THEORY BY DESIGN

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Why game theory? What functions does theory serve during a moment when a medium is undergoing rapid transformation, when it is still defining its aesthetics, its functions, and its audiences? What forms will give theory maximum impact? Does theory serve a different function when a medium is new than when a medium is well-established?

If one looks at the emergence of film theory, the most important early work did not come from distant academic observers but rather from direct participants. It came from trade press reporters like the Moving Picture World's Epes Winthrop Sargent who documented cinema's evolving formal vocabulary and pushed the medium to achieve its full potential.[i] Sargent's readers were filmmakers, distributors, and exhibitors, who made a direct impact on the kinds of films produced. Early Soviet film theory came from expert practitioners, such as Eisenstein, Vertov, Kuleshov, or Pudovkin, who wanted to record and share discoveries made through their own production practice and, in the case of Kuleshov, to train future professionals.[ii] It came from public intellectuals like Gilbert Seldes who wanted to spark a discussion about the aesthetic merits of contemporary popular culture and thus wrote for mass market magazines, not specialized academic journals. [iii] Theoretical abstraction and distanced observation came much later, once cinema was more fully established as a medium and had achieved some cultural respectability. More specialized language emerged as cinema studies struggled for acceptance as a legitimate academic discipline. In the process, many now feel it sacrificed the potential for dialogue with media practitioners and consumers.

Game theory seems to be teetering on a threshold: many academics want to see game theory establish itself as a predominantly academic discipline, while others seek to broaden the conversation between game designers, consumers, journalists, and scholars. The opportunity exists for us to work together to produce new forms of knowledge about this emerging medium that will feed back into its ongoing development.

Writers like Gill Branston and Thomas McLaughlin have made the case that academic theorizing is simply a subset of a much broader cultural practice, with many different sectors of society searching for meaningful generalizations or abstract maps to guide localized practices. Branston draws parallels between the productive labor of a car mechanic and the intellectual work of academic theorists: ‘Theory, always historically positioned, is inescapable in any considered practice. Our hypothetical car mechanic may find her work intolerable, and indeed replaceable, if it consists entirely of behaving like a competent machine. She will be using some sense of the whole engine to fix bolts successfully; she has to operate creatively with something close to theories — those buried traces of theories which we call assumptions or even, if more elaborated, definitions — of energy, combustion. Should she ever want to drive the car she will need maps.’ [iv]

Theory thus governs practice and practice in turn contributes to our theoretical understanding. McLaughlin writes, ‘Practitioners of a given craft or skill develop a picture of their practice — a sense of how it is or ought to be practiced, of its values and its worldview — and many are quite articulate about this 'theory,' aware for example that there are competing theories, that not all practitioners work from the same premises. These practitioners' theories may contrast sharply with the theories of their practice constructed by academic theorists.... It would be possible to find the nurse's theory of disease, the musician's theory of audience, the computer designer's theory of interpretation, the athlete's theory of sport, the bookstore designer's theory of reading, the casting director's theory of character.’[v] Or, one might add, a game designer or game player's theory of games. Theoretical terms are most often articulated by expert practitioners, McLaughlin argues, during moments of transition or disruption, when existing language prove inadequate to changing situations, common wisdom has not yet been established, competing models demand adjudication, contemporary developments demand new vocabularies, or the practice comes under fire from the outside and has to justify its own assumptions. We ascribe theoretical insights to avant garde artists, for example, when they push their media in new directions or provide aesthetic rationales for their work. Yet, when a medium is sufficiently new, all works produced are in a sense avant garde– they are mapping still unfamiliar terrain, requiring a heightened consciousness about the medium itself.

McLaughlin's formulation would suggest, then, that as game designers develop their genre and formal vocabulary, expand their audience, introduce new production processes, or contend with governmental and policy challenges, this 'vernacular theory' production will play a central role in their lives. Expert practitioners, such as Eric Zimmerman, Brenda Laurel, Doug Church, Will Wright, Peter Molyneux, and Warren Spector, among many others, have made significant contributions to our early understanding of this emerging medium. Professional conferences, such as the Game Developers Conference, have been at least as important academic conferences in formulating and debating game theory, if not more so. And the gamer community has also been actively and publicly involved in making sense of the medium, its audience, and its impact.

The MIT Comparative Media Studies Program has been actively involved in those public debates about games and game theory over the past several years. We hosted one of the first conferences to bring together academic theorists with game design professionals to talk about the current state and future development of the medium. We have conducted workshops at E3, GDC and other major industry gatherings, demonstrating how a broader humanistic knowledge of media might enhance game design. Many of our faculty members have participated in a series of workshops with some of the top 'creatives' at Electronic Arts, examining such core questions as genre, narrative, character, emotion, and community.[vi] We have also been involved in public policy debates, testifying before governmental bodies, speaking to citizens, educators, parents, and reporters. We are motivated by a commitment to applied humanism —

that is, the effort to mobilize theories, concepts, and frameworks from the humanities to respond pragmatically to real world developments during a period of media in transition.

The Games-to-Teach Project represents a new phase in our efforts to provoke discussion between game designers, players, policy makers, and scholars. A collaboration between the MIT Comparative Media Studies Program and Microsoft Research, the project seeks to encourage greater public awareness of the pedagogical potentials of games by developing a range of conceptual frameworks which show in practical terms how games might be deployed to teach math, science, and engineering at an advanced secondary or early undergraduate level. Much of the existing work in 'edutainment' has focused on the primary grades. We feel games can also be used to communicate more complex content aimed at older players, who now constitute the core gamer market.[vii] Our research has showed that incoming students at MIT are more apt to turn to games for their entertainment than film, television, or recreational reading; many respondents expressed enthusiasm for the idea of mastering classroom content through gaming.[viii] Our group starts from the assumption that educational games need to be inserted into larger learning contexts, not operate in a vacuum. Games can no more turn kids into scientists and engineers than they can make kids psycho killers; our task is to identify what things games do well, and how educators can leverage existing game genres and technologies.

Science and engineering faculty have long utilized digital models, simulations, and visualizations as teaching aids. There is an all-or-nothing quality to visualizations and lecture-style materials, however. Rather than presenting an explanation for a phenomenon (or a canonical illustration of 'how things work'), games present players microworlds; games offer players (students) a contexts for thinking through problems, making their own actions part of the solution, building on their intuitive sense of their role in the game world. A gamer, confronting a challenging level, finds personal satisfaction in success – and personal motivation as well, rehearsing alternative approaches, working through complex challenges (often well into the night!). Many parents wish that they could get their children to devote this determination to solving their problem sets – it is an open question, however, whether simply working toward a better grade is an effective educational challenge. Games confront players with limits of space, time, and resources, forcing them to stretch in order to respond to problems just on the outer limits of their current mastery. The best games can adjust to the skills of their players, allowing the same product to meet the needs of a novice and a more advanced student. Indeed, the concept of advancing in 'levels' structures the learning process such that players can't advance without mastery – something that curriculum- and test-designers have struggled to build into their work.

And games can enable multiple learning styles: for example, arts students might better grasp basic physics and engineering principles in the context of an architectural design program. Many of us whose eyes glaze over when confronted with equations on a blackboard find we can learn science more thoroughly when it builds upon our intuitive understandings and direct observations, yet many important aspects of the physical world cannot be directly experienced in the classroom. Students often complain that they see few real-world applications for what they learn in advanced math and science classes, yet they might draw more fully on such knowledge if it was the key to solving puzzles or overcoming obstacles in a game environment – if the knowledge were a tool rather than an end. It is both a motivational distinction and a matter of mindset (and what is the object of teaching if not literally to *change one's mind*?).

Games model not only principles but processes, particularly the dynamics of complex systems; students develop their own languages for illustrating those systems and grow incredibly adept at explaining them in their own terms. Researchers have found that peer-to-peer teaching reinforces mastery[ix]; why, then, do we dismiss such information exchange in the context of gameplay (a website devoted to strategies for a particular game, or picking apart the rules of a simulation to ensure maximum efficiency) as somehow intellectually illegitimate? Such interactions are a critical part of the gaming context, and in the case of educational games, perhaps the most pedagogically important interactions.

Games may also enable teachers to observe their students' problem-solving strategies in action and to assess their performance in the context of authentic and emotionally compelling problems. Teachers may stage a particularly difficult level during a lecture, comparing notes on possible solutions. And the gaming world represents a rich model for sharable content, putting authoring tools into the hands of consumers and establishing infrastructures for them to exchange the new content they have developed. The question for educators, then, is not whether games could someday work to teach students; they already do so. The question is how to help these two worlds, that of gaming and that of education, to work together.

By design, our conceptual frameworks constitute thought experiments that seek to address core questions in game theory, pointing towards directions still largely unexplored by the mainstream industry. One could draw an analogy between these thought experiments and the early work of the Kuleshov group. For more than a year, Kuleshov taught his students at the VGIK school how to make movies without having any access to film stock; they conceptualized movies, blocked movies, imagined ways of dividing the action into shots, and even re-edited existing movies, trying to develop a better understanding of how cinema operates. Kuleshov's experiments and insights have, however, guided decades of filmmakers as they sought to master the building blocks of film language. Similarly, our students are working through games on paper, examining existing games, brainstorming about future directions, and through this process, trying to address central issues surrounding games and education. As we developed these prototypes, we consulted with game designers, educational technologists, and the scientists and engineers most invested in the content areas, using them as a catalyst to get feedback and insight from practitioners.

We see these design documents as a form of game theory, one which starts with broad conceptual questions but addresses them through concrete examples. In the process of developing these frameworks, we have developed a much firmer grasp of the core challenges and opportunities that will shape the emergence of an educational games market. Operating within an academic space, removed from the immediate need to ship product, we were able to ask more fundamental questions about the medium and to imagine new directions games might take. This essay will discuss four of those frameworks – Hephaestus, Force Field, Biohazard, and Environmental Detectives – describing the conceptual and practical challenges we confronted and what we think these examples reveal about the potentials of educational gaming.

The 'games' we are describing have not been built – so far – though the next phase of the Games-to-Teach Project involves the development of playable modules which can be tested in educational contexts and the development of a government, foundation, industry consortium which can fund the actual production and distribution of the games. This essay describes games which are in a very real sense theoretical – games that might exist, someday, but whose current value lies in the questions they pose and the directions they point for future development. All of the game design documents and supporting materials have been published on the web and can be found at http://cms.mit.edu/games/education/. Take a look and send us your feedback.

Remediating Real World Play: *Hephaestus*

Hephaestus presented the challenge of translating the successful FIRST robotics competition to a digital space. FIRST (http://www.usfirst.org/) is a 'non-profit, educational organization that was founded to inspire and excite young people about science and technology by bringing together professional mentors with high school students from around the country.'[x] Started in 1989, FIRST was founded by Dean Kamen in the hopes that 'the act of invention – that is, the work of scientists, engineers and technologists – [will be] as revered in the popular culture as music, athletics and entertainment are today.' FIRST consists of two main competitions – the FIRST Robotics design competition and the Lego League, two competitions in which players design, construct, and operate robots in competitions. While *Hephaestus* incorporates elements of these other competitions, it is primarily based on the FIRST Robotics Competition.[xi]

Every January, the FIRST Robotics Competition pits over 650 teams from nearly every state in the United States as well as representatives from Canada and Brazil. Each team is typically comprised of 35 students and an adult mentor (mostly engineers who volunteer to work on FIRST). Teams have six weeks to design and construct their robots from a basic kit of robot parts, and a list of optional parts that they might cast or purchase. They must develop a team of remote-control robots and work in alliance with another team to move balls from one zone in the playing field to another, scoring points by placing the balls in a goal. (The playing field is depicted in Figure 1). One point is awarded for each ball that is in the goal at the end of the competition. Ten points are awarded for each ball that is in a goal inside the alliances' territory. This rule encourages players to move the goals, which are initially placed in the center of the field, into their own territory.

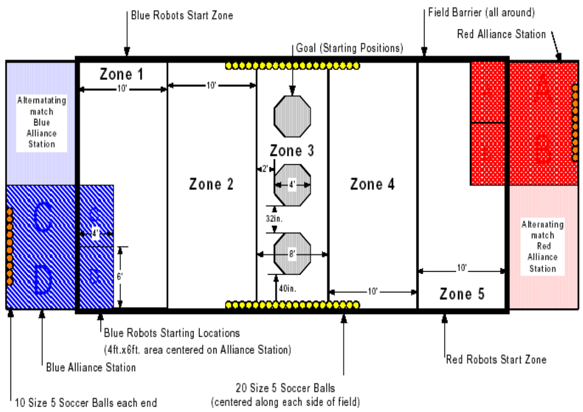

Figure 1: The Robot Playing Field

The two-minute long matches are designed to foster both collaboration and competition. Each alliance scores points as a team, and alliances shift every match. Both the winners and the losers of the match receive Qualification Points that determine their place in the FIRST Robotics Competition Standards. Unlike most competitive events, where teams receive points for a win (or tie) or perhaps even by goals scored, the winning alliance earns triple the points of the losing alliance. So, if the blue alliance beats the red alliance by a score of 100 to 50, the red alliance, who lost, earns fifty points, and the winning blue alliance earns 150 points. This point structure is designed to minimize sabotage between alliances. Knocking out an opponents' robot or preventing him from scoring points ultimately lessens the winning alliances' score.

The FIRST Competition shares much in common with established game genres. Most obviously, FIRST is a competitive game, with elaborate game rules and structures. The game itself has two phases – a design phase, where players are given fixed resources and limited time which constrain their design decisions, and a real time action game, where players deploy their robots to move balls, baskets, and robots across the floor. The robots' movements across the game floor, evading other robots, strategically positioning themselves near goals, and moving robots, baskets, and balls for their strategic advantage are elaborate contestations of space, which as we have argued in 'Games as Contested Spaces', is also a hallmark of computer and video games.[xii]

More than simply machines designed to score points, the robots quickly become personalized avatars for the players, who decorate and paint them, and in some cases, create movies and computer animations personifying them. In a live action film created by students in Hammond, Indiana, two robots prom dance in a high school parking lot. In another short, a computer-rendered robot flies through outer space. Emerging through hundreds of hours of work by dozens of people, each robot embodies not only functional design decisions and aesthetic considerations, but also, according to FIRST Competition co-founder Woodie Flowers, aspects of the players' collective identities.[xiii] This design and decoration are quite literally *performances of understanding* whereby the robots embody designers' understandings of robotics and aspects of their identities as designers; we wanted to leverage this identification process and preserve this pride in possession (and use) of knowledge in *Hephaestus*.

In designing *Hephaestus*, the Games-to-Teach team wrestled with how to leverage the engaging and educational aspects of the FIRST competition within a compelling computer game.[xiv] How could we balance single and multiplayer game dynamics? How could we create a rule set that fosters collaboration and competition, an online system that encouraged peer-to-peer teaching through the interaction between novices and experts? How could we integrate online and offline game play? And how could we support a variety of different player tastes? How does the computer-mediated nature of digital gaming change the robotic design process? How does the computer-mediated nature of gaming affect social interactions?

Hephaestus is a massively multiplayer game in which players design robots, down to the gear level, to colonize a fictitious planet located in the Alpha Centauri system. Heavily volcanic, the planet Hephaestus is currently too dangerous for human colonization. Lava serves as both a danger and reward to players. Players can perish by falling into a lava crevice, but can also earn rewards by diverting lava into pools for thermal energy collection. Players can also set up collectors for wind and solar energy. If players gather enough resources, they can collaborate with other teammates to construct bridges, walls, and buildings. Although players begin the game with simple stock robots, they gradually earn enough resources for customization. Players might change gear ratios, buy treads with greater friction, or add extra battery holders. Consistent with basic engineering principles, players must make trade-offs – for instance, between energy capacity, mass (which affects their fuel economy) and speed. The computer offers powerful methods for visualizing these tradeoffs in real time.

Massively multiplayer games are not only games, but also social systems — living, breathing communities with their own ecologies, life-cycles, and cultures. One way to characterize designed social systems is through the notion *of illuminative tensions*. In *Learning by Expanding*, Yuro Engestrom describes tensions as complementary and conflicting needs that reciprocally define one another and drive the dynamics of a social system[xv]. Mapping these tensions can enable researchers to identify the core activities and predict sources of change within a social system. For example, in their studies of a community of pre-service teachers (*Community of Teachers*), Sasha Barab and colleagues used design tensions to examine the practical and theoretical issues that 'fuel change and innovation.'[xvi]

In conceptualizing *Hephaestus*, the Games-to-Teach team identified several potential tensions: competition vs. collaboration, robust simulation tools vs. accessibility to new users, engrossing game dynamics vs. appeal to broad audiences and offline vs. online activity. These tensions, which drive change and innovation in a system, are overlapping and often mutually reinforcing. FIRST co-founder Woodie Flowers describes the process of balancing FIRST as one of manipulating rules so that players are recognized for achievement and motivated to excel within a competitive framework, yet encouraged to collaborate and play fairly.[xvii] Players are motivated by a desire to excel and gain recognition within their school communities, among the FIRST competitors, and from their adult mentors. However, success demands collaboration with their teammates, their alliances, and their adult mentors. The competition values collaborative design, teamwork, mentorship, and constructive (as opposed to destructive) goals.

For the purposes of this paper, we will focus on one such tension in greater depth: online and offline practices. Our initial interviews with Flowers and students revealed that much of the appeal and educational value of FIRST came through interacting with physical materials – building drive trains, wiring circuits, and creating a physical robot that scoots across the floor.[xviii] For many participants, the thought of learning engineering without interacting with actual steel, rubber, circuitry, and plastics is inconceivable. The *Hephaestus* team, then, didn't want to displace the physical aspects of the FIRST competition, but rather identify ways that computer games could extend that experience in new directions. By remediating the FIRST competition as a massively multiplayer game on a fictitious planet, *Hephaestus* enables players to confront novel challenges which would be harder to model in real world spaces, such as building robots to withstand immense amounts of heat, traverse in snow, or operate in high winds or on a planet with increased gravitational pull. *Hephaestus* players also face different design trade-offs. Players might need to design a robot with sufficient energy to cross an entire planet, or to traverse under water; such requirements might make it impossible to include certain features. The parallels to management or survival training (or experimental design – the game offering a way of reflecting on its own genesis as *theory*) suggest something of the polyvalence of this approach. In later phases of the game, players also are given access to materials and parts not available in FIRST, such as titanium alloys or solar panels. We incorporated a structural engineering component to the game, in which players can pool their resources and purchase bridges, walls, or other structures.

We also wanted to explore the ways that online and offline robotics competitions might inform one another. Engineers use computer-based tools in designing and prototyping, and *Hephaestus* could be used as a prototyping tool for FIRST competitors. Digital simulation technologies make robotics engineering accessible to a broader audience of students, and *Hephaestus* could be used by students who are looking for a less intensive introduction to robotics engineering, may not have opportunities to join a FIRST team at their local school, or might want to explore robotics engineering during the off-season. In order to support this fluid interplay between online and offline practices, we envision a separate robot design tool that enables prototyping and testing robot configuration, pre-made robots that novices could use, and a massively multiplayer game dynamic that encourages sustained participation. Finally, we hope that success in *Hephaestus* might motivate more players to build their own robots, and the *Hephaestus* robot design tools includes actual part numbers and links to facilitate purchasing actual robot parts or schematics.

Fostering Intuitive Knowing: *Supercharged!*

Hephaestus illustrates how digital gaming facilitates complex engineering practices within massively multiplayer worlds. A second unexplored application of gaming technologies is in using gaming environments as visualization tools. As Steven Poole highlights in *Trigger Happy*, game worlds are entirely fabricated spaces: everything that exists on the screen was placed there by a designer for some reason[xix]. While recent press attention has focused on the increased realism of current gaming graphics, game fans themselves just as frequently admire the whimsical landscapes of Shigeru Miyamoto's Nintendo games, or the romantic, gothic, surrealistic, or cyber-futuristic environments in other contemporary games.[xx] New improvements in game graphics may enable a much broader array of visual styles and game atmospheres – allowing players, for instance, to interact in landscapes designed to illustrate scientific phenomena. Imagine playing as a virus trying to infect the human body, fighting off antigens and phagocytes (*Replicate*). Or, much like *SimEarth*, the game board might be expanded to an entire ecosystem or solar system (with the player 'writing' the rules governing its behaviour). In addition to changes in scale, gaming technologies can make invisible phenomena visible, as in *Supercharged!*, where players fly through and navigate around electric and magnetic fields demarked with field lines. Educators note that students have difficulty grasping core concepts of electro-magnetism because they run counter to their own real world experiences, yet playing a game which requires mastery of those principles in order to win may give them an intuitive grasp of how they work which can be more fully developed in the classroom. *Supercharged!* builds on existing visualization and simulation techniques in science education to create a compelling gaming experience.

Supercharged!, is a 3D action / racing game designed in conjunction with Professor John Belcher, a Physics professor at MIT who has been researching the use of digital visualization tools in supporting learning in electromagnetics (See Figure 2). The player is a student in a college physics class. The class begins with an old (and we later find out, evil) physics professor showing a crackly black-and-white educational film on electromagnetism through an old 1950 16mm film projector. The projector is struck by lightning and the students are mysteriously sucked inside, trapped in the depths of the projector's ancient circuitry. Drawing on themes from 1950s science fiction films, the game puts the player in control of a small metallic space pod which has adopted the properties of a charged particle. The player eventually learns to navigate by placing electromagnetic charges throughout the environment – an indirect kind of motor control, in which the player learns to describe her environment by changing it.

The game play consists of two phases: planning and playing. As the player encounters a new level, she is given a limited set of charges that she can place throughout the environment; she will move either toward or away from the charge, enabling her to shape the trajectory of her ship. In the ‘playable’ portion of the game, the player switches her charge (either positive, negative, neutral, or dipole), and manages a limited amount of fuel that can be used to directly propel the ship. Each level contains a set of obstacles common to electromagnetism texts, including points of charge, planes of charge, magnetic planes, solid magnets, and electric currents. Each of these obstacles affects the player’s movement, according to laws of electromagnetism. The goal of *Supercharged!* is to help learners build stronger intuitions for how charged particles interact with electric and magnetic fields and use the laws of electromagnetism to solve novel problems in a variety of contexts.

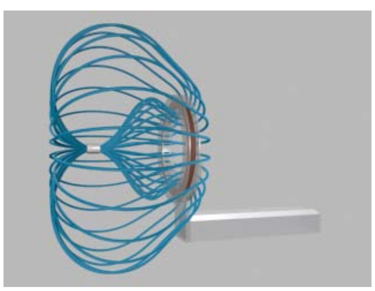

Figure 2: A visualization of Faraday’s Law, Photo used courtesy of John Belcher

Notably, *Supercharged!* is not designed to completely teach the student all there is to know about Electromagnetism. We do not believe that *Supercharged!* will ever replace Physics teachers, textbooks, or other educational materials. Rather, *Supercharged!* can be used as an instructional tool or resource within a broader pedagogical framework. Teachers might begin a unit on Electromagnetism by having students play several levels before encountering textbook or lecture explanations. Other teachers might use levels as demonstrations or as homework problems. One can even imagine Physics teachers using levels for testing purposes. However, *Supercharged!* affords players few opportunities for interacting with the laws of Electromagnetism quantitatively; those kinds of understandings may be best taught by more traditional means.

As Alex Rigopulos, co-founder of Harmonix Music Systems (makers of the PlayStation 2 game *FreQuency*), commented in one of our design meetings, electromagnetism is an intriguing area to explore through games, because Maxwell's equations translate readily into game mechanics. Much as *Super Mario Brothers* game players learn that ice causes Mario to skid across the floor, and quickly learn to predict where the intrepid plumber will *stop* skidding, *Supercharged!* players can learn that a positively charged particle traveling through a magnetic field careens in a specific direction, and get a 'feel' for the mechanics of it. As Ted Friedman suggests in 'Civilization and Its Discontents: Simulation, Subjectivity, and Space', part of the joy of playing a game such as *Civilization* is learning to 'think' like the computer; players intuit not only the rules of the game world, but the likely results of specific interactions.[xxi] Expert *Supercharged!* players might be able to predict the end location of a positive charge traveling at a given velocity through a magnetic field, just as experienced Civilization players might predict how a geographically isolated, resource-rich civilization will evolve. As Eric Zimmerman and Katie Salen argue, the process of game play can be thought of as observing a situation, making a decision, observing the results, and then continuing to make new decisions based on the outcomes of earlier decisions.[xxii] These stages closely mirror the 'scientific method' of constantly revising hypotheses through experimentation.

On the surface, *Supercharged!* has much in common with E+M visualization tools, such as Dr. Belcher's animations (which can be found at: http://web.mit.edu/jbelcher/www/anim.html), as well as traditional simulation exercises where players can change parameters of a system and observe the results. However, embedding challenges within the tool requires users to actively monitor their performance, observing, hypothesizing, acting, and reflecting. In addition to being potentially more motivating for learners[xxiii], engaging in such critical thinking processes is generally thought to be the basis of meaningful learning[xxiv]. As John Bransford and colleagues have shown, knowledge developed in the context of solving problems, is typically recalled better than knowledge learned by rote, and more readily mobilized for solving problems in novel contexts.[xxv]

Despite the pedagogical potential of *Supercharged!*', many questions remain. Just how robust are the understandings developed playing *Supercharged!*? Will players use concepts learned through playing the game to solve novel problems that arise in other contexts? There's still a large gap between, on the one hand, observing patterns and interactions in digital environments, placing charges, and devising strategies for solving puzzles, and on the other hand, using knowledge of electromagnetism to design circuitry, performing experiments, or solve engineering problems. We think it is only by explicitly coupling the game with a range of other pedagogical models, such as problem-based on inquiry-based learning, that this transfer across contexts is likely to occur. Regardless, these challenges, the limitations of *Supercharged!* for learning the quantitative aspects of electromagnetism, and the importance an instructor can play in providing explanations, demonstrations, and structuring learning experiences, remind us that a game is a tool or a resource in a learning environment, not a magic box that ensures mastery over the content.

Stories for Learning: *Biohazard*

The pitch for *Biohazard* is straightforward: the relentless pace and shotgun presentation of medical material of NBC's *ER*, and the eerily plausible apocalypse of Crichton's *Andromeda Strain* or the nonfiction novel *The Hot Zone*, in the interface style of the award-winning PC game *Deus Ex* (a first-person 'sneaker'/roleplaying game from Ion Storm, considered one of the best PC games of recent years). What makes the project interesting to us as educational researchers, however, are its goals: to teach AP-level biochemistry material, and to try to communicate the feeling of 'doing science', all the while making the presentation of the material interesting for players who are *not* students, and thorough enough for classroom teaching. Whew!

Educational theorist/computer scientist/ software designer Roger Schank (among others) argues that, since understanding is to be *performed* in certain contexts (bus drivers do not drive in classrooms, they sit in buses on roads; managers manage under particular office conditions, not in idealized training situations), information should be taught in similar contexts.[xxvi] This 'learning by doing' approach seems like common sense to those who've taught or learned by apprenticeship or on-the-job training, but the method is foreign to most in-school instruction (in which the retention of facts is tested very deliberately *out of context*, the rationale presumably being that the students should 'know the material cold').

However, not all tasks are equally well suited to this instructional approach. Training bridge builders by having them build bridges seems sensible enough, and the task of bridge building scales straightforwardly from the road to the classroom (balsa wood offers a good analogical medium for experimentation); training doctors without pathogens or patients, on the other hand, presents a problem of representation. The power of a learning-by-doing approach comes from its simultaneous stimulation of all the senses, a total acculturation of the learner *in the moment* that enables strong, extensible conditioning.[xxvii] But an instructional video can only offer visual and aural cues (and the links between them); a textbook presents problems linearly, offers textual solutions (explanations, answers), and gives a particular spatial organization that doesn't reflect physical (lived) experience; lab work cuts students off from the breakneck pace of the ER, the limited materials of in-the-field engineering, the minute conversational cues that characterize office politics. For activities that can't simply be replicated in the classroom (firefighting, emergency medical care, race car driving, real estate sales, etc.), a richer training medium is needed to acclimate students to a broader portion of the sensory spectrum associated with those practices.

Moreover, narratives have the peculiar quality of making readers (players, viewers, *interactors*) care a great deal about the events they represent. Everyone has had the experience of being lost in a story; being lost in a textbook is an entirely different prospect. Indeed, the word 'lost' is misleading, because readers or filmgoers who lose track of their physical surroundings are often hyperaware of what's going on in the story. The events are rendered with a vividness that leaves permanent memories, which can be evoked later with a turn of phrase or musical strain. That power of persuasion is used to full advantage in moral education (how many children *learned* to seek inner beauty from the story of the Ugly Duckling?), but the power of narrative contexts for teaching is underutilized in schools.

A walkthrough of the early moments of the game will make clearer the link between *Biohazard*'s educational goals and its method (and its qualities as entertainment). At startup, the player is presented with her world, seen over the avatar's shoulder (as in adventure games such as *Tomb Raider*). She is in a hospital; her character is in the garb of a doctor, and an onscreen character is talking animatedly about the player's new job, while motioning for her to follow. Players familiar with the mouse-and-keyboard interface of first-person games will instantly recognize the visual style: the keyboard is used to move the character and conjure up menus, while the mouse activates items presented in a *Deus Ex*-style series of inventory boxes, menus, and text streams. Moving through the hospital after the tour guide, the player is surrounded by the ebb and flow of medical technicians at work; one of the game's characters approaches to assign the player a task – in this case, something as simple as checking in with a lab down the hall. The character speaks hasty directions; the player's real task at this point is to get acclimated to the layout of the hospital, which – though it is a fictional setting – is a slightly simplified amalgam of actual hospital layouts.

But the heart of the game is its *dramatic* force, the fact that rather than a lecture, the player is compelled by a visceral or an *emotional* logic. Rather than regurgitating context-free facts, the player must take the next step and utilize knowledge in tense, contextually rich situations. A little girl endures uncontrollable coughing fits, her suffering audible as the player confirms the steps of a testing procedure in an online manual before clicking the mouse and *seeing herself perform the procedure*. Shots from the first-person perspective are intercut with schematics of the body, establishing shots of the entire operating hospital wing (the flow of foot traffic made visible and useful for later play), reaction shots of the little girl, her coughing a rhythmic counterpoint to the frenetic activity…The representational languages of film and television are known to nearly every American; they provide a shorthand for engaging our emotions in service of aesthetic experience. In the filmic or literary moment we are alert to subtle cues, hidden information, logics beyond the merely deductive; isn't this precisely what educators want for their students? Can't we remember AP Chemistry as vividly (and as fondly) as we remember *Casablanca*? To date, games have had more success at creating emotional reactions through visceral action than through compelling storytelling.[1] Elsewhere[xxviii], we have argued that game designers tell stories through the organization and manipulation of space. In *Biohazard,* we developed some of these ideas further, exploring how emotional intensity can be heightened through evocative spaces, embedded narratives, or emotionally reactive third parties.

Video game players are familiar with the concept of the in-game tutorial: the skills they need to play the game are taught in the context of some sort of in-game 'training period'. The opening of *Biohazard* works this way, starting with genre assumptions (about everything from TV medical dramas to the preferred interfaces for first-person video games) and the willingness of the player to go along with a story that begins *in medias res*. We (as 'readers') accept the

[1] Gamers will frequently cite games such as Planetfall or Grim Fandango as exceptions to this

limits and assumptions of the narrative and tailor our expectations to them *as if* they were 'real'; this iterative process of expectation-testing is itself a kind of learning, perhaps the most elemental kind (knowing what to expect from the world – whether expressed in language of physical causality or narrative logic). By matching the conditions of *Biohazard*'s virtual medical practice as closely as possible to those of the real world – accepting the limitations of a digital operating room, but simulating tempo, presenting real world problems, demanding that students apply what they know to novel situations — we give students a sense of the *practice* for which they're being trained. Video games can suggest, then, a model of learning as a kind of 'in-game tutorial' for *real life*.

While *Biohazard* may well be used to train doctors and emergency workers, we see its primary value in giving affective force and contextual relevance to AP science material. Rendering a six-hour emergency operation wouldn't work on a computer; telescoping into the body of a patient during a cutscene, to show internal state at a microscopic level, wouldn't work in real life. A video game can bridge between these two representations. *Biohazard* can present information *in situ*. Actual physicians have access to encyclopedic resources in which are organized centuries of medical knowledge; providing an even more efficient interface to such information, in 'heads-up' fashion, is a soluble task for video games. Students who have difficulty finding text in the dictionary often blast through the information landscapes of video games without a second thought. Students are using textbook information 'just in time' – that is, in practical situations – rather than constrained in the arbitrary conventions of the classroom exercise (45 minutes for a test, always think of calculus at 12:45pm). They will form the mental maps that make the most sense for them, associating information with its practical uses and real world consequences. And since, within a game, a given piece of information might be needed at any given time (players know this well!), players will demand of themselves a high

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pattern.

degree of information-retention and recall. We read stories because we want to; we learn to go along with their logic because, in order for the stories to make sense, we *have* to; compelling stories stick with us long after the screen has darkened. We have no choice in the matter.

At Play in the Fields: *Environmental Detectives* and Wireless-Enabled Simulation

We see the *Biohazard* proposal as the presentation of a complex problem and a real, implementable solution; there is no technology in the *Biohazard* précis that doesn't exist already. But one of the follies of the field of education is its conservative approach to new technologies; they tend to be met with initial enthusiasm, and on occasion find early adopters in schools, but new tools generally take a long time to reach their potential in schools (held back by a combination of very medium-based standards, unreliable performance, the need for technical education for teachers, and an ill-fittedness between the technologies' affordances and teachers' needs). Wireless computing is among the latest batch of panaceas to come out of Silicon Valley; in answer to the titular question of a CMS conference, 'We wired the classroom – now what?', new technologies promise an elegant solution: *unwire it* (the phrase is borrowed from another MIT research initiative, the 'Unwiring the World' initiative at the Media Lab). Network infrastructure will be gaseous; word processors will be handheld and voice-activated; the Web will be everywhere; computing will happen without computers.

But the revolution in the way we approach computers is all promise; right now we need solutions for bringing handheld, wireless networked technology into the classroom in ways that, to borrow a formulation from constructionist pioneer Seymour Papert, addresses issues for both the next decade and next Monday (when the kids arrive for class at 8am). Revolutions in education, ironically enough, can't just happen overnight.

Environmental Detectives is GTT's entry into a new, wide-open field – handheld (computer) games for education. The possibilities that the technology holds should be clear:

instant access, anywhere, to Web-based information and specifically tailored apps for education, along with lightning-fast communications in and out of the classroom (between students and teacher(s), and among students). But there are important questions to be answered: how does wireless technology offer richer *learning* experiences? How do they facilitate the *teaching* of material in and out of the classroom? If we afford this new distributed technology a central role in the teaching process, what changes should the classroom undergo to enrich and enable the exchanges that constitute the act of *education*? And perhaps the most immediate questions: when is the technology going to work consistently, seamlessly, and logically? And what do we do in the meantime? The broader work of theorizing about the unwired classroom (and more broadly, the learning environment afield) can't be divorced from the practical matter of making it work in the first place.

Consider a relatively minor sample problem: *Detectives* relies on GPS hardware, connected to a PocketPC via the serial port; the software is written in Microsoft's young object-oriented language, C# (a descendent of C++, a cousin of Java in appearance); there is no official, documented method for interfacing with the serial port on a PocketPC in C#.[xxix] We realized this days before the software framework was to be demoed to our collaborators in the MIT Environmental Engineering department – well *after* we had pitched the simulation. In sheer man-hours, the knowledge was pricey, though *in theory* there was nothing to the job of writing it. In developing a framework for educators to design scenarios (described below), such straightforward development snags translate into major usability considerations for end-users.

Environmental Detectives[xxx] is set to be beta-tested with MIT freshmen in Fall 2002; they will essentially take the part of environmental consultants, working in teams to determine the extent of contamination from a possible source of pollutant on MIT's campus, the affected locations, and possible plans for remediation (treatment of the contaminated area) if necessary. Their handheld devices – PocketPC's equipped with GPS radios and 802.11b network cards –

will allow them to simulate in-the-field data collection (testing for contaminant concentration based on GPS location data), site interviews and desktop research (the wireless networking cards offer access to mini-webs of data for the sake of conciseness and focus, from EPA documents to executive summaries of resident interviews), and plan formulation and analysis. An important consideration for us is that the PDA's are not simply digital notebooks; they offer the unique ability to maintain a consistent underlying simulation. The distinction is a vital one: a traditional view of wireless computing allows us to bring our work (or play) wherever we go (reading email on the subway, playing *Quake* at the doctor's office), but we see wireless technology as a tool for switching around the relation between place and activity – in effect, bringing 'wherever' into our work (or play).

From a practical standpoint, making the machine more aware of its surroundings makes the act of stepping outside more palatable to teachers for whom *outdoors = field trip*, with concomitant harm to student attention spans. Moreover, an activity that maps physical space and curricular space onto one another – in which physical location is another data structure for the software – lends continuity to the experience; the idea that setting should work in service of stories is old hat to authors of fiction, but that lesson has yet to be taken to heart by educational designers. But it's easy to make this pronouncement in a book chapter or corporate pitch; it must be tested by teachers, with students, on finicky hardware, or it remains an empty promise.

Conclusion: How and Why Game Theory?

As our four case studies illustrate, educational software design is neither a solved problem nor a single problem to be solved. But our conceptual designs respond to individual theoretical and practical concerns. Taken as a group, they also offer a methodology for 'doing theory' in a way that can be of use to both the academic world and those 'in the trenches' (a description that fits teachers and students equally well). Each design addresses different needs within the educational community; each reveals limitations in the ways that gaming and education are currently understood, and identifies opportunities for productively transforming that relationship. In this way, we see game design and learning as linked theoretical activities: the imaginative process of conceiving and testing frameworks for understanding, with the motivating need to communicate those frameworks to listeners with various knowledge bases.

The current phase of the Games to Teach project involves implementing versions of some of the designs (*Supercharged!*, *Environmental Detectives*) in-house and testing them with groups of students. This is a necessary, arguably the most important, phase in the process of theory construction; we can ask the question, 'What can we *possibly* make?' and follow a project through to its conclusion, asking the final questions, 'What did the *players* think?' and 'What did they learn?' The current media technologies, which are lower in cost, easier to use, and more accessible than traditional media production tools, enable a material component to brainstorming, blurring the lines between theorists and practitioners. Janet Murray has argued that the next generation of storytellers – the cyberbards — will be both artists and programmers; The same should also be said of critics and educators; blurring the lines between thinking about and making media should open up new opportunities for conversations across those various sectors. The language of critical theory can benefit from grounding in the experience of gameplay and game design; games themselves can be made immeasurably richer through the development of new models of interaction and representation (beyond the straightforwardly competitive and rigidly mimetic).

This is not to say, of course, that GTT offers a magic bullet for the problems of contemporary education, educational software, or game theory. Our team consists of students and faculty from across disciplines and areas of expertise, in the sciences, humanities, and outside the academy; a lingua franca does not develop overnight. And throughout our first year, we encountered the typical problems associated with projects of this scale (the tradeoff between lowest-common-denominator design and the complexity of new concepts; the competing research interests of more than a half-dozen graduate students; the need to work toward a common goal with common deadlines). Moreover, maintaining a balance between the academic rigor of an MIT graduate program and our sponsors' desire for deliverables on a certain date meant that the role of the students underwent continuous redefinition. But we see these as productive challenges, not mere stumbling blocks; the very nature of our program is an object for further study and development. We all learned from each other as we collaborated on meeting the challenge of putting theory into practice and meeting our ideal of applied humanism. Students not only mastered an existing body of theoretical literature but they also found ways to expand it, bringing it to bear on the practical challenges of creating games which would meet real world contexts. In the end, we argue that it is in the best interests of students, theorists of games and gaming, and designers to endeavor to bring not only Hamlet but Habermas and high school to the Holodeck.

[i] For a discussion of Sargent's role, see David Bordwell, Janet Staiger, and Kristen Thompson, *Classical Hollywood Cinema* (New York: Columbia University, 1985).
[ii] On the context that generated Soviet film theory, see David Bordwell, *The Cinema of Eisenstein* (Cambridge: Harvard University Press, 1994).
[iii] On the relevance of Gilbert Seldes on game theory, see Henry Jenkins, 'Games, the New Lively Art,' in Jeffrey Goldstein and Joost Raessens (eds.) Handbook of Computer Game Studies (Cambridge: MIT Press, Forthcoming).
[iv] Gill Branston 'Why Theory?' Christine Gledhill and Linda Williams (eds.) *Reinventing Film Studies* (London: Arnold, 2000), p. 30.
[v] Thomas McLaughlin, *Street Smarts and Critical Theory: Listening to the Vernacular* (Madison: University of Wisconsin Press, 1996), p. 22.
[vi] The word 'creative' in this context warrants comment. It is a term used in the games industry – and in the entertainment industry more generally – to refer to those involved in the process of creating cultural products. They often maintain a strict seperation in perspective and orientation from the front office personnel, who make the practical or business decisions. In any creative industry, there is a potential tension between those who control the purse strings and those who make the creative decisions and this tension gets embodied not only in academic theories of authorship and mode of production but the language used by expert practitioners.
[vii] Part of what has given 'edutainment' a bad name is that it has been done cheaply, often by educators who had limited awareness of the current state of game design and technology or by developers who knew little about current thinking about pedagogy. We have tried through the Games to Teach project to bring those two groups together, to develop games that reflect both the current state of game design and the current thinking about the best ways to teach.
[viii] This data was collected through a web-based survey of all MIT students in the fall of 2001 and is reported in Squire, Jenkins, and Games-to-Teach Team, Games to Teach Project Six Month Report. (Cambridge, MA: MIT, 2001).
[ix] See for example Timothy Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm.* (Mahwah, NJ: Lawrence Erlbaum, 1996).
[x] For Inspiration and Recognition of Science and Technology (FIRST). FIRST Website. http://www.first.org/. July 20, 2002.
[xi] For the sake of convenience, we say, '*Hephaestus* incorporates the following…' rather than '*Hephaestus* would include the following' or 'The design for *Hephaestus* proposes…' These games possess features in the same way that they exist: *in theory*.
[xii] Henry Jenkins and Kurt Squire, 'The Art of Contested Spaces.' Lucian King and Conrad Bain (Eds.) *Game On* (London: Barbican, 2002).
[xiii] Flowers, Woodie. Personal Interview. August 30, 2001.
[xiv] Our use of the term 'remediation' here owes much to Jay David Bolter and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, MA:: The MIT Press, 1999).
[xv] Engestrom, Y. *Learning By Expanding: An Activity-Theoretical Approach to Developmental Research.* (Helsinki: Orienta-Konsultit Oy., 1987).
[xvi] Barab and colleagues 'present these tensions in both an experience-near (local to the CoT experience) and experience-far (has possible connections to other projects) manner with the goal that the reader might take in these experiences, apply these experiences to new cases as situational constraints permit and, hopefully, develop a more refined gaze toward new phenomena.' Using tensions, Barab et al. hope to characterize the core elements of practical and theoretical interest in a manner that can be of use to designers of other social systems. Sasha Barab, Michael Barnett, and Kurt Squire, 'Developing an Empirical Account of a Community of Practice: Characterizing the Essential Tensions.' Journal of the Learning Sciences 11.4.
[xvii] Flowers, Woodie. Personal Interview. August 30, 2001.

[xviii] In preparing to create Hephaestus, the Games-to-Teach team interviewed several MIT students who completed robotics engineering, and attended the annual FIRST competition kick-off held at Dean Kamen's home in Manchester, NH on January 4, 2002.
[xix] Steven Poole, *Trigger Happy*. London: Arcade, 2000.
[xx]See, for example, *Newsweek* March 6, 2000.
[xxi] Ted Friedman, '*Civilization* and Its Discontents: Simulation, Subjectivity, and Space.' *On a Silver Platter: CD-ROMs and the Promises of a New Technology*, edited by Greg Smith (New York University Press, 1999)
[xxii] Eric Zimmerman and Katie Salen. *Game + Design*. (Cambridge, MA: MIT Press, in press).
[xxiii] See Tom Malone, 'Toward a theory of intrinsically motivating instruction.' *Cognitive Science*, (4), 333-369, 1981.
[xxiv]John D. Bransford, Ann L. Brown, and Rodney R. Cocking. *How People Learn: Brain, Mind, Experience, and School.* (Washington, DC: National Academy of the Sciences, 1999).
[xxv] John D. Bransford and Daniel Schwartz, 'Rethinking transfer: A simple proposal with multiple implications.' A. Iran-Nejad & P. D. Pearson (Eds.), *Review of Research in Education* 24, 61-101. (Washington DC: American Educational Research Association, 1999).
[xxvi] Schank, R., A. Fano, B. Bell, and M. Jona. 1993. 'The Design of Goal-Based Scenarios.' *Journal of the Learning Sciences* 3:4. 305-345.
[xxvii] Like 'dogma', 'conditioning' is a word used all too often as a pejorative, robbing it of its illustrative power for instructional design. Knowledge is most useful as *second nature*, it is dangerous for teachers to remain ignorant of the conditions of their environment, the condition of their students…Hans Vaihinger, in his *Philosophy of As-If* (1911/trans. 1924), provides a useful view of dogma as part of a continuum of assuredness, along with fictions and hypotheses (each with its own usefulness). A powerful extension of Vaihinger's ideas is found in Wolfgang Iser's *The Fictive and the Imaginary* (1993); Iser treats reading as a process of acculturation, in which we *learn* (in collaboration with the text) new ways of comprehending fictional worlds of meaning, as if they were 'real'.
[xxviii] Henry Jenkins, Games as Narrative Architecture. in Pat Harrington and Noah Frup-Waldrop (Eds.) *First Person* (Cambridge: MIT Press, 2002.)
[xxix] To be sure, there are a couple of user-written libraries for doing this; we had the devil's own time tracking them down. The wireless development community is young and dispersed enough to make finding publicly available code a nonnegligible project.
[xxx] At the time of this writing, the game is still in development, and the particulars are subject to change.