might be in the business of maintaining knowledge-aggregating tools, creating and supporting knowledge-building communities, and providing tools for teachers to identify and organize useful resources. In a digital era, teachers are not only consuming resources (checking out and assigning materials from the library) but also producing them (publishing information online and fostering their own professional development through participating in, and starting their own, professional knowledge communities). Currently, these functions are supported primarily by researchers or "Web sites for teachers," each of which has its limitations (scalability and protection of intellectual property, among others). We imagine a role for librarians to function in such a capacity, creating and supporting knowledge and community creation tools for teachers. Minimally, making a library truly "digital" means embracing the crucial "knowledge production" role of teachers. Given the ubiquity of digital resources that can be obtained outside the walls of the library, perhaps librarians' roles will be reframed as ones of supporting teacher adaptation of curricula, publication of materials, and knowledge production as they reflect on their practice and knowledge dissemination throughout a system.

Although students presented their work in community settings outside the classroom (i.e., to the school board) and planted a rain garden, most of their intellectual work did not feed back into community life in a meaningful way; they did not take any action pertaining to beach issues or investigate critical issues about the Milwaukee watershed. In previous games more intensively supported by researchers and with more flexible constraints, teachers have used these tools to have students create games that are then played in their communities (much as these teachers hope to do now; see Squire & Jan, 2007). They have presented the results of their game design research at community gatherings, city council meetings, and other public events. Current design iterations further encourage students to engage in these participatory practices.

Given how digital technologies enable participation in worlds beyond the classroom walls, we see the student production and dissemination of games as a logical next step to pursue. Crucially, these games—designed around contested local issues—are designed not just to facilitate the production of games to be played "by anyone," but to enable democratic participation by students in civic life. As such, game play might naturally lead toward active engagement in society, suggesting that educators might leverage the participatory nature of games to facilitate participation in social life beyond the classroom. Indeed, simulating the "experience" of being an active participant in shaping the world in which languages and literacies are mobilized seems like a worthy goal of education. A challenge and opportunity of digital learning, then, is how to create games that usher teachers and students from being knowledge consumers to being producers, and along trajectories of deeper participation in social life beyond the walls of the classroom. In this way, games serve as a "trial run," preparing students for future participation in the world.

To date, most of the work described here, from design to publication, has occurred largely outside the formal "library" structure. Resources, tools, and publication methods are all widely available via the Internet and outside the purview of traditional libraries. However, there is a clear role for information technology specialists to play in facilitating these processes, particularly in publishing students' work and enabling their participation in civic life. As the means for obtaining and publishing information become increasingly democratized, perhaps information technologists could be reframed as catalytic agents, helping make school more engaging for the thousands of students disaffiliated from it or assisting teachers in linking their curricula to the world outside the classroom.

Notes

1. Although these terms work as general ways to think about media, they are, of course, not entirely steadfast. Much fiction, and particularly television shows, can also be thought of as "worlds" as much as they are stories, and likewise, many games (particularly adventure games) do aspire to tell stories. However, as a medium, games seem particularly well suited toward world creation because worlds suggest a large possibility space that the player can explore and experience, rather than a prescriptive series of plot events that a player must reenact. My understanding of these dynamics is indebted to Henry Jenkins, who has written extensively on the subject.

2. As with most stereotypes, there are probably grains of truth in this characterization, and indeed, game companies themselves have been somewhat responsible for these images. The recent marketing push of the Nintendo Wii and Nintendo DS, both of which are marketed at families, particularly women, is an interesting counterbalance to these stereotypes.

References

Baines, G. K., & Stanley, L. (2002). Celebrating mediocrity. *Roeper Review, 25*, 11–13.

Barab, S. A., Hay, K. E., & Duffy, T. M. (1999). Grounded constructions and how technology can help. *Tech Trends, 43*(2), 15–23.

Barab, S. A., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*, 1–14.

Baudrillard, J. (1994). *Simulacra and simulation* (S. F. Glaser, Trans.) Ann Arbor: University of Michigan Press.

Beck J., & Wade, M. 2004. *Got game: How the gamer generation is reshaping business forever.* Cambridge, MA: Harvard Business School Press.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1991). Theory into practice: How do we link? In G. J. Anglin (Ed.), *Instructional technology: Past, present and future* (pp. 100–112). Englewood, CO: Libraries Unlimited.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn.* Washington, DC: National Research Council.

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* (Vol. 24, pp. 61–101). Washington DC: American Educational Research Association.

Bridgeland, J. M., Dilulio, J. J., & Morison, K. B. (2006). *The silent epidemic: Perspectives of high school dropouts.* Seattle, WA: The Bill & Melinda Gates Foundation. Retrieved June 25, 2007, from: http://www.civicenterprises.net/pdfs/thesilentepidemic3-06.pdf

Brown, A. L., Campione, J. C., Webber, L. S., & McGilly, K. (1992). Interactive learning environment: A new look at assessment and instruction. In B. Gifford & M.C. O'Connor (Eds.), *Changing assessments: Alternative views of aptitude, achievement and instruction: Evaluation in education and human services* (pp. 121–211). New York: Kluwer Academic/Plenum.

Clark, A. (2006, May 12). *School cell phone ban causes uproar: NYC moms and dads say they need way to reach kids in emergencies.* Retrieved from http://www.cbsnews.com/stories/2006/05/12/national/main1616330.shtml

Cobb, P., Stephan, M., McClain, K., & Gravemeijer, K. (2001). Participating in classroom mathematical practices. *Journal of the Learning Sciences, 10*, 113–163.

Cognition & Technology Group at Vanderbilt. (1993). Anchored instruction and situated cognition revisted. *Educational Technology, 33*(3), 52– 70.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920.* New York: Teachers College Press.

Davidson, D. (2005, May). Plotting the story and interactivity in *Prince of Persia: The Sands of Time.* Paper presented at the Media in Transition 4: The Work of Stories conference, Cambridge, MA. Available at: http://waxebb.com/writings/plotting.html

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

Friedman, T. H. (2005). *The world is flat.* New York: Farrar, Straus and Giroux.

Games, Learning & Society Group. (2007). Gaming as productive literacies. In J. P. Gee (Ed.), *Good video games and good learning: Collected essays on video games, learning and literacy: New literacies and digital epistemologies* (pp. 129–173). New York: Peter Lang. (Original work published 2005)

Gates, W. (2005). *Remarks to the National Education Summit on High Schools, February 26.* Retrieved September 24, 2007, from http://www.gatesfoundation.org

Gaydos, M., & Squire, K. (in press). Citizen science: Designing a game for the 21st century. In R. Van Eck (Ed.), *Interdisciplinary models and tools for serious games: Emerging concepts and future directions.* Hershey, PA: IGI Press.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave/St. Martin's.

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling*. London: Routledge.

Gee, J. P. (2007). *Good video games and good learning: Collected essays on video games, learning and literacy*. New York: Peter Lang.

Gee, J. P., Hull, G., & Lankshear, C. (1996). *The new work order: Behind the language of the new capitalism*. Sydney, Australia: Allen and Unwin.

Guba, E. G., & Lincoln, Y. S. (1983). *Effective evaluation*. San Francisco: Jossey-Bass.

Hagel, J. H., & Brown, J. S. (2005). *The only sustainable edge: Why business strategy depends on productive friction and dynamic specialization*. Cambridge, MA: Harvard University Press.

Jenkins, H. (2006). *Convergence culture*. New York: New York University Press.

Johnson, S. (2005). Your brain on video games: Could they actually be good for you? *Discover, 26*(7). Retrieved March 1, 2010, from http://discovermagazine.com/2005/jul/brain-on-video-games

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*, 75–86.

Kuhn, D. (2005). *Education for thinking*. Cambridge, MA: Harvard University Press.

Laurel, B. (2004). *Design research*. Cambridge, MA: MIT Press.

Leander, K., & Lovvorn, J. (2006). Literacy networks: Following the circulation of texts, bodies, and objects in the schooling and online gaming of one youth. *Cognition and Instruction, 24*, 291–340.

Levin, D., & Arafeh, S. (2002). *The digital disconnect: The widening gap between Internet-savvy students and their schools*. Washington, DC: Pew Internet & American Life Project.

Lemke, J. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Lemke, J. L. (2004). Metamedia literacy: Transforming meanings and media. In C. Handa (Ed.), *Visual rhetoric in a digital world: A critical sourcebook* (pp. 71–93). Boston: Bedford.

Partnership for 21st Century Skills. (2002). *Learning for the 21st century*. Retrieved June 25, 2007, from http://www.21stcenturyskills.org/images/stories/otherdocs/p21up_Report.pdf

Perkins, D. N. (1992). *Smart schools: Better thinking and learning for every child*. New York: Free Press.

Reich, R. B. (1992). *The work of nations: preparing ourselves for 21st century capitalism*. New York: Vintage Books.

Roth, W.-M. (1996). Knowledge diffusion in a Grade 4–5 classroom during a unit of civil engineering: An analysis of a classroom community in terms of its changing resources and practices. *Cognition and Instruction, 14*, 170–220.

Savery, J., & Duffy, T. (1996). Problem based learning: An instructional model and its constructivist framework. In B. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 135–148). Englewood Cliffs, NJ: Educational Technology.

Shaffer, D. W., & Gee, J. P. (2005). *Before every child is left behind: How epistemic games can solve the coming crisis in education* (WCER Working Paper No. 2005-7). Madison: University of Wisconsin-Madison, Wisconsin Center for Education Research. Retrieved September 23, 2007, from http://www.wcer.wisc.edu/publications/workingPapers/Working_Paper_No_2005_7.pdf

Sizer, T. (1984). *Horace's compromise: The dilemma of the American high school*. Boston: Houghton Mifflin.

Squire, K. D. (2005). Educating the fighter. *On the Horizon, 13*(2), 75–88.

Squire, K. D. (2006). From content to context: Videogames as designed experiences. *Educational Researcher, 35*(8), 19–29.
Squire, K. (in press). Critical education in an interactive age. In D. Silberman Keller (Ed.), *Popular culture and education.* New York: Rowman.
Squire, K. D., & Giovanetto, L. (2008). The higher education of gaming. *E-Learning and Digital Media, 5*(1), 2–28.
Squire K. D., & Jan, M. (2007). Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology, 16*(1), 5–29.
Squire, K., & Johnson, C. (2000). Supporting distributed communities of practice with interactive television. *Educational Technology Research and Development, 48*(1), 23–43.
Squire, K. D., & Steinkuehler, C. A. (2005, April). Meet the gamers: They research, teach, learn, and collaborate. So far, without libraries. *Library Journal.* Retrieved March 1, 2010, from http://www.libraryjournal.com/article/CA516033.html
Stake, R. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.
Starr, P. (1994). Seductions of Sim. *American Prospect, 5*(17), 19–29.
Steinkuehler, C. A. (2005). The new third place: Massively multiplayer online gaming in American youth culture. *Tidskrift Journal of Research in Teacher Education, 3,* 17–32.
Steinkuehler, C. A. (2006). Massively multiplayer online videogaming as participation in a discourse. *Mind, Culture and Activity, 13*(1), 38–52.
Steinkuehler, C. (2007). Massively multiplayer online gaming as a constellation of literacy practices. *eLearning, 4*(3), 297–318.
Steinkuehler, C. A. (2008). Cognition and literacy in massively multiplayer online games. In J. Coiro, M. Knobel, C. Lankshear, & D. Leu (Eds.), *Handbook of research on new literacies* (pp. 611–634). Mahwah, NJ: Erlbaum.
Steinkuehler, C., & Duncan, S. (2009). Informal scientific reasoning in online virtual worlds. *Journal of Science Education and Technology.* doi:10.1007/s10956-008-9120-8
Steinkuehler, C. A., & Williams, D. (2006). Where everybody knows your (screen) name: Online games as "third places." *Journal of Computer-Mediated Communication, 11,* 885–909.
Turkle, S. (2003). From powerful ideas to PowerPoint. *Convergence: The Journal of Research Into New Media Technologies, 9*(2), 19–28.

APPENDIX: SOUTH BEACH END OF UNIT REPORT

What is the problem?

Create an opening statement:

Three important details

1.
2.
3.

What is causing the problem? ______________________________
Create an opening sentence:

Three important details
1.
2.
3.

What are some issues that could have been the problem but were not?
Create an opening sentence that states that there were some issues that could have led to the problem but turned out not to be the cause.
Create an opening sentence:

Identify three of these issues & state how you knew they were not the problem causers:

Issue	Proof this issue did not cause the problem
1.	
2.	
3.	

What should be changed to avoid the problem from happening again?
Restate the problem: ______________________________________
What should be changed?
1.
2.
3.

KURT SQUIRE is an associate professor of educational communications and technology and an associate director of educational technology and development at the Wisconsin Institutes for Discovery. He is author of over 60 scholarly articles and chapters, including "From Content to Context: Video Games as Designed Experiences" (published in *Educational Researcher*) and *Video Games in Education* (forthcoming). Squire's current interests are in using video games to increase public understanding in science, and the design of game-based assessment systems.