Educational Games and Virtual Reality as Disruptive Technologies

Joseph Psotka

U.S. Army Research Institute for the Behavioral and Social Sciences, 1436 Fallsmead Way, Rockville, MD 20854 // Psotka@msn.com

ABSTRACT

New technologies often have the potential for disrupting existing established practices, but nowhere is this so pertinent as in education and training today. And yet, education has been glacially slow to adopt these changes in a large scale way, and innovations seem to be imposed mainly by students' and their changing social lifestyles than by policy. Will this change? Leadership is sorely needed. Education needs to become more modular and move out of the classroom into informal settings, homes, and especially the internet. Nationwide certifications based on these modules would permit technology to enter education more rapidly. Smaller nations may be more flexible in making these very disruptive changes.

Keywords

Disruptive technology, Educational games, Virtual reality, Modules, Assessment, Leadership

Introduction

We are at the cusp in time when the use of Virtual Reality (VR) environments and games and edutainment are resulting in a creative output that foreshadows a new Renaissance in learning—affording entirely new options for human creativity and global social interaction in science, business, and government. These technologies, as well as those emerging within the new cyber-enabled landscape of social networking and advancing neural computer technology in an emerging global technological workforce, are disrupting traditional education practice; producing new learning processes, environments, and tools; and expanding scientific discovery beyond anything this world has ever seen. In the context of these disruptive innovations, why are learning technologies, specifically game-based learning and VR environments, so glacially slow to be adopted in schools, universities, or across informal science education institutions, at a time when our world is in dire need of a highly creative, innovative, and technologically sophisticated workforce to manage its complexities on a global scale? It is time that the political forces in this world begin to understand this potential and own up to their responsibilities for transforming education. Education needs to become more modular and move out of the classroom into informal settings, homes, and especially the internet. Nationwide certifications based on these modules will permit technology to enter education more rapidly. Smaller nations may be more flexible in making these very disruptive changes.

Many computer visionaries have foretold the coming transformation of education by computing (e.g., Seidel & Rubin, 1977; Feurzeig & Papert, 2011), yet in retrospect, these prognostications sound alarmingly redundant year after year. It is unclear; however, whether there is negligible, slow, or incremental change, or is it building to a potentially massive disruptive revolution in school-based education? An early, respected pioneer, Seymour Papert, whose MIT Logo lab spawned many innovations, was known to believe that computer technology would not have much of an impact until education changed fundamentally. What sort of changes could facilitate the implementation of new technology. Collins and Halverson (2009) have suggested that the problem is not better simulations, games, and intelligent tutors; but a radical restructuring of the curriculum. We need smaller curriculum modules than entire schools of four or five year long course sequences. These modules need nationwide certification based on formally monitored assessments. With these smaller modules, technology could be focused on improving instruction or radically altering its form in a completely disruptive way.

What we are witnessing, however; is not that education is looking to change, but, conversely, technology is pushing fundamental change in education, and education is not willing to make any changes to adopt it. How education leadership and emerging education policies address this significant and emerging reorganization of where, when, and how children can now learn through technology will determine the extent to which education will experience a fundamental transformation and produce the creative knowledge workers of the future.

Disruptive technology

When mainframe computer manufacturers ignored the encroachment of personal computers they held back the development and innovation surrounding their use; and by doing so they ensured their own demise. Instead of seeing the enormous popular advances that PCs held, they adamantly refused to use their skill and expertise to promote and accelerate this marvelous new technology development: this cost them their pre-eminence. We worry that similar strategies may be delaying adoption of technology in education and thwarting, ultimately, every nation's opportunity to augment their intelligence.

In reality, mor than 2 Billion people are using the Internet globally as of 2010. This includes three quarters of the American population more than a doubling increase since 2000. Online learning increased from 45,000 enrollments in 2000 to roughly one million in 2007, and shows signs of continuing to grow at more rapid pace, a power function expansion.

Simulations and games, especially those that invoke the hyperrealism of Virtual Reality are burgeoning in many commercial and military enterprises but have made less impact on education then the very first rudimentary games, such as Rocky's Boots (Robinett & Grimm, 1982). About 30 years ago, it was both easy to incorporate computers in education and easy to ignore the technology. Today the touch-sensitive, easy to use direct manipulation interfaces on cell phones, with voice commands for many common tasks, were unthinkable for those early machines. With 64K (not megabytes, not gigabytes, just kilobytes) of memory, the early computers did little more than turn pages of text; provide simple drill and practice mathematical problems; or provide text-based quizzes. At the time, these affordances fit well with teachers' competences and were relatively easy to integrate into classroom activities and remediation. These simple educational activities were not sufficiently important then to justify the purchase of expensive machines, so often one or two machines sat frequently unused in the corner of classrooms or in special computer rooms with locked access. Yet, commercial successes that spread widely such as word processing, accounting, and producing business spreadsheets forced schools to recognize them. New processes demanded new workforce skills; therefore, a market developed around teaching these targeted skills, but educators safely ignored the main issues by relegating computers to teaching tasks like keyboarding.

In 1978, the National Science Foundation (NSF) and the Department of Education (DoED) funded a groundbreaking effort to build computer technology for education. Out of this enterprise came some very successful research and development, including the highly successful and dominant games: *Rocky's Boots*, *Carmen Sandiego*, and *Oregon Trail*. The use of these games became popular in mathematics, English, and history classes, and their use was undergirded, theoretically and practically, by new insights into motivation and emotion in learning. It was obvious that computer games were serious fun; subsequently launching the beginning of a new media industry and culture.
From these early efforts, theoretical frameworks emerged that focused on learning with levels of challenge, or social interaction, or intrinsic motivation (Malone, 1981b), and toward a theory of intrinsically motivating instruction (Malone, 1981a). Early games of the 1940s were based upon missile defense systems and then adapted in the 1950s into low-level games. During the 50s and 60s, mainframe computers were used to increase the complexity of games and gaming platforms. The first viable commercial game, sold in coin-operated settings that laid the foundation for the entertainment industry was the 1971 game *Computer Space*. The gaming industry experienced commercial ups and downs until ultimately console gaming crashed in 1977. Rising again in the 80s with low publishing costs, game development expanded with different genres, such as adventure, beat 'em up, fighting, and interactive movie games; maze, platform, platform-adventure, racing, and role-playing games; rhythm, scrolling, stealth, survival and horror games; and vehicle simulations. Video games became widespread and deeply established in the 1990s when they became mainstream entertainment and consolidated with publishers. Increasing computer power and lower costs afforded the integrated use of 3D graphics, multimedia capabilities, and the production of newer genres, such as MUDs (Multi-User Dungeons), multiplayer, real-time virtual worlds; first-person shooter games; and the massively multiplayer online role-playing games (MMORPGs) or Persistent Worlds (PWs).

Although the gaming industry spawned dozens of multibillion-dollar companies, most current commercial games and their predecessors have had little explicit education content, such as chemistry, mathematics, or physics, nor have they been designed with embedded pedagogical strategies that would make them appealing to teachers or parents (Kafai et al., 2007). Commercial games; however, have been shown to develop physical and cognitive skills in learners (Lin, Linn, Varma, & Liu, 2010). Many teachers and administrators are waiting for definitive proof that games and VR environments are more effective than traditional text-based ways of instruction, although we already

know from innumerable studies that students are not learning well using traditional and text-based instructional methods.

Virtual reality environments, games, and learning

Most games and VR environments emphasize intrinsic motivation strategies, focusing on participants' internal motivation to perform a task, which is derived from the participation itself (Malone, 1981a; Malone & Lepper, 1987). Research on intrinsic motivation has found greater success when students engage in creative or complex tasks (Utman (1997); however, this is not to state that extrinsic motivation has no role in effective game design; intrinsic and extrinsic objectives are often entwined. Immersive experiences in a VR environment can be pleasurable as well as disturbing or frightening so acute is the experience (de Strulle, 2009). Immersion or presence, is a state of consciousness where awareness of one's physical self and surroundings is diminished or nonexistent, and one's experience in the virtual world becomes acutely heightened and seemingly physiologically embodied (Psotka, 1995). Being immersed in a virtual environment provides a very specific set of affordances both internal and external to the environment itself. In *Why Virtual Worlds Can Matter* (2007), John Seely Brown discusses that some of the things that occur in and around virtual worlds "may in fact point us in the direction of new forms of knowing and acting in virtual spaces and give us insight into what new, technologically mediated worlds may look like in the coming decades." It is to this future world that this chapter is devoted; to the evolving interplay of humans and machines, and the emergent learning processes found in subtle and self-evident corners of invented realities and environments.

Can education cope with the new technologies?

The slow adoption in education of games and VR environments for learning may remain as is for reasons that have little to do with their effectiveness (Meltzoff et al., 2009). The problem at the core is that technology cannot be effective until the curriculum is fundamentally changed to allow for specific technologies to be integrated in meaningful ways. If however, the curriculum will not be changed until each technology is proven effective, this is a standoff and counter-productive to progress. Scaffolding is a widely used educational practice in which directed instruction gradually decreases as a student's competence increases, and this graduated weaning from assistance results in increased independence in the learning process (Quales et al., 2009) Through merging real and virtual objects, the authors address the issue of the augmented emergence of abstract from concrete knowledge. Results of the study with a large sample of students suggest that the merging of real and virtual spaces can offer "a unique level of educational scaffolding," as well as "an improved learning-transfer from abstract to concrete domains." Embedded, or augmented reality may not be just effective; it may in fact place a new premium on informal learning outside of school. This may do to the education environment what the Internet has done to bricks and mortar stores.

Distinguishing the good from the bad has not been easy, especially when past evaluation studies have generally found mixed effectiveness results. Although it is more difficult to demonstrate learning gains from higher-level tasks than from tutorials that focus on drill and practice, the benefits to be derived from real-world tasks that require the student to explore, analyze, interpret, solve, and communicate are acknowledged widely (Bangert-Drowns & Pyke, 2001; Kearsley & Schneiderman, 1998; Kozma, 2003; Yang, 2003). While technology can be made subservient to traditional teaching practices of drill and practice and page turning, and numbingly passive delivery of knowledge, it is evident that this robs not only the student, but the effectiveness of the technology. VR simulations and games bring motivation and challenge back to students with a powerful force.

Funded with generous support from the Carnegie Corporation, the National Research Council of the National Academies of is drafting a "Conceptual Framework for New Science Education Standards" articulating a vision of the scope and nature of the education in science and engineering that is needed in the 21st century (Strulle & Psotka, 2012). The NRC's framework is committed to the notion of learning as an ongoing developmental progression and seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K-12 science education. It recognizes "the increasing importance of engineering and technology in developing understanding and using scientific knowledge and practices."

Research summarized in *Taking Science to School* (National Research Council, 2007) reveals that children entering kindergarten have surprisingly sophisticated ways of thinking about the natural world based on direct experiences

with the physical environment, such as watching objects fall or collide, and observing animals and plants. Many of these early experiences can be simulated in VR environments.

Bringing motivation and challenge to learning

The most longstanding and direct benefit of VR and games for education has been their power to motivate learning. At first it was thought to be a novelty effect, but it has sustained its power over the years (O'Neil, Wainess, & Baker, 2005). VR and games continue to expand and transform themselves to also provide continuing novelty effects, but this is now clearly subsidiary to the main effects of challenge, social interaction, peer feedback, and the instantiation of local goals that are intrinsically motivating. In part, the motivational effects transpire from the power of immersion and the feeling of presence in creative and dramatic environmentsThis aspect of VR and educational games is the easiest to adapt to current pedagogical goals and environments, since motivation is an essential part of pedagogy under any system of instruction.

Virtual reality and games have the potential of embodying abstract concepts in concrete experiences. Perpetual motion machines can be built to demonstrate the force of gravity without the drag of air or any other friction. Complex interacting systems can be seen from the simplest perspective and complex abstractions, such as the meaning of words and the links between concepts shown tangibly in a complex three-dimensional space. Imagine a starfield of related concepts that can be explored by walking among the concepts, touching the invisible links that connect them, experiencing the distance among them, vibrating one to discover all the others that resonate to similar meanings, activating the concept to see it in movies and textual explanations: all this is possible to create concrete meaning out of ambiguous abstractions. For teachers, however, this is a monumental challenge. How to use the obvious insights in the real world and the semantic world of mental life remains unexplored to modern pedagogy, and the insights are as new and strange to teachers as they are to their students. Examples of success are River City, an NSF-funded virtual world for middle school science classrooms (Ketelhut, Nelson, Clarke, & Dede, 2010) containing content developed from *National Science Education Standards, National Educational Technology Standards,* and *21ˢᵗ Century Skills*. The River City world allows students to conduct scientific investigations around an illness spreading through a virtual city and based upon realistic historical, sociological, and geographical conditions. The authenticity of the world allows learners to engage in scientific practices, such as forming hypotheses, running controlled experiments, and interpreting data to inform courses of action. (http://muve.gse.harvard.edu/rivercityproject/curriculum_p21_standards.htm).

The most popular social networks, such as *Facebook*™, the virtual world *Second Life*™, and massively multiplayer online games (MMOGs), such as *World of Warcraft* and the SIMs have inspired the public's imagination and their motivation to learn. World of Warcraft and Second Life have reported participation of 8.5 and 6.5 million users, respectively (Bainbridge, 2012; Squire & Steinkuehler, 2006). With such expansive participation in social media, informal learning has been "virtually" transformed by these emergent settings.

The public's enthusiastic adoption of new technologies has evolved a resounding need for informal education institutions to design increasingly sophisticated exhibits that incorporate immersive VR, augmented reality, game-based technologies, visualizations, and other emerging media. Advances in simulations for training pilots and astronauts; ubiquitous robots and nanotechnology; satellite imagery; and emerging, sophisticated visualized data have provided new opportunities for engaging the public in modern science. Findings from a study of a virtual reality science exhibit (de Strulle, 2009) revealed that some learners were frightened by specific types of nonrealistic virtual environments and positively affected by realistic images. Nonrealistic images decreased feelings of immersion, while some visual images moved or changed too frequently to produce any sense of immersion. Avatars were intended to personalize the VR experience; however, data reveal that avatars did not personalize the experience. Conversely, avatars were found to detract from learning. Options for interaction were confusing within the virtual environments, leading to cognitive load issues and frustration in participants, and the mix of audio, text, colors, movement, and navigation tools were together found to distract from learning. As far back as 1996, Cazden and Beck (2003) argued that it was critical for exhibits to model effective learning strategies based upon research on learning and be assessed for their pedagogical value. This remains true. Synchronizing exhibits to the learning strengths of students, multiage learners can provide unique options for self-directed learning. Differences emerged in understanding of exhibit content learning styles of multicultural audiences; differences in gender-based learning; consideration of age

differences among learners; and a new way of understanding how people learn within immersive environments (de Strulle, 2009).

WolfQuest is a highly successful NSF-funded science game, downloadable and free of charge (www.wolfquest.org). Developed by Educational Web Adventures and the Minnesota Zoo, the game is coordinated with a national network of informal science education institutions, including wolf research and conservation organizations. It is important to note that *WolfQuest* was designed to bring the same compelling, game-playing quality of commercial video games to online informal science learning and had the goal of teaching wolf behavior and ecology in an authentically rendered VR environment developed for scientific accuracy by wolf conservation scientists and wolf habitat ecologists. In a summative analysis of the game by the Institute for learning Innovation, several issues were identified as being notable: about 4,000 users downloaded the game in the first few hours after launch and over 350,000 people have downloaded the game in the 21 months post launch. On average, players have engaged in over 100,000 multiplayer game sessions per month. The game's online community forum has over 80,000 registered members who have made over 850,000 posts to the forum, with a current average of 1,400 posts daily. The game also successfully reached its target audience of 9-15 year olds with nearly 70% of players in that age range. Findings from a web survey, indepth phone interviews of learners, and content analysis of the conversation forums, reveal that interest in, connection to, and knowledge of wolves, wolf behaviors, and wolf habitats increased significantly. This is significant because the game's science content was woven throughout the game and rarely made explicit. In self-reported knowledge, a definite cognitive gain is found with respondents naming either general or specific facts related to habitats, hunting behaviors, territories and threats to wolf survival, social behaviors, and other facts related to the anatomy and species of wolves. Over three quarters of the survey participants either have, or intended to expand their interest in furthering their learning about wolves. Over half of the individuals correlate playing *WolfQuest* with their desire to visit zoos, nature centers and state parks and to participate in outdoor activities. This demonstrates that science rich games can be a significant factor in encouraging interest in grade-appropriate subject matter and advance visits to zoos and wildlife centers and as form of enhancement to traditional subject matter instruction.

Tüzün et al. (2009) studied the effects of computer games on primary school students' achievement and motivation in geography learning. Researchers designed and developed a three-dimensional educational computer game for 24 fourth and fifth grade students in a private school in Ankara, Turkey to learn about world continents and countries for three weeks. The effects of the game environment on students' achievement and motivation and related implementation issues were examined through quantitative and qualitative methods. An analysis of pre- and post-achievement tests showed that students made significant learning gains. In comparing student motivations while learning in the game-based environment and in the traditional school environment, it was found that students demonstrated statistically significant higher intrinsic motivations and statistically significant lower extrinsic motivations from learning in the game-based environment. In addition, students had decreased their focus on getting grades and were more independent while participating in the game-based activities. These positive effects on learning and motivation, and the positive attitudes of students and teachers suggest that computer games can be used as a tool in formal learning environments to support effective geography learning.

The military's leadership in game-based learning

In America's military there has been little opposition to innovation in education and training. None surpasses the military's leadership in education and technology; therefore, it is imperative that we understand the difference between the military's approach to leadership in education and training, and the American school system's rather lethargic approach to modernization. Why is one massive enterprise nimble enough to react to the changing dynamics of national interest, and one system entrenched in antiquated ideas, outdated textbooks, poor teacher preparation, and a serious lack of attention to the rise of technology?

Military officers often have an engineering background. Computers and technology are not unfamiliar but this is not the basis of the military's success. The military is driven by pragmatic urgency to improve their odds against very clever foes in very high-stakes environments. As a result, computer games and simulations were explored thoroughly at the beginning of the digital revolution and found to merit vast investment in research and development because these environments provided a unique learning edge. The military already used simulations of simultaneous linear equations to model weapons effects, called constructive simulations, and so there was an incremental change to qualitative digital simulations. Initially, the machinery of war, tanks and planes and ships were simulated with

mockups, and then embedded in computers to create virtual environments where Soldiers could learn their profession as realistically as possible. The Army created a vast desert stronghold to verify the success of these simulators in live training that is unparalleled in the world. Not only did they confirm the success of simulators and games, which was attested to by commanders in actual combat in Desert Storm and Operation Freedom, they also created an extensive modeling and simulation bureaucracy to guide the research and development of more formidable systems.

The U.S. Army has successfully emphasized "training as you fight" to instill the best possible fighting effectiveness in its Soldiers. Over the last two decades, this philosophy has heavily emphasized simulators and simulations that range from virtual environments of networked armor simulators with veridical motion and scenery to live training ranges with laser detectors pioneered at the National Training Center. In 2002, the U.S. Army created America's Army (http://www.americasarmy.com/), a game to provide entertainment while creating implicit skills and tacit knowledge about the variety of occupations in the military. The game was based on a commercially successful gaming platform and engine and was a huge success with millions of downloads and online players. Its effectiveness at creating Army skills and an improved understanding of the Army environment had been widely acknowledged as self-evident. America's Army has been going strong for more than 8 years with millions of downloads and players throughout the world. The success of this training has propelled the widespread development of less detailed simulators, such as DARWARS Ambush! (Foltz et al., 2008) for training convoy skills; videos in communities of practice (COPs) environments, (Cianciolo et al., 2007) (companycommand.com); and even professional discussion in text-based environments (Dixon et al, 2005). The range of training domains has been fairly broad, including interpersonal interactions (Hill et al., 2006; Barba et al., 2006); convoy operations (Roberts, Diller, & Schmitt, 2006); squad/platoon leadership (Beal, 2005); tactical operations (Beal, 2005); language and culture (Johnson & Beal, 2005), among others.

To avoid the high monetary costs and time requirements for developing scenarios in these high-fidelity environments, assessment of individuals was conducted in a low-fidelity environment. The use of a low-fidelity environment also provides a near-transfer demonstration of the skills/abilities developed through training with high-fidelity environments. With a low-fidelity environment, the training domain knowledge and decisions can be parsed from the skill in using the training tool, so the assessment can target the intended cognitive components of the training material.

ELECT BiLAT is a prototype game-based simulation for Soldiers to practice conducting bilateral engagements in a notional Operation Iraqi Freedom environment (Hill et al., 2006). The prototype provides students with the experience of preparing for a meeting, including familiarization with the cultural context, gathering intelligence, conducting a meeting, negotiating a successful resolution, and following up the meeting agreements, as appropriate. The ELECT BiLAT architecture is based on a commercial game engine that is integrated with research technologies to enable the use of virtual human characters, scenario customization, as well as coaching, feedback, and tutoring.

Military's assessment methods

To assess the effectiveness of military games for learning, simple facts are not enough. Improved decision-making based on experience is the goal; so multiple-choice tests and even essays are not appropriate. While essay answers may bring out the sought for skills, they are too time-intensive for everyday group use, so a new technology for testing has been developed: Situation Judgment Tests (SJT).

For ELECT BiLAT, an SJT was developed and used to assess how well learners made appropriate decisions. The SJT included nine scenario descriptions with multiple alternative actions presented as possible answers for each scenario. The learners rated each possible action (a total of 31 actions per scenario) on a Likert scale (0 = very poor and 10 = very good). The learner responses were standardized (i.e., a Z-score based on their own mean rating and the standard deviation of their own ratings). Learners' standardized ratings were then compared to a subject matter expert (SME) based rating key, using a correlation. The higher the correlation between the learner and the SME ratings the better the agreement on the relative goodness/badness of various actions in the highly complex situation of bilateral negotiations.

One of the benefits of using the SJT to evaluate progress was that there were no clear right/wrong answers for the ratings, and the scoring was based on a correlation to SME ratings. By taking the SJT without any feedback, a learner

would not be able to improvise a personal scoring key leading to improve scores based solely on repeatedly taking the test. Therefore, a pre-training assessment could be given prior to the training session, followed by the training, and then the post-training assessment could be conducted. Then by comparing the pre- and post-training correlation scores, it was possible to see how much a person learned from the training.

To our knowledge, no one at any level of the education system has yet adopted this new SJT technology, just as there is little use of educational games across the education enterprise.

Not all military training via games and game technology is combat-oriented. When deployed outside the U.S., for example, soldiers often are in different cultures and unable to speak the language. Various companies and university research programs are working to solve these problems. In 2004, researchers at the Information Sciences Institute at the University of Southern California were working on *Tactical Iraqi*, a game-based effort to teach Arabic to U.S. soldiers. These types of games involve work with speech recognition technology, since speaking a language is vitally important to learning it. A human facilitator monitors and corrects trainees, since the technology is still relatively new.

Most military personnel are not involved in frontline combat. The actual warfighters are supported by a host of analysts, drivers, cooks, and so on, who are doing traditional jobs under extremely adverse conditions. The military is aware that they need training for non-combat personnel. During the fighting in Iraq, non-combat troops suffered more casualties than combat troops. Games have been used to train these personnel as well.

In 1999, the U.S. Army in conjunction with the University of Southern California created the Institute for Creative Technologies (ICT), bringing together educators, video game developers, and other entertainment companies to create the next generation of military training tools and simulations. The Army's Joint Fires and Effects Trainer System, or JFETS, is one of the projects to come out of the ICT. In JFETS, the location of the mission, with simulated personnel and defenses, is presented to the player-trainee. Since most missions are team missions, the training becomes a multiplayer game experience. Superiors can monitor the performance of individuals, as well as the entire team, and can provide feedback, both positive and negative, in debriefings after the mission is completed. If the design of the simulation is engaging enough, it's not impossible to assume that soldiers would be willing to play the games in their off hours, combining unsupervised entertainment with training.

Live training operations, deploying hundreds or even thousands of military personnel into the field, have been a staple of military training for centuries. The cost of such operations, in terms of both men and equipment, makes them less than ideal. With massively multiplayer online games (MMOG) technology, bringing together troops from around the world, operations can be done less expensively and with much more secrecy. In addition, the military is contemplating Virtual Reality trainers.

Training for the military has advanced significantly in the past decades, and games for training have played a large part. Though there are still many in command and training positions that distrust games as teaching tools there is evidence of its success and the use of games will become even more important in the years to come. For the military's games, After Action Review (AAR) is particularly important. The process reviews what was supposed to happen, establishes what actually happened, and then determines what went right—essential to assessing both the game and a Soldier's performance. Past studies always have mixed effectiveness results.

Conclusions & recommendations

Outside of classrooms, students and adults are highly engaged in using a range of complex technologies and have generally surpassed the expertise of their teachers. Technologies of many kinds, from online universities to interactive learning environments and distance education are nibbling at the edge of school systems (Collins & Halverson, 2009). The failure to recognize technology and its affordances for improving teaching and learning is thwarting our ability to develop a technologically skilled workforce and thereby inhibiting our ability to compete in

the global marketplace. Students in less affluent public schools are unable obtain a modern and competitive education, and our system of education is not consonant with the goals of other high performing Western countries. Technological innovation is creating rampant discord in well-established industries that have been entrenched at all levels of the education enterprise. Textbook, magazine, and newspaper publishers are in a quandary about how to deal with current digitization of information and massive amounts of data, and the vast global networks now used for global information and communications (Jones, 2009). To what extent, we ask, do the industries tethered to the education system, such as textbook and publishing companies, student exam preparation companies, college boards, and an array of resource providers with contracts to schools constrain the use of technologies and software applications because their business is not yet technology-based? Although few groups adopt the Luddite strategy of destroying technological innovation, other strategies may be equally destructive, preventing the level of creativity, innovation, and progress our nation needs. Change demands radical new skills and practices.

Future learning progressions

The inferential processes of children in their genetic epistemology of knowledge remain largely a mystery to our understanding, although some generalizations about the progression from sensory experience to concrete manipulation and formal knowledge (Piaget, 1926) are superficially understood. What is clear, is that the implicit creation of concepts and knowledge structures during the first few years of life where every new experience seems to add measurably to a child's progress. The meanings of words grow in parallel with each other incrementally; so that within five years (1825 days) more than 5,000 unique conceptual meanings are learned while only one or two new words are encountered each day (Landauer & Dumais, 1998). With the exception of some parental assistance, *no teacher was involved in these learning achievements*.

Exposing children at early ages and grade levels to complex ideas could turn around children's natural learning progressions. For example, a game has the potential to provide young children with experiences that convey the impact of human behavior on an ecosystem, giving them immediate insight into the concept traditionally taught in high school. Although we do not know how the mind can extrapolate from VR experiences at such early ages, we do know that simulated environments, as previously mentioned, can create immersive states of consciousness that are "as if" the student is there. In addition to basic gains, VR could be tested as an intervention. As an example, exposure to novel learning experiences outside of school has been linked to higher academic performance in elementary school. Affluent children typically spend summers hours traveling or in learning activities, as opposed to economically challenged children who have little enrichment outside of school. Academic gains made by affluent students over the summer are compounded yearly resulting in a perpetually widening academic gap between affluent and economically challenged students during the formative school years. Because VR and games can provide simulations with experiences of real environments, including augmented reality, these environments can expose students to "realistic" and "authentic" enrichment activities potentially closing the learning gap in the early years. Our minds are attuned to implicit inferential learning from experiences provided by our perceptual systems; yet, education largely fails to stimulate and leverage these powerful learning systems. Imagine allowing children to experience and explore the conceptual universe of atomic and chemical structures; an unspoiled ecosystem; historical reenactments; the plays of Shakespeare, just as concretely as they now explore their playrooms and backyards. Imagine not just two-dimensional graphs of forces and relations, as in *SimCalc* but embodied forces moving and changing dynamically in complex relationships that students can be engaged with using all their perceptual and intellectual systems. Games, VR and other emerging technologies are strategies for learning that embrace complexity and rely upon the amazing capabilities of the neural networks of the brain to create organized knowledge and understanding. The formation and ingrained acceptance of many misconceptions is prevalent in K-12. Ideas such as the geocentric solar system; medieval theories of circular motion; or overly simplistic views of predator and prey relations, can easily be eliminated through VR and games in early elementary school, allowing for complex and accurate conceptions of the world to form at early ages, freeing up valuable academic time for more meaningful and detailed exploration. At this point of unprecedented opportunity for learning, we should be exploring a plethora of possibilities.

Scientific misconceptions

Misconceptions about the world abound in students from the obvious flat Earth and geocentric solar system; to the much less obvious impetus theories of motion for objects swung in circles and let go, or objects dropped from

moving vehicles. Misconceptions in science and mathematics have an important role in creating graduated and more complex understanding of the world; just as the Bohr atom is a crude approximation of more detailed atomic structure; however, some misconceptions are the direct byproduct of our perceptual system. Even after seeing the Earth rise from the moon's surface it is still difficult to conceive perceptually that the sun is not orbiting the earth in the sky. In spite of this perceptual conflict, VR can provide the direct experience to understand more directly and convincingly that a heliocentric view of the solar system is a more scientifically congruent conception. Similarly, it can provide a point of view of objects being dropped from moving vehicles that takes either the perspective of the moving vehicle or the stationary ground, and the accurate flight of objects can be made clearly visible. In this way, VR provides pedagogic agency of novel and unrivalled power. In order to use this power, teachers must understand these misconceptions; must understand the role of misconceptions in the cognitive growth of their students; and must be able to integrate these things into their curriculum, and nothing seems as imaginative and compelling as seeing and doing through immersive technologies.

Exploiting the power of disruptive technology

Reviewing these strengths of VR and educational games, the pattern of their disruptive powers becomes obvious. Instead of providing facts and abstractions, VR and educational games offer an embodiment of selected, refined experiences distilled from real life. An example of leading-edge work with experiential simulation is *ScienceSpace*, an evolving suite of virtual worlds designed to aid students in mastering difficult science concepts (Salzman, Dede, Loftin, & Chen, 1999). Whether to counter misconceptions; provide access to normally unperceivable phenomena of Earth's systems and processes and inaccessible environments; or immerse students in exciting, motivating adventures with incidental but important meaning, games and VR technologies offer unprecedented educational opportunities. These opportunities may never fit into the existing framework of education unless current approaches to the use of educational technologies change. VR and games can stretch and shape students' minds in ways that have not yet been explored by educators in large-scale implementations. This is disruptive technology at its core.

Students live in this world of immediate sharing, with cell phones, instant messages, online social networking sites, and games, in a continuing evolution of technology that dominates their lives. The education system used to be the access point for new information and knowledge, now the Internet and social networking technologies offer resources of unparalleled magnitude making information and knowledge gained in classrooms appear outdated. New technologies offer fresh and highly effective new approaches to creativity in the context of education, such as ways to adjust pedagogical structures in favor of a more individual approach to learning that creates opportunities for teachers to engage students individually and provide feedback. Technology provides opportunities for individualized, automatic feedback, and promotes collaboration and peer interaction in new powerful ways. Online games in particular demand teamwork and sharing expertise.

Humans are endowed with magnificent sensory systems to investigate and explore the world. Children use these systems to make powerful, far-reaching generalizations about complex everyday events and structures that are so amazingly accurate that they survive to reach school age and beyond. It does not take much imagination to see that the structures and function of the brain are intimately in harmony with these perceptual systems. Yet, once in school these powerful systems and exploratory urges are harnessed, reined in, and often constrained only to focus narrowly on text-based learning and images in books. The advanced new technologies of VR and games make these persistent restrictions unnecessary, but the education system must be radically changed to position itself to take advantage of these new teaching and learning opportunities.

The future workforce

Workplace employment demands increasingly more knowledge adeptness with online interaction and collaboration essential to job functions. Education has moved much too slowly in taking an active lead in promoting these skills and focusing on higher order thinking skills that leverage these technological breakthroughs. Many technologies are inherently educational in ways that could easily be exploited by schools; yet, it appears that the zeitgeist is predominantly one of shutting these technologies out of school-based learning, preventing cell phone use in classes because of their potential disruption of teachers' lectures and control. The true disruption, however; is not inside classrooms, it's outside the classroom, in out of school learning where information and communications technologies,

games, and virtual worlds are dominating the attention of youth and perpetuating and evolving with such sophistication that it will ultimately cause the educational system to change, but when, and at what cost to our nation's leadership?

It is up to leaders, principals, administrators, school boards, and local officials to begin to design the necessary educational technology framework for how schools might undergo a transformation and oversee it through to a successful end. A demand for new curricula with a culture of embracing technologies for learning must evolve. Schools of education must teach preservice teachers how to teach and collaborate through technology; foster student research using technology; and engage students in the use of current technologies in order to gain necessary competitive expertise in using technology for a range of interdisciplinary career opportunities; evolve essential abilities to solve problems through analysis of emerging data; and design new forms of innovation for a technological world.

VR can present science content through sophisticated simulations allowing users to interactively experiment, collect and interpret data, pose questions, explore new hypotheses, and analyze results of their own virtual experiments. Conducting scientific inquiry within a VR environment allows learners to progress to more difficult and sophisticated science investigation experiences at their own pace of inquiry. Such experiences promote improvement in learners' critical thinking and problem-solving skills through manipulation of scientific data, data analysis, and speculation of results.

For teachers with students who have varied academic backgrounds, propensities, and abilities, VR can integrate a range of personalized strategies. Students who may have difficulty performing in class could potentially have time away from teachers and peers to engage in virtual problem-solving strategies synchronized to a learner's individual pace.

Learning from experience

Researchers have created innumerable prototypes and disseminated them to educators, researchers, and schools only to continue to flounder alone. Such a piecemeal research agenda and implementation strategy will not effect any change in education in radical ways. The education enterprise must systematically draw from the body of evidence but also and most importantly, from the real-world exchange of ideas in the world marketplace in order to absorb visionary new ideas and recommendations. Leadership is needed in government and industry to forge a bold new plan to let America's children learn.

Change in the structure of schools

Collins & Halverson (2009) have offered a stimulating new program for integrating technology into schools. Just as education had to change dramatically in response to the industrial revolution, the knowledge and technology revolution are demanding a similar degree of change. The two changes they suggest are national certification and modular assessment systems. The main proposal they make is to create a national set of credentials that could be administered online on any learning center or school by trained professionals. By creating smaller certifications that are nationally recognized students could use their own motivation to decide which certification tests they take, when they take the tests, and the topics to research. These certifications would rely on assessment systems that are nationally standardized. Not only would this increase student motivation to pursue their own interests when and where they want, the modular architecture would allow the penetration of research innovations into school based, informal, and internet based curricula. This motivation factor has the potential to improve education in many ways.
Education is somewhat modular already, with materials broken into years, or semesters. This should provide a start, but smaller modules would be more amenable to technological simulations, games, and VR. The changes it demands maybe too great for huge national systems, but smaller nations may be more agile and flexible in creating these new systems. Everywhere, however, dynamic leadership is needed to overcome stagnant lethargy and implement change that may well be disruptive in its short term consequences.

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