Teaching and Participatory Culture in the Digital Age

Kurt Squire
Foreword by James Paul Gee
Featuring contributions by Henry Jenkins

Teachers College, Columbia University
New York and London
CHAPTER 5

Games-to-Teach: Designing Games for Learning

Having discussed what properties cutting-edge games should include and why we need to design social interactions around them to make them participatory, we turn our attention to designing games for learning. Specifically, this chapter asks:

- Can we design games for learning that reflect the best contemporary gaming and learning theory?
- What would next-generation educational games look like?
- What kinds of design teams and processes do we need?

Let’s start with my first day on the job at MIT.

BROADENING THE DISCUSSION OF EDUCATION AND GAMES

“Kurt, why don’t you tell them the story of Pirates?” Henry Jenkins suggested. I scanned the room of 25 MIT scientists. Many were skeptical that you could learn science from a video game. Heck, I was skeptical. But this was exciting. Microsoft Research had funded iCampus, a collaboration with MIT to develop educational technology. They wanted to combine MIT’s tradition of inventing new technologies with Microsoft’s publishing power.

The Games-to-Teach project, led by Henry Jenkins from MIT’s Comparative Media Studies department and Randy Hinrichs at Microsoft, strove to ignite a global conversation about educational games. This was back in 2001 and video games were mostly considered violent or misogynistic at best. Henry wanted to
change that.¹ At about the same time, the serious games movement, led by Ben Sawyer with support from David Rejeski (2002) at the Woodrow Wilson Foundation, made similar observations. The serious games movement asks, How can we promote the nonentertainment use of gaming tools, knowledge, and teams?

So I related to the scientists my anecdote about swashbuckling in high school. In response, Matt Ford, a game designer working on Asheron’s Call, shared how, after playing Starcraft, he surveyed the blighted battlefield and couldn’t help but see the futility of war. Could kids play games in academic domains and reflect on them?

Henry shared how his son, Henry IV, tried to bring Doonesbury’s Election Game (1996) to school. Playing at home, Henry IV noticed that the 1996 election would come down to California, because it was the only remaining large swing state. He showed the game to his teacher, but she sent it home because video games were banned. Henry was appalled. How could you ban an entire medium, regardless of content? If game designers didn’t do something quickly, video games would go the way of the comic book. Comic books were a mainstream medium in the mid-20th century, but because of concerns about their effects on children, a “comic code” was enacted limiting what content could be displayed in comic books. Now most people think of them as media for children, although Spiegelman’s Maus (1986), the story of a Holocaust survivor, is but one example of how graphic novels can convey mature content. (For more on this topic, see Michael Bitt’s [2010] When Commas Meet Kryptonite, one of several recent texts on how literacy skills can be developed through comics.)

Over cocktails at the Electronic Entertainment Exposition (E3), Henry and Alex (with me along for the ride) outlined a plan to produce 10 prototypes that would demonstrate the potential of educational games. Our goal was to create a suite of games with a wide variety of features, rather than a one-off game that could be critiqued for its specific features (such as for being multiplayer or not being multiplayer and for being too open ended or not being open ended enough).

I returned to Bloomington to explain that I was taking off to MIT to work with Henry Jenkins, a guy who researches video games, pro wrestling, and Quentin Tarantino’s Star Wars. My colleagues expected me back within a few days, and frankly I wasn’t sure what to expect.

¹. Ironically, Henry has written extensively about both, as they are unavoidable topics. For two excellent examples, see “Professor Jenkins Goes to Washington,” the story of his testifying after the Columbine massacre, or Henry’s work on video games as gendered spaces. As I raise my own boys, I appreciate Henry’s argument that many games are built on traditional boys’ play and that parents’ discomfort with games is in part due to mothers’ unease with boys’ culture in their living rooms.
When I arrived at MIT, Alex showed me my office, a small closet next to Henry's suite, and told me to get going. It was a long drive back to Indiana, so I started typing.

**GAMES, POPULAR MEDIA, SCIENCE, AND LEARNING**

Trying to channel Henry Jenkins, I noted that he approaches ideas historically and liked the Bell Labs Science Films series. Thanks to the Internet, I learned that these were top-notch educational films produced by Jack Warner and Frank Capra, animated by the legendary Chuck Jones, and featuring Walt Disney in the final episode. It was all part of a broader initiative, dubbed Operation Frontal Lobe, that was designed to teach science with television.

I soon realized that the educational media I loved as a kid—*Donald Duck in Mathmagicland*, Legos, programming games in BASIC—were *entertainment*. I did them for fun outside school. Thom Gillespie, a professor at Indiana, also argues that most media used in schools (i.e., *SimCity*, *Oregon Trail*, *Reader Rabbit*) were *entertainment* products that had been reappropriated for learning (personal communication). Henry provided an exhaustive list of similar media, such as Hugo Gernsback's *Amazinger Stories* from the 1920s and 1930s and the educational films of Max Fleischer (inventor of Betty Boop). Could we continue the same tradition with video games?

I interviewed faculty and students at MIT, and most interviewees attributed their interest in science to parents, museums, "gadgets," and media. Famously, Richard Feynman, a physicist who attended MIT, credited his interest in science to tinkering with radios. This story was oft repeated, becoming central to the cultural landscape. Later, we surveyed the student body and found that *half* of the interviewees credited video games with sparking their interest in computer science. Those who mentioned school cited a specific teacher or experiences with LOGO.

Suddenly, teaching cutting-edge science through popular culture seemed possible. But what would our games look like? Educational video games *should* be about finding the game in the content, but few had done it successfully outside the military or *Hidden Agenda*, an early role playing game that paved the way for

---

2. This is not to suggest that Alex, who is now executive director of the Learning Games Network, a nonprofit company promoting games for learning, wasn't a good host. In fact, we joke that Alex should open an academic finishing school in which he teaches academics how to give presentations, dress properly, and host dinner parties.

3. Many interviewees described early experiences with LOGO (in or out of schools) as instrumental to their interest in computer science. LOGO (Papert and colleagues' programming language) has been criticized for not transforming education, but I was impressed by how many MIT students cite it as a formative learning experience.
today's games and learning (as noted in Prensky, 2000). Lloyd Rieber (1996) describes this tight match between game play, content, and practices as endogenous game play. As a designer, you want the game play to be about the same things that players learn.

We knew skeptics would argue that, even if you could design a good game, it would never be built, used by teachers, or adopted by schools. That is a sound critique, but over the long term, an initiative might leverage tools, assets, and designs across multiple titles. Once we had generalized approaches (or genres) for education, perhaps there could be savings. Plus, even a $10-million video game could become very cheap on a per-user basis if it were distributed to 1 million users online. Imagine the publishing revolution once an educational distribution platform on the Kindle, One Laptop Per Child, or iPad becomes established.

After holding up for a week, I brought my vision to Alex, and it was later reprinted in Game Studies (Squire, 2005). "Well, that saves us some work," he said. We were on to our first prototype.

We had 8 weeks to flesh out an idea to be used in MIT undergraduate classes. We started by examining AP curricula looking for ways that science is good for solving problems. Alex argued that the AP curricula gave us inroads into three distinct markets: college classes, advanced high school classes, and supplemental education markets.

**CREATING A RESEARCH AGENDA FOR GAMES AND EDUCATION**

Our first challenge was to articulate a coherent rationale for design as a means toward theorizing learning and media. Our project challenged a dominant view that design is largely a logical extension of theory. The theory-driven approach says that we first build a theory and then develop a design to instantiate it.

One problem is that theory-driven work can treat a single design as if it's the only way to instantiate theory. What if that one design is poorly executed? Even in the entertainment industry, where there is no pressure to educate, most projects fail. It puzzled Henry and Alex that researchers would ever draw strong inferences from one intervention; putting together a compelling television program, book, film, or game has nowhere near a 100% success rate (unless you are Pixar). That's why publishers release a range of books, films, or television programs if...

---

4. Granted, there remain many more reasons that games may not be used in schools and these are discussed throughout this book. For the classic study of technology in schools, see Larry Cuban's Teachers and Machines (1986).
the hopes that a few catch on. You learn from the successes, absorb your losses from the failures, and move forward.

**The Perils of Overgeneralizing from One Game**

Logically, there is still the problem of generalizing toward a medium from one intervention (even if we somehow created an amazing game). Ecological psychologists such as James Gibson (1979) and Urie Bronfenbrenner (1979) wrote about this problem, but their arguments seem arcane for those untrained in experimental methods. But as a rule of thumb, any time someone says, "We know that a game about science won't work because . . .," you should be skeptical.

To explain why you can't infer too much from one instantiation of an idea, let's return to video games, circa 2003. I was visiting the Electronic Entertainment Expo, the annual game publishers' convention. I was particularly interested in massively multiplayer online (MMO) games because *EverQuest, Ultima Online*, and *Asheron's Call* all had enjoyed some success and the market seemed ready for a breakthrough hit. MMOs, recall, are essentially graphical versions of the text-based MUDs that I played with the McGuffey kids. *EverQuest* sold about 500,000 copies, which, at $49.99 each, plus another $9.99 a month per subscription, makes it a significant financial success.

Everyone thought *The Sims Online* was going to be that breakthrough hit. *The Sims*, the best-selling game franchise, boasted an enormous, dedicated player base. Over half its players were women, who seemed poised to purchase a multiplayer game. Many thought that if hundreds of thousands of women started gaming online, men would follow. What could go wrong? (See *Sims Online* sidebar.) After about 100,000 initial purchases, it got bad reviews and quietly folded a few years later.

Next came *Star Wars Galaxies*. Wisely, Sony hired the *Ultima Online* developers to work with the *Star Wars* franchise. Backed by the publishing muscle of Sony (which produced *EverQuest*) it was another surefire hit. Their development process was literally a textbook example of how to do participatory design, and I wrote a case study of it for Joystick101.org. They engaged users for years, introducing designs, soliciting feedback, and turning 500,000 fans into evangelists. On paper, it was amazing.

---

5. Both Gibson and Bronfenbrenner discussed the problem in terms of the representativeness of the stimuli. Even in something as basic as visual perception research, in which you are trying to learn how the eye figures out visual depth, you can't use just one stimulus. You need to sample from all the possible things that one might see in the world in order to make valid assertions about how the eye sees. By way of analogy, then, you'd want to theoretically outline an infinite number of designs based on a theory and then randomly select a subset (which usually ends up being about 20) to test.
The Sims Online

In The Sims Online, players took on the role of a Sim who interacted with other Sims in an online universe resembling the universe in the single-player game. The Sims Online failed for many reasons, ranging from poorly balanced game mechanics to issues with the target audience. In The Sims Online, players bought a home and then sought to improve their Sim so as to earn more credit and buy more stuff. Players were compensated based on how much time other Sims spent in their home, theoretically rewarding those players who were entertaining.

What happened was that massive virtual sweatshops emerged in which players could level up their skills quickly and earn as much money as efficiently as possible. The online world became full of sweatshops advertising leveling up. My favorites were those that offered "greening up," which was essentially taking your tired worker Sim and eating, using the bathroom, and napping (ideally on a comfortable couch) so that the worker could get back to work. This emergent phenomenon, as amusing as it was to watch, wasn't fun to play.

Even if it had worked, the context of The Sims Online wasn't thoroughly considered. Although millions of people (many of whom are women) play casual games at work, this does not mean that they necessarily want an MMO that takes on the features of a casual game. As anyone who has played online hearts during a temp job knows, you do this to kill time, to socialize, and maybe as an act of rebellion against your employer—not necessarily to take on a new identity. Plus, many women have time constraints, between family and work obligations, and must navigate cultural stereotypes (often enforced by women) against gaming. Women often report preferring to spend free time improving themselves or their family. This theory of self-improvement may be why games such as Brain Age, Wii Fit, and Rock Band have been such a hit.

So why was it a disappointment?

Well, the answer is a long one, but most agree that (1) they shipped too soon and (2) they never got the combat right. In postmortems, designer Raph Koster confessed that they spent so much time on macrosystems (such as the game's economy) that they overlooked simple moment-to-moment interactions (like combat or movement), which is what players spend the most time doing. Raph reflected that if he could do it over, he'd first polish the systems that constitute the bulk of game play. This is a good lesson for educational designers and a reason to privilege rapid prototyping.
But back at E3, Blizzard was introducing a little game called *World of Warcraft*. The Blizzard fan boys were fawning. I got a walk-through and saw nothing remarkable. I said, "We already had three fantasy-themed games about elves and orcs, and they all compete for the same 500,000 people. Why will you succeed when they can't?"

As everyone knows, I was wrong. *World of Warcraft* has sold upwards of 12 million copies and is one of the largest media franchises ever. Why? Lots of reasons (see Wallace, 2006), but a big one is that *WoW* was *incredibly* polished. Blizzard spent more money developing *WoW* than had ever been spent on a game, including a several-month beta period. Educational game designers—and funding agencies—could learn from their policy of never shipping a game until it's ready.

Yet the game itself offered almost *nothing* new. On the surface, the core features of *World of Warcraft* were a simplified version of what already existed—in a market in which *more features* are considered good! The character progression system was taken from MUDs. The quests were from *EverQuest*. Famously, the death mechanic was lifted directly from *Ultima Online*, causing Rich Vogel to comment that Blizzard used good mechanics that other developers *forgot* about. What worked was not the idea as much as Blizzard's *execution*.

**Games Literacy**

In education, we don't test *ideas*; we test their *execution*. This is why educational game designers need to be literate with the medium. Just as educational film directors know about composition, sound, lighting, cuts, and so on, educational software designers need to understand avatar creation and customization, overlapping roles, reputation systems, embedded narratives, and other elements (see Prejudice in Educational Media Design sidebar). Indeed, the idea that researchers or designers should even *play* games is controversial. Some educational game designers haven't even tried *WoW*. If asked why, usually they claim they are too busy (imagine an author being too busy to read best-selling books). I would love it if they said, "Well, I don't play *WoW* because it's a rehash of 1990s MUDs, and I'm more

---

6. Outside forces intervened, as well, including the maturation of the games market, a lack of good PC games at the time, cross-platform availability (it was one of the only AAA titles to launch on the Mac), the penetration of broadband, and the growth of the global games market. Blizzard has a huge reputation in East Asia thanks to *Starcraft*, and it had the infrastructure to pull off a strong Asian release. *WoW* sells as well in China as it does the United States.

7. The implementation of the rogue and warrior classes were new, as was the concept of warlocks and druids. I still get misty-eyed when I think of my warlock.
interested in indie games such as *Flower*, *Braid*, or *Parallel Kingdoms* (see Chapter 10), but that generally doesn't happen. Others don't want to become game “advocates,” lest we lose neutrality. Imagine proudly proclaiming that you don't read books because you don't want to become biased toward reading. It's thinly veiled cultural fear.

---

**Prejudice in Educational Media Design**

Imagine wanting to publish educational books, but only by people who don't read. Could I have used that as an excuse for my poor term papers in English class? I could have justified my lack of theme, narrative structure, or spelling by arguing that I don't want to waste my time reading and I don't trust the teacher and his culture of books (in fact, many struggling readers react to school just this way).

Many of the designers of educational games aren't players. Imagine a social science researcher deriding book culture because he or she watched a few people reading books at a coffee shop and a few studies, and found that if people were forced to read violent books (e.g., *Beowulf*, Shakespeare, or the Bible), they reacted with aggression to fictional literary characters. Thus proving that reading violent books causes aggression.

As a result of educational media specialists' negative bias toward video games, some of the materials being tested as “game-based learning” don't contain the core features of games as we defined them in the opening chapters. Many educational games lack transgressive play, character progression, competition, interesting choices and consequences, the chance to try on different social identities, or interesting artwork. It's as if someone strung a bunch of words together on paper and then dismissed the educational potential of books because no one could understand the text.

We need to treat the first wave of game-based learning research with caution. By way of another analogy, it's as if we're in 1925, we've given educators films and cameras, and we want to make judgments about the medium. We would never expect to definitively evaluate the educational potential of motion pictures for all subject matters, across all time and space. Indeed, the enterprise of “judging” a medium assumes that execution is more or less trivial.

This execution is why Robert Kozma (2000) described educational technologists’ task as *making* links between media and learning, rather than *discovering* them. We don't just discover media in the wild; media are designed, developed, executed.
and implemented within particular contexts. There is no “one” television, but there are *Sesame Street*, *Super Why*, and *Bill Nye the Science Guy*. And, there’s no one way to watch these shows. Cook and Conner (1976) showed that many learning effects of *Sesame Street* came from parents’ and peers’ encouraging children and friends to watch and participate in media. Some social scientists sought to isolate the effects of watching *Sesame Street* from this context, as if watching alone in a controlled setting was somehow natural. If our goal is make connections between media, learning, and context, then we need to identify issues such as encouragement to view and build better mechanisms to support learning. Basic and design research need to reinforce one another so that we understand how mechanisms like in-jokes work and how parents’ participation in viewing reinforces good viewing habits.

We cannot study the educational benefits of media until after they are designed, so that our findings are linked to those designs. Similarly, we can never draw summative conclusions about a medium from one example; indeed, we probably can’t draw summative conclusions about that medium in any circumstance, given the nearly infinite ways that ideas can be expressed. Thankfully, most teachers understand that some media work with some kids some of the time but, other times, might be less effective.8

These same design techniques flow seamlessly across *nongame* websites such as Facebook and eBay. Designers who can employ these features toward learning software have a huge, untapped market waiting for them. Those designers who act like it’s still 1996 will struggle.

**DESIGNING GAMES FOR LEARNING**

The remainder of this chapter shares experiences from the Games-to-Teach project, in particular the games, genres, and research on learning from game play. However, the biggest successes are actually the dozens of people who, like myself, are out leading research groups, working in games companies, and exploring these ideas.

---

8. Janet Kretschmer, from the McGuffey School, once said that the “way” her school worked was to not have one way. The trick was getting different teachers, methods, materials, and programs to work in concert toward meeting kids’ needs. Some kids at certain times need certain methods (including certain teacher personalities), and other kids at other times need other ones. Teachers (as professionals) understand the dynamics of implementing different instructional techniques and do so creatively as the situation requires. Games like *Model UN* played a role in the McGuffey curriculum, but McGuffey would never propose that students play games all the time.
in different ways. Altogether, we created 17 game prototypes (ideas demonstrated via a variety of media that are available on the archived Games-to-Teach website), and four were developed into playable, testable games. The two that we produced internally (Environmental Detectives and Supercharged!) are described in this chapter. Here's what we learned.

**Art Direction**

Visual artists approach game design differently from the way most educational researchers do, and it is critical to have visual artists involved early in the design process. Whereas I might think about themes, concepts, and relationships, visual designers might think about settings, characters, colors, and worlds. Coming up with “fantasy” ideas (such as those leafy shoulders on my druid) is second nature to most visual artists. Educational researchers pay virtually no attention to aesthetics. Our educational system seems to weed out skilled visual communicators through year after year of text-heavy assignments. In many educational games, graphics, inasmuch as they exist, are merely functional. Good graphics are derided as “eye candy,” suggesting that a pleasurable visual experience detracts from learning.

*Cuckoo Time! is a great example of how good games require creative visual thinking. Our team was discussing games about elementary physics that included gears, pulleys, levers, and pendulums. David Moisl, an animator, took that idea and designed an entire world of fat little gnomes set inside a cuckoo clock (see Figure 5.1). Their iconography became power-ups so that Birkenstocks boot other gnomes, while accordions move the cuckoo bird. Knockwurst added mass, while lederhosen reduced mass. By using visual humor, David took an academic idea and made it a game.

Lessons from *Biohazard* (a game developed by partners at Carnegie Mellon’s Entertainment Technology Program; see Figure 5.2) reinforced the same thing. *Biohazard* was designed to teach AP-level biology through investigating diseases, an idea that has spread into subsequent games, some of which I describe in Chapter 9. We wanted the student who was playing the role of the doctor to feel emotionally compelled to help people. Players become specialized forensic scientists by investigating anthrax scares, flu viruses, and so on, drawing on the appeal of shows like CSI. Carnegie Mellon University’s team adapted our design to use *Biohazard* with emergency responders who were preparing for terrorist attacks.⁹

---


¹⁰. Pursuing homeland security grants was common after September 11, 2001. The...
I studied firefighters, high schoolers, and children as young as age 3 playing Carnegie Mellon’s version of Biohazard. The most critical part of the game was its artwork. The moment players put on those suits, no matter who they were in real life—firefighters, paramedics, college students, 3-year-olds—they became heroic saviors. The appeal of this fantasy is nearly universal; everyone enjoys braving danger to help people.

The firefighters loved using Biohazard as a training tool. Rural firefighters wanted to play authentic scenarios, such as an urban anthrax outbreak or rural water contamination, and compare their performance with that of urban units. “Let’s see how the New York Fire Department deals with a Brown County brush fire!” one challenged. They believed that if an online training game that included tournaments, high scores, and bonus levels for advanced techniques was in breakrooms, it would be so popular they’d have to tear it away.

Skeptics often argue that educational games are inherently not fun, but I think the opposite is true. If done well, there are few fantasies better than having a positive impact on the world. If a player can put down the game and know that he or she is better at something useful, all the better. This allure of self-improvement is part of the success of games such as Brain Age. The trick is that educational game designers have to use art, aesthetics, and design in the same ways that entertainment designers do.

---

Bush administration gutted educational technology research programs such as the Fund for the Improvement of Postsecondary Education to give out earmarks for programs such as the Strom Thurmond Wellness and Fitness Center at the University of South Carolina. In fact, we spend much more on educational technology in the military than we do on such technology in all public K-16 schools combined. See National Academy of Sciences (2003),
From Content to Experience

Once the design is set and artists are involved, designers focus the game experience so that it requires thinking with content rather than just memorization. How do you design this sort of game play? We developed user scenarios—game play descriptions written from the player’s perspective. Here’s an excerpt from *Hephaestus*, a game prototyped in Mathematica (a high-end mathematical visualization software—seriously).

Ana’s father purchased *Hephaestus* to encourage her interest in engineering. Ana gives Strider, her robot, a three-speed gearbox, allowing her to switch between 1:1, 1:4, and 1:10 gear ratios so that she can have fast movement or raw power. Strider will need to traverse diverse locations from marshes to mountains, so she purchases an engine with power to spare. Her friend’s robot has a recharging station.

In an after-school robotics club, Ana plans to build a “real” version of Strider, using *Hephaestus* as a design tool.

This design exercise requires entering the player’s head, speculating what he or she might be thinking, and then using that knowledge to enable academically valuable interactions. *Hephaestus* featured a design-then-play rhythm. This combines visceral game play (scouting the terrain, mining resources) with reflection through design. It also explored how to connect home and school and how to relate educational gaming with hobbyist pursuits such as robotics.
Connecting to Learning Theory

We tried to engineer "memorable moments," a phrase that describes how players' intentions, game systems, and representations on screen converge to produce transcendent emotions. Can we trigger game play that challenges our current models of the world and creates flashes of insight? As we fleshed out the design, we began scouring the research literature for design ideas. Hopefully, that sentence caused pause. How could educational research be useful in such a nuts-and-bolts endeavor? When viewed from the prism of a game designer looking for puzzles and problems, research is actually full of potential. We asked several questions: (1) What are the purposes for learning that content? (2) What is known about how people learn in that domain? and (3) What strategies have worked in the past?

To explain, consider Cuckoo Time! We had a relatively creative idea (learn Newtonian physics by jumping around the inside of a cuckoo clock). David's sketches proved to us that it could be a game and that it could be fun (or better, or interesting) to use power-ups to change velocity, acceleration, mass, or gravity. But how would players learn?

The research literature shows that most people have really bad understandings of classical mechanics. For example, what's the effect of changing the mass of the bob of a pendulum on its period? How do mass, length, or gravity affect angular acceleration? Knowledge areas in which people have naive misconceptions make great starting puzzles. For example, people often think that the heavier a pendulum bob, the shorter its period. You could imagine someone swinging on a pendulum, hoping to fly up to a new platform. They miss. So they use a power-up to reduce their mass and swing higher. It doesn't work.

Integrating content and game play can produce puzzlement, as constructivists like John Savery and Tom Duffy (1995) would call it. The idea of puzzlement is that we're naturally motivated to learn when the world does not conform to our expectations. As this puzzled player tries different power-ups, he or she might check the "hint" section, which offers a textbook-style physics explanation. This puzzlement would drive the intellectual life of the game (beer 'n' brats drove the fun). Because

11. I won't bore you with more of my memorable moments, which range from epic space races in Civ to my first confrontation with marines in Half Life. Drew Davidson's ongoing Well Played book series does a good job of relating such experiences and tying them to theory.
12. Entertainment game designers do this, too. Tower of Hanoi, the classic mathematical puzzle used in cognitive science research, has been used in many games, most famously Star Wars: Knights of the Old Republic.
Cuckoo Time! is collaborative, players could also teach one another or debate ideas while playing, just as WoW players can argue about strategies.

Across all 10 prototypes, we proposed how intrinsically interesting aspects of science could be turned into games. The upshot of this work was a general process for finding the game in the content (Rieber’s notion of endogenous games), published by the Games-to-Teach team (2003). Before the project, people mostly laughed at the suggestion, but now we had a process for thinking through design and development. Next we needed to build a game and try it out.

BUILDING AN EDUCATIONAL GAME FROM SCRATCH

“Have you seen the real-time physics in Halo? They’re incredible!” said Dr. John Belcher, a winner of NASA’s Exceptional Scientific Achievement Medal. Belcher had played Halo with his grandson and was now lecturing me on its real-time physics engine. For years, Belcher had been building electrostatics visualizations to help explain ideas to funders and to physics students. The problem was that these visualizations weren’t interactive. You watched them, but you couldn’t test your understanding. Belcher thought that video games were the next logical step. It was insanely cool to hear this from someone who led experiments on the Voyager spaceship.

Finding the Game in the Academic Domains

Over the next few months, John explained to us the big ideas students needed to learn, what they struggled with, and what he thought were good game ideas. Our first idea involved manipulating electrostatic forces in a simulated world game like Deus Ex. Players could send electricity through wires to create magnetic fields, or somehow change the Earth’s magnetic field. I knew nothing about electromagnetism, so John invited me to audit his technology-enhanced physics course. I was blown away. John used simulations, probe wear, clickers, circuit boards, and lectures in one integrated course. And he did it with an entire class of 144 students.

However, we struggled to design a simulated world electrostatics game. Simulated world games rely on what Doug Church (2005) calls problems, not puzzles. Problems are challenges facing the player that can be solved any number of ways. Consider Thief (a game he designed), in which the player must break into a house. He can march in the front door and knock out a guard, he can distract the guard with a noise and then sneak in behind him, or he can break in through a window and dodge the guards altogether. There are many ways to succeed, and the “fun” is thinking creatively to solve the problems. The educational content is
such games comes from learning the underlying properties of the system. Thief players learn the layout of the house and the rules governing how guards react; we wanted players to learn the rules of electromagnetism. This basic model is at the core of how I think about educational games, but our game just wasn’t gelling.

Our best game ideas all involved puzzles. Puzzles have single solutions. Adventure games are full of them. The classic format is “find the key that unlocks a door.” To solve an electromagnetic puzzle, players might set an electric wire next to a compass in order to alter the magnetic field immediately surrounding it and unlock a new level. Sadly, we couldn’t identify “problems” that could be solved a variety of ways. Puzzle games are certainly OK. Puzzles are especially good at serving as choke points to test understandings. But for a physics game—a content domain that is capable of being simulated—to be built entirely around puzzles and not simulated problems seemed ironic (and not in a good way). Adding to our distaste for this approach was our play-testing of Physicsus, an adventure game featuring physics puzzles with minimal simulation. Physicsus made sense as a game, but playing Physicsus confirmed our fears that a physics game not based on simulation felt flat.

We were finally rescued by a visit from Alex Rigopoulos and Eran Egozy, two Harmonix game developers (fittingly suggested to us by Doug Church). As Alex and Eran riffed back and forth with one of our team members, Walter Holland, they proposed that the way to do an electrostatics simulated world game was to build an abstract world around Maxwell’s four equations. Maxwell’s equations can be used to determine electric force, and force can be described through movement. This could translate readily into game mechanics. They argued for keeping it simple, so that anyone playing the game developed an intuition of these ideas, which are the foundation of electrodynamic physics.

Thus Supercharged! was born. Supercharged! was a 3-D simulation game designed to help introductory physics students develop intuitive understandings of electrostatics. (See Figure 5.3.)

Players control a spaceship that places charged particles. They spin and fly about the world, bouncing off walls and soaring through abstract spaces. It is possible to use the game as a predictive simulation by taking note of your position and conducting measurements to mathematically infer Coulomb’s law or Maxwell’s equations, but we didn’t think any normal person would do so. We did think, however, that students might develop a better grasp of these underlying concepts, working back and forth between homework problems, lecture notes, and the game to think through the content. To encourage this sort of thinking, levels were designed to correspond with classic textbook problems and thought experiments.
We knocked out a narrative: After a physics experiment goes awry, the player is sucked into an abstract world of electrostatic forces. The art direction followed the bright, abstract style used in *Rez* and *Frequency*, which was in vogue as a reaction against many developers' obsession with photorealism. This approach enabled us to make a fully 3-D game while avoiding costly character modeling and animation, which we didn't have the resources to do well.

We ran the idea by John Belcher, who signed off. Belcher confirmed that most students lack an intuitive grasp of Maxwell's equations. I delved into the research literature and found plenty of confirming evidence. Andrea DiSessa's (2000) and Kenneth Forbus's (1996) work showed that intuitive, qualitative understanding in physics is desirable before learning physics equations.

I started designing levels to walk the player through a series of classic physics problems after closely studying John Belcher's teaching in his classroom. John frequently used thought experiments such as, "Imagine that you are a charged particle flying through a magnetic field that is perpendicular to your velocity. What direction would you go?" There were even more basic ideas that we could translate for younger audiences, such as Coulomb's law, or the inverse square law, which states that some physical quantity or strength is inversely proportional to the square of the distance from the source of that physical quantity. Through games, players could inhabit these fundamental laws and test them interactively.

**Design Research: Developing Supercharged!**

We hired a team of four undergraduate programmers, managed by Philip Tan (now an executive director for the Singapore-MIT GAMBIT Game Lab) to make *Supercharged!* Immediately, we had questions: How does the world look when viewed from the perspective of a charged particle? Should players be able to move their ship however they wish, or should they be forced to move according to electromagnetic forces, like a ping-pong ball getting bounced back and forth? We argued about this for a few days, and finally one of the undergraduate students, Rob Figueroa, coded a demo in Direct X over the weekend. The demo revealed that it was kind of viscerally enjoyable, but discombobulating, to be spun around by these forces. Having no direct control was frustrating, and placing charged particles in real time while flying was not going to happen—at least not in 3-D. Prototyping saved us countless hours of arguing, and to this day I'm a fan of prototyping early and often rather than writing design documents (for a thorough case study, see Jenkins, Squire, & Tan, 2003).
This still didn’t resolve the artwork concerns. Because 3-D artists were in short supply at MIT, we hired an award-winning artist, Patricia Beckmann of Bunsella Films, to create art assets and manage a team of students. We soon learned that when you want game-ready art that works in-engine, it’s best to have a professional. Novice artists are great for conceptual art, but for final art, find a “pro” or be ready for students to learn on the job.

One mistake we made (lo and behold) was to get too far in game play design without active art direction. Ideas coming from the art team were inevitably bumped down the priority list because programmers thought the “fuzzy little creatures” or “eye candy” were silly. Yet game art must communicate concepts such as providing feedback on players’ actions or guiding players in ways that other media don’t. This was an incredibly useful insight for me as a games theorist. I appreciated the functional role of art in games, but I didn’t understand just how critical art was for communicating concepts to the player. For example, our initial walls were translucent, which meant novice users had no idea what they were. As one asked, “What is that thing? A warp shield?” Through play testing, we learned that walls must communicate their “walliness” as well as the player’s position and velocity. Similarly, the goals in the game needed to call out to the player, “Hey! I’m where you want to go,” so that the player intuitively understood the point of the game without having to think about it. In games, as in life, we use objects in the environment to understand where we are, how fast we’re going, and so on, and some objects are better
at this than others. Interestingly, this finding comes from Gibson's (1979) work on visual perception, which is foundational to situated learning theory.

*Everything* in a game has to show players how to play. A well-designed game builds loads of information into the environment (e.g., high-up ledges suggest jumping). Good art makes important clues "pop" off the screen. Good games use more-subtle techniques, such as color saturation to communicate the boundaries of walls or enemies. Otherwise, the game becomes about navigation rather than more-interesting concepts. When it works in harmony, the art is pleasing while underscoring what the gamer needs to be doing. It's truly an art form.

More broadly, designers must communicate the goal of the experience itself. Our first user tests included various types of levels (flying levels, 2-D mazes, and rail-tunnel levels), but players didn't understand anything except the maze levels. Once you give someone a maze, he or she immediately has a frame for the activity. The person knows the goal; anticipates constraints (such as time pressure or an enemy); and—hopefully—develops a desire to get out.

Helping players develop goals may be elementary for veteran game designers, but this was new to me. Given how incredibly *simple* this example is, imagine what we could learn by studying larger projects. For example, I recall a conversation about *Metroid* with Nathan McKenzie (a game designer who used to work at Raven and Rainbow Studios). I was impressed by how the levels alternated closed and open spaces, providing a rhythmic feel. Nathan agreed, and he pointed out that this alternating structure enabled the levels to load while playing. I had never bothered to think about how such loading concerns manifest themselves in design, but as a practicing developer he couldn't miss it. This anecdote isn't to suggest that all game theorists need to become designers (although it might be useful to do so) but, rather, that substantive conversation across areas of expertise can generate new insights. If only more game developers allowed researchers to study their practice For notable exceptions, see Malaby's, 2009, study of Linden Lab and Dae's, 2010, study of GameLab).

**Implementing Games-Based Research in Classes**

By the spring, the game was ready to test in classrooms. This was a fast development cycle (from concept to classroom in under 1 year), but we wanted to test in early stages. Our plan to work with John Belcher's Technology Enabled Active Learning (TEAL) course met some snags. The course was expanding so that in the following term, *all* sections of Introduction to Electricity and Magnetism (about 1,000 students) would learn through TEAL's innovative, hands-on approach. The conversion wasn't going well. Many students feared that they were receiving "easier"
assignments than previous courses. (Only at MIT could students be personally af-
fronted by the lack of difficulty in problem sets). In reality the problem sets were the
same. Students also feared that they missed the "real" information from traditional
classes, a common fear in any non-survey-style course. By March 2003, a group of
students threatened to walk out of class (LeBon, 2003).

Yet when they studied learning through TEAL, Dori and Belcher (2005) found
that students did in fact show higher learning gains via TEAL than through tradi-
tional methods—almost twice as much. It's hard to communicate how impressive
this was; the majority of such studies rarely finds any statistically significant differ-
ences. Belcher and colleagues have since smoothed over the transitional difficulties,
and the course is integrated into MIT life. This goes to show you how things change
if you have patience, and how different a story looks depending on when you tell it.
The story of TEAL in spring of 2003 looked like a failure. Now it's a crown jewel in
MIT's undergraduate curriculum.

Regardless, John didn't want to make things even more difficult by introducing
a video game. He allowed us to recruit 20 students who would use the game and do
interviews with us about the experience. If the project continued, he would use the
game at the beginning of the course to build students' conceptual understandings
and then refer back to it throughout the term.

### Working in Schools

We set out looking for another site to test Supercharged! We did demonstration
projects in a few secondary schools, including a technology charter school. Massa-
chusetts (like many states) was moving toward a physics-first curriculum, where
physics would be the first science course in the high school curriculum. Teachers, of
course, had no idea how to teach physics to 9th graders. Supercharged!, which built
on Forbus's idea of qualitative physics understandings, seemed like a good place to
start. We hoped to show how games for higher education could migrate across mar-
kets, such as K–12 schools or homes. Mike Barnett, a colleague at Boston College,
had a master's in physics and was willing to teach the unit to middle school students.
We taught the 2-week unit on electricity and magnetism to five classes. Three classes
played the game in the experimental condition and two received traditional lectures
and assignments in the control condition. We wanted to see what conceptual under-
standings emerged and how learning in a game-based class compared to learning in
a traditional one. Considering everything, the experiment was a success; going from
design to a classroom implementation in under a year is no small feat. Our findings
(reported in Barnett, Squire, Higgenbotham, & Grant, 2004) follow.
The Floor Versus the Ceiling

Educators have debated whether educational games can succeed because “they can’t compete with Grand Theft Auto.” Commonly called the “floor or ceiling” debate, the question it poses is, do commercial video games create such a high ceiling that educational games can never succeed? Or, is the floor of standard school curriculum so low that halfway decent games will be welcomed?

Supercharged!, when brought into school, proved very engaging. Kids compared it to “what they did at school” rather than “the games they played at home.” We saw no evidence of kids rejecting Supercharged! because it wasn’t Grand Theft Auto. There was not one complaint about the graphics or lack of violent content. We presented Supercharged! as a game, and students played it.

These kids were critical of bad design. Poorly arranged levels that didn’t match the ship’s controls (e.g., levels that were too big or too small) were criticized. Likewise, when the pacing was off—when new levels did not introduce new challenges or challenges graduated too quickly, students tuned out. Finally, sometimes the collision detection clipped or players got stuck near a wall, which was deadly for engagement. I couldn’t help but wonder how often we say, “They didn’t like my game because it’s not Grand Theft Auto,” when in reality they didn’t like the game because of its lack of polish.

These experiences solidified my take on the “floor or ceiling” debate: Kids don’t expect educational games to be Grand Theft Auto, but they do expect good design. This means clear, compelling objectives; intuitive controls; clean interfaces; aesthetically pleasing worlds; and difficulty curves that ramp well—the same kinds of things that separate Sid Meier’s Pirates! from Sea Dogs. As kids grow up awash in software, their expectations evolve. Twenty years ago, when I was a kid, the computer was so interesting it really didn’t matter what we did with it. We were happy just to be on the computer. Now, almost every kid has access to an iPod touch, gaming console, and personal computer. They are sophisticated consumers who expect good design.

Accommodating Diverse Play Styles

We saw a wide range of play styles, even in a “targeted” game as straightforward as Supercharged! Some kids burned through levels trying to “win” as quickly as possible. One kid even spiked the controller afterward, declaring, “Ha! I beat your game!” I gravitate toward games that are “unbeatable,” so this struck me as odd behavior, even though it’s quite common. Other players, many of whom were girls, replayed levels and sought more elegant solutions. I also replay levels, obsessing about how to do it “right” at the expense of ever finishing.
The “playing to win” kids beat our original levels the first day. I suggested they replay, but I might as well have suggested that they go read War and Peace. They had won, and to them that was the point. I told them I'd bring in more levels the next day, that they had simply beat the first chapter. This type of highly competitive student never enjoyed Supercharged! as much as the others. The teacher was careful to remind us that these same kids generally paid “no attention” during normal school activities. For her, the game was a godsend.

In many respects, we hadn't honored the genre. Our levels didn't sufficiently build players' understandings, teach them new abilities, extend their skills in new directions, and then let them be creative in their problem solving. In fairness, many *entertainment* games make this mistake. Full Spectrum Warrior (a great game otherwise) teaches the player all their skills in the first hour and then spends the next 7 hours simply applying these skills in new contexts. Reviews said that it “got boring.” More precisely, good games don't throw people in over their heads with an hour-long tutorial and then say, “Go practice.” They build skills over time.

Observing the “control” curriculum in this context was enlightening. Mike created an excellent curriculum that mixed hands-on demonstrations (such as using balloons to create static electricity) with videos, experiments, and the occasional lecture. As good as it was, you could see that for many kids the big question was, “Why do I care?” Few students participated in discussions. When asked why, one responded, “We're not used to talking in school. You're supposed to just take notes.” Memories from junior high school flooded back. Sure, it was important not to look dumb, but you also didn't want to look smart, lest you get beaten up, teased, or picked on. The social game in junior high is how to attract as little attention as possible.

The results were positive. Kids in both the control and experimental conditions did about 20% better on the post-tests than on the pre-tests. Surprisingly, the only statistically significant effect we found between the control and experimental groups was for the girls. Girls did about the same in the control pre- and post-tests but did about 10–20% better in the experimental condition than the control. We weren't totally sure why, but we had some theories. First, the girls played reflectively, as we'd hoped. They were our model user. They didn't play to win, but rather to understand. Second, many girls shied away from the collaborative activities in the control condition. Maybe they didn't want to “look too smart” in science, something that's an issue for some girls at this age (although the girls did better than the boys across conditions). Video games enabled girls to dig in and play at their own pace, and many took pride in their work.

Being labeled as a “gamer” wasn't an issue for any girl we studied. The girls all reported playing The Sims, and most played console games. Many girls also
reported liking fighting games. I found it more interesting that our data suggested that “participating in class discussions to show what you know about science” was not a game many girls liked.

Figure 5.4, taken from the pre- and post-tests, illustrates some of the learning gains. On the left (from the pre-test), the student is asked to draw the field lines around a single positive charge, and he draws a baseball bat and ball. (It is springtime in Boston, after all.) On the right (from the post-test), he is asked to draw the field lines between charges and does a pretty good job. It’s not a perfect response, but it’s not bad. This was typical for many students. Dramatic differences between groups emerged in the interviews—even among those who got the answers “right” in the control. The following excerpt comes from a student in the control group who scored well on the post-tests.

Interviewer: What do you think the electric field looks like around a positive charge?  
Alex: It has lines going outward from it like this [drawing lines with arrows pointing outward].

Interviewer: Why?  
Alex: I don’t know. The teacher said so and showed us a picture and that was what it looked like.

Compare this response to the student from the experimental condition.

The electric field goes from the positive charge to the negative charge like this [drawing a curved line from a positive charge to a negative charge].

This is what it looked like in the game, and it was hard to move away or toward it because the two charges are close together, so they sort of cancel each other out.

The control response recapitulates familiar findings across the learning sciences. Just because students copy back the correct answer on a test doesn’t mean that they understand the concept (see Bransford, Brown, & Cocking, 1999).

Second, it’s difficult to understand why concepts are important. In physics, we don’t want students simply to draw field lines correctly; we want them to understand that these representations show force. Some students in the experimental condition “got” this in a visceral way. They understood that the field lines showed force because they were tools in the game. Supercharged! was particularly good at tying academic ideas to action. It helped students understand movement via cause and effect.

We struggled to make Supercharged! relevant to average 8th graders. We tried—through cut scenes, lectures, and presentations—to connect our representations of
electrostatic forces to the real world, but it was tough. The abstract world of Supercharged! (even when we included wires and magnets) was a huge leap from the world around them. These kids needed more connections to see science as important to their lives. They needed to see themselves as scientists, actively solving problems. For these kids (think of the girls who may not want to speak up in class), science wasn’t something you cared about; it was something you did for a passing grade to stay out of trouble. Maybe a game in which they used knowledge to act in the world would be more successful. Our attention turned toward Environmental Detectives, another Games-to-Teach game.

**INVENTING NEW GENRES: ENVIRONMENTAL DETECTIVES**

*Environmental Detectives* began by our team scouring chemistry textbooks and arriving at a simple, but ultimately doomed, concept.

“I’ve got it! A lot of chemistry is about how chemical processes can hurt you! What if we simulated a chemical spill right here on campus?” In a post-September 11 atmosphere, these scenarios were easy to imagine. A series of gruesome game scenarios could tie together environmental science and chemistry standards and be used across a variety of areas. This had promise.

Wally begged us to reconsider.

“Please! Let’s not have a game in which we faithfully re-create the MIT campus in glorious 3-D.” With the infinite possibilities for what artists could do in virtual worlds (travel to other planets, nonrepresentational art), surely we could do better than building 3-D classrooms.

Eric Klopfer suggested a way out. Why not build the games on handhelds and run the simulation in the background? Eric, who is director of the MIT Teacher
Education Program, joined the Games-to-Teach team during our first year. Eric is a gifted educational technologist who understands the affordances of technology and builds systems that leverage them smartly. Eric also might be the kindest, most generous collaborator I've known.

Immediately, the room reverberated with ideas. We wanted to make a game using the Global Positioning System (GPS). Soon, GPS devices would be available for pocket PCs. If we could write software that tied the device to the player's GPS location, we could model how a toxin moved across campus in real time and enable players to interact with characters, pass diseases, and investigate events based on where they were standing (Klopfer, 2008).

So, once again it was back to the research literature. At MIT, we found Dr. Heidi Nepf, a hydrologist who does problem- and case-based learning. Nepf argued that trichloroethylene (TCE), a common degreasing agent, was the perfect chemical for the game. TCE is found everywhere and is cancerous. A number of high-profile TCE spills are causing the Environmental Protection Agency (EPA) to re-evaluate TCE safety levels. It would make a great foil, in that we could build a story around the scare of a terrorist attack, but it would actually be an accident with a common toxin.

**Building an Engine for a Game Genre that Doesn't Exist**

We began coding Environmental Detectives, but because we had no idea how it would work, we went through several cycles of building prototypes, repeatedly throwing them away and starting over (see Klopfer & Squire, 2007). Although it was technically feasible, no one was doing GPS positioning outside of custom dedicated hardware devices. Eric led the team and ran the code base. A trusty undergraduate, Gunnar Harboe, did the grunt of the work. If Supercharged! was an exercise in rapid development using known tools, Environmental Detectives was the exact opposite. Working in C# and .NET (new tools at the time), we encountered an insane number of bugs and setbacks.

I remember looking out the window and seeing Gunnar standing on the roof with his laptop, a personal digital assistant (PDA), and some sort of blanket. An extension cord ran through the window to charge his tools. I asked if he was camping. No, he wasn't camping. It took 4 to 8 hours to get a GPS fix. While running a GPS device, Pocket PCs had 3 hours of battery life. He plugged the GPS into the laptop, but it drained that as well. The alarm clock reminded him to look for a GPS signal every few hours, while he coded from the roof.

It was thrilling to play with these technologies and worry about the next decade of education, rather than next Monday. It was a stark contrast to the
current fixation upon "use-inspired research." Although politically expedient, use-inspired research was strategically designed to ensure that we don't disrupt the system and miss key technologies (such as smartphones; see Chapter 10). A point of educational technology research should be to anticipate and study these developments as they unfold.

As I looked out the window and saw Gunnar with his setup, I feared that we were completely crazy. None of this technology was tested. If we couldn't even get a device to find its location in under 2 hours, it would be 10 years before we got into schools. My fears were misplaced; sure enough, these learning technologies went from cutting edge to commonplace in about 5 years. Today, our group works in nearly 40 classrooms with thousands of kids, albeit in a research context. By the time this book comes out, GPS may be standard on just about every cellphone. Cellphones might not be commonplace in schools, but they are commonplace in people's lives, and if students start bringing them to schools on their own, schools may face pressure to respond.

Our educational goal was to communicate the idea of science as a social enterprise. Students enter college with an idealized vision of science as the pursuit of perfect answers free from context. In reality, scientific investigation is imperfect. Investigators always make trade-offs between the quality of data and the time and resources it takes to obtain these data. For example, when an investigator learns about a rash of illnesses, he or she considers, do we immediately notify local law authorities? If so, will it cause unnecessary panic? Or will people die if we take 6 months to order evacuations?

Science Mystery Games

Environmental Detectives' core mechanic was deciding between desktop research and fieldwork. Investigators told us that, in general, "an ounce of desktop research is worth a pound of fieldwork." They often rule out causes simply by researching what chemicals are used in the area. Some investigations require gathering little "hard" data at all. Our science education partners hoped that if students conducted an investigation, they might be prepared to understand these ideas in class.

---

13. Maybe it's my Montessori background, but it seems odd to direct future innovations by what is happening now in schools, given that they are just one social configuration. Seymour Papert called this the horse and buggy problem; you can't design a car by studying the horse and buggy. Moving to the automobile from the horse and buggy was revolutionary and required new values and new infrastructure (roads, service stations, etc.).
Consider the following fictitious scenario in *Environmental Detectives* (see Figure 5.5). On the MIT campus, a TCE spill was uncovered during routine testing during construction. MIT's president is anxious. What does the spill mean for residents' health? The water supply? The environment? When the public learns that MIT dumped tons of toxins into the watershed, they will demand answers. Is their drinking water safe? Is it safe to continue eating Atlantic fish (such as cod)? Who is to blame? Can we keep this from happening again?

This is the scenario that we posed to students. To give away the mystery (again, this is fiction), TCE was spilled in an engineering machine shop but wasn't reported. TCE is a carcinogen and if inhaled or ingested, is damaging to the liver and kidneys. The TCE plume flowed through the groundwater and into the Charles River. Then, it flowed into Boston Harbor and into the Atlantic. However, because no one drinks the groundwater or swims in the Charles, there were no anticipated human health effects. Still, having a toxic chemical flow off the campus is bad for PR, if not against EPA regulations (depending on the concentration as it leaves MIT property).

The game started with a dramatic, secret video transmitted from MIT president Chuck Vest, shot X-Files style. Teams had 60 minutes to brief the president, who was about to face reporters. He demanded that players brief him on the health consequences, the EPA limits for TCE, how TCE moves through groundwater, and remediation strategies. Players' proposals needed to include an analysis of the cause, the anticipated severity, and a solution.

At every key point, players must decide what information is good enough to meet the investigation's goals. Whereas pinpointing the exact source of the pollution

---

**Figure 5.5.** *Environmental Detectives* Data Analysis

- **Choose Sample Analysis:**
  - Field Lab: 50% accurate, 10 second lag
  - University Lab: 75% accurate, 1 minute lag
  - EPA Lab: (admissible in court) 99% accurate, 5 minute lag

---

**Results**

The case study teaches us several related concepts.

*Jenny:* The parts.

*Steve:* They're related.

*Steve:* We need to look at the synthesis.

*Bill:* 150 feet... start with the radiation...
could take a few hours, if one discerned the general size, location, and age of the plume, one could use the process of elimination to discern the location in about an hour. The first version enabled players to place up to three wells at a time to sample the groundwater, and they could talk with characters to get information about TCE, its health effects, and so on. We included a branching narrative path in which the player could discover the culprit. To unlock this chain of events, the player had to find the general location of the spill, confront a virtual character, and then chase the culprit across campus.

**Results**

That fall, we ran Environmental Detectives with 25 first-year environmental science students. We hoped it would dazzle them, cementing forever their desire to become environmental engineers, but it wasn’t quite that successful. It did, however, teach us about using this platform for education. The following excerpt details one related conversation (edited for readability). Jenny begins by interpreting a read-out.

*Jenny:* The results of the lab said “30,” so it [the concentration of TCE] might be 30 parts per cubic feet.

*Steve:* That is not as bad as the military base in Cape Cod. So just remember that it can be nasty or something.

Steve had read about TCE at Cape Cod, and he used that information to puzzle through this problem. Next, Steve has a breakthrough. He realizes that they must use their data to construct a model of where the spill occurred. As he reads the text, he synthesizes its implications for their team.

*Steve:* We need to build a model of how TCE moves through the groundwater. [There are] lots of things to take into account. You have a certain mass of stuff that’s been spilled, and it’s covering a larger and larger region every day because of spread. As a rule of thumb you might assume that it spreads at a rate of 150 feet per year.

Bill started building the model, and thought aloud for his group.

*Bill:* 150 feet per year. OK. So, decaying at about half of its concentration. So if you start with 100 parts per billion, that’s . . . 50 parts per billion at 150 feet per year. The 30 and 70 could be possible.
This exchange was typical as groups modeled the spill. They were initially skeptical of desktop research, just as the teacher predicted. Many students—the males in particular—thought, drill first, ask questions second. However, the game forced them to build crude models of the spill on the fly. This kind of model-based reasoning is quite sophisticated and hard to engender. We didn’t overtly teach them this model-based reasoning, but they “constructed” it to play the game. In playing the game, it made sense to build models. Games excel at creating teachable moments for teachers to explain investigative and model-building skills. Students frequently used personal knowledge about the location to solve the problems, as in this exchange:

**Bill:** We know that it’s in the Charles, which is already disgusting. It’s possible that TCE is such a ridiculously small effect compared to the big mess of the Charles—and I have friends by the way who study the Charles River and are not impressed. We also know that the water isn’t used for drinking.

**Jenny:** We used to go canoeing on the Charles River. And we always had to watch out. People fell out of their canoe; their eyes were stinging and stuff.

Students spontaneously connected background knowledge to their game experiences, which was exciting. Bill’s knowledge of the Charles became a tool for anticipating academic concerns such as **concentration**.

Players were forced to ask what they knew, what they needed to know, and then predict the quality of information they would get from data. Almost every group “invented” triangulation as a sampling strategy to maximize the information gained from their samples. Students even built back-of-the-envelope models in the field. Everyone naturally started asking about the ethical and legal consequences of the spill. These pilots encouraged us that this sort of environmental mysteries scenario had potential for connecting game play and scientific thinking, and this led us to develop future projects such as *Saving Lake Wingra*, described in Chapter 9.

**THEORY AND PRACTICE**

This chapter opened by asking how we might design games for learning that meshed the content and the game play so as to reflect contemporary learning theory as well as best practices in game design.

- After building and researching our prototypes, we generated existence proof for meshing compelling game play with meaningful academic content and
ways of thinking. *Supercharged!* showed that even an imperfect game can be compelling for classroom use. We became even more convinced of the importance of honoring good game design techniques and processes. Our design process uncovered three key themes for educational game design: (1) respecting the importance of art design, (2) focusing on experience rather than content, and (3) making explicit connections to existing learning theory.

- Genres, or family likenesses among media that use similar techniques to achieve similar goals, are a good way to think about next-generation games. Some games will build on existing genres (just as *Supercharged!* built on puzzle games), but we also need to create new genres of experience (e.g., *Environmental Detectives*).

Table 5.1 highlights five genres of educational games, which are clusters of games that share some family likenesses. One might imagine different organizational schemes, but this framework, which mirrors genres in entertainment, ties them to key educational issues. For example: How long is the game meant to be played, both in and out of the classroom? How open is the game and its meanings, and is it flexible for supporting many learning goals (see *Civilization*, next chapter) or is it relatively fixed, as in *Supercharged!* and designed to teach specific objectives?

A key question for educators is, “In what ways can players be creative?” Games like *Supercharged!* afford fairly constrained opportunities for creativity, most of which are centered around how players complete levels. Action games add to this the capacity to solve problems in meaningful and varied ways (see Chapter 7). Role-playing games enable players to *affect* or change the world, and open-ended games allow players to *build* worlds. The collaboration opportunities available in persistent world games (games such as *WoW*, which are online worlds that are open 24/7) are among the most interesting to educators because they enable players to be creative through social engineering.

We are still exploring how to build educational games, put together good design teams, and construct processes, but we learned from Games-to-Teach. At this point, we know that:

- **Teams should integrate learning scientists, game designers, and subject matter experts.** In the best cases, a producer understands aspects of all three areas. Educators must appeal to all learners (not just those who enjoy that genre, such as the girls who like *Supercharged!*). Similarly, educators can’t be allowed to make decisions at the expense of game design, and game designers can’t...
make decisions where they are entertaining at the expense of learning goals. These game design teams should include, not just programmers, but artists and interface designers as well.

*Development should be iterative, with frequent prototyping and testing.* This means favoring lots of quick builds and test plays with users rather than excessive storyboarding and preproduction. We recommend building playable "toys" very early in the process so that teachers, students, subject matter experts, and learning scientists can all play with the basic interactions. This is beneficial because, first, there are few established models of educational games, so educational game designers are always negotiating multiple unknowns. Second, and most important, educational game designers have to create, not just compelling *game play* experiences, but compelling *educational* experiences. Extensive user testing can help ensure that players are gaining the kinds of insights that educators desire.

---

**Table 5.1. Emerging game genres**

<table>
<thead>
<tr>
<th>Genre</th>
<th>Time (hours)</th>
<th>Timescale</th>
<th>Openness of Goals</th>
<th>Creative Expression</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microworld</td>
<td>1–4</td>
<td>Days</td>
<td>Low</td>
<td>Style of completion; Level creation</td>
<td><em>Supercharged!</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Surge</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Immune Attack</em></td>
</tr>
<tr>
<td>Linear Action</td>
<td>6–20</td>
<td>1–4 weeks</td>
<td>Low</td>
<td>Solution paths; Machinema</td>
<td><em>Environmental Detectives</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Full Spectrum Warrior</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Dow Day</em></td>
</tr>
<tr>
<td>Role Playing</td>
<td>12–80</td>
<td>3–12 weeks</td>
<td>Medium</td>
<td>Solution paths; Character progression; World outcome</td>
<td><em>Civilization</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Sim City</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Saving Lake Wingra</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>WolfQuest</em></td>
</tr>
<tr>
<td>Sandbox</td>
<td>1–4</td>
<td>2–24 months</td>
<td>High</td>
<td>Solution paths; World state; Modding</td>
<td><em>Hephaestus</em></td>
</tr>
<tr>
<td>Persistent World</td>
<td>1–4</td>
<td>6+ months</td>
<td>High</td>
<td>Social engineering</td>
<td><em>Whyville</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>Quest Atlantis</em></td>
</tr>
</tbody>
</table>
LEARNING TO BE A FULL-SPECTRUM WARRIOR

by Kurt Squire and Henry Jenkins

Full Spectrum Warrior, the “Military Operations in Urban Terrain Simulation” (MOUT) developed by USC's Institute for Creative Technologies and Pandemic Studios, is a fascinating test case for educational games. The game's roots are in a military simulation that has been revamped for commercial release, creating a number of interesting paradoxes.

On the one hand, proponents laud Full Spectrum Warrior's realistic graphics and original gameplay for reinvigorating the atrophying military-strategy genre. Critics argue that the tutorial, which takes about an hour, is too long, and the game grows stale. They complain that there is little room for exploration, and players must (almost) always do as they are told.

Some learning tool! Most players learn through trial and error, experimentation, and information presented just in time and on demand, in levels that build upon one another. With its PowerPoint-ready bullet points that recap each mission, Full Spectrum Warrior has the feel of being designed by instructional designers who don't trust the medium. Games "teach" players by building systems in which players can experiment and infer from gameplay what strategies work. We don't need anyone to tell us that the corners of buildings are the best places to stand in a game; let us run into the street a few times, get our butts shot off, and then realize we need a better tactic. Learning through such experimentation is a powerful experience because we learn why we need to do something instead of just taking it on faith.

Aesthetically, this is why Full Spectrum Warrior is interesting: Everything in the game communicates, "You're in the army now." The barking voiceover demands 100% perfection. Full Spectrum Warrior invites the player to inhabit this identity of a combat soldier, thinking, acting, and evaluating the world from that perspective. After playing for a few hours and realizing that you are now diligently waiting to press buttons only after you are told, you start thinking, "Hey, I'm a regular soldier."

Playing Full Spectrum Warrior provokes us to reflect on what doing a real MOUT mission might be like and whether we would submit our will to military discipline. Such a game could function as propaganda if we accepted its
demands for our obedience, but it might also encourage us to reflect on what it means to be in the military.

Some may counter that these games are making entertainment of war, something called militainment. Yet, in World War II, psychologists recommended that children enact the horrors of war through play in order to bring their fears of death and destruction under their own control. Used wisely, such games can be employed as tools for reflection on the situation confronting our nation. For some, these games may be a call to arms. For others, like me, dying in Full Spectrum Warrior is a reminder that war has enormous human costs and I'd rather play soldier from the comforts of an overstuffed couch than on a hot dirty street in the war-torn Middle East.