Southern New Hampshire University

SABBATICAL PROJECT REPORT – PART I

Serious Games: The Confluence of Virtual Reality, Simulation & Modeling, and Immersive Education

Dr. Robert H. Seidman, Ph.D.
Professor of Computer Information Technology
August 31, 2009

Southern New Hampshire University

Discrete-event Simulations in Virtual Worlds: A Future for Serious Games*

Dr. Robert H. Seidman
Southern New Hampshire University
August 2009

*[*By design, this is a draft of a paper meant to be tuned-up later for a conference presentation or a journal article.]*

> My crazy dream is that someday we'll replace the education system everywhere with emotion-cognizant video games that children demand to play even in their spare time. Such games would be played with a sensor suite that provides a real-time stream of human-state data as input to the game. Games then become human-state aware and adapt directly to the live player, understanding when the student is/is not learning, and with what level of difficulty. With emotion-cognizant games, we might potentially reduce the school system to a tutoring service for questions and answers not yet incorporated into the online edusphere. (Zyda, 2007, p. 28).
>
> Learners today need to be able to synthesize and evaluate information and knowledge in the face of a constantly changing technological environment. The virtual worlds with their simulated environments as well as modern digital games provide diverse environments in which this approach to learning can take place, provided educational designers are up to the challenge of designing and using simulations and game environments that retain those qualities of games that make them compelling, while at the same time offering sound instructional interventions. (Becker & Parker, 2009, p. 20)

I. Introduction

I have been teaching a discrete-event simulation (DES) and modeling course to both undergraduate and mostly graduate students at Southern New Hampshire University for many years: IT630 Computer Simulation & Modeling. The course teaches how to create models (i.e., mathematical abstractions) of existing systems, and of systems that do not yet exist. Then, using computer simulation software tools, students implement and run their models. These models can then be altered to reflect proposed changes in the system and the results used to compare different “what-if” scenarios. Comparisons are made through statistical hypothesis testing procedures so that students not only learn the techniques of model creation and computer simulation, they also learn the scientific experimental method and the use of statistical hypotheses testing techniques.

DES is widely used for business re-engineering and business process modeling (Alkhaldi, F. , Olaimat, M., Rashed, A., 2008) as well in areas such as logistics, transportation, product distribution, homeland security, emergency-response, defense, military, risk analysis, manufacturing applications, and health care . (Winter Simulation Conference, 2009) The material in this course is challenging for students and over the years I have tried different pedagogical approaches and techniques to make the learning easier and more fun.

Recently, simulation software has become better at 3D virtual reality renderings (Simio, 2009) which led me to think that DES could be embedded in a gaming environment to increase student learning and the transfer of knowledge and skills. That led me on an exploration into the field of serious games where I quickly discovered the wealth of research on educational games and simulations as well as some definitional controversies. In the end, I was able to conceptually situate DES within a serious games framework inside a highly interactive virtual environment scheme and propose the embedding of DES in a serious games format. This paper describes my journey.

But first, conceptual clarity is needed since the literature on serious games shows a propensity to overlap terms like: games, simulators, simulation-games, simulation modeling. Afterwards, it will be possible to talk clearly and to see just how situational cognition learning theory applies to serious games in immersive education. Finally, all this will allow me to sketch my view of a DES future in serious games.

II. Short-take on the game industry – the big picture

Hardly a day goes by that I don't come across something on electronic games and virtual worlds whether in the popular press or in the professional and scholarly literature. Here's a small sample of recent scholarly and professional society publications that have come across my desk. They give a feel for the extent and depth of the field.

- *Science*, the publication of the American Association for the Advancement of Science (2009) contains a special section on Education & Technology that prominently features articles on immersive educational games and virtual worlds.
- The Communications of the ACM published an article "Learning Through Games" (Hoffmann, 2009) and "Alternative Reality Gaming" (Kim, Allen, and Lee, 2008).
- The IEEE-Computer Society journal *Computer* published: "Testing Behavioral Models with an Online Game" (Zyda, Spraragen and Ranganathan, 2009); A cover feature "Second Life and the New Generation of Virtual Worlds" (Kumar, et. al., 2008); In their Standards section of the same issue we find "Innovation and Value" (DeMarie, 2008), an article on state of industry and academic partnerships in electronic games; In its Entertainment Computing section, it published "The Future is Virtually Here" (van Lent, 2008).
- The *Journal of Educational Computing Research* published "Relationships between Computer and Video Game Play and Creativity among Upper Elementary School Students" (Hamlen, 2009).
- *Educational Researcher*, the premier publication of the American Educational Research Association, published "Learning, Teaching, and Scholarship in a Digital Age" (Greenhow, Robelia, Hughes, 2009) which included a section on online identity formation through immersion in virtual worlds.
- IEEE *Software* published "To Game or Not to Game?" (von Wangenheim and Shull, 2009) which covers game-based learning for software education.

- The *Journal of Educational Technology Systems* published "Games and Web 2.0: A Winning Combination for Millennials" (Spiegelman and Glass, 2009).
- *Innovate: Journal of Online Education* published two recent special issues: "Academics in Second Life." (Dec. 2008); "Virtual Worlds and Simulations." (June 2009).
- The *International Journal of Gaming and Computer-Mediated Simulations* published a Harvard University study "Lessons Learned about Designing Augmented Realities" (O'Shea, et. al., 2009). Also, "Computational literacy in online games: The social life of mods" (Steinkuehler, 2009).
- IEEE *Computing Now* published a special issue on "Serious Games" (Barnes, 2009) and a special issue on "Building, Populating, and Interacting with Virtual Worlds" (O'Sullivan, 2009).

Several important games-related books were published this this year:

- <u>Handbook of Research on Effective Electronic Gaming in Education</u>, 3 Volumes (Ferdig, 2009).
- <u>Digital Simulation for Improving Education</u> (Gibson & Baek, 2009).
- <u>Design and Use of Serious Games</u> (Kankaanranta & Neittaanmaki, 2009).
- <u>Serious Games: Mechanisms and Effects</u> (Ritterfeld, Cody, Vorderer, 2009).
- <u>The Complete Guide to Simulations and Serious Games: How the Most Valuable Content Will be Created in the Age Beyond Gutenberg to Google</u> (Aldrich, 2009a) [Available in Oct. 2009).

How popular are video games?

- "Some 53% of American adults age 18 and older play video games, and about one in five adults (21%) play every day or almost every day. While the number of video gamers among adults is substantial, it is still well under the number of teens who play. Fully 97% of teens play video games." (Pew, 2008)

- In Australia "88% of homes have a device for playing computer or video games; 68% of Australians play computer or video games; 46% of gamers are female; the average age of an Australian gamer is 30 years; 84% of Australians aged 16-25 compared with those 50+ play computer and video games; the average adult gamer has been playing for 11 years; half of all gamers play daily or every other day, a quarter play once a week; the average game play session is one hour; 70% of parents in game households play computer and video games, 80% of these parents play them with their children." (Interactive Australia, 2009)

- The New York Times reports that 27 colleges which include Harvard, Yale, MIT, Berkeley, and John Hopkins are in a league to play StarCraft, a three-way galactic war game amongst humans, aliens and alien-humans. Colleges and people from all over the world play this game and tournaments via the internet are common (Cohen, 2009). There are many other popular press reports on the popularity of specific computer video games.

- The electronic game industry revenue is huge - more than double that of the movie industry. "The $21.3 billion in 2008 revenue was a 19 percent increase over the previous record of $17.9 billion in 2007." (Kim, 2009) By contrast, the movie industry "both blockbusters and not-so-blockbusters propelled record-setting revenues to an estimated $9.78 billion in 2008 … narrowly edged out last year's by two percent." (Chartier, 2009)

Although serious games revenues are not tracked separately, we can assume a similar growth as the proliferation of research articles on serious games attest to.

Serious games – games explicitly made for education and training - sits within the bigger picture, called Highly Interactive Virtual Environments (aka, HIVE), see Figure 1, which we will come back to later in this report. (Aldrich, 2009b)

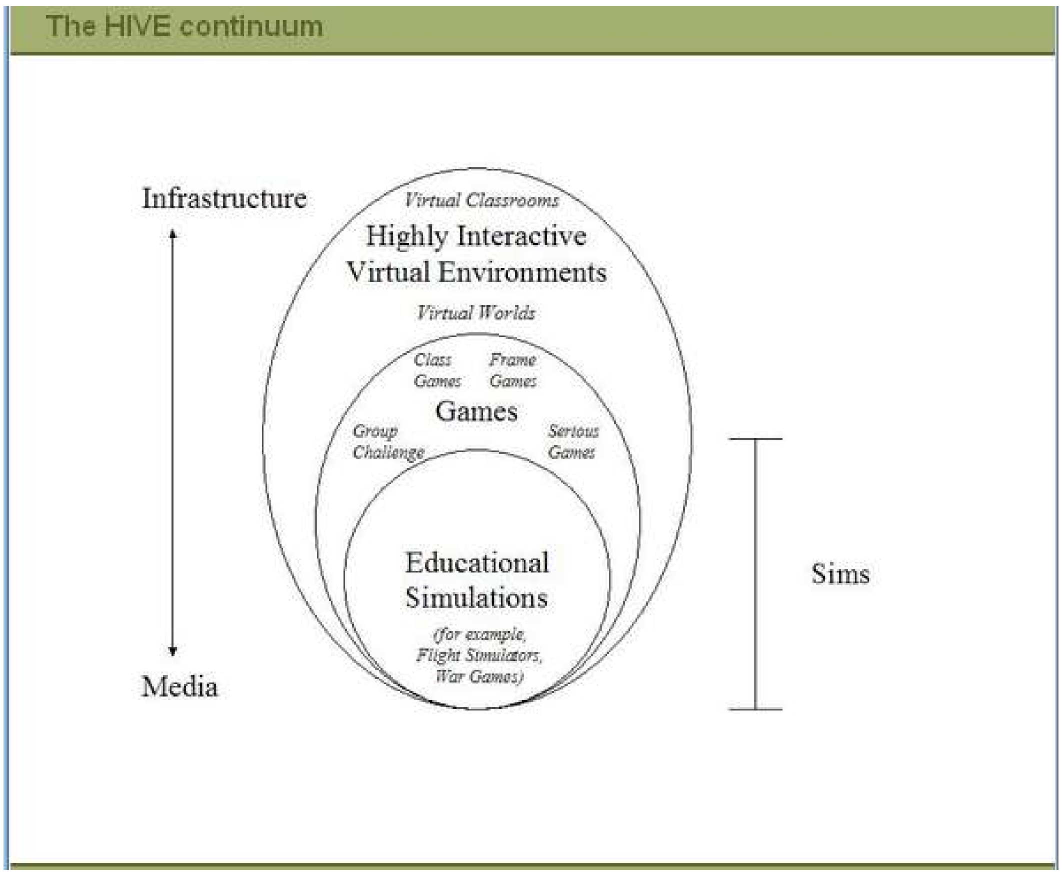

Figure 1. The HIVE continuum. (Aldrich, 2009b)

III. Literature Overview

The published literature on computer games is undeniably vast and very broad. To focus on games as learning tools narrows things a bit, but not much. A recent qualitative meta-analysis of the literature on computer-based instructional games by Ke (2009) focuses on the evidence for using games for learning and factors in effective applications of gaming for instruction. On the effects of instructional gaming, Ke found that out of 65 game effectiveness studies, only 12 reported no difference between computer games and conventional instruction. The rest reported either positive differences or mixed results. Only one, reported negative results.

A number of literature reviews of the educational efficacy of computer games specifically have been done, as reported by Ke (2009). Garris, Ahlears & Driskell (2002) found that computer games seem to invoke an "intensity of engagement in learners." Vogel, et al. (2006) found "strong, positive effect sizes of interactive simulations and games vs. traditional teaching methods for both cognitive gains and attitude." Randel, et al. (1992) review of the video game literature found 70% of the studies showed either no differences or positive differences of video games over traditional classroom instruction on student performance. Wolfe's (1997) literature review found significant knowledge-level increases due to business games used in strategic management courses. Emes (1997) and Hays (2005) literature reviews both found no clear evidence that games are "preferred instructional method in all situations."

One problem is that a lot of the work in the field is "anecdotal, descriptive or judgmental" as Key (2009, p. 5) points out. The empirical and experimental "literature base is sparse" and fragmented.

I believe that one reason for this is terminology confusion. But, before tackling definitions, it is important to say something about the psychological/social underpinnings of educational games.

IV. Immersion: Cognitive underpinnings of games

> "Immersion is the subjective impression that one is participating in a comprehensive, realistic experience. Immersion in a digital environment involves the willing suspension of disbelief … and draws on sensory, actional, and symbolic factors." (Dede, 2009, p. 66)

Dede discusses research findings that show "… a broader range of students gain substantial knowledge and skills in scientific inquiry through immersive simulation than through conventional instruction …. immersion may enhance transfer through simulation of the real world." (p. 67)

More broadly, research shows that "immersion in a digital environment can enhance education in at least three ways: by enabling multiple perspectives, situated learning, and transfer… [and that] immersive media may have the potential to release trapped intelligence and engagement in many learners …." (Dede, 2009, p. 67).

Multiple perspectives: Research shows that "the ability to change one's perspective or fame of reference is a powerful means of understanding a complex phenomenon." (Dede, 2009, p. 66). This is accomplished by "shifting between an exocentric and an egocentric frame of reference" – something that video games do well – views from outside and inside of objects.

Situated learning: This is done through immersive interfaces along with "authentic contexts, activities, and assessment …" (Dede, 2009, p. 66) Immersion, together with situated cognitive theory can have "significant impacts on immediate learning." Although the research was done in an augmented reality setting, I believe that it may hold outside of that setting as well. Situate cognition theory posits that "individuals' interactions with their social teams lead to their adoption of learned behaviors." Also, see O'Shea (2009). That is why there is a great deal of research on game-like virtual simulations for educating young people about higher-order inquiry skills. (Dede, 2009, p. 67).

Transfer: "Transfer is defined as the application of knowledge learned in one situation to another situation …" Dede (2009, p. 67) reports that this is a promising area and that there are a number of studies under way.

Henry Jenkins, Director of Comparative Media Studies at MIT, and the Peter de Florez Professor of Humanities, has this to say about games in teaching and learning. "Games enable players to: drill deep into subject matter; explore choice and consequence; play with complex variables; simulate real world processes; create peer to peer teaching opportunities; engage in an immersive and highly motivated mode of learning." (Jenkins, 2009)

These are, in my view, why interactive games, social and otherwise, and simulations are so important in education and could help explain some of their popularity. IT also explains why we may see educational theory changing in light of today's learners and digital games they play. "Game design elements are infused into the instruction at all stages in order to motivate students and engage their social- and cognitive-connectedness schemata more fully." (Sontag, 2009).

V. Defining the field: simulations and games

Becker and Parker (2009) say that "a common source of friction and debate, especially in the design of interactive educational software is the distinction between the terms 'simulation' and 'game.'" The professional simulation and modeling community defines "model" as an abstraction of a system whether existing or imagined. Simulation enacts or implements a model. Simulations have "consistency" which means that they have "some set of rules we can describe, and some pre-determined purpose." (p. 4)

There is no precondition that a model, and thus a simulation, must be based upon reality. This feature is a hallmark of DES. On the other hand, Ke (2009) points out that in the educational community, simulations "necessarily model reality and are distinct from games which do not."

The simulation modeling community considers all games of the discrete variety (which are the preponderance of games) to fall “under the category of discrete-event simulations.” (Becker and Parker, 2009, p. 4) Under the hood, all digital games contain algorithms that control game behavior and user interactions. This is the same characteristic of all DESs. DESs divide time into small *discrete* chunks, hence the “*D*” in “DES” and advance time through these chunks. You can find an extended explanation of DES in any computer simulation and modeling textbook. E.g., Harrell, Ghosh and Bowden (2004); Rossetti (2010).

While some in the education community argue that simulations do not necessarily have fidelity to reality and thus can’t be considered games (i.e., serious games), the US Department of Defense counters saying “fidelity is in fact a measure of the faithfulness of a simulation to the models it seeks to implement.” (Becker and Parker, 2009, p. 6)

The distinctions are important especially when it comes to designing games/simulations. I support the Becker & Parker (2009) definition that games are indeed a category of simulations and I support the need for clarity by examining Narayanasamy’s (2006) taxonomy of games, simulation-games, simulators and serious games later in this paper.

VI. Serious games in a picture

Games come in many flavors (aka, genres). There are two-dimensional and three-dimensional games. There are single player and multi-player games such as: MUVEs (online, multi-user virtual environments); MUDs (multi-user dungeon), MOOs, (MUD, object oriented) and MMORPGs (Massively multiplayer online role-playing game). There are games that entertain, educate, train and inform. Games reside on computers, on game-consoles and in virtual worlds.

Simply put, serious games are games whose intended purpose is to educate. Here are some recent examples of their use:

- “Florida Summer School Programs Fuse Learning with Immersive Educational Video Games” Educators from Florida’s Hillsborough and Escambia Counties were determined to combine summer fun with learning by incorporating Tabula Digita’s DimensionM™ Multiplayer educational video games into their summer school programs. (Business Wire, 2009)

- “Serious Games Entertain, Educate Employees” Simulation games can also help companies get their employees in line with corporate strategy during a business transformation. The desire to do so led Assurant Employee Benefits, a subsidiary of insurer Assurant Inc., to partner with game maker Propaganda 3 to produce four games customized for its workforce. Within six weeks of launching its first game in July of 2008, 95 percent of its 2,100 employees had played. (ITBusinessEdge, 2009).

- "The INNOV8 BPM simulation game brings IT and business together for process model innovation. INNOV8, the IBM Business Process Management (BPM) simulation game, gives both IT and business players a better understanding of how effective BPM impacts an entire business ecosystem." (Innov8, 2009)

Sometimes a picture is truly worth a thousand words. Figure 2 is Michigan State University's way of showing how serious games are situated in the constellation of theory, content and game design. Notice how many diverse disciplinary fields contribute to serious games making it truly cross-disciplinary.

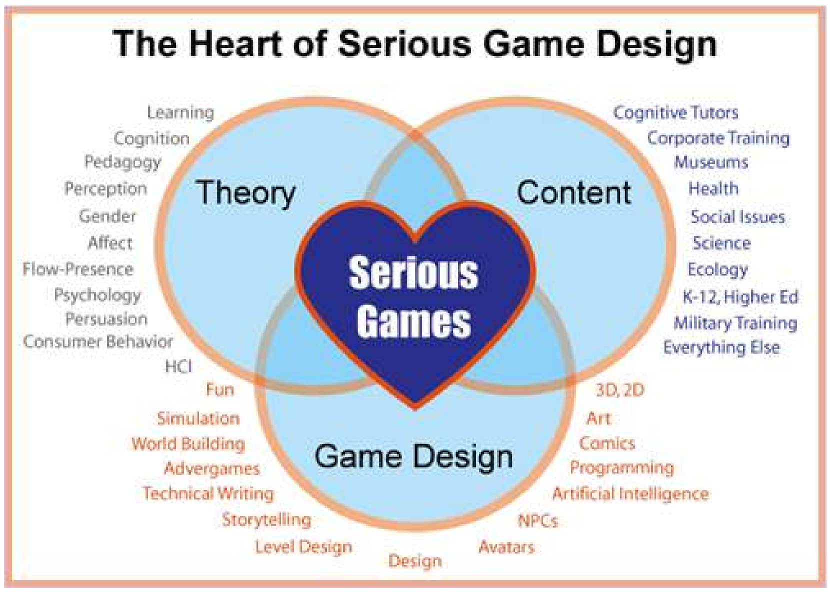

Figure 2. Michigan State University Degree in Serious Game Design (MSU, 2009)

Here are three more formal definitions of "serious" games for consideration.

> Reduced to its formal essence, a game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context. A more conventional definition would say that a game is a context with rules among adversaries trying to win objectives. We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. (Abt, 1970)

Abt is talking primarily about board and card games given that the first edition of his book titled "Serious Games" was written in 1970. His definition is apropos. Note that to him, games are designed for educational purposes and not solely to entertain.
The following more current definition and description emphasizes the simulation of "realistic situations" with no mention of not being for entertainment.

> Serious games use video game technologies to simulate realistic situations, providing valuable experience that can support discovery and exploration while saving money and lives. Serious games have been used for many purposes, including flight and vehicle

simulation, scientific simulation and visualization, industrial and military training, medical and health training, education, and geographic information systems, as well as to raise public awareness and spur policy change. (Barnes and Encarnação, 2009)

Zyda provides a progressive logical approach in defining serious games. Notice that he includes entertainment in his definition. I support his definition as a working definition for this paper.

- Game: "a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participant."
- Video Game: "a mental contest, played with a computer according to certain rules for amusement, recreation, or winning a stake."
- Serious Game: "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." (Zyda, 2005)

These three quotes serve to show that the definition of serious games has not yet reached the point where it is standardized across authors. In addition, there are some definitional controversies concerning what exactly constitute games, simulation-games, simulators and by implication, serious games. Before we move forward, we need to find conceptual clarity in this realm.

VII. Games, simulators, simulation-games and serious games

Previously, I pointed out that confusion exists in the literature between the terms games and simulations (Becker and Parker, 2009). Drilling down further, Narayanasamy (2006) introduces a taxonomy to clarify the distinctions between games, simulation-games, simulators, and serious games. His taxonomy helps put serious games into a *categorical* perspective. Afterwards, I show how Aldrich (2009b) places serious games into a *continuum* perspective. It is Aldrich's perspective that will be useful to me in conceptualizing the kind future I see for DES-serious games embedded in virtual worlds supported by a cloud computing infrastructure platform.

Computer games: Narayanasamy (2006) points out that a game is a "goal-directed and competitive activity that involves some form of conflict, conducted within a framework of agreed rules." (p. 2). There are players (aka, gamers) who are decision makers and games contain conflicts in the form of obstacles that typically prevent players from reaching a goal or set of goals. Games typically embody challenges which give rise to competition and/or cooperation amongst the players (human or otherwise).

<u>Games have rules, game-play gestalt, and goals:</u>

- <u>Rules</u> are procedural, governing or control. According to Narayanasamy (2006), procedural rules describe the "essential components" of games. Governing rules are the specifications of the "end state" of the game. Control rules comprise the game's model of "action-consequence" behavior. He observes that rules can be imposed explicitly (i.e., built-in by the game designer) or be implicit (i.e., by player agreement).

- Game play gestalt: Unlike games such as chess, where it is necessary to know the rules prior to play, in modern electronic games it is only necessary that one's "course of action" follows the rules. Operationally, today's gamers tend to approach games by "clicking around" and "blazing away" - terms coined by Snyder (2008) to describe how people find out how to use new software "without having to be taught or to read the manual." (pp. 42-43).

  But, the rules in contemporary games are designed to "implicitly develop the player's understanding of the governing and control rules." (Narayanasamy, 2006, p. 3). As a result of the clicking around learning process, "user-developed patterns" emerge and these patters of interaction are called "game-play gestalt."

- Game goal: This is an end-state that is typically predetermined by the game designer and can include attainable objectives. (p. 3).

Narayanasamy points out that games need to be fun – otherwise, they won't sell and we would have nothing to talk about.

Computer simulation games: There are many computer game genres. For example: "action, strategy, adventure, role-playing, sports, simulations and classic puzzle and board games." All games involve some form of simulation because "game developers make considerable effort to recreate, to a high degree of verisimilitude, some aspect of the real-world." (Narayanasamy, 2006, p. 4) What distinguishing simulation games from other genres, is that that are not always goals oriented.

Narayanasamy (2006) classifies simulation games as:

- Participatory: The player is within the game setting and is required to perform some actual physical action. Examples could be virtual reality and augmented reality games.

- Iterative : The players create an end result by "plugging in known variables one at a time and observing the results of iterative changes." (p. 4) We will see this again at the end of this paper where I propose embedding DES computer simulation & modeling into virtual reality environments.

- Procedural: Reenact a "real-life process" using an "action-consequence module." These kinds of computer simulation games provide training "to complete a well-documented set of procedures." (p. 4) Simulators, seen later, do this.

- Situational: Contain a simulation model that "deals with the behaviors and/or emotions of people that relate closely to a group of circumstances. An example is The Sims 3, which is one of the most popular games of all time. (SIMS, 2009)

Simulators: Narayanasamy (2006) explains that "in the past, simulations were mainly used to study the behavior of a system as it changed with respect to time." (p. 4) According to Narayanasamy, computer simulation is what is behind simulators. One must develop a model of a system before creating the simulator. Think of a flight simulator for example. The model behind it must take into account the handling and aerodynamics of the plane and the characteristics of the environment through which the plane is traveling, amongst many other things.

Simulators are classified by the simulation model that they adopt:

- A Monte Carlo-based simulator uses state-sequencing and does not explicitly represent time. For example, we can use a computer random-number generator to simulate a coin-flip. While, our coin-flip simulator could certainly flip coins over a period of time, the model itself is not time-bound.

- Discrete event-based simulators use a model that specifies changes of state at discrete points in a time-line. For example, data packets entering a network to be transmitted over communication lines and queuing up at routers and data-channels calls for us to view the system states at various points in time in order to describe it accurately and to run the simulator. (Altiok and Melamed, 2007)

- Continuous simulation-based simulators "portray state changes" in a continuous, rather than a discrete mode, over time. System dynamics difference equations are examples. (Stella, 2009)

Narayanasamy (2006) uses the word "simulator" as the physical/virtual incarnation of a simulation "model." Amongst the many uses of simulation (e.g., system analysis, education, acquisition and system acceptance, research, efficiency tests for predictions, optimization), it is now being used in the realm of "interactive entertainment." Simulators are seen as being used in "real-time interactive mode to derive pleasure and entertainment." (p. 5)

- Training simulators (e.g., flight and driving simulators) are what Narayanasamy claims are closest to what we know as computer games. Of the ten characteristics he posits, these are the ones which are most supportive of serious games:

    1. Goals of maximizing operator's task performance.
    2. Emphasis on reproducing real-world experience.
    3. Real-time performance.
    4. "Virtual reality technologies … improve immersiveness and interactivity…." (p. 6)

I believe that it would be useful to classify the extant research on games, simulation games and simulators (i.e., training) using a common taxonomy. See Figure 3. Narayanasamy (2006) is the only one I know of, outside of Aldrich (2009b) to have proposed such a classification system. See Birta, L. and Arbez, G. (2007) for a standard view of simulators. Narayanasamy's taxonomy is worth considering as we move forward to what I will propose later in this paper: the embedding of discrete-event simulators in a highly-interactive-virtual-environment in order to add to our repertoire of serious games.

Table I. Identifying Simulation Games and Simulators

Identifying Characteristics		*Games*	*Simulation Games*	*Training Simulators*
1.	*Involves simulation*	1. A virtual environment is present. 2. The application interactively engages the user in a form of simulation.		
2.	*Imaginative experience*	1. May provide an imaginative or fictitious simulated environment.		1. Only provides recreations of real-world environments.
3.	*Entertaining, fun, and engaging*	1. Provides entertainment. 2. Provides interesting & engaging challenges. 3. Provides a fun experience.		1. Not intended to be entertaining, fun, or engaging. 2. Operator may possibly find the application entertaining, fun, and engaging.
4.	*Skills development*	1. Does not provide an application-specific skill development. 2. Possible, although not as a primary feature.		1. Operator skills-development is the primary purpose of a simulator.
5.	*Type of challenge*	1. Ideally, a continuous and intelligent challenge.		1. Challenges depicted accurately with respect to an equivalent real-world scenario.
6.	*Gestalt*	1. Presence of game-play patterns. 2. Game-play patters may vary. 3. Possible development of a game-play gestalt.		1. Presence of standard operational procedures. 2. Procedures do not change.
7.	*Goal-oriented*	1. Goal-oriented activity present. 2. End-state present.	2. No obvious end-state.	1. Goal-oriented activity absent. 2. No obvious end-state.

Figure 3 Taxonomy for distinguishing games, simulation games & simulators (Narayanasamy, 2006, p. 7)

Identifying Characteristics of Narayanasamy's Taxonomy

1. Involves simulation: Virtual environment that tries to recreate some form of fictitious or real-world environment.
2. Imaginative experience: Has elements of fiction or fantasy or an experience that deviates from reality. Training simulators typically do not do this. But, I will argue later, with Becker and Parker (2009) that discrete-event simulators can and do.
3. Entertaining, fun and engaging: "Entertaining" - defined as interesting or amusing. This is the highest priority feature of games and simulation-games. "Interesting" engages player attention and gives excitement. "Fun" - Leblanc (2000) provides a taxonomy of fun in games: sensation (i.e., pleasurable experience); fantasy (i.e., immersion in fantasy world); narrative (i.e., role-play); challenges; fellowship (i.e., social network building) discovery; self-expression, masochism

(i.e., game character engages in negative activity and produces pleasurable sensation not possible in real world). Not all aspects of fun need to be present, of course. (Narayanasamy, 2006, p. 7). Narayanasamy argues that the absence of fun is one way to differentiate games and simulation games from simulators. I will argue differently later.

4. Skill development: Highest priorities for simulators.
5. Type of challenge. These challenges engage players. They occur continuously. “Emergent” challenges introduce “random, varying, unpredictable, or sometimes nondeterministic, content in [training] simulators … is undesirable ….” Narayanasamy argues that the inclusion of emergent challenges distinguishes games and simulations-games from simulators. I’ll argue the opposite later.
6. Gestalt: Narayanasamy argues that for training simulators this is undesirable since we don’t want ‘operators’ to deviate from standard procedures. I’ll argue that for discrete-event simulations, it is fine to do deviate.
7. Goal-oriented: Activities lead to end-state in a game. Some common ones are: game-specific goals; piece-elimination; puzzle-guessing; races; structure-building (“acquire and assemble a set of game resources into either a predefined winning structure or one that is somehow better than those of opponents”) - I’ll have much to say about this later; territory control; victory points (highest points wins). (Narayanasamy, 2006, p. 6)

Narayanasamy says that games (i.e., simulation applications) “can be identified as a game by the presence of (any) goal-oriented activity.” (p. 9) But that simulation-games might have some activities that “allow victory conditions to be met; but successful completion of these activities and reaching the end-state of the game are optional.” As for training simulators, goal-oriented activities are not present nor are there any “obvious” end-states. It really comes down to what Narayanasamy calls “scenario-based objectives” that simulators center their activities on. Simulators are for qualifying and tracking the “development of specific skills.”

Narayanasamy exercises the taxonomy he developed by comparing a simulation game (i.e., SIMS 2) with a simulator (i.e., Microsoft Flight Simulator). Table II in Narayanasamy (2006, p. 10). The taxonomy seems to work well.

It is worth noting that Narayanasamy is not the only one who seeks to distinguish between simulations and games. Sauvé, Renaud, Kaufman, & Marquis (2007) utilize dimensions that are not applicable to my analysis.

Discrete-event simulations (DES) & serious games

The kind of discrete-event simulations I am interested in are best exemplified by an example taken from Altiok & Melamed (2007). In Figure 4, you see an Arena model of a hospital emergency room. I’ll spare you the details except to say that patient entity arrivals are generated according to a probabilistic distribution (i.e., Create block) and go to the Reception area. Then, a decision is made according to some criteria distribution that mirrors real data previously collected whether each patient’s condition is critical or not. If critical, the patient goes directly to a doctor (i.e., Wait for Doctor block). If not critical, the patient goes to a Waiting Room. You can follow patient progress in Figure 4. Time moves forward and the simulation runs.

There are a number of stochastic processes in this simulation model which means it must be run (i.e., simulated iteratively) to get results that converge. We need to validate the model to be sure that it corresponds to the real world situation. If, for example, the average patient waiting times in the various queues (e.g., waiting room), and the average utilization of the medical personnel (e.g., nurses, staff and doctors) are within the real range then we say the model is valid. Then, we can run the model with different logic (e.g., different paths through the system) and parameters (e.g., more doctors, more staff, etc.) to see what the performance parameters results would be. Even if a real-life hospital emergency room did not actually exist, we could model one with the help of speculated information.

We then use hypothesis testing statistical techniques to determine which alternative models are best using some criteria (e.g., minimal waiting time for patients, larger utilization times for staff).

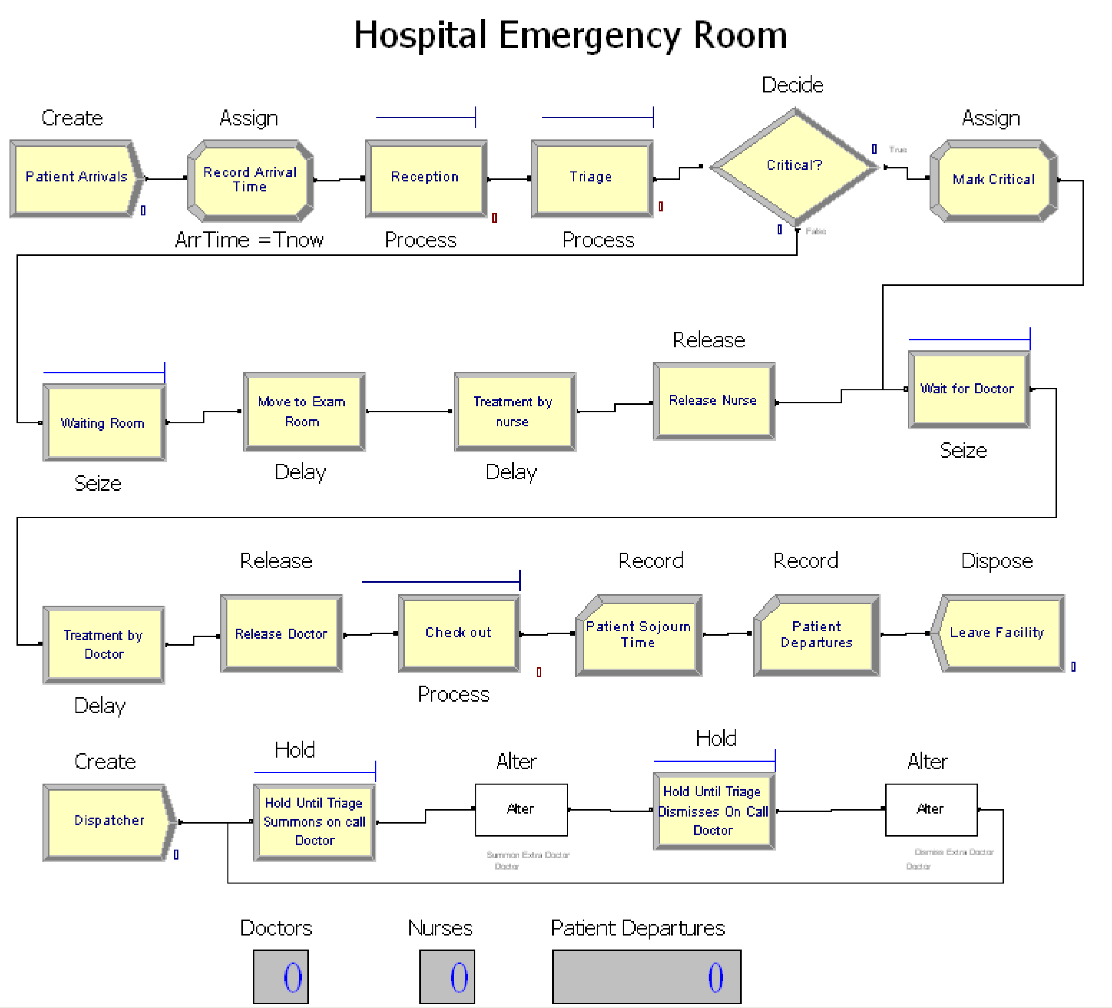

Figure 4 Emergency Room discrete-event simulation model. (Altiok & Melamed, 2007).

When the simulation model runs we are able to see animation effects. Some simulation languages create 2D and 3D effects. Figure 5 is a snapshot of a real-time rendering of part of an order processing simulation using ProModel. Of course, objects would be moving around during the run, reflecting their movement through the system. (ProModel, 2009)

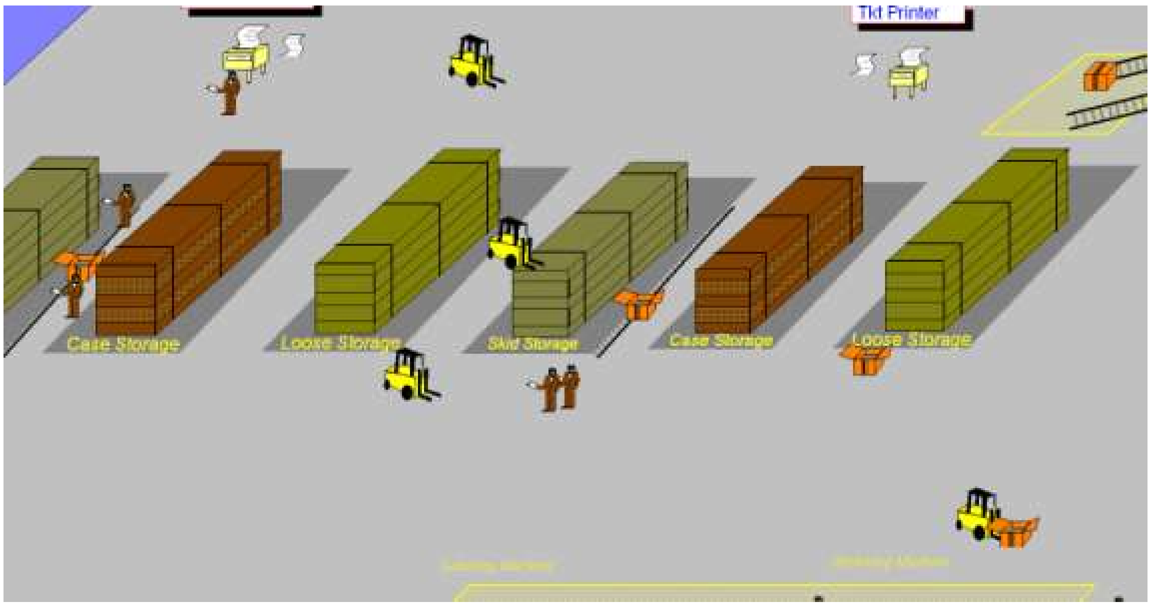

Figure 5. Simulation animation snapshot. (ProModel, 2009)

Another simulation example is shown in Figure 6. It is an Arena model of a two-tier client-server network. (Altiok and Melamed, 2007) The modeler sets the parameters for a database request distribution, the speed of the packets through the system, channel capacity, database response service time, etc. Then, runs the model. Results are observed and alternative models can be created and compared against the base model and other alternative models. Animation is possible showing packets moving and queuing up.

3D animations of discrete-event simulation are easier now with newer simulation software such as Simio (Simio, 2009). To make a DES simulation into an interactive game we will want to immerse the user in the simulation model itself, perhaps using an avatar in a virtual world, and give him/her control over model logic and parameters with various goals or challenges in mind. The avatar (controlled by the user) could alter logical structure and model parameters for each alternative model - maybe on-the-fly dynamically - thus changing the simulation results. Multiple players could collaborate and/or compete. In addition, avatars could be forced go through several learning obstacles or challenges in order to qualify to make model changes. For instance, they might need to master certain knowledge in

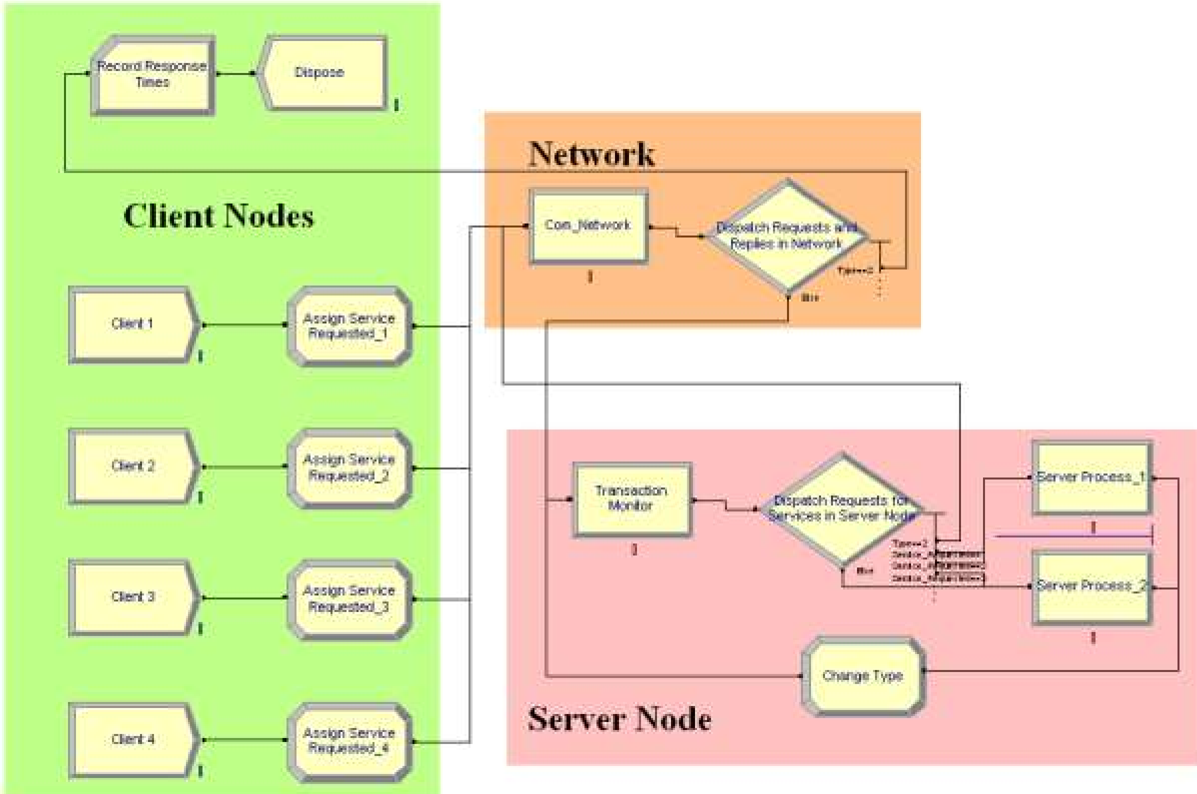

Figure 6. Two-tier client-server Human Resources network. (Altiok and Melamed, 2007)

order to rise to certain management levels of responsibility where they would gain privileges and access to altering the models. These are hallmarks of serious games.

We have now covered games, simulations-games, training simulators with a taxonomy that can distinguish one from another. I have introduced discrete-event simulators and briefly discussed their potential future use as games. It is now time to situate serious games within the games milieu and then discrete-event simulations within serious games. After that, we will orient everything in a highly interactive virtual environment paradigm, which is the object of this paper.

Narayanasamy (2006) says that serious games are games that “attempt to provide some form of simulation for non-entertainment purposes” and includes serious games in his taxonomy in Figure 7, below. Note that skill development is an important distinction between the two. A good example would be America’s Army 3. Narayanasamy (2006) also acknowledges the confusion between different types of simulations available. This definitional confusion is also addressed by Becker and Parker (2009) as I have noted earlier in this paper.

Table IV. Identifying Simulation Games and Serious Games

<table>
<tr><th colspan="2">Identifying Characteristics</th><th>Simulation Games</th><th>Serious Games</th></tr>
<tr><td>1.</td><td>Involves simulation</td><td colspan="2">1. A virtual environment is present.
2. The application interactively engages the user in a form of simulation.</td></tr>
<tr><td>2.</td><td>Imaginative experience</td><td colspan="2">1. May provide an imaginative or fictitious simulated environment.</td></tr>
<tr><td>3.</td><td>Entertaining, fun, and engaging</td><td>1. Provides entertainment.
2. Provides interesting and engaging challenges.
3. Provides a fun experience.</td><td>1. Built for non-entertainment
2. Can provide interesting and engaging challenges.
3. Can provide a fun experience.</td></tr>
<tr><td>4.</td><td>Skills development</td><td>1. Does not provide an application-specific skill development.
2. Possible, although not as a primary feature.</td><td>1. Usually designed to provide some form of skill development, especially in training applications.</td></tr>
<tr><td>5.</td><td>Type of challenge</td><td>1. Ideally, a continuous and intelligent challenge.</td><td>1. The challenges vary with the type of simulation.</td></tr>
<tr><td>6.</td><td>Gestalt</td><td>1. Presence of game-play patterns.
2. Game-play patterns may vary.
3. Possible development of a game-play gestalt.</td><td>1. Presence of game-play patterns and gestalt vary, depending on the application.</td></tr>
<tr><td rowspan="2">7.</td><td rowspan="2">Goal-oriented</td><td colspan="2">1. Goal-oriented activity present.</td></tr>
<tr><td>2. No obvious end-state.</td><td>2. May or may not have an obvious end-state, depending on application.</td></tr>
</table>

Figure 7. Taxonomy that includes serious games. Narayanasamy (2006)

Crawford (1997) makes this interesting distinction between games and simulations.

> The distinction between objective representation and subjective representation is made clear by a consideration of the differences between simulations and games. A simulation is a serious attempt to accurately represent a real phenomenon in another, more malleable form. A game is an artistically simplified representation of a phenomenon. The simulations designer simplifies reluctantly and only as a concession to material and intellectual limitations. The game designer simplifies deliberately in order to focus the player's attention on those factors the designer judges to be important. The fundamental difference between the two lies in their purposes. A simulation is created for computational or evaluative purposes; a game is created for educational or entertainment purposes.(There is a middle ground where training simulations blend into educational games.) Accuracy is the sine qua non of simulations; clarity the sine qua non of games. A simulation bears the same relationship to a game that a technical drawing bears to a painting. A game is not merely a small simulation lacking the degree of detail

> that a simulation possesses; a game deliberately suppresses detail to accentuate the broader message that the designer wishes to present. Where a simulation is detailed, a game is stylized. (Crawford, 1997)

I adopt the following definition of games, serious games and endorse the placement of simulations within games.

> "Any contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory, or pay-off)." (Abt, 1970) Educational games (or serious games) are designed to reach people about a certain subject, expand concepts, reinforce development, or help them drill or learn a skill or change their attitudes as they play. For our purpose, we also include simulations in this category. Simulations resemble games in that both have some underlying model, allowable actions that the leaner can take, and constraints under which those actions should occur. Additionally, learners observe their actions' consequences." (von Wangenhein and Shull, 2009).

The description I have provided of an extended DES fits this definition and Narayanasamy's (2006) taxonomy for serious games. My view is validated and reinforced by the MODSIM World Conference and Exp 2009. See Figure 8.

The MODSIM World conference is quite comprehensive and has seven program tracks, including one on serious games: Defense & Homeland Security**;** Education & Training**;** Engineering & Science**;** Health & Medicine**;** The Human Dimension (Modeling Human Behaviors & Interactions)**; Serious Games;** Transportation & Logistics**.** Conference sponsors include: Northrop Grumman, Lockheed Martin, Virginia Modeling, Analysis, and Simulation Center (VMASC), NATO's Allied Command Transformation (ACT), Raytheon, and General Dynamics.

MODSIM caters to business, industry and military researchers as well as academics. There are even special sessions that require US Government security clearance. To see a serious games track at a conference like this signals its emerging importance in many fields of endeavor.

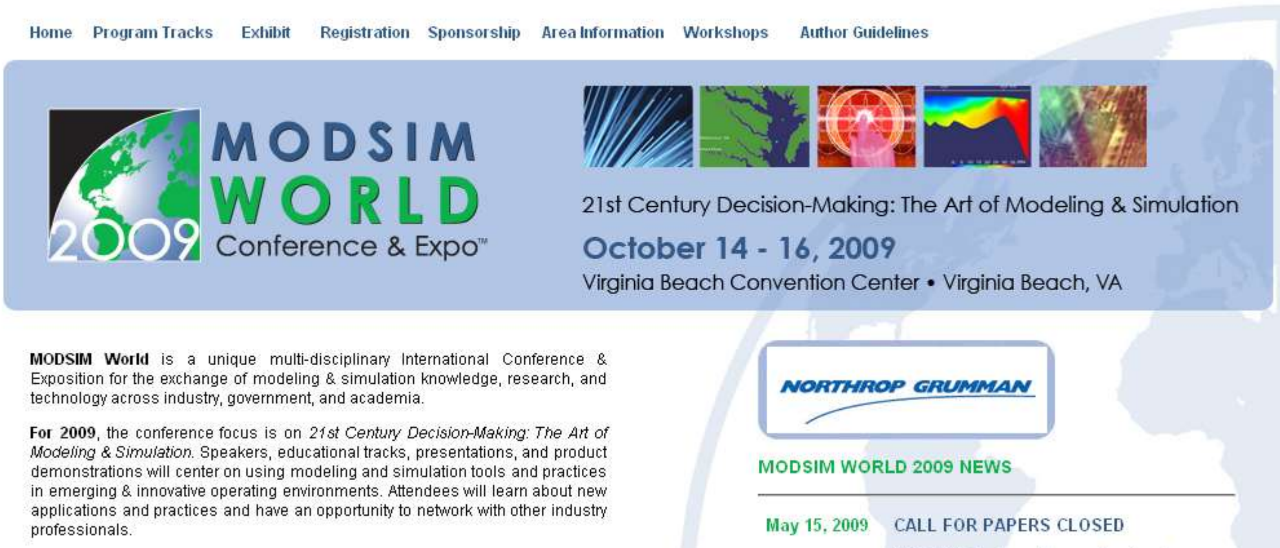

Figure 8. MODSIM World Conference and Exp 2009. (MODSIM, 2009)

Here is the description of the serious games track:

> Even before computers, people performed complex modeling and simulate activities – directing state-of-the-art technologies – to explore and understand complex phenomena. Over the years, computer hardware and software developments have made increasingly advanced computation covering a broader range of issues possible. *Recently, the application of game concepts, design and technologies has brought new perspectives to modeling and simulation. This track focuses on the area of "serious games" – the discipline that leverages game concepts, design and technology for modeling and simulation, training, advertisement, education and social change.* Presentations in this track will focus on exploring all dimensions of serious games including those relating to the broader MODSIM World 2009 tracks: Defense & Homeland Security, Education & Training, Engineering & Science, Health & Medicine, Transportation & Logistics, and the Human Dimension. By exploring the tools, technologies, design and implementations of serious games this track intends to challenge traditional perspectives to induce *new ideas* for how these capabilities can be applied to modern day challenges. (MODSIM, 2009)

In this paper, I put forward what I consider to be a contribution to the "new ideas" that the MODSIM serious games track talks about.

VIII. Highly Interactive Virtual Environments and Serious Games

Now that DES has been situated within serious games let's see how serious games are situated along a continuum of highly interactive virtual environments. This will set the scene for extending DES into the virtual environment and the "new idea" that I have been working up to.

Aldrich has noted a paradox in that there is an overlap between virtual worlds, games and simulations. While not synonymous they "look similar ... [and] all typically take place in three-dimensional worlds that are populated by three dimensional avatars." (Aldrich, 2009a, 2009b). Aldrich goes on to say although similar, their differences are "profound" and this is what has led him to develop a unifying 'view' that I explore below.

Aldrich argues the view that games, simulations and virtual worlds are best seen as lying along a "continuum" where they are all instances of highly interactive virtual environments (HIVEs). See Figure 1, repeated below for convenience. Like von von Wangenheim, C. and Shull, F. (2009), Aldrich posits that simulations are subsumed by games.

It is useful to see how Aldrich situates games, simulations and virtual worlds.

- All games take place in some kind of virtual world. Rules become stricter as the intricacies of games and simulations increase.
- "Simulations share key characteristics with games, including the use of a virtual world and the focus on a particular goal, but simulations use a more highly refined set of rules, challenges, and strategies to guide participants in developing particular behaviors and competencies that are highly transferable." (Aldrich, 2009b) He seems to be talking mostly about training simulators.
- "Participants often shift subtly between the various modes, moving from undirected exploration of a virtual world then to games and then to the more structured simulation as they become more comfortable in the environment." (Aldrich, 2009b).

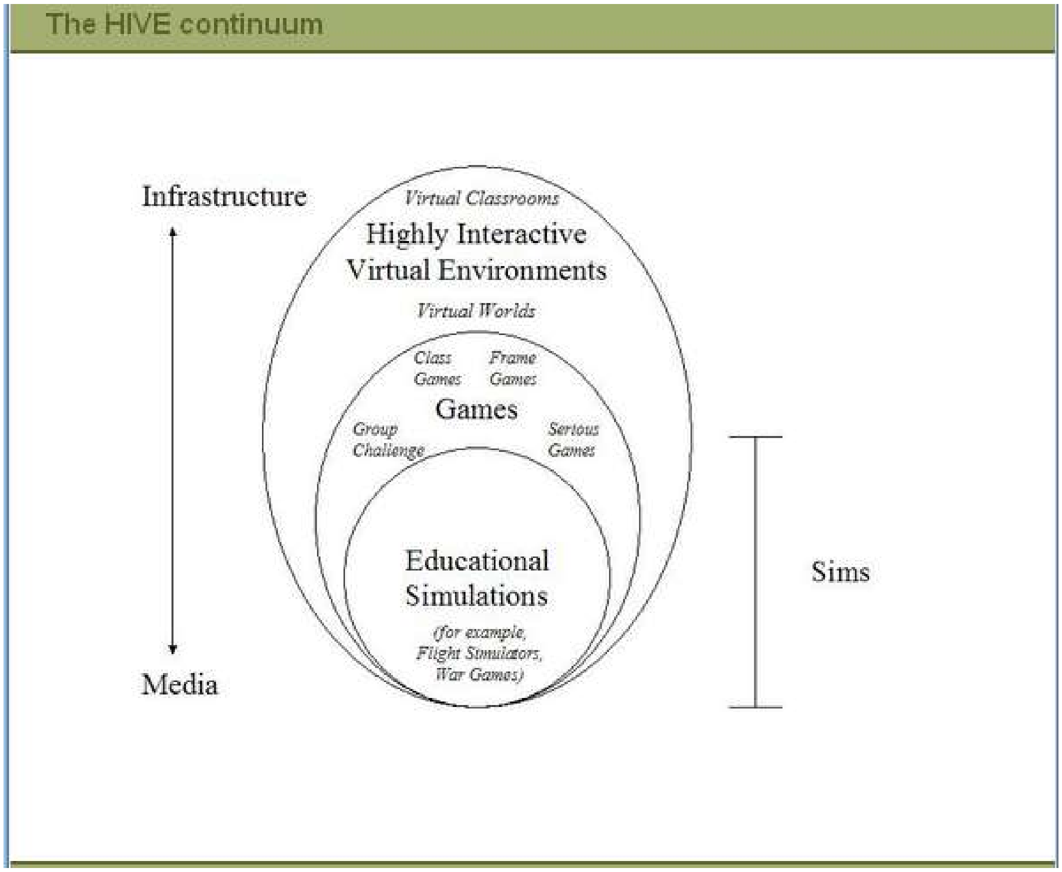

Figure 1. The HIVE continuum. (Aldrich, 2009b)

Aldrich (2009b) appears to agree with Narayanasamy (2006) about the nature of games, training simulators (aka, simulations) and serious games.

The distinctions: Aldrich (2009b) acknowledges that virtual worlds, like Second Life, offer "only context with no content …. An educational simulation may take place in a virtual world, but it must be rigorously designed and implemented." He also acknowledges that a game is not always an educational simulation in the sense of deep learning, transferable and measurable skills. Also, he rightly points out that a purely educational simulation "may not be very much fun" like games are supposed to be.

The connections: "The ease with which players in a new virtual environment move from exploratory behaviors to more structured simulation structures illustrates the connection between virtual worlds, simulations, and games." Setting up a "custom challenge" that the player must can be efficacious in moving them to a level where they will get the most from the endeavor. Building communities around the simulations and games are seen as a connection. Students get, in Aldrich's words, "to do things." In formal learning programs (i.e., school) students learn "how" to do things not just "what to know." (Aldrich, 2009b)

Aldrich suggests that classes in virtual worlds, serious games and educational simulations be conceptualized to reflect the continuum of use: “an instinctive progression from experiencing to playing to learning.” (Aldrich, 2009b) And, he suggests that incorporating community is important.

This is exactly what I am about to suggest with regard to extending traditional discrete-event computer simulation and modeling. Nearly all of the conceptual pieces are now in place.

IX. DES as a serious game situated inside an interactive virtual world

DES is primarily taught at the university level using textbooks and software user manuals. The textbooks (e.g., Harrell (2004); Altiok and Melamed (2007); Rossetti (2010)) teach simulation and modeling concepts in the context of particular computer software packages. Students learn to create models, and implement those modes using the software. Then, they run the base model simulation, collect output performance data, change the model and the software implementation, collect more output performance data. Then they compare the base model and alternative models’ output data using statistical hypothesis testing techniques to make decisions about which are the most optimal model configurations for the purposes of the experiment. The purpose could include minimal queue length and waiting time, utilization of the servers, and many other possible performance indicators.

This textbook and hands-on software method of instruction not only teaches model abstraction and the simulation software itself, but it also teaches experimental design and statistical interpretation. However, this is fairly static process. The student is not “inside” (i.e., connected to) the simulation in any meaningful way - the student is carrying out the role of engineer/scientist performing experiments and comparing results.

I use IBM’s Innov8 2.0 Business Process Management simulator to illustrate the potential I see to embed DES inside a serious game which in turn can be embedded inside a virtual world like Second Life which would in turn run in a cloud computing infrastructure. (Prunty and Prichard, 2006)

IBM’s Innov8 2.0 Call Center Simulator

Innov8 2.0 teaches and tests for various business process management techniques by simulating a work environment where the user takes on the role of an employee who has been given the choice of three different challenging scenarios: auto traffic, call center and supply chain. We will consider the call center as our working example.

IBM is correct in that simulation “can play a vital role” in supporting business process reengineering and impact such things as: business environment relate skills; business management related skills; leadership related skills; employees empowerment level; process improvement; ethical issues; stakeholder’s management skills. This is well chronicled by Alkhaldi, Olaimat, and Rashed (2008) and many others.

There are two versions of Innov8 2.0. One that can be played strictly online. (Innov8, 2009a) The other, is a downloadable client which adds a 3D Second Life-like quest game where the single-user's avatar receives a challenge from her boss and then travels through a set of corporate offices in search for information. (Innov8, 2009b) This is the first goal of the downloadable full academic edition. The rules for the user are to move the avatar through the maze of offices looking for the right people with the pertinent information about the project at hand. See Figure 9 and Figure 10.

Figure 9. Innov8 2.0 home page. (Innov8, 2009a)

Figure 10. Innov8 2.0 3D virtual world. (Innov8, 2009b)

When 3D version quest part is complete, the user sees the base model of the call center and then has the opportunity to choose between 3 alternative business process model scenarios. This is where the online version starts. See Figure 11 and Figure 12.

Figure 11. Opening page for model scenarios (Innov8, 2009a, 2009b)

Figure 12. Base call center scenario. (Innov8, 2009a, 2009b)

At this point, the user gets to choose between three alternative model configurations. See Figure 13 and Figure 14 for incorrect choices and Figure 15 for the correct choice. Note that key performance indicators (i.e., goals) appear in the upper-right in Figure 15, now that the correct choice has been made.

Figure 13. Incorrect scenario choice. Note the middle blocks. (Innov8, 2009a, 2009b)

You can see the “Apply Bus. Rules” block. But, we are not privy to these business rules at this point in time. Of course, a traditional DES would require exposure to these rules and in fact, the modeler would need to know the rules in order to create the simulation model. One of the drawbacks to Innov8 2.0 is that the logic behind certain blocks is not known to the player. Another example is the call arrival distribution. Players do not know the precise arrival rate or probability distribution shape of the incoming calls. Nor, do they know the call mix (i.e., % difficult, % average, % easy) incoming to the call center. Players also do not get to choose or set any of the key performance indicators (i.e., goals) as would be done in a traditionally constructed DES model.

Figure 14. Another incorrect scenario choice. Note the middle blocks. (Innov8, 2009a, 2009b)

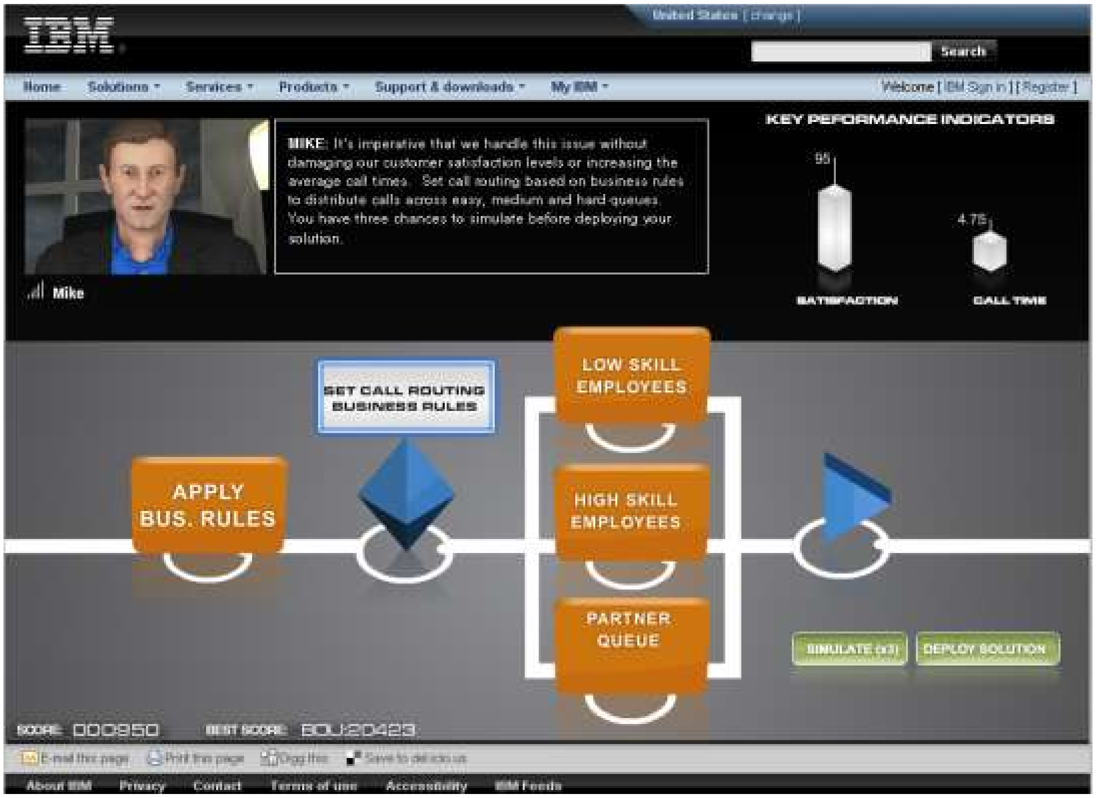

Figure 15. Correct scenario. Note the middle blocks and goal key performance indicators. (Innov8, 2009a, 2009b)

Now that the player has chosen the correct scenario, apparently without incurring a penalty for guessing, the next stage is to choose the number and right mix of employees and their skill levels by call type (i.e., difficult, average, easy). See Figure 16. Then, Figure 17 shows the deployment of the model with the selected personnel mix along with a comparison (in red) of the goal and simulated key performance indicators. A mouse-over the areas on Figure 17 would show the consequences of making the decisions, for good or for ill. This feature is not shown in the Figure 17.

Figure 16. Use slider bars to choose number and mix of employee by skill level for call type. (Innov8, 2009a, 2009b)

Figure 17. Results of model simulation and deployment. Color bars in upper right compare the simulation results with the goals. (Innov8, 2009a, 2009b)

The next part of Innov8 2.0 has to do with outsourcing. The player needs to figure out the best outsourcing scenario personnel level and mix with respect to call mix. See Figure 18. The results for the key performance indicators attained for running this simulation model are seen in Figure 19. The resulting deployment is shown in Figure 20.

There is a third stage in the Innov8 2.0 model configuration that I do not show here: link type of customer to type skill level of personnel in order to facilitate cross-selling and up-selling opportunities even while sacrificing call times. But, the idea is the same. User makes configuration and parameter level choices and runs the simulation to see how the model compares against key performance indicator goals that are set by the makers of the simulator.

Figure 18. Outsourcing (i.e., "external partner") scenario personnel mix.
(Innov8, 2009a, 2009b)

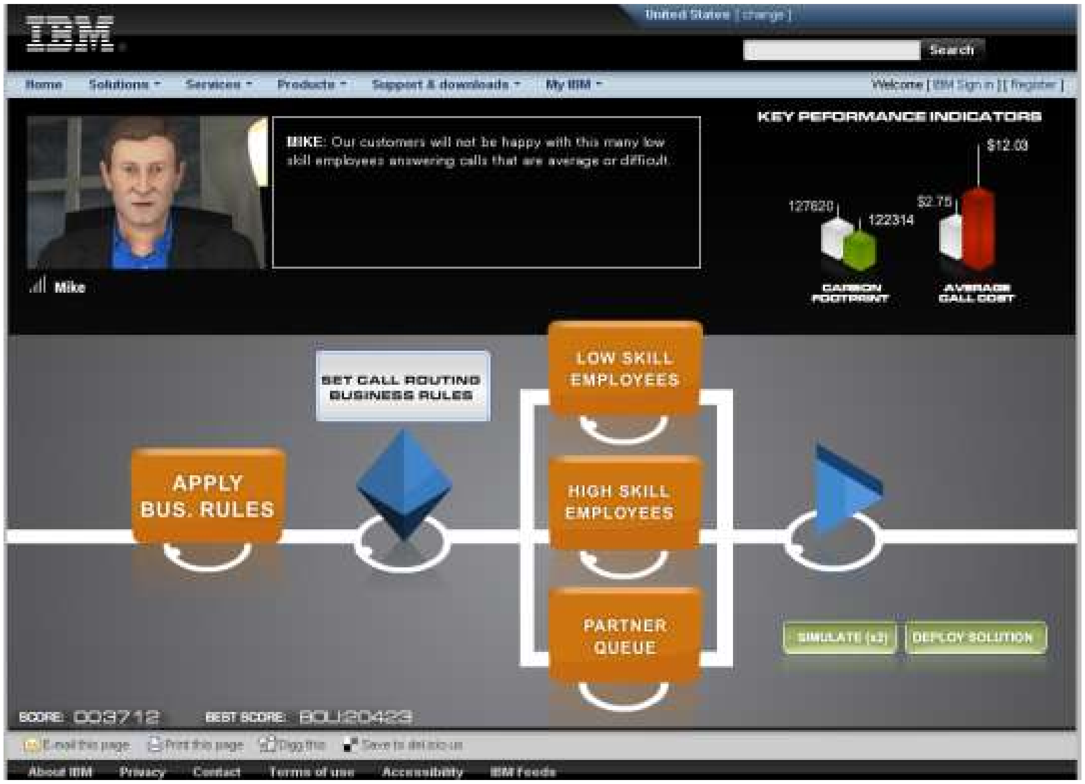

Figure 19. Simulation results for outsourcing personnel mix. See color bars.
(Innov8, 2009a, 2009b)

Figure 20. Simulation and deployment outsourcing results. (Innov8, 2009a, 2009b)

In summary, Innov8 2.0 is a simulator that exercises the user's knowledge and skills in business process management using a base model configuration for each of three different scenarios. Then, for each scenario there are three alternative configurations only one of which is deemed correct. Within each of the correct configurations, the user has the three choices to alter the model logic and then alter up to eleven parameters in order to compare the resulting key performance indicators against the indicator goals after the simulation is run.

This is a good example of scientific experimental design although somewhat restricted in the parameters and logic that the user can manipulate. Note that there are no statistical tests of significance when comparing alternative scenarios against the base or against one another. Thus a fundamental part of DES experimental design is missing in Innov8 2.0.

Altering model configurations (i.e., logic) and parameters and then running simulations of these models is exactly what DES simulation and modeling is all about. Except in the DES software, the modeler has complete control over all aspects of the model and simulation including the probability distributions for the incoming calls, service times and transmittal times. In Innov8 2.0 parameter control is only allowed for the number of personnel and their expertise mix. DES iterations and statistical tests of significance are always used to determine whether or not the changes made in alternative models really do make a difference. But, not in Innov8 2.0.

Call Center DES model via Arena

Computer simulation & modeling students typically build call center models, using DES languages, like the one you see in Figure 21. This call center model is done in the Arena simulation modeling software. Figure 22 focuses on the part of the Arena model concerning the assignment of call types to personnel. This is akin to what Innov8 2.0 does in Figures 15 and 16. Each of the Arena blocks in Figure 22 allows the user to set parameters that affect the simulation model. Figure 23 shows some of the simulation output graphically. The full set of output statistics are collected in tables and in aggregate statistics that the modeler can use to compare scenarios. In DES languages, the user sets the length of the simulation run and the number of run iterations in order to satisfy model output statistical analysis needs.

Granted, the Arena model shown is not exactly the same as the Innov8 2.0 call center model, but it shows how DES simulation software like Arena allows the user to manipulate details of the model: configuration (i.e., blocks can be rearranged and deleted or added to), block links can be changed, and parameters (i.e., the values of all blocks) can be altered. This kind of flexibility is not built into Innov8 2.0, but it perhaps could be in a future version, like the one I will soon propose.

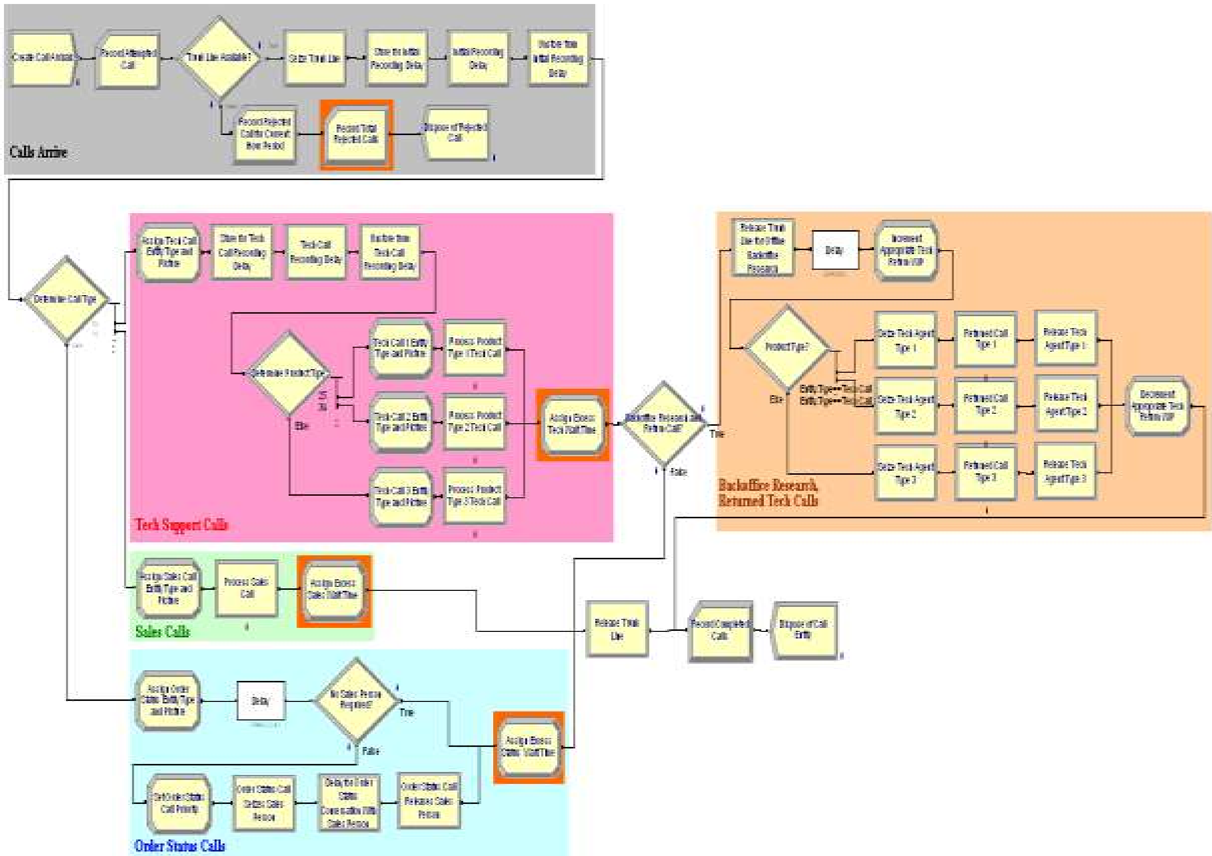

Figure 21. Arena call center model. (Kelton, Sadowski and Sturrock, 2007)

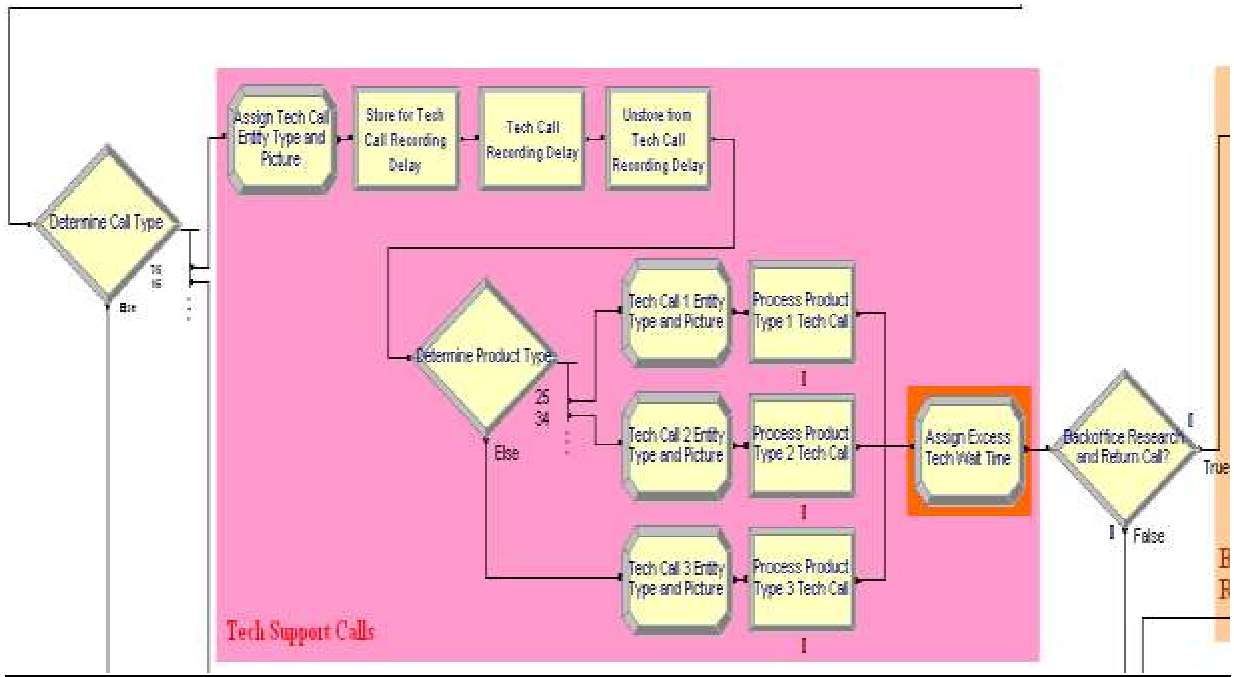

Figure 22. Arena call center model with focus on assigning calls to personnel. (Kelton, Sadowski and Sturrock, 2007)

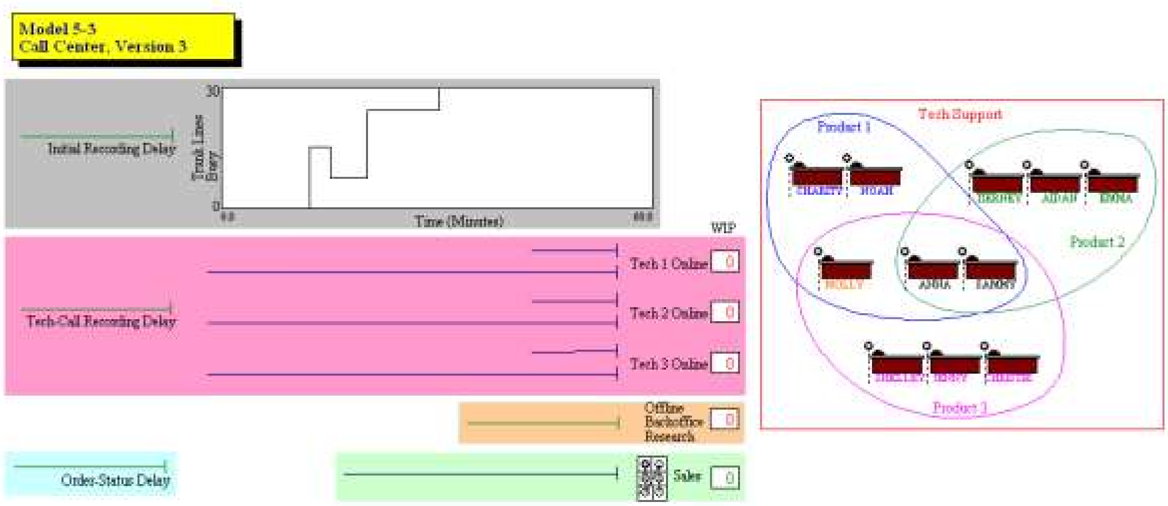

Figure 23. Arena call center model – graphical output. (Kelton, Sadowski and Sturrock, 2007)

X. Proposal to situate a DES serious game inside an interactive virtual world

The idea is to construct a serious game that has all of the DES language controls of a simulation and modeling computer language built-in. This could enhance and advance computer simulation education given the research on the advantages of immersive games with respect to learning. As I have shown, DES can be considered a serious game and with the right extensions. I use Innov8 2.0 as an example of how this can be accomplished.

I propose giving an Innov8-like avatar complete control over creating and/or altering the base model and allow for changes in the model logic itself and all of its parameters. In other words, provide a user friendly simulation and modeling language, detail-oriented like Arena, where the use can build DES models and runs simulations inside a virtual world like Second Life

In addition, I propose that a modeling facility such as this be embedded in a 3D virtual world so that a game can be played cooperatively or competitively with a community of real users (via their avatars) from anywhere on the planet through the internet. Challenges could be set up so that players must advance their knowledge and skills in a particular area or context (e.g., business process management, simulation) in order to achieve certain privileges allowing them tool access for model alteration. Instead of 'correct' model configurations as in Innov8 2.0, any configuration would be possible.

Also, players would have the capability to compare the results of running the various simulations against one another by using statistical hypotheses testing - the only sure way to know whether or not the changes they made produced a statistically significant difference. Game levels could be built into the simulation which could not only provide challenges, but goals worthy of learning the context material (e.g., business process reengineering) and/or how to do actual simulation and modeling.

Gamers would be 'modding' which is a movement in gaming where the players change the existing game or create a new one out of the one they are playing. Steinkuehler and Johnson (2009) say that "modding illustrates what it means to be technically literate in the contemporary participatory sociotechnical world." (p. 53) Denning (2004) claims that "modeling" is one of the four core practices of "computational literacy." What I am proposing contributes to what Wing (2006 and 2008) calls "computational thinking" – "… using abstraction and decomposition when attacking a large complex task or a large complex system." (Wing, 2006, p. 33)

Such an extended "modded" DES virtual game would contain all of the identifying characteristics of serious games in Narayanasamy (2006) taxonomy (see Figure 7) and would subsume the identifying characteristics of simulators in Figure 3. And we have established that simulators are subsumed under simulations.

With this extended Innov8 2.0 simulator, users/players can more fully participate in the business process simulation life cycle: define modeling objectives; define model boundaries; collect data and analyze to create input distributions; develop the business process simulation model; test the model;

experiment with alternative models; analyze the output to determine best solution(s) using statistical hypothesis testing techniques; recommend business process change (if any). (Alkhaldi, Olaimat, and Rashed, 2008) They would be learning computational literacy and thinking. Such a game would make things more “realistic” and enjoyable for the student studying simulation and modeling in the context of business process re-engineering and for the business student studying business process management.

Application programming interface (API). Simulation languages like Arena have the facilities for working with Excel and Access files. Also, for example, Arena has the ability to create models and such things as fill-dialogs through Visual Basic for Applications (VBA) which is Microsoft’s macro language for applications that are built on top of Windows. Of course, an API would have to be created in order for, say, Arena programming features to be embedded in simulators like Innov8 2.0.

Cloud computing**.** Innov8 2.0 – without the 3D virtual world-like interface - runs via the internet (Innov8, 2009a) and with the 3D virtual world via downloadable client software on a computer (Innov8, 2009b). But, Innov8 2.0 might just as easily run it’s 3D version in a cloud computing environment so that the user need not download a client to her/his own game console or computer.

Cloud computing is essentially, the distribution of computer hardware and software availability in a client-server context that can take the place of local data storage and the need for client software on separate user/player computers. (Sun, 2009) See for example, GoogleDocs where word processing and spreadsheet software resides on Google’s servers so that users do not have to purchase and/or keep separate software on their own computers. Word processing and spreadsheet files can also be stored in the cloud and made available to others for collaborative purposes. (Google, 2009)

All three major cloud systems would necessarily be involved in my proposal: software-as-a-service, platform-as-a-service, and infrastructure-as-a-system. (Viega, 2009) See Figure 24.

Figure 24. Full DES language capability embedded into a virtual world simulator such as Innov8 2.0 running in a cloud computing environment with user avatars immersed in a serious game.

XI. Conclusion

I have situated serious games within the category of simulators and simulations and have shown how Narayanasamy's (2006) taxonomy applies. I have suggested that traditional discrete-event computer simulation and modeling instruction can be augmented by utilizing a collaborative and/or cooperative serious game embedded in a 3D virtual world running on a cloud computing platform where one or more students utilize avatars.

I conclude with three quotes which are apropos to the ideas I have put forth.

Here's what Dede says about immersive virtual games – like the kind I am proposing.

> Through underlying software models such as distributed simulation, a learner can be immersed in a synthetic, constructivist environment. The student acts and collaborates not as himself or herself, but behind the mask of an "avatar": a surrogate persona in the virtual world. Distributed simulation is a powerful educational delivery mechanism developed by the U.S. Department of Defense in the late 1980s. This instructional approach enhances students' ability to apply abstract knowledge by situating education in authentic, virtual contexts similar to the environments in which learners' skills will be used (Dede, 1992).

To show that something like what I propose can be done, here is a summary of a virtual science environment laboratory complex built in the virtual world Second Life. Why not a game-enhanced DES laboratory in Second Life?!

> Genome Island was created for teaching genetics to university undergraduates but also provides a public space where anyone interested in genetics can spend a few minutes, or a few hours, interacting with genetic objects—from simple experiments with peas to the organization of whole genomes. Each of the approximately four dozen activities available in the island's various areas includes background information, model objects with data sets, and suggestions for data analysis. The island also has a presentation theater, an indoor conference setting, and separate meeting spaces suitable for small group conversations. [The paper] describes some of the activities available on the island, offers advice for their use, and discusses the results of a pilot project that identified some pedagogical and technical challenges arising in this virtual setting. (Clark, 2009)

And finally, here is Media Grid's Immersive Education initiative description showing that hosting a game-based virtual reality DES in a cloud-like infrastructure may indeed be feasible.

> The Immersive Education Initiative is a nonprofit collaboration among colleges, universities, research institutes and various companies. Among its members are Boston College, Columbia University, Sun Microsystems, The Burke Institute for Innovation in Education, the Israeli Association of Grid Technologies and the New Media Consortium, itself with more than 200 members. The Initiative was founded in '07 to, in the words of its literature," define and develop open standards, best practices, platforms, and communities of support for virtual worlds and game-based learning and training systems."
>
> The initiative's parent organization, the Media Grid was founded in '03 to promote the use of a computational grid platform as a public utility for developing and delivering virtual reality and 3D simulation programs. The Media Grid was designed specifically for networked applications that produce and consume large quantities of digital media, and is currently powered by renderfarms, clusters, high-performance computer systems, computational grids and other systems. (Media Grid, 2009)

I think that it is entirely possible that the future I propose could come to pass.

==

XII. **Bibliography**

Abt, C. (1970). *Serious Games*. NY: Viking.

Aldrich, C. (2009a) *The Complete Guide to Simulations and Serious Games: How the Most Valuable Content Will be Created in the Age Beyond Gutenberg to Google*. NY: Wiley.

Aldrich, C. (2009b, June). Virtual Worlds, Simulations, and Games for Education: A Unifying View. *Innovate*, *5*(5), Retrieved August 21, 2009, from http://innovateonline.info

Alkhaldi, F. , Olaimat, M., Rashed, A., (2008). The Role of Simulation in Business, Process Reengineering. Chapter in Sheikh, A., Ajeeli, A. and Abu-Taieh, E., *Simulation and Modeling: Current Technologies and Applications*. NY: IGI Publishing.

Altiok, T. and Melamed, B. (2007). *Simulation Modeling and Analysis with Arena*. NY: Elsevier.

American Association for the Advancement of Science (2009, January 2). *Science* - Special Issue on Education & Technology, *323*, 53-93.

Arena (2009). Rockwell Automation. Retrieved August 21, 2009, from http://www.arenasimulation.com/

Barnes, T. and Encarnacao, M. (2009, March). *Computing Now* - Special issue on Serious Games. Retrieved August 21, 2009, from http://www2.computer.org/portal/web/computingnow/archive/march2009

Becker, K. and Parker, J. (2009). A Simulation Primer. In D. Gibson & Y. Baek, Digital *Simulations for Improving Education Through Artificial Teaching Environments* (pp. 1-24). NY: IGI Global Information Science Reference.

Birta, L. and Arbez, G. (2007). *Modeling and Simulation: Exploring Dynamic System Behavior*. London: Springer-Verlag.

Business Wire (2009, August 5). Florida Summer School Programs Fuse Learning with Immersive Educational Video Games. Retrieved August 21, 2009, from http://www.businesswire.com/portal/site/google/?ndmViewId=news_view&newsId=20090805005159&newsLang=en

Chartier, D. (2009). What piracy? Movie biz sees record box office in 2008. *Ars Technica*. Retrieved 2009, from http://arstechnica.com/media/news/2009/01/what-piracy-movie-biz-sees-record-box-office-in-2008.ars

Clark, M. (2009, June). Genome Island: A Virtual Science Environment in Second Life. *Innovate* - Special Issue on Virtual Worlds and Simulations. Retrieved August 21, 2009, from http://innovateonline.info

Cohen, P. (2009, April 12). At Princeton, Video Game Becomes Spectator Sport. *New York Times*, p. Sports:6.

Crawford, C. (1997). The Art of Computer Game Design. Retrieved August 21, 2009, from http://www.vancouver.wsu.edu/fac/peabody/game-book/Chapter1.html

Dede, C. (1992, May). The future of multimedia: Bridging to virtual worlds. *Educational Technology*, *32*, 5, 54-60.

Dede, C. (2009, January 2). Immersive Interfaces for Engagement and Learning. *Science* - Special Issue on Education & Technology. *323*, 66-69.

DeMarie, A. (2008, September). Innovation and Value. *Computer*, *41*(9), 92-94.

Denning, P. (2004). The field of programmers myth. *Communications of the ACM*, *47*(7), 15-20.

DiVE (2009). Duke immersive Virtual Environment. Retrieved August 21, 2009, from http://vis.duke.edu/dive.

Emes, C.E. (1997). Is Mr. Pac Man eating our children? A review of the effect of video games on children. *Canadian Journal of Psychiatry*, *42*(4), 409-414.

Ferdig, R. (2009). *Handbook of Research on Effective Electronic Gaming in Education* (Vols. I, II, III). NY: IGI Global, Information Science Reference.

Garris, R., Ahlers, R., & Driskell, J.E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming*, *33*(4), 441.

Gibson, D., and Baek, Y. (2009). *Digital Simulations for Improving Education: Learning Through Artificial Teaching Environments*. NY: IGI Global, Information Science Reference.

Google (2009). Google Docs. Retrieved August 21, 2009, from http://docs.google.com

Greenhow, C., Robelia, B., Hughes, J. (2009, May). Learning, Teaching, and Scholarship in a Digital Age. *Educational Researcher*, *38*(4), 246-259.

Hamlen, K. (2009). Relationships between Computer and Video Game Play and Creativity among Upper Elementary School Students. *Jrnl. of Educational Computing Research*, *40*(1), 1-21.

Harrell, C., Ghosh, B., and Bowden, R. (2004). *Simulation Using ProModel*. NY: McGraw Hill.

Hays, R.T. (2005). The effectiveness of instructional games: A literature review and discussion. *Storming Media*, Retrieved August 21, 2009, from http://www.stormingmedia.us/53/5391/A539144.html

Hoffmann, L. (2009 August). Learning Through Games. *Communications of the ACM*, *52*(8), 21-22.

Innov8 2.0 (2009a). Innov8: A BPM Simulator: Online version. Retrieved August 21, 2009, from http://www-01.ibm.com/software/solutions/soa/innov8/index.html

Innov8 2.0 (2009b). Innov8: A BPM Simulator: Full Academic Edition. Retrieved August 21, 2009, from http://www-01.ibm.com/software/solutions/soa/innov8/full.html

Innovate (2008, December). Special issue on Academics in Second Life. Retrieved August 21, 2009, from http://innovateonline.info

Innovate (2009, June). Special Issue on Virtual Worlds and Simulations. Retrieved August 21, 2009, from http://innovateonline.info

Interactive Australia (2009). Interactive Australia – 2009 Report. Retrieved August 21, 2009, from http://www.ieaa.com.au/research/IA9%20-%20Key%20Findings%20Summary.pdf

ITBusinessEdge (2009, August 5). Serious Games Entertain, Educate Employees. Retrieved August 21, 2009, from http://www.itbusinessedge.com/cm/community/features/articles/blog/serious-games-entertain-educate-employees/?cs=34730

Jenkins, H. (2009). Immersive Learning. *Education.au*, Retrieved August 21, 2009, from http://www.educationau.edu.au/jahia/Jahia/pid/851#goto-4670

Kankaanranta, M. and Neittaanmaki, P. (2009). *Design and Use of Serious Games*. NY: Springer Science & Business.

Ke, F. (2009). A Qualitative Meta-Analysis of Computer Games as Learning Tools. In R. Ferdig, *Handbook of Research on Effective Electronic Gaming in Education (Vol. I).* NY: IGI Global, Information Science Reference

Kelton, W., Sadowski, R. and Sturrock, D. (2007). Simulation with Arena 4/e. NY: McGraw Hill.

Kim, J. Allen, J, and Lee, E. (2008, February). Alternative Reality Gaming. *Communications of the ACM*, *51*(2), 36-42.

Kim, R. (2009, January 16). Video game announces record revenue. *San Francisco Chronicle*. Retrieved August 21, 2009, from http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2009/01/15/BU7L15BAEJ.DTL&type=tech.

Kumar, S., Chhugani, J., Kim, C., Kim, D., Nguyen, A., Dubey, Bienia, C., Kim, Y. (2008, September). Second Life and the New Generation of Virtual Worlds. *Computer*, *4*(9), 46-53.

LeBlanc, M. (2000). Formal Design Tools – Emergent Complexity & Emergent Narrative. *Proceedings of the Game Developer's Conference San Jose, CA, 2000*.

Media Grid (2009). Immersive Education Platforms. Retrieved August 21, 2009, from http://www.mediagrid.org/

MODSIM (2009). MODSIM World Conference and Exp 2009. Retrieved August 21, 2009, from http://www.modsimworld2009.com/index.html

MSU (2009). Michigan State University Degree in Serious Game Design. Retrieved August 21, 2009, from http://seriousgames.msu.edu/

Narayanasamy, V., Wong, K., Fung, C., Rai, S. (2006, April). Distinguishing Games and Simulation Games from Simulators. *ACM - Computers in Entertainment*, *4*(2).

O'Shea, P., Mitchell, R., Johnston, C., Dede, C. (2009, January). Lessons Learned about Designing Augmented Realities. *International Journal of Gaming and Computer-Mediated Simulations*, 1(1), 1-15.

O'Sullivan, C. and Badler, N. (Aug. 2009). Building, Populating, and Interacting with Virtual Worlds. Retrieved August 21, 2009, from http://www2.computer.org/portal/web/computingnow/archive/august2009

Pew (2008). Adults and Video Games. Pew Internet and American Life Project. Retrieved August 21, 2009, from http://www.pewinternet.org/Reports/2008/Adults-and-Video-Games.aspx?r=1

ProModel (2009). ProModel Corporation. Retrieved August 21, 2009, from http://www.promodel.com/

Prunty, M. and Pritchard, A. (2006). The Customer Focused Contact Center: A Companion Paper to IBM's Advocacy in the Customer Focused Enterprise Paper. In *IBM Global Business Services White Paper - Innov8: A BPM Simulator*. Retrieved August 21, 2009, from http://www-01.ibm.com/software/solutions/soa/innov8/index.html

Randel, J.M., Morris, B., Wetzel, C., & Whitehill, B. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation & Gaming, 23*(3), 261.

Ritterfeld, U.   Cody, M., Vorderer, P., (2009). *Serious Games: Mechanisms and Effects*. NY: Routledge.

Rossetti, M. (2010). Simulation Modeling and Arena. NY: Wiley.

Sauvé, L., Renaud, L., Kaufman, D., & Marquis, J. S. (2007). Distinguishing between games and simulations: A systematic review. *Educational Technology & Society*, *10*(3), 247-256.

Seidman, Funk, Isaak & Lewis (2009). *Fluency with Alice*. Boston: Pearson-Addison Wesley. Retrieved August 21, 2009, from http://media.pearsoncmg.com/aw/aw_snyder_fluency_3/alice/index.html.

Seidman, R. (2009a). Alice via Interactive Game Programming. *The 2009 Duke University Alice Symposium – June 17, 2009*.

Seidman, R. (2009b). Alice First: 3D Interactive Game Programming. *Proceedings of the 2009 ACM-SIGCSE Annual Conference on Innovation & Technology in Computer Science Education*. Paris: Universite Pierre et Marie Curie.

Simio (2009). Simio Corporation. Retrieved August 21, 2009, from http://simio.biz/

SIMS (2009). The SIMS Official Site. Retrieved August 21, 2009, from http://thesims.ea.com/

Snyder, L. (2008). Fluency with Information Technology: Skills, Concepts, & Capabilities 3/e. Boston: Pearson-Addison Wesley.

Sontag, M. (2009, April). A Learning Theory for 21st-Century Students. *Innovate*, *5*(4), Retrieved August 21, 2009, from http://innovateonline.info

Spiegelman, M. and Glass, R. (2009) Games and Web 2.0: A Winning Combination for Millennials. *Jrnl. of Educational Technology Systems*. *37*(3), 273-289.

Stella (2009). Stella Education and Research. Retrieved August 21, 2009, from http://www.iseesystems.com

Steinkuehler, C. and Johnson, B. (2009, January). Computational literacy in online games: The social life of mods. *International Journal of Gaming and Computer-Mediated Simulations*, 1(1), 53-65.

Sun (2009). Cloud Computing Primer. Sun Microsystems. Retrieved August 21, 2009, from http://www.scribd.com/doc/18179414/Cloud-Computing-Primer.

Van Lent, M. (2008, August). The Future is Virtually Here. *Computer*, *41*(8), 87-89.

Viega, J. (2009, August). Cloud Computing and the Common Man. *Computer*. *42*(8). 106-108.

Vogel, J.F., Vogel, D.S., Cannon-Bowers, J., Bowers, C.A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, *34*(3), 229-243.

von Wangenheim, C. and Shull, F. (2009, March). To Game or Not to Game? *IEEE Software*, 26(2), 92-94.

Wing, J. (2006). Computational Thinking. *Communications of the ACM*. *49*(3), 33-35.

Wing, J. (2008, July). Computational Thinking and Thinking about Computing. *Philosophical Transactions of the Royal Society*, *366*, 3717-3725

Winter Simulation Conference (2009). Retrieved August 21, 2009, from http://wintersim.org/program.htm

Wolfe, J. (1997). The effectiveness of business games in strategic management course work. *Simulation & Gaming*, *28*(4), 360-376.

Zyda, M. (2005, September). From Visual Simulation to Virtual Reality to Games, *Computer*, 38(9), 25-32.

Zyda, M. (2007, July). Creating a Science of Games. *Communications of the ACM*, *50*(7), 36-42.

Zyda, M., Spraragen, M., Ranganathan, B. (2009, April). Testing Behavioral Models with an Online Game. *Computer*, *42*(4), 103-105.