A REVIEW OF RECENT GAMES AND SIMULATION RESEARCH AND POTENTIAL EDUCATIONAL APPLICATIONS

November 3, 2006

by
The Center for Technology in Education
Johns Hopkins University

INTRODUCTION

In the 1990's federal, state and local governments as well as the private sector collaborated to facilitate the introduction of computers and internet access in many American schools and provided professional development for teachers in the effective utilization of these technologies. Within the past six years, schools have focused on upgrading computers and networks, purchased additional software and provided more teacher professional development so that students have access to advanced multimedia resources, such as streaming video, virtual/ augmented reality, video conferencing, educational simulations and games, etc. The past several years have also seen the increasing adoption in classrooms of Palm and Pocket PC handheld computers and growing interest in how iPods or even cell phones might facilitate student learn learning.

In the meantime, companies such as Sony, Nintendo, and Microsoft have developed and marketed sophisticated software and hardware platforms for playing games and simulations on personal computers and game consoles, such as *PlayStation*, *GameCube*, and *X-Box*. In addition, Yuen (2006) has estimated that by the end of 2006, 38% of the world's population (2.5 billion people) will own cell phones that will increasingly play sophisticated games and simulations over high-speed cell networks.

Online games and simulations have become a world-wide phenomenon over the past several years, with reported sales of $7-10 billion dollars per year or more. Online games and simulations such as *EverQuest* and *America's Army*, involve millions of players who engage in simulated battles around-the-clock. In online virtual worlds, such as *The Sims* and *Second Life*, players have literally built virtual lives complete with simulated homes and families. *Second Life* describes itself as "a 3-D, online digital world imagined, created and owned by its residents." (Second Life, 2006). It includes a currency called Linden Dollars that is used by residents to buy and sell virtual items they make or acquire, such as virtual clothing, furniture, land, homes, and electronic fictional characters representing themselves and their families. There is even a variable exchange rate between American Dollars and Linden Dollars (as of September 14, 2006, the exchange rate was 298 Linden Dollars for each U. S. Dollar). According to *Popular Science* (September, 2006), the Second City economy has an annual Gross Domestic Product of $64 million U.S. Dollars. Many children and adults, including both males and females, have become avid players of such simulations and games, both virtual and otherwise, much to the amazement and, in some cases, chagrin of parents and educators.

Commercial games and simulations, such as *SimCity*, *Civilization*, *Oregon Trail*, and *Where in the World is Carmen San Diego*, have found their way into classrooms, though their effectiveness has usually not been evaluated using rigorous experimental designs. One notable exception to this is the now classic study by Harold Wenglinsky (see Archer, 1998), who investigated the impact of games and simulations on math achievement of 4^{th} and 8^{th} grade students on the National Assessment of Educational Progress (NAEP). Using the nationwide NAEP math data and controlling for such factors as socioeconomic level and teacher qualifications, he reported that 4^{th} graders using computer-based math learning games showed significantly higher NAEP math scores. Likewise, NAEP math scores of 8^{th} grade students were found to be higher if they used computer-based simulations and applications. For both 4^{th} and 8^{th} graders, use of computer-based games, simulations and applications was also associated with higher teacher and student morale. Conversely, use of computers for drill-and-practice was associated with significantly lower NAEP math test scores.

The past six years has seen a surge in research on factors that may contribute to the effectiveness of educational games and simulations in the classroom (for example, Kirriemuir & McFarlane, 2004). Also, games/simulation research and development centers have received funding at such academic institutions as MIT, University of Wisconsin—Madison, and the University of Michigan—Ann Arbor. These academic centers have created new computer-based games and simulations and measured their impact on student learning. In addition, many books and scholarly articles have appeared which discuss important issues in game/simulation development and utilization, particularly their implications for reforming schools (for example, Gee, 2003 and Shaffer, Squire, Halverson and Gee, 2005).

Klabbers (2006) has noted in the literature a distinct difference in the approach to the study of learning between the research methodologies of game/simulation designers and analytical scientists, such as behavioral psychologists. He believes that designers typically build simulation and game environments and then modify these programs based on feedback about their usability. Analytical scientists, on the other hand, focus on building and testing theories using quantitative data collected to determine the impact of various factors on performance. Klabbers believes that this divide between what he calls the design and analytical sciences is further exacerbated by the belief of many in the analytical sciences that <u>their</u> methodology is the only legitimate way of evaluating the work of the design sciences. What he believes is required to enhance research on gaming and simulation is that both groups come to value the theories and research methodologies of the other.

Dimitri Williams (2005) has described still another division in the field of game research-- namely between what he calls social science researchers (who often study the impact of games on users) and humanists—whose research frequently focuses on the societal context in which games are played. Another common divide in games research that Williams has noted is the dichotomy between qualitative and quantitative methodologies for studying the outcomes of game play. Like Klabbers, Williams believes that the strategies and methodologies of these diverse groups should be seen as legitimate and potentially useful sources which can add to our understanding of the factors involved in effective games.

Shaffer, Halverson, Squire and Gee (2005) have noted:

> ....(M)ost educational games to date have been produced in the absence of any coherent theory of learning or underlying body of research. We need to ask and answer important questions about this relatively new medium. (pg. 11)

This literature review will begin by comparing two theoretical and methodological approaches to studying factors that may impact learning with games and simulations. An in-depth discussion of the viewpoints of three researchers/developers of games and simulations will follow. In the subsequent section, “positive” and “negative” outcomes of games and simulations will be described, followed by a general discussion of future multimedia and educational games research and development. Finally, recommendations are provided for creating *Learning Games to Go* materials based on principles of multimedia learning and games/simulations development.

THEORETICAL AND METHODOLOGICAL APPROACHES FOR STUDYING MULTIMEDIA LEARNING AND EDUCATIONAL GAMES AND SIMULATIONS

Introduction:

As noted previously, Williams (2005) and Klabbers (2006) have commented on the divergent theoretical and methodological approaches to the study of multimedia learning and educational games and simulation. This can clearly be seen in recent books by James Paul Gee, a linguist and Professor of Reading in the Department of Curriculum and Instruction at the University of Wisconsin—Madison and Richard E. Mayer, a Professor of Psychology at the University of California—Santa Barbara. The title of Gee’s 2003 book is: *What Video Games Have to Teach about Learning and Literacy*, whereas

Mayer's 2005 book is entitled, *The Cambridge Handbook of Multimedia Learning*. Both authors have been leaders in their respective fields for many years and have been prodigious publishers of scholarly articles and books. Though they both share a commitment to enhancing of teaching and achievement, the methodologies and learning principles they have developed in some cases could not be more dissimilar.

Methodological Approaches:

Gee (2003) explains that he first became interested in videogames after watching his 4-year-old son play such videogames as *Winnie the Pooh* and *Freddie Fish*. Gee was so impressed by how engaged his son was with the games and by their surprising complexity that he decided to learn how to play himself. Drawing on a combination of this game-playing experience and research and theory in the cognitive sciences and literacy, Gee developed 36 learning principles that he believes are incorporated in successful video games (see Table 1).

Mayer has spent much of his career studying multimedia learning, of which videogames are an obvious example. He reports that there has been a very large increase in multimedia research over the past 10 years, which necessitated assembling a group of researchers to summarize the current state of the field. In *The Cambridge Handbook of Multimedia Learning* edited by Mayer, (2005) key principles of multimedia learning are described, based on extensive empirical research over the past 30 + years. Multimedia learning is defined by Mayer as "building mental representations from words and pictures." Table 2 contains a summary of some of the major learning principles that he and his colleagues have described in the book.

TABLE 1

What Video Games Have to Teach Us About Learning and Literacy (Gee, 2003)

Gee's Learning Principles Seen in Video Games Principle	Research Cited Supporting Each
1. **Active, Critical Learning Principle**: (1989); "...(A)spects of the learning environment (2001); are set up to encourage active and critical, not passive, learning."	Freire (1995); Bereiter & Scardamalia Pellegrino, Chudowsky & Glaser Schon (1987)
2. **Design Principle**: "Learning about and coming to appreciate design...principles is core to the learning experience."	New London Group (1996)
3. **Semiotic principle**: "Learning about and (2001); ...coming to appreciate interrelations within across...images, words, actions, symbols... (and) artifacts...is core to the learning experience."	Kress, Jewitt, Ogborn, & Tsatsarelis Lemke (1990); Ogborn Kress, and Martins, & McGillicuddy (1996)
4. **Semiotic Domains Principle**: "Learning involves mastering...semiotic domains, and being able to participate...in the affinity...groups connected to them."	See references for Principle #3 above
5. **Metalevel Thinking about Semiotic Domains Principle:** "Learning involves active and critical thinking about the relationship of the semiotic domain being learned to other semiotic domains."	See references for Principle #3 above
6. **Psychosocial Moratorium Principle**: "Learners can take risks in a space where real-world consequences are lowered."	Erikson (1968)
7. **Committed Learning Principle**: "Learners participate in an extended engagement...as extensions of their real-world identities in relation to a virtual identify to which they feel some commitment and a virtual world that they find compelling."	diSessa (2000)
8. **Identity Principle**: "Learning involves taking on and playing with identities in such a way that the learner has real choices in developing (their) virtual identity... and ample opportunity to meditate on the relationship between new and old ones."	Alvermann, Moon, & Hagood (1999); Bauman (2000); Beck, Giddens, & Lash (1994); Fleck (1979)

9. **Self-Knowledge Principle**: “The virtual world is constructed in such a way that learners learn not only about the domain but about themselves and their current and potential capacities.”

10. **Amplification of Input Principle**: “For a little input learners get a lot of output.”

11. **Achievement Principle**: “For learners of all levels of skill there are intrinsic rewards from the beginning, customized to each learner’s level, effort and growing mastery...and ongoing achievements.” — Bransford, Brown, & Cocking (1999)

12. **Practice Principle**: “Learners...practice in a context where the practice is not boring (i.e., in a virtual world that is compelling to learners ...and where the learners experience ongoing success...They spend lots of time on task.” — Scribner and Cole (1981)

13. **Ongoing Learning Principle**: “(L)earners ...undo their routinized mastery to adapt to new or changed conditions. There are cycles of new learning, automatization, undoing automatization, and new reorganized automatization.” — Bereiter & Scardamelia (1989)

14. **“Regime of Competence” Principle**: The learner gets ample opportunity to operate within, but at the outer edge of, his or her resources, so that at these points things are felt as challenging but doable.” — diSessa (2000); Vygotsky (1978)

15. **Probing Principle**: “Learning is a cycle of probing the world...reflecting...on this action...forming a hypothesis, reprobing the world to test the hypothesis, and then accepting or rethinking the hypothesis.” — Schon (1987); Gee (1997)

16. **Multiple Routes Principle**: “There are multiple ways to make progress or move ahead. This allows learners to make choices, rely on their own strengths and styles of learning and problem solving, while also exploring alternative styles.”

17. **Situated Meaning Principle**: “the meanings of signs (words, actions, objects, artifacts, symbols, texts, etc.) are situated in embodied experience. Meanings are not general or decontextualized. Whatever generality meanings come to have is discovered bottom up via embodied experiences.” — Brooks (2002); Brown, Collins, & Dugid (1989); Clark (1997); Gee (1996); Lave &Wenger (1991)

18. **Text Principle**: "Texts are not understood purely verbally...but are understood in terms of embodied experiences...More purely verbal understanding (reading texts apart from embodied action) comes only when learners have had enough embodied experience in the domain and ample experiences with similar texts."	Hill & Larsen (2000); Lakoff (1987); Lakoff & Johnson (1987)
19. **Intertextual Principle**: "The learner understands texts as a family ('genre') of related texts and understands any one such text in relation to others in the family, but only afer having achieved embodied understandings of some texts. Understanding a group of texts as a family (genre) of texts is a large part of what helps the learner make sense of such texts."	Bakhtin (1986)
20. **Multi-Modal Principle**: "Meaning and knowledge are built up through various modalities (images, texts, symbols, interactions, abstract design, sound, etc.) not just words."	Kress (1985); Kress (1986); Kress & van Leeuwen
21. **Material Intelligence Principle**: "Thinking, problem solving, and knowledge are 'stored' in material objects and the environment. This frees learners to engage their minds with other things...to achieve yet more powerful effects."	diSessa (2000)
22. **Intuitive Knowledge Principle**: "Intuitive or tacit knowledge built up in repeated practice and experience, often in association with an affinity group, counts a great deal and is honored (in video games)..."	Gee, Hull, & Lankshear (1996)
23. **Subset Principle**: "Learning even at its start takes place in a (simplified) subset of the real domain."	Beaufort (1999); Coe, Lingard, & Teslenko (2001); Dias, Freedman, Medway, & Pare (1999); Dias, Pare, & Farr (2000)
24. **Incremental Principle**: "Learning situations are ordered in the early stages so that earlier cases lead to generalizations that are fruitful for later cases..."	Elman (1991a); Elman (1991b); Karmiloff-Smith (1992)
25. **Concentrated Sample Principle**: "The learner sees, especially early on, many more instances of... (f)undamental signs and actions so that learners get to practice them often and learn them well."	
26. **Bottom-up Basic Skills Principle**: "Basic skills are not (in video games) learned in isolation or out of context;	See Principle #23 above.

rather, what counts as a basic skill is discovered bottom up by engaging more and more of the game/domain..."	
27. **Explicit Information On-Demand and Just-inTime Principle**: The learner is given explicit information both on-demand and just-in-time, when the learner needs it... or where the information can best be understood and used in practice."	Gee, Hull and Lankshear (1996)
28. **Discovery Principle**: "Overt telling is kept to a well-thought-out minimum, allowing ample opportunity for the learner to experiment and make discoveries."	Gee (1994)
29. **Transfer Principle**: "Learners (in video games are given...opportunity to practice and support for transferring what they have learned earlier to later problems, including problems that require adapting and transforming that earlier learning."	
30. **Cultural Models about the World Principle**: "...(L)earners come to think consciously and reflectively about some of their cultural models regarding the world without denigration of their identities, abilities or social affiliations..."	D'Andrade (1995); D'Andrade & Strauss (1992); Holand, Lachicotte, Skinner, & Cain (1996); Holland & Quinn (1987); Shore (1996); Strauss & Quinn (1997)
31. **Cultural Models about Learning Principle**: "...(L)earners come to think consciously and reflectively about some of their cultural models of learning and themselves as learners, without denigration of their identities, abilities or social affiliations..."	See references for #30 above
32. **Cultural Models about Semiotic Domains Principle**: "...(L)earners come to think consciously and reflectively about their cultural models about a particular semiotic domain they are learning, without denigration of their identities, abilities, or social affiliations..."	See references for #30 on the previous page
33. **Distributed Principle**: "Meaning is distributed across the learner, objects, tools, symbols, technologies, and the environment.	Brown (1994); Brown, Collins, & Dugid (1989); Hutchins (1995); Latour (1999)
34. **Dispersed Principle**: "Meaning/knowledge is dispersed in the sense that the learner shares it with others outside the domain/game, some of whom the learner may rarely or never see face-to-face.	Brown & Campione (1993); Brown & Palincsar (1989)
35. **Affinity Group Principle**: "Learners constitute an "affinity group," that is, a group that is bonded primarily through shared endeavors, goals, and practices and not shared race, gender, nation, ethnicity or culture."	Beck (1992); Beck (1994); Rifkin (2000); Wenger (1998); Gee, Hull, & Lankshear (1996)

36. **Insider Principle**: "The learner is an "insider," "teacher," and producer (not just a 'consumer') able to customize the learning experience and domain/game from the beginning and throughout the experience."	Kelly (1998); Rifkin (2000)

NOTE: Certain of the 36 principles were truncated in order to reduce redundancy or save space.

TABLE 2

The Cambridge Handbook of Multimedia Learning (Mayer, 2005)

Multimedia Learning Principles	Chapter References Cited
1. **Multimedia Principle**: "People learn better from words and pictures than from words alone."	Fletcher & Tobias, Chap. 7
2. **Modality Principle**: "People learn better from graphics and narration than graphics and printed text. This is similar to Mayer's modality principle."	Low & Sweller, Chap. 9 Mayer, Chap. 11
3. **Split-attention Principle**: "People learn better when words and pictures are physically and temporally integrated...This is similar to Mayer's spatial contiguity and temporal contiguity principles."	Ayres & Sweller, Chap. 8 Mayer, Chap. 12
4. **Redundancy Principle**: "People learn better when the same information is not presented in more than one format...This is similar to Mayer's redundancy principle."	Sweller, Chap. 10; Mayer, Chap. 12
5. Segmenting, Pretraining and Modality Principles: "People learn better when multimedia is presented in learner-paced segments rather than as a continuous unit, people learn better from a multimedia message when they know the names and characteristics of the main concepts, and people learn better from a multimedia message when the words are spoken rather than written."	Mayer, Chap. 11

6. **Coherence, Signaling, Spatial Contiguity, Temporal Contiguity and Redundancy Principles**: "People learn better when extraneous material is excluded rather than included, when cues are added that highlight the organization of the essential material, when corresponding words and pictures are presented near rather than far from each other on the screen or page or in time, and people learn better from graphics and narration than from graphics, narration and on-screen text."	Mayer, Chap. 12
7. **Cognitive Load Principle**: "The human mind has the capacity to remember a maximum of 7 elements of information in working memory, but can only manipulate 2-4 elements. In addition these memories can only be sustained for about 20 seconds maximum unless the information is rehearsed."	Sweller, Chap. 3
8. **Animation and Interactivity Principles**: "People do not necessarily learn better from animation than from static diagrams.	Betrancourt, Chap. 18
9. **Personalization, Voice, and Image Principles**: "People learn better when the words of a multimedia presentation are in conversational style rather than a formal style and when the words are spoken in a standard-accented human voice rather than a machine voice; but people do not necessarily learn better when the speaker's image is on the screen."	Mayer, Chap. 13
10. **Guided-discovery Principle**: "People learn better when guidance is incorporated into discovery-based multimedia environments."	deJong, Chap. 14
11. **Worked-out Example Principle**: "People learn better when they receive worked-out examples in initial skill learning."	Renkl, Chap. 15
12. **Collaboration Principle**: "People can learn better with collaborative online learning activities."	Jonassen, Lee, Yang, & Laffey, Chap. 16
13. **Self-explanation Principle**: "People learn better when they are encouraged to generate self-	Roy & Chi, Chap. 17

explanations during learning."	
14. **Prior Knowledge Principle**: "Instructional design principles that enhance multimedia learning for novices may hinder multimedia learning for more expert learners."	Kalyuga, Chap. 21
15. **Navigation Principles**: "People learn better in hypertext online environments when appropriate navigation aids are provided."	Rouet & Pottelle, Chap. 19
16. **Site Map Principle**: "People can learn better in an online environment when the interface includes a map showing where the learner is in the lesson."	Shapiro, Chap. 20

Learning Principles:

In comparing Tables 1 and 2 you will note two quite different sets of learning principles, partly reflecting contrasting traditions of scholarship, with Gee in his book being more the qualitative, philosophical, social scientist and linguist, while Mayer is a rigorous, empirical researcher in cognitive psychology who bases his principles on multimedia theories and research designs. Another difference between the two books is the unabashed belief by Gee in the value of video games based on his own experience with games. Mayer, on the other hand, takes the position of an impartial scientist who studies how multimedia learning can be enhanced in whatever context it is used. Yet, both of these perspectives may be valuable for developers and researchers as we move towards creating a theoretical framework for designing effective educational games and simulations.

Aside from the terminology used, it would appear that Gee and Mayer are addressing some of the same learning principles, though they utilize markedly different terminology. For example, one of the principles that Mayer describes is the Modality Principle, whereas Gee's discusses the Multi-Modal Principle. The Modality Principle that Mayer describes in Chapter 1 is specific, namely that individuals learn best when they are presented with narration accompanied by graphics rather than text plus graphics. Mayer also describes the Multimedia Principle which states that individuals learn more by using pictures and words rather than only words. Gee, on the other hand, does not make clear how many modalities should be presented simultaneously, but assuredly more than only pictures and words [his list includes “images, texts, symbols, interactions, abstract design, sound, etc.” (pg. 111)]. In the typical commercial action game, multimedia may mean every conceivable sensory input—even vibrations. However, based on multimedia research, Sweller (2005) believes developers of educational games should be aware that using too many different modalities at one time could result in cognitive overload for learners and therefore poorer performance.

Other examples of the intersection of the learning principles of Gee and Mayer are their common recommendation that multimedia activities be learner-paced, segmented, and that examples and pretraining should be offered using a subset of the learning materials. However, they each describe principles that the other does not. Examples of principles that only Gee discusses include: motivation that can result from identifying with characters in games and the importance of affinity groups in collaborating and supporting learning. However, Mayer mentions several principles that Gee does not, such as: redundancy of information can disrupt learning (having extraneous information that is not necessary to do a task); conversational style in multimedia environments (like games) results in better learning than computer-generated voices; and guided discovery requires guidance for the learner in multimedia environments.

Theories of Multimedia Learning:

As noted in the introduction to this review, the field of games and simulations suffers from not having a coherent theory to guide future development and research. However, the same applies to the whole field of multimedia learning, to which games and simulation would seem to be conceptually related (or at least members of the same family). If it is any consolation to game researchers and developers, the field of multimedia learning has been searching for a unifying theory to guide future research and development for at least 15 years.

Three “theoretical foundations” of multimedia learning that are identified by Mayer (2005) in *The Cambridge Handbook of Multimedia Learning* (Mayer, 2005) include:

- Cognitive Theory of Multimedia Learning (Mayer, 2005), which has been developed by Mayer and his colleagues over the last 15 years, during which time its name has changed seven times;
- Cognitive Load Theory (Sweller, 2005);
- Four-Component Instructional Design (4C-ID) Model (Van Merrienboer and Kester, 2005).

These cognitive science-based approaches to understanding and guiding multimedia learning provide principles, structures and diagrams that attempt to explain various components and processes that interact to produce learning outcomes with multimedia resources.

In spite of the extensive empirical research and theoretical underpinnings of multimedia learning, Clark and Feldon (2005) have provided a stinging critique of the outcomes of this work. In *Five Common but Questionable Principles of Multimedia Learning* they lament the expectation that emerging technologies will permit us to finally motivate learners and help them perform at much higher levels than does traditional or "live" instruction. They caution that 75 years of promises that multimedia was going to reform education have come to naught. As Mayer (2005) has noted, Thomas Edison believed that movies would change the way schools teach. When radio arrived, it too was going to reform education, as was educational TV. It never happened. Clark and Feldon review the challenges that these new technologies face today and describe five multimedia instruction principles that have not been supported by research:

Questionable Principle #1: Individuals **learn more** from multimedia instruction than "live" instruction.
Clark and Feldon have found no credible evidence of superior performance resulting from using multimedia materials that cannot be explained by other possible factors. The mistake made by many such studies is to employ one teaching method with classes using multimedia materials and a non-equivalent teaching method for the comparison group. Clark and Feldon found that the most reliable finding is that multimedia materials decrease the time required to learn information rather than leading to superior achievement.

Questionable Principle #2: Multimedia instruction enhances **motivation** more than traditional or "live" instruction.
Bernard, Abrami, & Lou (2004) in a meta-analysis of 232 empirical studies have reported that multimedia (distance education) classes may be more appealing to students but that they may perform less well. They also found a negative correlation between student interest in the course and achievement.

Questionable Principle #3: Multimedia instruction can be better **aligned with** individual learning styles.
Unfortunately, studies have found it is difficult to identify stable, reliable learning styles OR to customize instruction with multimedia materials to address these learning styles and thus improve student achievement [see for example Duff & Duffy (2002) Henson & Hwang (2002); Richardson (2000); Stahl (1999)].

Questionable Principle #4: Multimedia instruction can utilize active pedagogical agents to improve motivation and aid learning.

Clark and Fenton reported mixed effects from using pedagogical agents, but generally these do not appear to enhance learning and motivation.

Questionable Principle #5: Multimedia instruction provides learner control and discovery approaches to enhance learning.
Clark and Fenton note that many educators and trainers appear to believe that unstructured multimedia environments where novel problems are solved (discovery learning) can improve achievement. However, 40 years of research have shown that for discovery learning environments to assure adequate transfer of knowledge the following conditions should be met: 1) removal of extraneous, redundant information that otherwise puts excessive demands on working memory; 2) incorporation of extensive instructional guidance during discovery learning, but fading this out as learners gain expertise; 3) teachers may need to provide suggestions for how to solve problems presented.

Towards Theories of Educational Games and Simulations:

In the previous section the work of Richard Mayer (2005) was compared with that of James Paul Gee (2003) for the purpose of determining their similar and dissimilar viewpoints about learning. In the present section, a detailed description of the learning principles of Gee (2003), as well as those of Clark Aldrich (2005) and Lloyd Rieber (2005) will be provided.

James Paul Gee on Six Factors in Effective Games:

Gee discusses what he believes video games tell us about learning under the topics: semiotic domains; learning and identity; situated meaning and learning; telling and doing; cultural models; and the social mind.

Games as semiotic domains: Gee thinks that current attitudes about schooling and learning can be traced back to the viewpoints of Aristotle and Plato, who he believes stressed learning information passively. If instead we encourage active, experiential learning, we would do more to engage students in real-world events, provide ways for affiliating with others; help students learn how to innovate; and engage them in critical learning (which Gee calls meta-level thinking). It is Gee's contention that learning to operate in new semiotic domains, such as videogames, should be an integral part of educating our children because:

> To understand or produce any word, symbol, image or artifact in a given semiotic

> domain, a person must be able to situate the meaning of that word, symbol image, or artifact within embodied experiences of action, interaction, or dialogue. (Gee, pg. 24)

<u>Learning, identity and schooling</u>: It is Gee's belief that three types of identity are important in video games/simulations and in any truly effective learning experience: the person's identity in real life; a virtual identity; and a projected identity. He explains that we each have developed a real-world identity that comes from life experiences and interactions, including perceptions of our appearance, values, beliefs, competence, etc. By taking part in a classroom simulation where the individual plays the role of a scientist or as a "shooter" in a role-playing video game, we can experience a virtual, fantasy self which may be very different from who we are in the real-world. When students begin to project their real-world identities onto fictional characters and situations, as occurs in successful video games and classroom simulations, they map their wished-for and real-world values, beliefs, and feelings of competence onto their virtual identities. By so doing, they experience learning from the perspective of the characters who inhabit the knowledge domain. Gee believes that this projected identity, real or virtual, is highly motivating and necessary for knowledge to be remembered and applied in practical situations.

According to Gee, the virtual world of video games and successful learning experiences in schools provide the opportunity for risk-taking without the consequences of real-world failure. One process through which this occurs is by extending and melding the individual's real-world identity into a compelling virtual world. This virtual world stimulates experimentation with new identities and opportunities to reflect on the intersection between their real-world, virtual and projected identities. By investing a relatively small amount of time and effort in a video game or a successful learning experience in school, the individual may gain greater self-knowledge and a more realistic view of their abilities. Gee believes that the customization of the virtual environment according to the individual's level of learning, effort and mastery of the game encourages a growing sense of achievement.

Paradoxically, though learning obviously requires practice, schools often have little time for it, according to Gee. Successful video games, on the other hand, permit the user to practice a skill or concept until they master it. Observe small children watching complicated but much loved videos (like *Thomas the Tank Engine)* over and over and over again and the crucial importance of practice in learning will be revealed. Without this practice, Gee believes, individuals are likely to quickly forget information learned and not be able to apply what they have learned or use it in new situations. Because many video games engage players in an exciting world in which they can take on meaningful identities, players willingly practice skills over and over without being fully aware of their repeated practice. Though individuals learn skills that can be performed "automatically," successful learners are able to adapt and modify these skills based on new conditions. Gee also thinks that learners need the opportunity to learn information that is at the outer limits of their understanding, similar to Vygotsky's "zone of proximal development," to maximize motivation and achievement.

Situated meaning and learning: Gee contrasts two different views of how learning occurs. The traditional view is that learning involves acquiring a set of concepts, principles, rules, and generalizations that are logically related—similar to how they might be stored on a computer. This view of learning emphasizes memorization which is disconnected from the real world experience of students. The other view of learning is that the mind solves problems by reflecting on previously stored real world experiences, but adapts the solution when necessary to the current situation, stores the new encounter, and makes associations between these experiences in solving future problems. However, Gee notes that these experiences are not stored as verbatim recordings, but rather are encoded based on the individual's interests, values and goals and memberships in various social groups (friends, professional associations, political affiliations, perceived social class, etc.). When a new problem needs to be solved, we rely on our previously stored perceptions of real-world events. This view of learning as situated in specific real world experiences is considered by Gee to be a more accurate picture of how we acquire information.

Gee provides an example of how successful videogames have the potential to make learning more experiential and situated and therefore more consistent with how we solve problems and store information. The video game he chooses for this purpose is Deus Ex, a combination first-person shooter and role-playing game. Deus Ex is situated in the year 2050, when the world has reached an advanced stage of degeneration with uncontrolled crime, disease and other maladies.

Game participants play the role of J. C. Denton, who is a special agent for the United Nations Anti-Terrorist Coalition. Players are allowed to augment their character through the use of nano-augmentations, which can be inserted into various parts of the virtual body of J. C. Denton via "nanite organisms" to enhance skill in the use of various weapons.

Deus Ex is open-ended in the sense that players can make different decisions about problems presented in the game, providing strong motivation for learning the game. In a video game like Deus Ex the choices that players can make are partially constrained by the designer, but the specific order that events unfold and the actions carried out by players determine the outcomes. In Deus Ex every decision of a player is embedded in the emerging story line and an invitation to engage in an “embodied” action defined as an “action actually carried out or simulated in the mind” (Gee, pg. 85).

Thus, Gee sees video games as very different from traditional teaching strategies in schools, where words and concepts are generalized and disconnected from real-world embodied actions. For traditional instruction to utilize the format of a successful video game, it would be necessary for the words, concepts and procedures to be much more frequently embedded in materials and actions. Also, players would need to make critical decisions, deal with the consequences and reflect on whether the actions taken and the meanings derived are appropriate. Gee notes that this approach for teaching any school subject would be dramatically different from having students read books, listen to lectures and then take a test to determine how much of the material had been memorized. According to Gee, students often forget what we teach because it can be retained only for short periods of time without being stored as embodied actions. However, Gee insists that he is not saying that all school learning need be done via video games, but that there are various ways successful teachers can situate learning in embodied actions. What teachers do need to know is that unless learning is anchored in concrete, situated experiences, it will often not be understood and therefore will be useless to the learner.

Gee believes that young children are experts at perceiving patterns as well as probing the world to generate guesses (hypotheses) about the results of their actions. Through a combination of pattern recognition and probing and re-probing and reflecting on outcomes and then engaging in embodied actions again and again, the child engages in self-teaching. Watch a child learn about the qualities of a book by squeezing it, laying on it, and dropping it, and you will see this process unfold, according to Gee. Watch a person learn to play a video game like Deus Ex and you will see the same process unfold as the individual looks for patterns and probes and re-probes and reflects on outcomes, followed by further embodied actions “carried out or simulated in the mind.”

Another process that Gee sees in successful games is the development of what he calls “appreciative systems” as participants learn what sorts of actions are acceptable by people involved in a particular domain (law, government, videogames, etc.). Game players and other domains form affinity or social groups to discuss the latest strategies and acceptable and unacceptable behaviors. The development of these norms results from reflection by participants and communication with fellow participants using internet sites, magazines, books, etc. Ultimately, Gee believes, the participation in these affinity groups leads participants to become designers or re-designers of elements of the domain. In the case of video games, some players add or change components of the game (called “modding”). There are also various “cheats” devised by players to modify the underlying computer program or to acquire more game resources.

Though most games come with manuals, Gee notes, it does not appear that many gamers use them other than to obtain a general overview of the game. Games, in fact, are designed to permit users to begin learning the game without doing much reading. According to Gee, the problem with reading text materials in the gaming world is much like learning science in the traditional classroom: until considerable experience has been obtained, the text will not make much sense. Without the ability to situate the words and sentences in previous experiences, the only outcome is a vague verbal understanding that does not make sense to the learner. Gee believes that once learners have sufficient experience with particular genres of games (such as role-playing games) they begin to comprehend them more easily. The same is true of learning science or other school subjects.

Another principle that Gee believes successful games utilize is what he refers to as the multimodal principle: combinations of pictures, video, graphics, symbols, texts, sounds, and interactions that enhance learning. Likewise, accessible knowledge is in a sense "stored" or linked with environmental objects and artifacts or what Gee calls the "material intelligence principle." After repeated practice in using the game and development of knowledge about its various components, players are said by Gee to show evidence of the "intuitive knowledge principle."

<u>Telling and doing</u>: Gee describes several video games that illustrate what he calls the "subset principle"—namely that players need some guidance in how to initially play a computer game. Though many video games permit players to begin the game without consulting detailed instructions, Gee believes the most successful games offer guidance in the context of playing a subset of the game. In one game mentioned by Gee the "guidance" was supplied by a Sergeant shouting demands as the player engaged in a subset of the game. This situated learning, Gee believes, is much more effective than reading game manuals or in schools primarily listening to de-contextualized lectures.

Gee also states that successful video games provide structure by utilizing scenarios that can be used later in solving more complex problems in the game or what he refers to as the "incremental principle." Other features of games that help learners is to introduce many of the actions during the early stages of the game so that players can gain sufficient practice in their use and learn basic game skills by building these throughout the game in context rather than in isolation. Learners in these video games are also provided with a small amount of explicit information on an as-needed basis and just-in-time. Overt telling is minimized, but the learner is given many opportunities to experiment and discover game components. Players are also given many opportunities to practice and to generalize what they have learned about a particular game type to new situations in the game.

Cultural models and the social mind: Gee describes the insights that players of successful video games develop about the cultures in which they live, as well as the risks that games can present. He notes that after the 9/11 attacks, video games were developed and sold in which players acting as American soldiers attacked Arabs. Subsequently, a game called *Under Ash* was developed by a publishing company in Syria. The hero of the game, Ahmed, is a young Palestinian who fights Israeli soldiers and settlers with stones. He also attacks a holy Islamic site and drives out the Israeli soldiers who hold it. “Civilians” in the game are not to be attacked, but

Israeli settlers are considered to be advance units of the occupying army. In another part of the game, Ahmed participates in a guerilla action in Southern Lebanon and infiltrates an Israeli settlement. Gee reports that the producers of this game consider *Under Ash* to be “a “call to humanity to stop killing and shedding blood...a call to dialogue, coexistence and peace” (quoted in Gee, pg. 149). As perplexing as these comments might seem, Gee notes that no cultural storm occurred in the U. S. after the release of the video games featuring the killing of Arabs. Gee sees these and many other video games as providing insights into the cultural models that different nations or groups of people develop to explain behavior--in the case of *Under Ash* that violence can make people seek peace. By playing these games, participants act out and confirm their cultural beliefs and values.

However, Gee notes that such games also have the potential of helping individuals develop insights into their own cultural models of the world. For example, he asks what if a version of Under Ash were to permit a player to not only play the role of a young Palestinian but at another time to be an Israeli settler? Would that provide new insights for the player about their implicit cultural perceptions and interpretations? Would players choose to play a role that conflicted with the views of their cultures? Gee believes that if they did, this could lead to a greater appreciation of the perspectives of other cultures. Unfortunately, he notes, it is also possible that in the future we will see the development of more video games that promote new forms of hatred, such as *Ethnic Cleansing* created by the National Alliance (a white-supremacist group).

The degree to which video games increasingly engage players in communication and collaboration is seen by Gee as a reflection of the “social mind.” He points to the dramatic rise in the number of video games that permit participants to collaborate with and play against each other—either online or through using multiple controllers attached to their computers or their PlayStations, X-Boxes, etc. In the technology-infused and connected era in which players live, knowledge is increasingly distributed across many individuals and fields, much of which can be accessed by the click of a mouse.

Collaborations between players of games become affinity groups that are bonded more by knowledge than by emotional ties. This shared knowledge is wide-ranging in content and available to many individuals. However, Gee notes that meaning or knowledge is distributed in successful video games not only between individual learners, but "across objects, tools, symbols, technologies and the environment" (Gee, pg. 197). Video game players are members of various affinity groups based on shared interests and activities, not what racial or ethnic group they belong to or the nation in which they reside. Many video games provide access to parts of the software code, thus allowing players to become not only consumers of games but producers and teachers. Gee contrasts this world of video games (and increasingly the business community) with the current view of knowledge as a precious commodity residing in the minds of individuals and measured by standardized tests.

Gee (2003) used research on learning, cognition and literacy and his experience in playing videogames to formulate his 36 learning principles in successful videogames. On the other hand, Becker (2007) has undertaken a somewhat more modest quest, namely to plug key features of commercial videogames into components of various theories of learning and cognition. She
begins by identifying what she sees as the qualities of commercial videogames that lead to "enjoyment" for the learner:

- "(Players) can achieve the specified goal, but not too easily.
- The task is perceived to be fair: all participants have a similar chance of "winning"....
- The stakes (risk) for failure are not too high, but (are) still present.
- There is sufficient positive feedback (rewards for achievement), which must occur *during* the process and must be in context or at least measure progress toward (the) goal.
- There exists...negative feedback as well.
- There is some element of chance (among other things, this allows people to minimize or off-load "guilt" of failure...which in turn encourages people to keep trying or try again)." (Becker, 2007, pg. 25)

She then describes how such features of videogames can be seen in the specific learning principles of theorists such as Gagne ["Nine Events of Instruction" (1985)], Bruner ["Psycho-cultural" learning theory principles (1996)], and Gardner ["Theories of Multiple Intelligences" (1983)]. Becker believes that videogames utilize some of the same learning principles seen in these theories, but recognizes that there is a difference between mapping videogame features onto learning theories and being able to use these learning theories to design more effective educational games:

> ...(I)t is one thing to retrofit a learning theory onto a successful game, or even analyze a bad game to see where it fails and...use some

> learning theory to design a successful game...Although some of us still mean to...come up with ways to do exactly that, I also suspect we are going to experience similar problems...(as)...other disciplines...(like) film and fiction. (E)ven though movies have been around for over 100 years and books for 500, we still have no sure-fire formulas for creating blockbusters and bestsellers. [Becker (2007, pg. 23]

Aldrich on the Development of Effective Educational Games and Simulations

Clark Aldrich (2005) has been involved in the design, development and implementation of many business and educational games and simulations. Most recently, he led a team of developers who created *Virtual Leader*--a simulation-based learning environment which won the Best Online Product of the year in 2004 from the Society for Training and Development. He has been active in describing the essential components and genres of games and simulations and what he sees as their future, but has not focused on creating educational games and simulations using the building blocks of various learning theories.

Aldrich has indicated that he has engaged in many debates over how to differentiate between games and simulations, but now believes that successful educational games require a combination of gaming, simulation and pedagogical elements. The challenge, however, is to get the proper mix of each of these components. Each of these components are discussed below.

Game elements: Effective games, according to Aldrich, are designed to entertain and ultimately engage, causing players to spend more time and participate more intensely. Examples of common game elements designed to engage participants include: elaborate graphics, sounds and music; role-playing; making order out of chaos, choosing screen characters or objects for the game; providing a mystery or problem to solve; immersion in a simulated real-world experience (a battle, a corporate board meeting, etc.); utilization of familiar game types, such as a Jeopardy game format; intense competition for the highest scores; and giving the player choice of game difficulty level.

Simulation elements: Aldrich notes that simulations contain interactions with and representations of real-world environments. When we learn, he states, we are not only processing concepts, but the environment in which these occur. This makes using simulations a powerful way to learn because they provide context for enhancing performance. Other important elements in simulated learning, he believes, are key concepts, role-playing, and active involvement in systems that capture some of the complexity of real-world social and economic systems. Feedback to participants, he believes, should identify clearly the likely consequences of their actions in a real world context. Another important component he highlights is choosing appropriate simulation genres or types for the material to be learned, such as branching storylines or virtual environments.

Pedagogical elements: Aldrich believes that pedagogical elements are the third crucial component of effective educational experiences. At one point in the history of gaming/simulation, he notes, it was expected that students participating in games and simulations would learn key concepts without having to take time out to extract meaning from the experience. He reports that in observing real players utilizing his simulations, he has come to realize that this was a false assumption—that students need time to analyze the concepts they have learned and to critically examine erroneous conclusions formed as a result of participating in games and simulations.

According to Aldrich (2005), examples of pedagogical elements that need to be incorporated in games/simulations are: debriefing of concepts learned and connecting these to real-world situations; visualizations of key concepts and their interactions (for example, via graphic organizers); pop-up prompts and help screens; examples of successful and unsuccessful ways of playing games and simulations; chat rooms where students can compare concepts learned; scaffolding which summarizes game/simulation play and makes suggestions for enhancing concepts learned; and providing relevant background information about the concepts being addressed in the game/simulation.

In the next section of this literature review we will see confirmation of many of Aldrich's essential components of games and simulations in the work of Lloyd Rieber, who has come to many similar conclusions regarding effective multimedia design.

Lloyd Rieber on Multimedia Research on Educational Games and Simulations:

Lloyd Rieber was first an elementary school teacher before becoming a Professor of Educational Psychology and Instructional Technology at the University of Georgia, Athens. His research and development work has spanned such subjects as games, simulations, microworlds, animation, and software development with young children (Kid Designer). Rieber (2005) distinguishes between multimedia instruction that focuses on scripted explanations of information using graphics, animation, sound, and text and highly interactive experiences in games and simulations where users have dynamic control over how and when information is learned. An example would be the distinction between multimedia instruction that explains how airplanes work using text and graphics (such as on the internet site "How Stuff Works") vs. interactive, experiential learning where participants learn how to fly an airplane using a computer-based flight simulator. According to Rieber, constructivist theorists believe that multimedia instruction should play a supporting role to interactive, experiential, learning.

Examples of simple simulations and games. Rieber and Noah (1997) developed a simple computer-based simulation to study how users learn Newton's laws of motion. Participants were told to observe on the computer monitor a small ball sitting on a long board; the board could be tilted to make the ball move left or right. They added a game element to the task in a second study by asking participants to see how many times they could cause the ball to do a "flip-flop" inside of a small yellow box in the middle of the board. Each time they got the ball to do a "flip-flop" (change direction) they earned a point; if the yellow box holding the ball was narrow, the task was more difficult (and vice versa). The questions that Rieber and Noah asked were whether this game format made the task more enjoyable for learners and what impact the game had on learning. The results showed that the students in the "flip-flop in the yellow box" game did report greater enjoyment than students not involved in the game. However, the participants in the game format scored significantly lower on the physics post-test than users not participating in the game. A qualitative study done to investigate why this result occurred found that the users of the game format went into what some have called "twitch" mode and mostly concentrated on increasing their score. This resulted in them not reflecting on the physics components of the task, which caused them to receive a lower post-test score on the physics assessment.

Multimedia learning in simulations: Rieber and his colleagues have conducted a series of studies investigating the impact of different kinds of feedback on simulation performance. Typically, these studies have utilized the physics simulation described in the previous section, but varied according to whether feedback was provided via text, animated graphics, or both. For example, textual feedback in a simulation might display numerical readouts of the position of an object the user is manipulating and the location of the target at which the user is aiming. When participants used the simulation without any additional instruction (discovery format), performance with graphical feedback was sometimes found to be superior to textual feedback or graphical + textual feedback (Rieber, 1996; Rieber et al., 1996). On game-like ("implicit") tasks, graphical feedback was superior, but on the "explicit" tasks where the user had to answer multiple-choice questions about physics principles the differences between graphical and textual feedback were not as large. To further explore these findings, Rieber and his colleagues interviewed users as they were participating in the simulation and found that few individuals were able to decipher the laws of motion without some assistance from the interviewer. This assistance did not require a great deal of time and mostly consisted of pointing out important features or asking brief questions that provided guidance to participants at precisely the right time. It was not even necessary to interrupt user interaction with the simulation.

A follow-up study inserted brief embedded text and animations during the simulation and found that participants who received graphical feedback far surpassed those receiving textual feedback; however, this effect occurred ONLY when brief explanations were provided at just the right time. When participants began to master the physics principles, their preference for feedback shifted to textual materials.

The potential pitfalls of using discovery learning in simulations has been explored by de Jong and van Joolingen (1998) and Rieber and Parmley (1995). One common finding of these studies is that students are quick to reach erroneous conclusions and slow to discard incorrect hypotheses. Both Rieber and his colleagues and de Jong and van Joolingen have reported that guidance and instructional support needs to be given during such simulations rather than prior to it. Also, de Jong and van Joolingen reported that student performance in the use of discovery in simulations is improved if the tasks become progressively more difficult and build on skills learned earlier.

Multimedia learning in educational games: Rieber notes that research on the value of using educational games to enhance student achievement has been mixed (Kirriemuir & McFarlane, 2004). Yet, Wenglinsky (see Archer, 1998), using data from the National Assessment of Educational Progress (NAEP), reported that 4th grade students using math games had significantly higher NAEP math scores than did comparison groups that did not use these games. Eighth-grade students using math simulations had significantly higher NAEP math scores. However, a number of other studies, have reported few differences between classrooms using games and simulations and those relying on traditional teaching methods [see Dempsey, Lucassen, Gilley and Rasmussen (1993-1994), Gredler (2003), Randel, Morris, Wetzel, & Whitehill (1992)].

Both Kafai and Rieber and their colleagues took another approach to incorporating video games in the classroom by having students design their own games. Kafai and her colleagues (1994, 1995, 1997) involved 5th grade students in designing games for 3rd grade students in their school and evaluated the outcomes for students. They reported that students used the designing of games as a vehicle for discussing the school curriculum. Also, they found that increased learning of astronomy concepts was related to participating in the game design effort.

Rieber, Luke, & Smith (1998) described the Kid Designer program, which for nearly 10 years helped teams of elementary and middle school students learn to design their own digital educational games. Rieber and several of his graduate students met frequently with these elementary/middle school teams to assist with design issues and do the computer programming on a quick turn-around schedule so that teams could view the impact of various enhancements of the game design. Rieber, Davis, Matzko, & Grant (2001) evaluated whether children who did not participate in designing the games students developed would find the games motivating to use. Also, they wanted to determine the exemplary features of these student-made games. Over a period of three weeks, as these students played the student-designed games, data was obtained on how frequently and how long each game was played. In addition interviews were held with 12 of the participants (out of a total of 30 students). The results showed that the games students played most frequently and for the longest time periods were the same ones they rated most highly; furthermore, their opinions of the student-produced games developed rapidly and changed very little over time. The three features of the games that students liked most were: storyline, competition and challenge, qualities which have also been identified as important by commercial game designers. However, incorporation of educational concepts in the game did not matter much to children in the study!

Future research on multimedia learning in games and simulations: Rieber (2005) is not optimistic that randomized controlled research designs recommended by the National Research Council (Shavelson & Towne, 2002) will lead to higher quality studies on the impact of multimedia factors in games and simulations. This is because Rieber believes it is not possible to control many of the variables that contribute to student performance in the complex environment of school classrooms. What seems to Rieber to be a better approach is the use of mixed methods designs. This would necessitate a combination of quantitative and qualitative methods, where questions of "what" learning happened could be analyzed using quantitative data and "why" this learning occurred or did not could be investigated through qualitative approaches like interviews and questionnaires. For example, Rieber notes that in a number of studies he has conducted, the expected results were not obtained, but that after interviewing and observing learners, the factors causing the non-significant results were revealed.

Multimedia theory and the study of games and simulations: Rieber (2005) believes that various multimedia theories may be useful in better understanding how interactive multimedia impacts on learning. As an example, he cites Paivio's dual-coding theory (1986), which states that information is stored in either a verbal system or a non-verbal system; the verbal system processes verbal information arriving via either auditory or textual sources, whereas the non-verbal system processes where pictures and graphics are processed. Rieber predicts that the verbal system is more likely to store explanations, whereas the non-verbal system is more attuned to processing experiential information. In order to build connections between explanations and experiences, learners need time to reflect on these relationships and guidance in testing their understanding.

We have not yet developed unifying theories of multimedia learning or educational games and simulations (and may never do so). Many learning principles described in this document have been supported by empirical research, while other principles may need further study and verification, using both quantitative and qualitative methods (such as those employed by Rieber and his colleagues).

SOME OUTCOMES OF UTILIZING GAMES AND SIMULATIONS

Kirriemuir and McFarlane (2004) undertook a comprehensive review of the learning outcomes of playing computer games and found the results were mixed (positive and negative) and often limited to one type of digital game (adventure, role-playing, sports, etc.). Malone (1981) identified three game components that motivate learners: fantasy, challenge and curiosity. Amory et al. (1998) found that for children to enjoy playing a game it should be neither too easy or too difficult. One of the often-heard statements about games and motivation is that in order to be motivating they should foster "flow" (Csikszentmihalyi, 1990) or complete immersion in the gaming experience, during which players become so engrossed that they lose track of time. Examples of conditions that Malone (1980) predicted would produce "flow" are being able to control the level of challenge faced, concrete feedback, and various levels of player challenge. According to Kirriemuir and McFarlane, other features of games that been found to make them motivating are challenge, interactive social experiences, and entertainment.

Positive Outcomes of Playing Digital Games:

Spatial skills: Research has shown that computer games that require 3-D mental rotation of objects can significantly enhance the spatial skills of 3^{rd}, 7^{th}, and 9^{th}-grade students (McClurg & Chaille, 1987). Miller & Kapel (1985) also found a positive effect from playing games on two-dimensional mental rotation for 7^{th} and 8^{th} graders. Both girls and boys improved their spatial skills significantly after playing video games in studies by De Lisi and Wolford (2002) and Perzov and Kozminsky (1989).

Cognitive abilities: Long-term or short-term playing of computer games was found by Greenfield and her colleagues to significantly enhance understanding and interpreting of scientific information (Greenfield, Brannon, & Lohr, 1994; Greenfield et al., 1994). Doolittle (1995) reported that students playing video games and solving computer-based riddles generated a greater variety of hypotheses for problems presented. Computer games have also been found to improve thinking skills and enhance strategic planning (Keller, 1992).

Academic performance: Van Schie and Wiegman (1997) found a positive association between the amount of time playing nonviolent video games and intelligence test measurements. Also, Durkin and Barber (2002) reported that children who were moderate players of video games had higher grade point averages in school.

Sociability: The popular assumption has been that intensive users of computer-based games would become less sociable, but the evidence is that more frequent players show higher self-concept, family closeness and attachment to school (Durkin and Barber, 2002). In another study, heavy game users saw their friends more often (Colwell, Grady, & Rhaiti, 1995). Philips, Rolls, Rouse, & Griffiths (1995) also reported that students who played computer games frequently had as many friends as players who did not play as often.

Negative Outcomes of Violent Videogames:

Aggressive feelings: Anderson and Bushman (2001) developed the General Aggression Model (GAM) in order to explain both the short-term and long-term impact of violent video games on aggressive behavior, cognition, affect, physiological arousal and desensitization to aggression. It is their belief that violent media teach individuals how to be aggressive, while also increasing their arousal level and priming them to think about being aggressive. By repeatedly playing violent video games, cognitive scripts for aggression are formed, as well as aggressive behavioral scripts. Ultimately, the authors believe frequent users of violent video games can develop a persistent, aggressive personality.

Violent videogames appear to produce more intense feelings of aggression than non-violent videogames (Ballard & West, 1996). Also, violent games induce a higher level of anxiety than nonviolent games (Anderson & Ford, 1986). Subsequent research, however, has failed to show a significant impact of playing violent video games on feelings of hostility (Anderson & Dill, 2000). Scott (1995) also did not find that violent games increased feelings of aggressiveness as measured by a hostility inventory.

Aggressive behaviors: In one study, post-game aggression was predicted by the duration of violent video game play (Anderson & Dill, 2000) and in another study by intensity of game play (Cohn, 1996). However, in other research (e.g., Winkel et al., 1987; Kirsh, 1998) no such relationship between playing violent video games and aggressive behavior could be established.

Aggressive thoughts: Significant effects of video games on aggressive thoughts have been repeatedly reported (see, for example, Anderson & Dill, 2000; Calvert & Tan, 1994).

Physiological arousal and desensitization: Violent video games have been shown to consistently increase heart rate and blood pressure (Ballard & West, 1996; Fleming & Rickwood, 2001). Reduced P300 brain wave components have been found for violent videogame players, signaling desensitization to aggression and violence (Bartholow, Bushman, & Sestir, 2006).

Other social/psychological effects: Playing violent video games has been found to reduce charitable giving (Chambers and Ascione, 1987) and increase under-age drinking and destroying of school property (Anderson & Dill, 2000). Bushman and Huesmann (2006) reported greater short-term impact of violent media for adults, but much larger long-term effects of violent media for children. As Bushman and Huesmann note, the size of the long-term impact of exposure to violent video games will depend on whether "....the child perceives the violence as realistic, justified, and rewarded as well as on the extent to which the child identifies with the perpetrator. Action heroes are more dangerous teachers of violent behavior than villains." (pg. 351)

However, Kirriemuir & McFarlane (2004) have noted that much of the data on violence in games has been collected during or immediately after participating in the activity and that long-term effects have often not been studied.

Gender stereotyping: In a survey of 1,716 characters in videogames by *Children Now* (2001) it was found that 64% were males, but only 17% were females; the gender of the remaining 19% of characters was uncertain. Male characters were portrayed as hypermasculinized, while females were described as sexy with thin or voluptuous bodies. Female characters were often victims in the game storyline, while males usually were portrayed as heroes who rescued the females. Kirriemuir and McFarlane (2004) have noted that the proportion of female gamers appears to be increasing as a result of their participation in new online role-playing games; it is thought that this may ultimately result in a change in the way women are portrayed in games and simulations.

RESEARCH AND DEVELOPMENT OF EDUCATIONAL GAMES AND SIMULATIONS

In mid-October of 2006, two important announcements were made that may have an important impact on the future of educational games and simulations in the United States. First, the MacArthur Foundation announced that it would invest $50 million over five years to support research on the impact of digital technologies on society and development of emerging technologies to enhance learning. The second announcement was the release of a report by the Federation of American Scientists (FAS) entitled, *R & D Challenges in Games for Learning* which describes a roadmap focused on expanding the development of "games for learning" and their utilization in educational settings and other learning environments. The plan envisions a new public-private-foundation partnership at the federal-state-local levels which will:

- Study the features of effective games which developers can utilize to create new educational games that will motivate and engage learners and can be integrated into the school curriculum.
- Modify already existing games for use in various educational settings (which should reduce development costs. These games/simulations need to be of high quality, authentic, incorporate compelling narratives, include virtual actors with skills, knowledge, and personalities, and permit users to alter the outcome of the story.
- Create tools for easily and quickly developing games and simulations at a much lower cost, permitting much more tailoring of these products to meet local and state content standards. These tools need to use common standards and protocols to assure interoperability across game platforms.

The report notes that the initiative will require the collaboration of many research disciplines, such as game design, education, psychology, human-computer interaction, software engineering, and information science. Because there is currently no community of researchers, corporations and educational institutions that could form teams to undertake the coordination of this effort, a comprehensive research management plan will need to be developed and implemented. The plan recommends that this new initiative complement any ongoing learning science/technology research programs.

Fortunately, there are currently a few public-private collaborations that are developing, implementing and evaluating sophisticated games and simulations. Five examples include:

Revolution (Henry Jenkins and colleagues--MIT): A multiplayer virtual world where students play roles as colonists in 1775

Environmental Detectives (Henry Jenkins and colleagues--MIT): An augmented reality game using handheld computers to solve a mystery about a simulated toxic spill

River City (Chris Dede and colleagues--Harvard University): A multiuser virtual environment set in the 19th century town of River City where teams of students investigate health problems of its virtual citizens

Quest Atlantis (Sasha Barab and colleagues--Indiana University): A multiuser virtual city of Atlantis where citizens carry out quests to save the city and learn various social studies Content

Cooties (Elliot Soloway and colleagues--University of Michigan): A simulation game in which diseases are spread when using a handheld computer to communicate.

Perhaps because of new funding for games and simulations research, scholars from both the multimedia learning and games/simulation communities will get re-acquainted (or acquainted). It would seem to this reviewer that these “semiotic domains” (Gee’s term) have a lot to learn from one another in building coherent theories and principles of multimedia/games/simulation learning.

What many game/simulation developers have not enjoyed is stable funding of sufficient size over an extended period of time. This would permit games/simulation programs to be developed, evaluated, revised, implemented again and then this process continued over several iterations. Some of the university-based initiatives have attempted to become self-sustaining by forming private companies to continue the development and distribution of their products. However, when the major client is public schools with limited funds, this is a difficult and problematic road to navigate, especially for academics whose forte is often not entrepreneurship. Hopefully, the educational games and simulation initiative that the Federation of American Scientists is attempting to organize will permit the establishment of stable R & D centers around the country in which researchers, designers, evaluators, teachers, students and curriculum specialists will collaborate to produce high quality game/simulation products

Integration of games and simulations developed will likely continue to be a challenge unless the barriers between the research centers and the schools can be lowered. One way that this may be done is to invite elementary and secondary school teachers and students to become members of design teams. Developers can create very high quality innovative games and simulations, but if the individuals who will implement them do not see themselves as part of the team, the probability of successful implementation will be reduced. Teachers and students will also need significant professional development focused on how to incorporate the games and simulations in their curriculum and sufficient technical support to keep their hardware and software functioning well.

An outstanding Ph.D. dissertation in 2005 by Simon Egenfeldt-Nielsen of the University of Copenhagen is available on the internet. It provides a thorough review of both theory and research on games, plus an eloquent description of the study he did to measure the outcomes when games were implemented in the classroom. It is a moving and brilliant story which is a cautionary tale of what happens when the aforementioned suggestions for developing and implementing games for learning are not utilized. This 280+ page document can be found at http://www.it-c.dk/people/sen/egenfeldt.pdf

REFERENCES

Aldrich, C. (2005). *Learning by doing: A comprehensive guide to simulations, computer games, and pedagogy in e-learning and other educational experiences*. San Francisco, CA: Pfeiffer.

Amory, A. et al. (1998). Computer games as a learning resource. Retrieved on June 9, 2006, from Ed-Media: http://www.und.ac.za/und/biology/staff/am_ory/edmedia98.html

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science*, 12, 353-359.

Anderson, C. A., & Dill, K. E. (2000). Video games and aggressive thoughts, feelings, and behavior in the laboratory and in life. *Journal of Personality and Social Psychology*, 78, 772-790.

Anderson, C. A., & Ford, C. M. (1986). Affect of the game player: Short-term consequences of playing aggressive video games. *Personality and Social Psychology Bulletin*, 12, 390-402.

Archer. J. (1998) Technology counts: The link to higher scores. Retrieved on August 14, 2006 from Education Week website at: http://counts.edweek.org/sreports/tc98/ets/ets-n.htm

Ballard, M. E., & West, J. R. (1996). Mortal Kombat™: The effects of violent videogame play on males' hostility and cardiovascular responding. *Journal of Applied Social Psychology*, 26, 717-730.

Bartholow, B. D., Bushman, B. J., & Sestir, M. A. (2006). Chronic violent video game exposure and desensitization to violence: Behavioral and event-related brain potential data. *Journal of Experimental Social Psychology*, 42, 532-539.

Becker, K. (2007). Pedagogy in commercial videogames. In D. Gibson, C. Aldrich & M. Prensky (Eds.), *Games and Online Learning: Research and Development Frameworks*. Hershey, PA,

Bernard, R. M., Abrami, P. C., & Lou, Y. (2004). How does distance education compare withwith classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research*, 74, pp. 379-439.

Bruner, J. S. (1996). *The culture of education*. Cambridge, MA: Harvard University Press.

Bushman, B. J., & Huesmann, L. R. (2006). Short-term and long-term effects of violent media on aggression in children and adults. *Archives of Pediatrics & Adolescent Medicine*, 160, 348-352.

Calvert, S., & Tan, S. L. (1994). Impact of virtual reality on young adults' physiological arousal and aggressive thoughts: Interaction versus observation. *Journal of Applied Developmental Psychology*, 15, 125-139.

Chambers, J. H., & Ascione, F. R. (1987). The effects of prosocial and aggressive video games on children's donating and helping. *Journal of Genetic Psychology*, 148, 499-505.

Children Now (2001). Fair play: Violence, gender, and race in video games. Oakland, CA: Children Now.

Crawford, C. (1982). The art of computer game design. Retrieved on September 5, 2006, from: http://www.vancouver.wsu.edu/fac/peabody/game-book/Coverpage.html

Clark, R. E., & Feldon, D. F. (2005). Five common but questionable principles of multimedia learning. In R. E. Mayer (Ed.) *The Cambridge handbook of multimedia learning*. Cambridge, UK: Cambridge University Press.

Cohn, L. B. (1996). Violent video games: Aggression, arousal, and desensitization in young adolescent boys. *Dissertation Abstracts International*, 57, 1463.

Colwell, J., Grady, C., & Rhaiti, S. (1995). Computer games, self-estem, and gratification of needs in adolescents. *Journal of Community and Applied Social Psychology*, 5, 195-206.

Csikszentmihalyi, M. (1993). *Flow: The psychology of optimal experience*. New York: HarperCollins.

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, 68, 179-201.

De Lisi, R., & Wolford, J. L. (2002). Improving children's mental rotation accuracy with computer game playing. *The Journal of Genetic Psychology*, 163, 272-282.

Dempsey, J., Lucassen, B., Gilley, W., & Rasmussen, K. (1993-1994). Since Malone's theory of intrinsically motivating instruction: What the score in the gaming literature? *Journal of Educational Technology Systems*, 22, 173-183.

Doolittle, J. H. (1995). Using riddles and interactive computer games to teach problem-solving skills. *Teaching of Psychology*, 22, 33-36.

Duff, A., & Duffy, T. (2002). Psychometric properties of Honey and Mumford's learning styles questionnaire. *Learning and Individual Differences*, 33, 147-163.

Durkin, K., & Barber, B. (2002). Not so doomed: Computer game play and positive adolescent development. *Journal of Applied Developmental Psychology*, 23, 373-392.

Egenfeldt-Nielsen, S. (2005). Beyond edutainment: Exploring the educational potential of computer games. Dissertation Thesis: University of Copenhagen, May, 2005. Retrieved on October 23, 2006, from: http://www.it-c.dk/people/sen/egenfeldt.pdf

Fleming, M., & Rickwood, D. (2001). Effects of violent versus nonviolent video games on children's arousal, aggressive mood, and positive mood. *Journal of Applied Social Psychology*, 31, 2047-2071.

Gagne, R. M. (1985). *The conditions of learning and theory of instruction*. New York: Holt, Rinehart and Winston.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Gredler, M. E. (203). Games and simulations and their relationships to learning. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology*. Mahwah, NJ: Lawrence Erlbaum Associates.

Greenfield, P. M., Brannon, G., & Lohr, D. (1994). Two-dimentional representation of movement through three-dimensional space: The role of video game expertise. *Journal of Applied Developmental Psychology*, 1, 87-103.

Greenfield, P. M., Camaioni, L., Ercoloni, P., Weiss, L., Lauber, B. A., & Perrucchini, P. (1994). Cognitive socialization by computer games in two cultures: Inductive discovery of mastery of an iconic code. *Journal of Applied Developmental Psychology*, 15, 59-85.

Hammer, D. (1996). Misconceptions or p-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions? *Journal of the Learning Sciences*, 5, pp. 97-127.

Henson, R. K., & Hwang, D. (202). Variability and prediction of measurement error in Kolb's learning style inventory scores: A reliability generalization study. *Educational and Psychological Measurement*, 62, 712-727.

Jenkins, H. (2002). Game theory. *Technology Review*, 29, 1-3.

Kafai, Y. (1994). Electronic play worlds: Children's construction of video games. In Y. Kafai & M. Resnick (Eds.), *Constructionism in practice: Rethinking the roles of technology in learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Kafai, Y. (1995). *Minds in play: Computer game design as a context for children's learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Kafai, Ching, C., & Marshall, S. (1997). Children as designers of educational multimedia software. *Computers and Education*, 29, 117-126.

Keller, S. M. (1992). *Children and the Nintendo*. (ERIC Access No.: ED405069)

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning.* Retrieved on September 30, 2006 from: http://www.futurelab.org.uk/research/reviews/08_01.htm

Kirsh, S. J. (1998). Seeing the world through Mortal Kombat-colored glasses: Violent video games and the development of a short-term hostile attribution bias. *Childhood: A Global Journal of Child Research*, 5, 177-184.

Klabbers, J. H. G. (2001). The emerging field of simulation & gaming: Meanings of a retrospect. *Simulation and Gaming*, 32, pp. 471-80.

Klabbers, J. H. G. (2006). Artifact assessment versus theory testing. *Simulation & Gaming*, 37, 148-154.

MacArthur investing $50 million in digital learning (10/19/06). Retrieved October 30, 2006, from http://www.macfound.org/site/c.lkLXJ8MQKrH/b.1139551/apps/nl/content3.asp?content_id={6B08E360-3409-4010-835B-0C7301E1CAC4}&notoc=1

Malone, T. (1980). *What makes things fun to learn? A study of intrinsically motivating computer games*. Palo Alto, CA: Xerox

Malone, T. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, 4, pp. 333-369.

Mayer, R. E. (Ed.) (2005). The Cambridge handbook of multimedia learning. Cambridge, UK: Cambridge University Press.

McClurg, P. A., & Chaille, C. (1987). Computer games: Environments for developing spatial cognition? *Journal of Educational Computing Research*, 3, 95-111.

Miller, G. G., & Kapel, D. E. (1985). Can non-verbal puzzle-type microcomputer software affect spatial discrimination and sequential thinking skills of 7th and 8th graders? *Education*, 106, 160-167.

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Perzov, A., & Kozminsky, E. (1989). The effect of computer games practice on the development of visual perceptions skills in kindergarten children. *Computers in the School*, 6, 113-122.

Phillips, C. A., Rolls, S., Rouse, A., & Griffiths, M. D. (1995). Home video game playing in schoolchildren: A study of incidence and patterns of play. *Journal of Adolescence*, 18, 687-691.

R & D challenges in games for learning (10/17/06). Retrieved October 25, 2006, from Federation of American Scientists website at: http://fas.org/gamesummit/Resources/R&D_Challenges.pdf

Randel, J. M., Morris, B. A., Wetzel, C. D., & Whitehill, B. V. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation and Gaming*, 23, 261-276.

Richardson, J. T. (2000). *Researching students' learning: Approaches to studying in campus-based and distance learning*. Buckingham, UK: Society for Research into Higher Education and Open University Press.

Rieber, L. (1996). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research and Development*, 44, 5-22.

Rieber, L. (2005). Multimedia learning in games, simulations and microworlds. In R. E. Mayer (Ed.) *The Cambridge handbook of multimedia learning*. Cambridge, UK: Cambridge, University Press.

Rieber, L., Davis, J., Matzko, M., & Grant, M. (2001). Children as multimedia critics: Middle school students' motivation for and critical analysis of educational multimedia designed by other children. Paper presented at the annual meeting of the American Educaitonal Research Association, Seattle, WA.

Rieber, L., Luke, N., & Smith, J. (1998). Project KID DESIGNER: Constructivism at work through play. Meridian Middle School Technology Journal. Retrieved on September 25, 2006 from: http://www.ncsu.edu/meridian/jan98/feat_1/kiddesigner.html

Rieber, L, & Noah, D. (1997). Effect of gaming and graphical metaphors on reflective cognition within computer-based simulations. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Rieber, L., & Parmley, M. W. (1995). To teach or not to teaching? Comparing the use of computer-based simulations in deductive versus inductive approaches to learning with adults in science. *Journal of Educational Computing Research*, 13, 359-374.

Rieber, L., Smith, M., Al-Ghafry, S., Strickland, W., Chu, G., & Spahi, F. (1996). The role of meaning in interpreting graphical and textual feedback during a computer-based simulation. *Computers and Education*, 27, 45-58.

Roe, K., & Muijs, D. (1998). Children and computer games: A profile of the heavy user. *European Journal of Communication*, 13, 181-200.

Scott, D. (1995). The effect of video games on feelings of aggression. *Journal of Psychology*, 129, 121-132.

Shaffer, D. W., Squire, K. R., Halverson, R., & Gee, J. P. (2005). Video games and the future of learning (WCER Working Paper No. 2005-4). Madison, WI: Wisconsin Center for Education Research.

Second Life homepage. Retrieved on September 30, 2006, from http://secondlife.com

Richard J. Shavelson, R. J., & Towne, L. (Eds.) (2002). *Scientific research in education: Committee on Scientific Principles for Education Research*. Washington, DC: National Research Council/National Academy Press.

Stahl, S. A. (1999). Different strokes for different folks? A critique of learning styles. *American Educator*, 23, 27-31.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning*. Cambridge, UK: Cambridge University Press.

Van Merrienboer, J. J. G., & Kester, L. The four-component instructional design model: Multimedia principles in environments for complex learning. In R. E. Mayer (Ed.) *The Cambridge handbook of multimedia learning*. Cambridge, UK: Cambridge University Press.

van Schie, E. G. & Wiegman, O. (1997). Children and videogames: Leisure activities, aggression, social integration and school performance. *Journal of Applied Social Psychology*, 27, 1175-1194.

Williams, D. (2005). Bridging the methodological divide in game research. *Simulation & Gaming*, 36, 447-463.

Winkel, M., Novak, D. M., & Hopson, H. (1987). Personality factors, subject gender, and the effects of aggressive video games on aggression in adolescents. *Journal of Research in Personality*, 21, 211-223.

Your second life is ready. Retrieved on October 4, 2006 from Popular Science website at: http://www.popsci.com/popsci/technology/7ba1af8f3812d010vgnvcm1000004eecbccdrcrd/3.html

Yuen, M. (2006). A vision of mobile gaming in 2016. Retrieved on October 3, 2006, from Gamasutra website: http://www.gamasutra.com/php-bin/news_index.php?story=11087.