ENTERING THE EDUCATION ARCADE

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Responding to social, economic, and technological trends that make games the most powerful medium for reaching young learners, The Education Arcade project, based in the MIT Comparative Media Studies Program, seeks to prototype games that teach, develop curricular materials which support existing commercial titles, and help prepare teachers to use games in the classroom. This article reports on the first three prototypes that are producing: Supercharged! (electromagnetism); Environmental Detectives (environmental science);and Revolution (American history).

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INTRODUCTION

You have entered a typical public high school just a few years from now.

In the American history class, the teacher has just told the students to log off a multiplayer game that simulated the events leading up to the American Revolution and to begin comparing their experiences through class discussion. One student has been a merchant embittered by British taxation, another a banker fiercely loyal to the crown, a third a blacksmith trying to do business with all sides, and a fourth a slave being tempted by British soldiers with promises of freedom if he joins their ranks.

In the biology class, students compare notes on last night's homework, which had them design their own virus to see if it could overcome the antibodies and infect the human host. The teacher asks the students to identify properties that enable viruses to spread fast and survive longer. One student has cheated by reading ahead in the textbook, which produces groans from her classmates and a secret smile from her teacher.

In the psychology class, students are doing experiments on "sims," trying to determine which model of mind governs behavior, and keep consulting the blackboard where the teacher's notes from yesterday's lecture are still visible.

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The environmental science classroom is empty. Teams of students are wandering the school grounds, going back and forth between data displayed on their handhelds and observations of their real-world surroundings, trying to be the first to locate and remedy the source of a fictional chemical leak.

In the physics classroom, students are taking a test. You can tell because they have turned off the volume on their GameBoys and are trying to solve a series of challenging levels that require them to plant electronic charges, which they use to propel themselves through mazes.

Has education become nothing but fun and games? Not exactly. In each case, the games are being integrated into a range of other curricular activities. Games are enhancing traditional educational tools such as lectures, discussions, lab reports, homework, fieldtrips, tests, and textbooks. Games are being allowed to do what games do best, while other kinds of teaching support those lessons.

These are just a few of the scenarios for the future of games and education developed over the past two years by the Microsoft-MIT iCampus project, Games to Teach. Faculty and students in the MIT Comparative Media Studies Program, consulting with educators and game designers, developed more than fifteen conceptual prototypes: design documents for games which might support teaching across math, science, the humanities, the arts, and the social sciences at an advanced high school or early college level. You can access them at http://cms.mit.edu/games/education/proto.html.

These games reflect different pedagogical models, game genres, platforms, and classroom uses, showing the diverse ways in which educators of the future may be able to deploy computer and video games to enhance learning. Pretty much everything described in those design documents could be done now, given the current state of game technology and existing approaches to game design. The next challenges will be as much economic (how do we pay for the development of educational games); social (how do we train a generation of teachers to integrate such games meaningfully into their total curricular activities); and political (how do we make a case for the kind of in-depth understanding these games facilitate in an era of standardized testing?).

There are several factors fueling the push for educational games. First, there is a growing recognition that for the current generation of high school and college students, games constitute the medium of choice. The Pew Internet and American Life Center recently reported the results of a survey of more than a thousand undergraduates from 27 American colleges and universities. One hundred percent of all respondents had played computer games; 65 percent described themselves as regular or occasional gamers. Similar results were found in our survey of some 650 MIT freshman, which found that 88 percent of them had played games before they were 10 years old, and more than 75 percent were still playing games at least once a month. The average MIT student spent more hours each week playing games than going to the movies, watching television, or reading nonassigned books. Right now, the bulk of educational games are aimed at early childhood education, while the core of game players are in their teens and twenties. The challenge is how to design games that communicate more sophisticated content.

Second, there is the astonishing rate of technological development in the games industry. The current generation of commercial games includes powerful simulations of real-world systems, complex AI embodiments of human thought processes, and immersive and responsive environments which allow players enormous flexibility in making their own decisions and playing out the consequences. The medium is now robust enough to support a broad range of school content. At the same time, these games often ship with their own level editors or other mod tools allowing amateurs to customize the content, design their own "skins," and develop their own environments. These tools are sophisticated enough to allow educational researchers to develop games that are as sophisticated and graphically compelling as those currently on the market. They will also support the exchange of customized materials among a global network of educators. -

Third, many of the top-selling titles – *Sim City, Civilization,* and *Railroad Tycoon* – already inform as well as entertain. These games are being used in classes now, but we need to develop customized modifications, curricular materials, instructional activities, and teacher-training programs to assist deployment in the schoolhouse.

While educators have historically displayed open suspicion and hostility towards games, blaming them for everything from school shootings to poor attention spans, a critical number of new teachers have grown up as gamers, and so have a greater appreciation of what the medium can do. A swelling number of government agencies, educational experts, think tanks, and corporate labs also embrace educational gaming.

Responding to these opportunities, the Games to Teach Project is evolving into The Education Arcade, a collaboration of MIT's Comparative Media Studies Program and the University of Wisconsin-Madison's Educational Technologies Program. The Education Arcade will support research and prototyping of educational games, with the hopes of partnering with game companies to spin the games off for commercial development. The Arcade will launch new efforts in the area of game literacy education, which will help teachers and students learn to develop their own games; it will develop curricular materials to support the classroom application of existing commercial games; and will work to pull together key stakeholders to form a consortium to do for games what the Children's Television Workshop did for broadcasting: support experimentation and implementation of fresh new ideas, which might not emerge otherwise in the current commercial context. Next May, thanks to the generous support of the Entertainment Software Association, the Education Arcade will host a special track of programming at the Electronic Entertainment Expo (E3), the leading trade show in the games industry. Two days of programming will bring game companies, textbook publishers, major cultural institutions, major research universities, governmental agencies, and foundations together in one room, to examine the existing research, share best practices, and figure out how we can work together to develop concrete plans for taking educational gaming to the next level.

Here, we describe work currently being done on three educational titles: *Supercharged!, Environmental Detectives*, and *Revolution.* In each case, the Education Arcade team is developing playable prototypes that can be tested in real classrooms and generate meaningful assessment data on their effectiveness.

SUPERCHARGED!

Computer simulations are changing the nature of science. Using digital technologies, scientists can build models of entire worlds, ranging from the insides of an atom to the infrastructure of cities. Scientists learn from simulations all the time, by visualizing

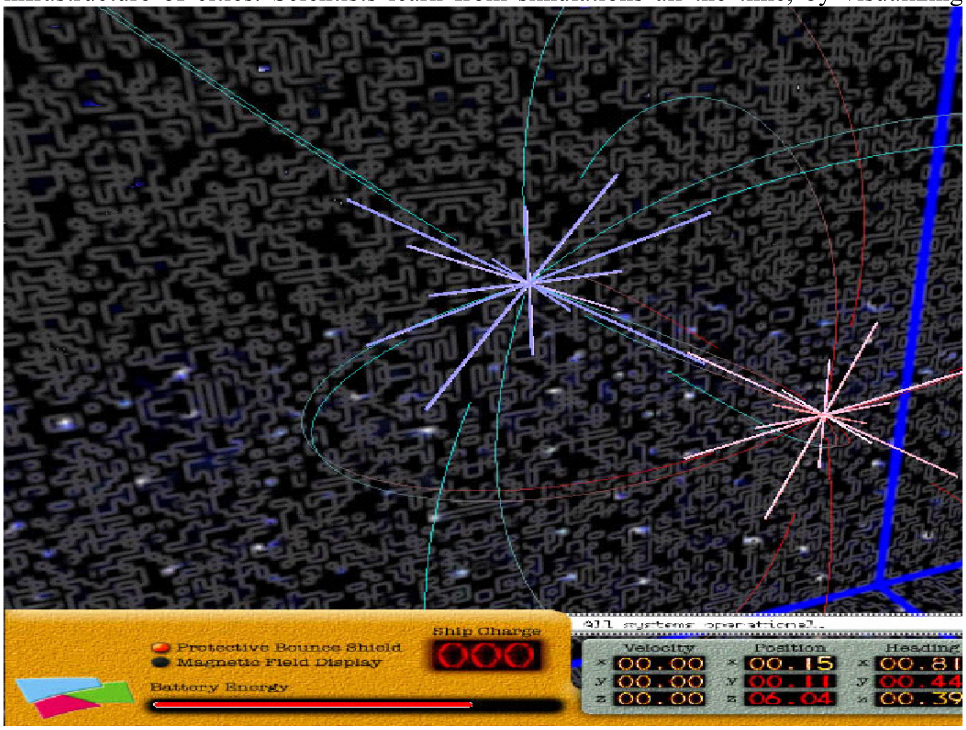

Fig. 1

systems, testing ideas, and ultimately gaining new insights into how systems behave as they compare simulations to the real world.

Digital simulations can give us new perspectives on systems; we can literally see what the world looks like from the perspective of, say, a charged particle flying through a magnetic field. Physics teachers frequently ask students to do "thought experiments" as a way to test students' understanding of complex phenomena.

At MIT we created a game, *Supercharged!,* to make this kind of scientific exercise more vivid and more widely accessible. The premise of the game is simple. A classroom of students is observing a classic standard physics experiment: the use of a Van der Graaf generator to create electric fields. The teacher flips on Supercharged, an educational film about electromagnetism. A plucky young student is distracted by the whizzing belts of the Van der Graaf generator, and decides to pick up the lighting rod herself to create some fun. This backfires, and she's propelled into *Supercharged!*, an abstract world of electric charges, electric fields, magnetic fields, charged spheres – all of the basics of a physics textbook, but come to life in 3D.

Players must try and save their class, leading the class through maze-like electromagnetic worlds. Players spin, careen, and bounce through levels by changing their charge and by strategically placing charges to move the ship through space. Building on the properties of racing, flying, maze and puzzle games, *Supercharged*! is

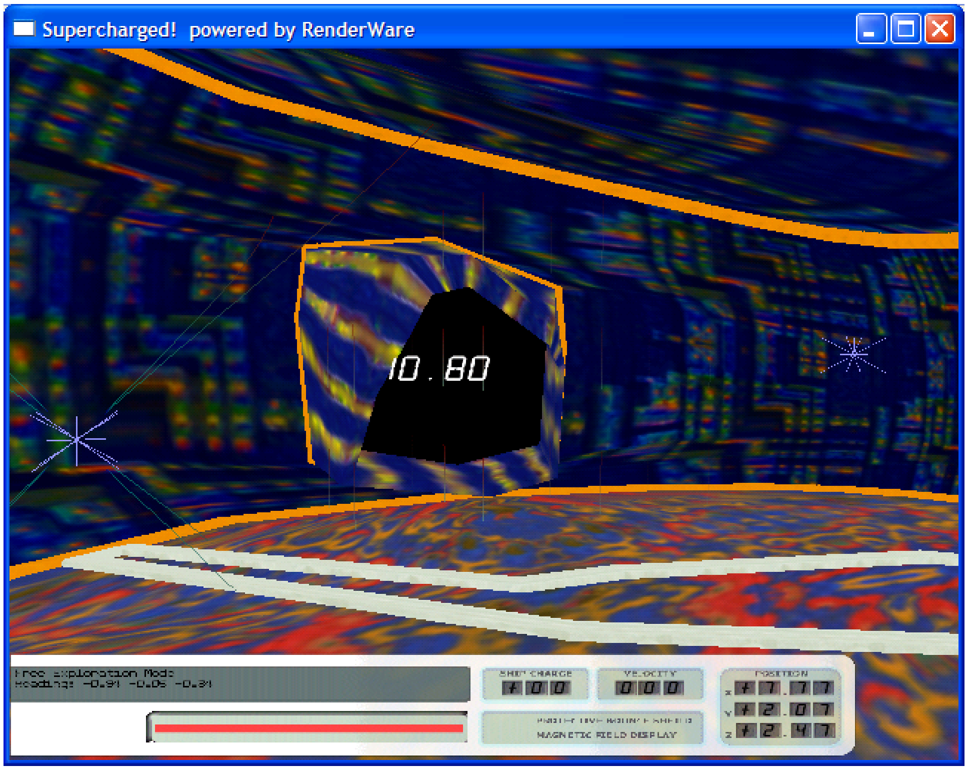

Fig. 2

designed to help students to systematically build understanding of electromagnetic worlds.

Over the past year, we have been testing *Supercharged!* in middle school, high school, and college classrooms. We found that the game can make very complex ideas accessible to a wide variety of students, from middle school students failing science to MIT students studying second-semester physics.

Observing MIT students learn with *Supercharged!*, we found that even MIT students had a number of inaccurate ideas about basic electrostatic concepts, which could be changed by playing the game. The following thought experiment is taken from John Belcher's physics course at MIT (it became the basis for a few of our levels). Imagine that you are a positively-charged particle free to fly through space, surrounded by an arrangement of negatively-charged particles. Which way do you think the particle will go? What forces are being exerted on the charged particle?

This kind of problem maps very cleanly to a computer game level where the player is a ship trying to move through electric fields to reach a goal. The positive charge is attracted to the closest negative charge, since the force of attraction between two particles grows weaker over a distance.

Watching students wrestle with the implications of this concept while they played the game, we constructed a series of levels where players had to confront similar problems. The level shown below tricked many students, as they believed that the two negative charges would “cancel” each other out and the positive charge would fly straight to the goal. Observing students play, and interviewing them about their conceptual understanding of charged particles, uncovered several misconceptions about how charges work. Many students believed that positive and negative charges negate one another or that distance had relatively little effect on the force created by two charged particles.

In the spring of 2003, we, along with Mike Barnett of Boston College, designed a curriculum for *Supercharged!* and took the game into three middle school classes. Both boys and girls were immediately drawn to the game; but frequently played the game differently. Many boys saw the activity as a direct competition either among themselves or against the game (and its designers). Once these boys cleared a level, they had no interest in replaying it or trying different strategies; the game was there to be beat. Other students, many of them girls, enjoyed replaying levels, or simply flying through the world, placing charges and testing ideas about how the electrostatics work.

Contrary to some worries, no students seemed to mind that the game graphics were not comparable to most commercial games or that the game was nonviolent. Echoing comments we heard from MIT students, the middle-school students *were* thoughtful critics, and complained if control mechanisms did not reflect standard game design practices or levels were poorly designed.

At the end of the unit, we gave post-tests to all students and interviewed roughly 20 of them, and then compared the results with those of students who learned electrostatics through more traditional means. On average, students who played *Supercharged!* did about 20% better on the post-test than students in the control group. There were no significant differences between boys and girls.

Perhaps most importantly, students who learned through the game had a much deeper understanding of scientific visualizations and the principles of electromagnetism. The game players explained how field lines (those around charged particles) depict forces useful for steering. Compare this level of understanding to that of the student in a control group who also answered the test question but could not explain why. Later, she told the researcher, “I don’t know why it looks that way. The teacher said so and showed us a picture and that was what it looked like.” Well-crafted levels confront students’ misunderstandings and help them see scientific concepts in new ways. Knowledge developed through game play is not pointless information to be recalled for tests, but is valuable information when confronting new challenges and solving problems.

ENVIRONMENTAL DETECTIVES

The students leave the classroom and head outdoors, carrying sophisticated environmental sampling equipment and spatial analysis tools capable of conducting real-time diagnostics on groundwater samples hundreds of feet below the surface. Their goal is to uncover the source of the environmental health problems that had recently been plaguing the community. In the process of their investigation, the students have to consult with experts, evaluate testimony, conduct environmental testing on toxic chemicals, and map their data in real time and real space. Time isn't on their side, since they have to file

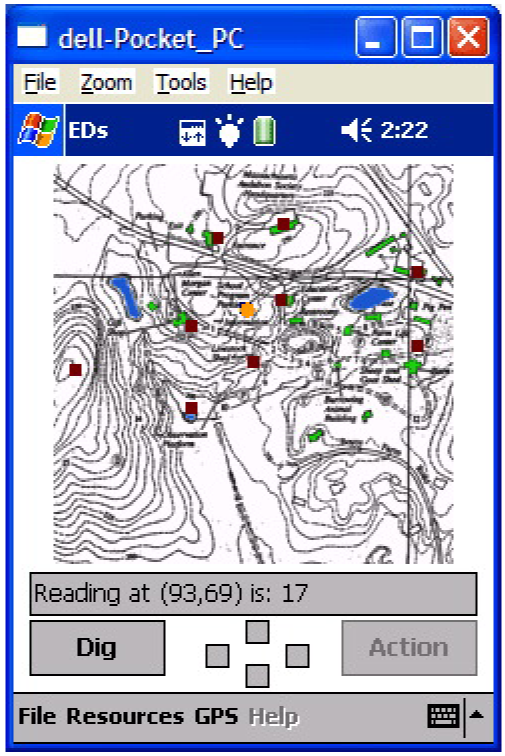

Fig. 3

a plan for containing the problem with the EPA that afternoon and the contaminant has affected a large area, which the students have to cover to collect the needed information.

There are elements of this scenario that probably sound familiar. It is now quite common for students to head out into the field and take samples from the local environment to measure indicators like pH, temperature or dissolved oxygen. However, in this case, the students deal with an environmental problem that affects the community, they handle toxic chemicals, employ sophisticated sampling equipment, and command drilling rigs that bore down into the earth.

While the latter format is motivating and authentic, it also sounds dangerous and expensive. This is where the technology steps in. While the students and the space in which they play are real, the chemicals and the instruments they use are virtual. We call this hybrid of real space and simulated data "augmented reality." Our first augmented reality game, *Environmental Detectives*, challenges teams of students to take on the roles of environmental engineers as they conduct simulated field tests, consult with virtual colleagues, and design solutions for problems. The game takes place outdoors, and data is provided to the students via location-aware GPS-enabled Pocket PCs. The game is both collaborative and competitive, as teams must work together to collect data but must also compete to present the best possible solution.

We found this combination of real and virtual experience effective in engaging students in the authentic practices of environmental engineers, an experience that most students would not have had otherwise. In our first year of research, we intensively studied the use of *Environmental Detectives* with high school and university classes at two locations. These studies provided insight into both the technology and what students know about the process they are trying to simulate. On the technological side, we found that students successfully navigated augmented realities, using cues from the real world to help them understand the problem in the simulated world. With the help of content experts, we analyzed the process that students follow in the game and found that the game accurately portrays the critical disciplinary practices of integrating primary data (quantitative data collected by the scientists themselves) and secondary data (often qualitative and collected from other experts). Students, however, had great difficulty with this, instead relying exclusively on qualitative secondary data collected from interviews or quantitative primary data collected from their virtual samples. Future iterations might provide greater scaffolding for this process by analyzing patterns of investigation and suggesting to students when it might be appropriate to switch modes if they are relying too heavily on one source of data or the other.

Due to their dependence on spatial and geographic information, these games are of necessity tied to particular locations. This is a great asset to the game, since the real location plays a large part in the course of events. It also means that the game cannot simply be played anywhere, but must be customized for each new location. Bringing the game to a new location requires more than just changing the GPS coordinates of events. Each game must incorporate local information, personalities, and concerns. The original incarnation of *Environmental Detectives* took place on the MIT campus, involved human health issues, and relied on the local faculty expertise. The second version of the game took place at a nature center and working farm. At this site, the game included animal health problems and relied on the expertise of the environmentalists on site.

Transporting these games across locations required the creation of a toolkit that allows customization. This toolkit enables teams to incorporate their own maps, media, contexts, and local data into the dynamics of *Environmental Detectives*. A single instance of the application is hosted on a GPS enabled Pocket PC. The team then uses desktop based software to collect their media, assemble their data, map the chemicals, craft their story, and deploy it all to the Pocket PC. This approach not only provides schools with customized versions of the game, but can involve students and teachers in the game-creation process as they design the specific scenario for their location. By creating their own games, they can build an even deeper understanding of the issues at hand.

REVOLUTION

Revolution is a multiplayer historical role-playing game, being developed in collaboration with Colonial Williamsburg. Each student assumes the role of a townsperson in a colonial Virginia community confronting the events leading up to the American revolution. Each has his or her own responsibilities, daily routines, and political allegiances as the town works through the events surrounding the revolution. Some are loyalists, some revolutionaries, some neutral (or as close as they can be to nonpartisan). Some are upper class, some working class, and some indentured servants or slaves. Each class forms its own town, though it may be possible for different classrooms to form villages up and down the Eastern seaboard and to send each other news about how the events impact their communities.

The game world is big enough so that each student can play an important part, small enough that their actions matter in shaping what happens. The game unfolds through a series of short episodes, each playable within about 40 minutes, each designed to stage a key event and play out its consequences for the different factions within the community. They (the factions) make decisions based on the information available: decrees issued by the royal governor, letters from the committees of correspondence, newspapers and pamphlets, oral gossip. Wherever possible, the game will draw on primary documents and encourage players to read them for what they are – partial and partisan accounts of a contemporary controversy.

Revolution builds on what we already know about the value of combining research and role-playing in teaching history, that is, the game offers kids the chance not simply to visit a "living history" museum like Williamsburg, but to personally experience the choices that confronted historical figures. Combining the perspectives of social, military, and political history, *Revolution* helps students to appreciate the interplay between personal and local concerns (making a living, marrying off your children, preparing for a party) and the kinds of national and very public concerns that are the focus of American history classes (the stamp tax, the Boston tea party, the shots fired at Lexington, the winter at Valley Forge). We want to push students beyond the platitudes carved in marble about the founding fathers to understand the ways in which the revolution emerged from decisions made by individual men and women who chose to risk their lives and property to fight for political ideals (or perhaps got sucked into the conflict because they had no choice but to defend their homes, or…). We want them to understand the risks and transgression in smuggling information to the revolutionary army or burning the royal governor in effigy in the middle of the night.

The power of a multiplayer game is that it is a living community, in which each student has a different set of experiences. Students can compare and contextualize experiences through class discussion. By bringing the game into the classroom, students are forced to pull back from the immediate play experience and reflect on the choices they have made.

Revolution is being built on an existing commercial role-playing game known as *Neverwinter Nights*, which includes powerful game modification (a.k.a. modding) tools provided by Bioware Inc., the game developers. *Neverwinter Nights* uses both the rules and milieux of the swords-and-sorcery *Advanced Dungeons and Dragons*, but a thriving fan community has already produced campaigns for *Neverwinter Nights* that draw from dramatically different cultural sources such as Japanese animation and Monty Python. Although initial prototypes will retain much of the user interface of *Neverwinter Nights*, the proposed complete version of *Revolution* is meant to be a "total conversion mod" for *Neverwinter Nights*. Bioware's underlying *Aurora* game engine is used to but every aesthetic aspect of the *Neverwinter Nights* campaign is altered to become a colonial American town.

Both the commercial and fan-built software tools for altering the appearance and behavior of *Neverwinter Nights* allow modders to implement most of the needed modifications without having to access and alter the source code of the *Aurora* engine. New sounds, 3D models, animations, textures, and 2D images can be introduced into the *Aurora Toolset* by using readily available software like Adobe Photoshop and 3D Studio Max, tools that are popular among nonprogrammers. For complex character and world interactions, Bioware integrates an extensive scripting language, loosely based on C++ syntax.

The process of creating the *Revolution* prototype should shed light on the actual challenges and rewards of modifying existing commercial software for educational purposes. By the end of summer 2004, we aim to test a single playable 40-minute chapter for about a dozen simultaneous players and another dozen nonplayer characters, accompanied by a tutorial for players inexperienced with digital role-playing games. Thus far, we have modeled about half of a Williamsburg-like town, allowing the colonial architecture to blend seamlessly with *Neverwinter Nights'* forest and river environs. We also have 3D models and animations of proper colonial fashions for the characters, although profession-specific clothing and hats are still in the pipeline. Over the next two school semesters, detailed planning of the events, characters, and dialogue will proceed, allowing a streamlined production-only workflow during the entirety of summer 2004.

These three games suggest what can be done right now: working in educational settings with small budgets, minimal equipment, inexperienced student programmers, and off-the-shelf software. Through the E3 conference, we hope to identify other teams of researchers both in the schools and in industry who want to collaborate in order to teach educational gaming to the next level. A tremendous amount of work needs to be done before we achieve our opening scenario – educational games meaningfully integrated across the school curriculum and made accessible to every school in America.

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