# Augmented Learning

## Research and Design of Mobile Educational Games

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# 1 Educational Innovation through Time

I peer through a portal into three biology classrooms—one today, one twenty-five years ago, and one fifty years ago. As I watch the first class I see a group of students pour into the classroom and settle into their wooden seats assembled in rows along the lab tables. They sit down, take out their notebooks, and prepare to copy notes from the teacher. The teacher walks into the classroom, takes out her notes, and begins to lecture. She writes notes on the board, and illustrates concepts with diagrams, also on the chalkboard. If it weren't for the hairstyles and clothing, I might need to watch for quite some time to determine which class is which. The instructional style has hardly changed in the last fifty years. If I happened to watch on a day in which the class had a test, I wouldn't have any greater luck in determining the era of the classes (aside from the quality of the reproduction of the test on photocopy) as assessment methodologies haven't changed much either.

Of course there are superficial differences. When showing illustrations, the class from fifty years ago uses only white chalk, the class from twenty-five years ago uses multicolor chalk and overhead transparencies, and today's class occasionally uses illustrations from CDs projected via LCD projector.

The striking thing is that there are tremendous differences in content. Fifty years ago the recent discoveries of Watson and Crick about the structure of DNA had not yet made their way to the classroom. Without DNA, Mendelian genetics were a bit of a black box and taught as such. Twenty-five years later DNA was something that was observed and well understood. The connection to genetics was taught, as was the mechanics of how DNA works. Jump forward another twenty-five years to the present and the number of classes about DNA has increased ten-fold and they now include information not only on how DNA works but also how it is manipulated and applied in science and medicine. The technologies (at least as they are presented in a book) are taught and tested in detail.

The relevance of the science has also changed dramatically over that fifty-year period. Fifty years ago biology was something that only doctors needed to learn into order to practice medicine (and something that physicists needed to take in order to fulfill requirements). Twenty-five years ago biology was still the poor relative of physics, but was a promising field of the future for scientists. Today biology and biotechnology affect not only scientists and doctors, but also citizens every day as they must weigh in on issues like stem cell research and assess their risks in the face of emerging diseases such as bird flu.

Ask any teenager—sitting in front of a computer—what DNA replication is and within thirty seconds with the help of Google or Wikipedia they can regurgitate a description that would pass most classroom tests today. Within the first few hits on Google you'll find definitions, animations, and activities that explain the process better than it was explained to me in high school or university.

Students today could similarly look up information on avian influenza, commonly called bird flu, and tell you about the genetic structure of H5N1 (the scientific designation for the strain of bird flu). But ask them to assess the risk of them getting infected by bird flu, and they are not likely to even know where to start. Online they can find many estimates by different organizations over time. How do they make sense of that disparate set of sometimes conflicting data? How do they break this question down into the necessary components to evaluate? For example, they could get bird flu from a bird, or another person. How would that happen? What is necessary for that to take place? And what is the biology behind these varied pathways? And then they must consider how they could estimate their individual chance of infection. How do they assess risk and use infinitesimally small probabilities? What do those numbers mean, and how do they pertain to individuals? How do they understand the different ways in which a person might come into contact with this disease? Can they examine their own social networks to understand the inherent heterogeneity across geography and subpopulations? What about vaccines and cross-immunity? Are all people equally susceptible and likely to come into contact with this virus?

The student in the biology class is hardly any more prepared to tackle these issues and provide an estimate than the student who has merely looked up a few facts on the Internet. And both of these students are only marginally more prepared to answer this question than their peers viewed through the portal twenty-five or fifty years ago. Yes, there are some concepts and terminology that the students from today may be able to recall, but that is the easy part of this problem. The hard part is breaking this into the component questions, understanding how these relate to each other, managing to make decisions with incomplete information, knowing which experts and sources to draw upon and trust, understanding systems and networks, analyzing data, interpreting numbers and graphs, and choosing and using the appropriate information technologies to make this possible.

Those are the hard tasks. Most twenty-first-century schools do no better a job at providing these skills than do the schools of twenty-five or fifty years ago (Hirsch 1996; Ravitch 2000). Yet the economy and the world itself are qualitatively different than they were in those eras. We currently face many new challenges in our educational system, yet maintain similar dilemmas from those previous times.

## U.S. Education Reform

The schools through the portal all exist at critical points in U.S. educational history. Fifty years ago schools were refocusing their efforts on science and math education during the Sputnik era. There was a national imperative on American competitiveness during that time. The United States needed to create a workforce that was capable of competing with the Soviets. While schools have traditionally been under state and local control, the federal government stepped in to boost efforts in schools to create a workforce with the knowledge deemed necessary to stay competitive. This marked a significant milestone in stressing particular content in the classroom.

By many metrics this educational initiative met with great success (not the least of which was putting a man on the moon first), producing the "baby boomer" generation that went on to produce great leaders in industry and government and in many ways defined the United States in the latter half of the twentieth century. Yet the schools of this time, as throughout much of American history, faced challenges as they tried to weigh competing priorities and conflicting philosophies. The mission of public secondary schools grew at this time to include accommodations for *all* students, not just an elite few. It also balanced the goal of training the future workforce with producing good citizens and creative thinkers.

The students in the room from twenty-five years ago are living in a different educational landscape, though one that faces many of the same challenges. Their classroom may be one of those harshly criticized in *A Nation at Risk* (National Comission on Excellence in Education 1983), a comprehensive report by the United States government published in 1983. This report was prepared by a panel of educational and industry experts to assess the current state of schools in the country at that time. There was the sense that schools were not adequately preparing students, and this report was an attempt to determine the extent of the problem. The fear was that the United States was falling behind Japan, South Korea, and Germany in key industries, and that the nation's schools were likely contributing to the problem (or could be a key to turning the situation around). *A Nation at Risk*, as evidenced by the title, in fact found that the schools, teachers, and students at that time were underperforming. They were scoring low on international benchmarks and standardized tests within the United States. Illiteracy was high and on the rise in both students and adults. Competencies in "higher order" thinking skills were very low. From the industry side there were complaints that employers consistently were required to train their incoming workforce with remedial education. Leaders expressed alarm at the time, particularly in light of the growing importance of science and technology in the workplace and lives of citizens, and the glaring deficiencies in understanding these rapidly changing fields in all but an elite minority. A series of recommendations were made through this study, which included a focus on a broad curriculum (notably including adding to English, social studies, science, and math the fifth discipline of computer science), new teaching methodologies, and metrics for success.

While many outcomes may be associated with this report, the standards movement is the most prominent outgrowth of both this report and the rationale for developing it in the first place. Greater standards needed to be put in place to ensure that students would meet minimum competencies in schools, and tests needed to be created to measure if those standards were being met. Great emphasis was placed on ensuring that all students had the opportunity to meet these minimum competencies. The culmination of the standards movement was the creation and enactment of the No

Child Left Behind (NCLB) Act of 2001, which placed the responsibility of setting and measuring standards in the hands of each state (without additional funding as the states are quick to point out). Those standards, however, had to meet federal guidelines in order for states to continue to receive federal funding.

Today those standards are firmly in place, yet there is still a perception that the country is again slipping behind. The nations we now fear are China and India. These massive countries, and their associated economies, have created the perception of an economic threat and have therefore raised a new national imperative to enhance the competitiveness of all citizens. As made well-known by Thomas Friedman in *The World Is Flat* (2005), many of the industrial and manufacturing jobs have moved overseas or been displaced by automation. Further, many of the clerical, support, and technical positions that had been a staple of the U.S. economy have also moved overseas. The result of this shift is that the schools that were preparing students for a world in which they could depend on those jobs are obsolete and must adapt.

## Modern Skills and Modern Education

A collection of some of the nation's leaders in education, industry, and government formed The New Commission on the Skills of the American Workforce. In 2006 this commission released the report *Tough Choices or Tough Times* (National Center on Education and the Economy 2007), which provided a harsh criticism of the current state of schools in the United States, and how they were failing to prepare students for the modern global economy. The commission argued that the skills that the standards movement has pushed are no longer sufficient to remain globally competitive. Those skills must be bolstered by a new set of skills:

> Strong skills in English, mathematics, technology and science, as well as literature, history, and the arts will be essential for many; beyond this, candidates will have to be comfortable with idea and abstractions, good at both analysis and synthesis, creative and innovative, self-disciplined and well organized, able to learn very quickly and work well as a member of a team and have the flexibility to adapt quickly to frequent changes in the labor market as the shifts in the economy become faster and more dramatic. . . . The core problem is that our education and training systems were built for another era, an era in which most workers needed only a rudimentary education. (Executive summary, *Tough Choices or Tough Times*, p. 8)

Others have similarly advocated that today's workplace demands markedly different skills than students currently are being prepared for in schools (see for example Murnane and Levy 1996; Levy and Murnane 2004). While schools do a reasonable job of preparing students in the "hard skills" (math, literacy, geography), they are not adequately preparing them in the "soft skills" (problem solving, communication, working in groups, and so on). Jobs increasingly are relying on these soft skills, as the hard skills alone are insufficient for managing the diverse tasks in the modern workplace.

Levy and Murnane (2004) identify two particular sets of skills that the modern workplace relies heavily upon—expert thinking and complex communication. *Expert thinking* applies to domain-specific problems that cannot be solved by following a simple set of rules. Complex problems often cannot be solved in a linear fashion, and require deep understanding of systems and processes, an understanding that comes with intricate familiarity with a particular area. This kind of thinking is not easily taught in the format of current schooling that emphasizes following rules, and superficial coverage of vast amounts of content. *Complex communication* describes a variety of personal communication skills necessary in many aspects of work. These includes persuasive speaking, inductive reasoning, communicating with colleagues, understanding clients, making inferences, and describing technical work in nontechnical ways. Again, students lack the opportunity and instruction in contemporary classrooms to hone these skills.

There is a strong overlap between these skills and information technologies. Much of expert thinking and complex communication relies on information technologies. One may assume that this is one place that current schools excel. Looking around at students in or just out of high school seems to show strong evidence for their abilities to use information technologies. And if we were simply to measure the ability to employ software and communication technologies to complete simple tasks, then the students would be doing okay. But this set of "contemporary skills," as defined as a part of Fluency with Information Technologies (FITness) by the 1999 National Research Council study on *Being Fluent with Information Technology* (and revisited in 2006 in NRC's *ICT Fluency and High Schools* [National Research Council of the National Academies 2006]), is just one component of preparation for using information technologies. In addition to contemporary skills are "fundamental concepts," the basic understanding of the workings of technologies, and "intellectual capabilities," a suite of cognitive abilities that must be learned in order to know how to apply information technologies to relevant tasks and problems.

Learning all of these components of information technology competencies (FITness) is critical to being prepared for the modern world, both in the workplace and out. This set of intellectual capabilities comprises a broad range of skills related to living and working in an IT-inundated world. None of them specifically mention technology, but all are tightly integrated with it. The skills (National Research Council 1999) are as follows:

1. Engage in sustained reasoning.
2. Manage complexity.
3. Test a solution.
4. Manage problems in faulty solutions.
5. Organize and navigate information structures and evaluate information.
6. Collaborate.
7. Communicate to other audiences.
8. Expect the unexpected.
9. Anticipate changing technologies.
10. Think about information technology abstractly.

This list looks distinctly different than the frameworks and standards set forth by most states to establish guidelines for what students need to know. While those sets of standards often pay some attention to scientific thinking, critical thinking, data analysis, and communication skills, these are most often the skills that are ignored on the assessment tools, and subsequently in the classroom. Instead, lists of facts and domain elements are ticked off as lessons touch on those concepts. In the rare cases where technology enters the assessments it is in superficial ways, asking students to define particular technologies or other tasks that are in the IT concepts category, squarely missing the suite of intellectual capabilities that will be required outside of school (in the workplace, in post-secondary education, or in being informed citizens).

In revisiting these skills (National Research Council 2006), experts have attested to the continued importance of these intellectual skills. While the particular technologies and concepts have changed (in 1999 the Internet was still in its infancy, without blogs, streaming video, or social networking), the intellectual skills are still critically important and are likely to remain so for a long time. However, further looking at this list makes apparent the difficulty in teaching these skills in the current school modality. With vast amounts of content to cover, how does one have the time to "engage in sustained reasoning"? How does one go deep enough into a single topic to learn to "manage complexity" or "manage problems in faulty solutions"?

Students cannot simply be taught FITness. You can't just provide an extra week of instruction on these topics, or even an extra class on this set of skills. Building FITness cannot be done abstract and discretely, but requires integration with existing subject matter. We need to find ways to provide students with meaningful experiences through which they can develop these skills in the context of their existing subject matter and coursework. The skills must also be learned in pursuit of improving skills in expert thinking and complex communication.

### IT as the Problem and the Solution

As much as IT has created a complex intellectual landscape that can only be navigated with a new set of skills, it has also provided the means to learn that navigation process, and at the same time make advances in the educational system that have been slow to come. Using new technologies we can engage students in deep, meaningful, realistic, and relevant problems, the kinds of complex collaborative problems that education reformers have been clamoring for for many years. Some of this can change through the use of desktop/laptop computers. Students can now work with data analysis tools, collaborative learning environments, simulations, multimedia authoring tools, and virtual environments, all of which offer access to new content and new ways of learning. Video games (see chapters 2 and 3) are particularly promising technologies for learning. This young field is just beginning to explore how games not only can motivate students, but also provide rich learning environments that challenge students in understanding complex problems, whether by jumping back in time to understand history, or inside of a blood vessel to explore the human body. Gaming technologies have a lot to offer despite their previously tenuous relationship with learning.

While some change can come through the use of traditional desktop computers in computer rooms, this setup in and of itself has become problematic. Rather than using tools such as the ones mentioned above to teach a new set of skills, most computer rooms have been appropriated to teach all of the old skills in slightly new ways (see chapter 6). Students collect information for reports from the Internet instead of the library, they type reports on word processors instead of typewriters, and make multimedia presentations on PowerPoint instead of poster board. But the content and skills are largely the same. They are often not provided with the opportunity to explore emerging ideas, work in distributed teams, take on complex issues, or take ownership of problems at hand. All too often students still are not engaged in their own learning. A famous study (Wenglinsky 1996) investigated the connection between different uses of computers in the classroom and academic achievement as measured by performance on the fourth- and eighth-grade National Assessment of Educational Progress (NAEP). Wenglinsky found that students who used drill and practice software for rote tasks did the same or worse than students who didn't use computers at all. However, math and learning games along with simulations and applications were associated with higher scores for students, with the added benefits of increased attendance and higher school morale. But we need to find ways to promote that kind of learning without getting bogged down in the routine of computer rooms.

What this means is that we need to harness IT for learning *outside* of the computer room. We need to put technology into the hands of teachers in their own classrooms, where they can use it to enhance and integrate with their own instruction, not simply add an IT component to their existing courses. Handheld computers, or personal digital assistants (PDAs), like the Pocket PC/Windows Mobile or Palm platforms provide such an opportunity. Relatively inexpensive handhelds can provide a one-to-one (one device per learner) solution in the classroom now. While some researchers and software designers have sought to make these serve the purpose of traditional computing resources, only in a smaller form (see chapter 4), the real opportunity comes in integrating computing with other social, collaborative learning activities that allow technology to facilitate learning and problem solving, rather than being the focus of such efforts. One successful application of handhelds in education of this vein has been the use of Probeware, which allows students to take their handhelds out of the classroom and into the field where they can sample data about the local environments. However, the rise of mobile gaming on cell phones, Game Boys (handheld game consoles), and other mobile devices (chapter 4) suggests that handheld computers can play an important role by bringing gaming technologies into the classroom (chapter 5). The handheld platform also avoids the stigma too often associated with video gaming technologies, by decreasing isolation of students from each other, and facilitating new gaming patterns and genres.

## Building FITness through Handheld Games

For a number of years I have been designing mobile games for learning that push the envelope of both what students learn "in" school and how they learn it. Much of this technology has subsequently been employed out of school in universities, in museums and other informal learning centers, and increasingly with adult learners. These games have been designed with FITness skills as a key set of desired learning outcomes. While the initial chapters of this book set the stage for the role of handheld games in learning, the later chapters explore the design and implementation of these games for a variety of learners. I set out to highlight key lessons learned through both the design and subsequent study of these games, and distill some design principles that have been particularly effective at targeting the FITness skills. I review these skills now in more detail, noting how they map to mobile games and where they are discussed further in the chapters to follow:

1. Engage in sustained reasoning. Learners engage in problems taking many days to solve, and must employ a variety of resources for problem solving. This is ture of most of the games that have been developed; see for example the participatory simulations of chapter 6.

2. Manage complexity. Learners must try to manage complex systems with unpredictable outcomes, such as epidemics (chapters 6 and 9) and virtual ecologies (chapter 12).

3. Test a solution. Learners encounter problems for which they must not only assess the situation but also design (see for example chapter 7) and implement (chapter 10) those solutions.

4. Manage problems in faulty solutions. Learners must understand that their interventions will not always lead to the perfect result. Sometimes

trade-offs must be made in designing solutions (chapters 7 and 8), guided by the feedback learners receive in implementing solutions (chapter 10).

5. Organize and navigate information structures and evaluate information. Learners must collect and evaluate information from a variety of sources, including primary data, documents, and witnesses, as demonstrated in many of the location-based augmented reality simulations. This task is particularly relevant to the games described in chapter 11.

6. Collaborate. Collaboration is indeed one of the key design principles that cuts across all of the games that we have designed. No game can be played alone. Chapter 9 includes a thorough discussion of this design principle.

7. Communicate to other audiences. Learners must be able to communicate with other players within the games (role playing different audiences as in chapter 11) and often have to present their findings to panels as part of the "end game" (as in chapters 7 and 8).

8. Expect the unexpected. Planning for the unexpected may seem like a paradox, but in managing complex systems, and understanding how they work, learners can begin to assess risk and plan for such contingencies as they must do in the games described in chapters 10 and 12).

9. Anticipate changing technologies. While the technology is not an explicit focus of any of the games that we design, learners must master a range of technologies including peer-to-peer messaging, wireless communication, spatial navigation, data collection, and analysis and visualization. The diverse landscape of changing technologies is represented across all of our work.

10. Think about information technology abstractly. Again the focus is not on the technologies themselves but how they are used. Thus we don't teach about the technology, but rather help learners understand the functionality that the technologies provide by presenting them with a problem and the means to solve that problem.

The themes of *expert thinking* and *complex communication* are also present in much of the work that we have conducted. Using role playing, learners in our games examine problems through the eyes of professionals in many fields, developing the expert thinking required to solve these problems. Similarly players must communicate with each other (often representing different roles and skills) and to outside audiences through a variety of media. They learn about new technical, social, scientific, and political concepts in order to understand and convey these messages to other players through complex communication.

## The Trojan Mouse

The next few chapters outline in more detail the case for handheld games for learning. They explain the sordid past of games in education (chapter 2), what games really are (chapter 3), the history of handheld games (chapter 4), and ultimately the small world of educational handheld games (chapter 5). Those chapters are followed by narratives that describe our work in designing, developing, and studying handheld games for learning.

But before proceeding into those chapters I'd like to contextualize my arguments for the use of handheld games in learning with these observations:

**Handheld games are not a panacea.** While I believe that handheld games afford great potential for learning, and are particularly well suited to address some of the issues previously outlined in a way that is both compatible with current schools and capable of changing them, handhelds are not the silver bullet to save education. They can, however, play an important role.

**Handhelds can play nicely with other technologies.** There are many technologies that can and should have a place in the educational arsenal of learning organizations. Collaborative tools (blogs, wikis, knowledge-building software), immersive environments (e.g., virtual worlds like Second Life), media processing and sharing tools, and many others have a home in education. Handheld games fill a new and less-well-known niche in this ecology of tools.

**It isn't all about the technology.** Most of the intellectual capabilities previously defined are relevant to understanding most modern issues and problems. They need not necessarily be associated with technology at all. Many of these skills are equally relevant to constructivist learning that has been promoted by education reformers for decades, and could be fostered without technology. Technology, however, is the vehicle for getting these intellectual capabilities into schools discretely. Others have called this use of technology the "Trojan Mouse." Though that metaphor doesn't work as well on handhelds, which employ a stylus, not a mouse. The "Trojan Stylus" just doesn't have the right ring to it.