Loh, C. S., Anantachai, A., Byun, J., & Lenox, J. (2007). *Assessing what players learned in serious games:* In situ *data collection, information trails, and quantitative analysis.* In proceedings of the 10th International Conference for Computer Games: AI, Animation, Mobile, Educational & Serious Games (CGAMES 2007), Louisville, KY.

ASSESSING WHAT PLAYERS LEARNED IN SERIOUS GAMES: *IN SITU* DATA COLLECTION, INFORMATION TRAILS, AND QUANTITATIVE ANALYSIS

Christian Sebastian Loh, Arnond Anantachai, JaeHwan Byun, and Joe Lenox

Curriculum & Instruction
625 Wham Drive, Mailcode 4610
Southern Illinois University Carbondale
Carbondale, IL 62901-4610, U.S.A.
E-mail: csloh@siu.edu

KEYWORDS

Serious Games, Assessment, Learning, Quantitative Analysis

ABSTRACT

What do students really learn as they play videogames for learning? Are they learning the content presented to them, or merely how to *play the game*? Educators want serious games that "*inform, monitor, assess* and *appraise*" students throughout the games and scientific evidence verifying the process. Likewise, policy-makers often require rigorous, large-scale empirical studies to help them determine if new technology, such as the serious games, could be effective in practice.

In addition, because of the fact that it is not easy to conduct large-scale random-assignment experiments in education, social researchers have learned to rely on inquiry methods based on quasi-experimental and qualitative methodologies. However, now may be the time for researchers to re-examine quantitative inquiry in serious games research. Massive amounts of data are constantly generated during game play by the game engines. These data can be collected and be used for quantitative analysis purposes.

This paper presents the rationale for quantitative analysis in games, as well as a method to collect *in situ* game data for that purpose, using a new design framework known as "Information Trails." This approach made use of gamers' actions within the game as the basis for assessment of their learning.

INTRODUCTION

School teachers do much more than presenting content materials to students when they *teach* (i.e. inform). They must also ensure that students understand the material presented to them (i.e. monitor), and are able to recall the information in times of need (i.e. assess). At the end of an academic year, teachers are also expected to provide a professional opinion about their students' standings in the class (i.e. appraise).

Outside of schools, the same – "*inform, monitor, assess* and *appraise*" – process is also used by managers in daily work. For example, a manager decides to try out a new software program for his sales team and arranges for a trial period with the software company. He makes sure that the sales team receives sufficient training in using the software (inform). Having observed how the sales team interacts with the program (monitor) during the trial period, he also asks for feedback from his team on the strengths and weaknesses of the software (assess). Finally, along with sales figures and other business indicators, the manager makes the final decision to adopt or reject the software (appraise). In many way, a teacher takes on the role of a "manager" in the classroom (Sasson 2007). Likewise, a manager is sometimes referred to as the "teacher" of his/her workplace (Communicare 1996).

As the traditional function of education broadens into lifelong continuing education, the role of a teacher also expands beyond the confines of a school building. In a workforce training environment, such as the military, business and healthcare sectors, a "teacher" can be a senior surgeon, a subject matter expert (SME), or a drill sergeant. From a recreational and personal development viewpoint, a "teacher" may come in the guise of dance instructor, personal tutor, museum curator, mountaineering guide, or Little League coach. Finally, in the age of computer technology and Internet connectivity, a "teacher" can be a computer program, a series of video lectures, a Website, a virtual "talking head," and even a video game (Aldrich 2004; Barab et al. 2005; Bergeron 2006; Kirriemuir and McFarlane 2003).

No matter the environment, a competent "teacher," real or virtual, must be able to execute the tasks of "*inform*, *monitor*, *assess*, and *appraise*," enable the students to seek new knowledge, and discover their shortcomings. From that point on, it is up to the learners to decide if they are willing to invest the time and effort in correcting and improving themselves.

SERIOUS GAMES

When considering videogames for serious, educational use (Feller 2006; Prensky 2001; Malone 1980); one needs to examine how well the tasks of "*inform*, *monitor*, *assess*, and *appraise*" are carried as an educational process. Interestingly, well-designed videogames have been found to contain sound learning principles (Aldrich 2004, 2005; Gee 2003). Such videogames often contained comprehensive lesson in the form of "tutorial levels" to *teach* first-time players how to control and navigate in the game. An analysis of these tutorial levels will reveal the same "*inform*, *monitor*, *assess*, and *appraise*" approach that were described in earlier sections.

For example, players are first *informed* of the play-button combination (or "combo") to execute certain move. The game then presents an obstacle that requires the pressing of the combo and *monitors* the controller-buttons for the required inputs. Once the game *assesses* that a combo has been correctly entered (presumably) by the player, the obstacle to the next, often more complex, area is removed. The player has been *appraised* to be ready for the next challenge in the game.

More than a hundred colleges have already begun to offer videogame design courses in their programs (Hill 2005; Associated Press 2005). Perhaps this is due to the fact that many early-adopters who believe in the potentials of videogames for education are researchers and college professors (e.g., Abt 1970; Ellington 1981; Gee 2003; Kafai 2001; Malone 1980).

One may expect to find a similar level of enthusiasm from the public schools. However, apart from the adoption of "Dance Dance Revolution" (DDR)[1] by several states in the U.S. to combat obesity among school children (Kim 2006), there are yet to be any large scale adoptions of serious games in the public schools. Somehow, the rising tide of serious games has been reduced to a mere trickle when it reaches the school's compound.

Problems Faced by Teachers

Obviously, well-designed tutorial levels alone are not sufficient for commercial off-the-shelves (COTS) videogames to become considered immediately useful for education. Videogames need to be transformed into "serious games" (Abt 1970) created for the primary purpose to "educate, train, and inform" the players (Michael and Chen 2006). The term *Serious Games* is also useful to distinguish the videogames developed, or adapted, for "serious play" (Rieber 1996; Rieber, Smith, and Noah 1998) from the rest of the games that are designed for entertainment. Apart from education, several industries, including the military, business, healthcare sectors and emergency response training (Bergeron 2006; Javid 2004; Michael and Chen 2006) have expressed great interests in this promising technology.

However, school teachers are not ready to make the leap based on heightened interests. They are asking for *verifiable evidence* that serious games actually work as claimed before allowing the technology into their classrooms (see Kirriemuir and McFarlane 2004; Michael and Chen 2006; Sandford and Williamson 2005). One problem faced by many teachers at the moment is the public perception of videogame as a form of "entertainment" technology. Educators who are interested in using serious games are worried about opposition from skeptical parents and teachers. Voluminous reports on the potentially detrimental effects of violent games on youths (Anderson 2003, 2004; Gentile and Gentile 2005; Ivory 2004; McIntyre 2004) also colored public perceptions and slowed down the process of technology adoption.

In the case where COTS games are being used in a classroom setting, one would hardly expect a game created for entertainment and profit making to line up with the classroom curriculum. For example, although the game Civilization has received high praises for serious play, it contains extraneous information that take up precious class time. So the issue becomes finding the right time and place to integrate or retrofit a COTS game into the curriculum.

In the case of serious games, educators want to see research findings with empirical data verifying that serious games really do "*inform*, *monitor*, *assess* and *appraise*" students throughout the games (and not just at the tutorial levels). Teachers also want another nagging question answered, "Did the students learn the content presented or merely how to beat the game?" (Kirriemuir 2005)

Furthermore, because "games are costly, and are therefore politically and fiscally difficult to justify" (Kirriemuir and McFarlane 2003), school administrators are likely to put off any commitment to an "unverified" technology lest they be asked to provide an account for wasting tax payers' money.

Problems Faced by Researchers

Gamers are not the only ones who find videogames to be highly complex and challenging. Researchers of serious games are equally perplexed by the rich virtual environment presented in game worlds. "What do students really learn as they play videogames for learning?" This question can only be answered through extensive research.

"Large-scale random-assignment experiments in education are few and far between" (Means, Haertel, and Moses 2003)

[1] a "dance game" by Konami

as education researchers became more entrenched in social inquiry methods based on quasi-experimental and qualitative methodologies. But now may be a good time for researchers to re-examine quantitative inquiry for research in serious games. Massive amount of data are being generated continuously during game play by the game engines, and these discreet and quantifiable data are highly suitable for statistical analysis.

Advances in camcorder technology and its ability to capture both audio and video data in highly compressed formats have made video camcorders a boon (and sometimes, a curse) to many researchers. Often, digital camcorders are used indiscriminately to record long sessions of interviews, *think-aloud* protocols, eye-fixations, screen captures, and videogame play as a means to collect "rich data." (Other data collected may include chat logs, server logs, written reflections, diaries, and other documents.)

Although video-recording is entirely appropriate for capturing rich data, the entire process from *data collection* to *data analysis* can be extremely time consuming. Not only must researchers spend long hours filming the *data collection* process (e.g. interview, game play), they must painstakingly transfer, store, tag, code, and transcribe every minute of the video footages into a usable format, before the *data analysis* process can begin. When every additional participant adds even more to the amount of data collected, it is no wonder that qualitative researchers tend to work with small groups, with frequent reports of case studies.

While case studies and small group reports are rich in details about the participants' experience, they are decidedly less useful to administrators and policy-makers, who rely on generalizable findings and statistical powers from quantitative research to formulate guidelines and policy for technology adoption, as in the case of serious games. Trochim (2006) provided a rather succinct observation, "much qualitative research takes an enormous amount of time, is very labor intensive, and yields results that may not be as generalizable for policy-making or decision-making…"

SCIENTIFIC RESEARCH

On the other hand, quantitative research tends to yield generalizable finding, and as such the implications can be reasonably applied across industries, and is therefore valuable to managers and decision-makers in both educational and non-educational sectors, including the military, business, and healthcare training sectors.

Medical Research in Serious Games

Thus far, scientific research reports have only just begun to surface, with many of them coming from the medical research community. They are largely positive, citing examples such as improved accuracy in surgery (Marriott 2005; Rosser, Jr. et al. 2004), improved spatial resolution of vision (Green and Bavelier 2007), body weight reduction in obese patients (Kreimer 2004), and rehabilitation of stroke victims (You et al. 2005). A review of these reports showed quantitative analysis to be the main thrust of the inquiry method, possibly because medical researchers were able to easily procure empirical data (such as patients' blood work, biochemical profiles, cerebral images, and other clinical tests) through bioassays that called for expensive equipment not available to other industries.

Unfortunately, such "bioassay" methods are not available to educators and social researchers. Even if, for example, brain scan images of students were obtained, it is unlikely that an image showing heightened activities in cerebral cortex would be any more informative to a brain surgeon than a teacher, as to what the student is actually learning. Social researchers and educators who wish to see serious games adopted in schools, must somehow find a way to collect large amount of data for analysis (in order to obtain statistical powers). They must, further, do so without the luxury of specialized equipment that may have been a given to some other research community.

Generalizable findings from quantitative research have allowed the knowledge from one industry sector to be applied to another, so researchers can build on one another's work with some level of confidence. This alone should be motivation enough for the serious games industry to strive towards more quantitative research work.

INFORMATION TRAILS[2]

Information Trails (Loh 2006, 2007) is a new design framework for serious games. When embedded in a serious game, the framework enabled discreet, *in situ* data to be stored and transformed into observable game-play actions for quantitative analysis.

During game play, players must make constant decisions to perform certain actions in overcoming the challenges thrown at them by the game (designers). For example, if going down a particular path means certain death by a high-level boss, players may make a detour to avoid fighting the boss for now; only to return for the challenge after they have leveled-up. When paths and actions taken by players are collected during game play and used to appraise gamers' decision, this process can serve as the basis for assessment of learning in serious games. Researchers may finally get a glimpse at *what goes on in the mind of gamers as they are playing games* through the players' actions and choices.

Theoretical Framework

At its core, *Information Trails* is all about path finding and virtual detective work (Loh 2007). Conceptually, "information trails" is a series of agent-detectable *markings*

[2] The project has been awarded a competitive Seed Grant for the initial development of a prototype application.

left by another *moving agent* within an information ecology. Operationally, it is the long track of information markings left behind by players' avatars as they traverse the virtual game environment. An example is presented in the movie, *The Lord of the Ring: Two Towers* (Jackson 2002), in which *trails* on the ground at the edge of Fangorn Forest led Aragorn to deduce the means for Merry and Pippin to escape the massacre.

From the perspective of videogame design and programming, it is not difficult to track players' actions. Examples of these *actions* include: who the members of the team are, what items to bring, when to attack, where to rest, etc. Based on the assumption that players' actions can be tracked, researchers should be able to answer WHAT mission objectives in the game had been met and HOW they were accomplished, simply by analyzing the WHO, WHAT, WHEN, and WHERE in the game.

Although this would leave the WHY unanswered; for that matter, even the players themselves may not always be able to explain "why they did what they did" – because the answer may be reflexive responses gained from years of playing twitch games (Jones 1997), or intuitive actions performed at the spur of a moment. On the other hand, if the actions are indeed premeditated, the WHYs can be easily answered by the players, as in an interview.

Mathematics educators should find this approach of Information Trails to be familiar, because in advanced mathematics, the *working* (process used to arrive at the answer) is often regarded to be just important as the *answer* itself. Points are often awarded for correct working, even when the answer is wrong. In the same way, Information Trails reveals the *process* of players' thoughts that resulted in their *actions*.

What to Capture

From the perspective of network management, each playable "world" within a Massive Multiplayer Online Game (MMOG) is just a high-end database server connected to a high speed Internet backbone. Once players login to a game world, the database server will track their whereabouts in the game while alerting the local client to simultaneously generate the appropriate environment to match up with the game storyline. Information managed by these database servers may include system-wide information, such as IP addresses, user IDs, passwords, login and logout time (i.e. the coming and going) of players, the passage of time in the game, the weather system, the physical laws of the game world, what each player did in the game world, etc. The server must also keep track of players' information: for example, amount of gold collected, armors, quest items, weapons, missions accomplished, number of trolls defeated, etc.

Bearing in mind that an online game must deal with so much data, game programmers often *optimize* their programs by sending only essential variables and data across the network, and discarding the unimportant ones. This is a common practice within the networking and gaming community to reduce processor load, cut down network lag, and speed up game play. However, one man's trash may be another's treasure; and some of the discarded variables may be of value to educators and researchers doing serious games research. Even in the case when the variables are not discarded, they are often considered proprietary and are locked away or encrypted along with players' account information, or other sensitive data. Hence, researchers still would not gain access to these in-game data because there is just no easy (and legal) way to retrieve them.

Therefore, it would do well for game companies interested in producing serious games to consider incorporating *Information Trails* into the game engine, to enable the tracking of such variables for later analysis. Serious game designers should collaborate with educators and researchers, to discuss the infrastructure for *Information trails* and the types of variables of interest to them before starting work on the storyline or level design.

This may not be as easy as it sounds because game programmers will then need to find new ways to shunt these variables effectively to external data storage without slowing down the connection or incurring additional load to the processor. On the other hand, this issue may be moot as database servers become more efficient, and the processors technology advances to multi-core architecture.

The issue at hand, however, is finding a game that will allow some prototype work to be done without having to create a brand new game engine; while knowing that game companies have no good reason to make these data/variables available to the research community.

PROTOTYPING INFORMATION TRAILS

The aim of the research project reported here was to develop a prototype model to verify the usefulness of *Information Trails* and that the design framework indeed works as proposed. It was decided that the prototype should be able to perform some, or all, of the following:

(1) To track players' actions in a game environment,
(2) To determine the appropriate nodes (places) for placement of the tracking triggers, and
(3) To provide a visualization of the data collected in a human-understandable format.

While a new game engine embedded with the framework of *Information Trails* would allow for maximum control, writing a new game engine is beyond the expertise of the development team (which consisted of college students). A survey of available open source and COTS games engine showed several promising alternatives. It was finally decided that *Neverwinter Nights* (by BioWare, Corp.) would best fit our current needs.

Neverwinter Nights

Since its release in 2002, *Neverwinter Nights* (NWN) has received many accolades and high praises from the computer gamers' community. More importantly, BioWare decided to release the graphical game development toolkit (GDK), known as the Aurora Toolkit, to the gamers' community for the purpose of after-sale content creation, or *modding*[3]. Several researchers have also found the toolkit to be versatile enough for serious research (e.g., Carbonaro et al. 2005; Gorniak and Roy 2005; Robertson and Good 2005). Nonetheless, the Aurora Toolkit by itself is only sufficient for developing new contents in the form of playable game modules. In order to "view" the data and variables within NWN as the game is in-progress and to retrieve them for external storage, a third-party "data viewer" like the *Neverwinter Nights eXtender* (NWNX) is needed.

The programmer of NWNX, Ingmar Stieger (Papillon), describes his software as follows: "NWNX attaches itself to certain scripting functions and is able to manipulate their results. Thus, it creates a well defined interface between the closed NWN world and countless external systems, which can be used to do things like accessing SQL database servers, use other programming languages, connect to web services, and many others." The NWNX allowed gamers to create a persistent world with NWN by storing the necessary player variables externally using a database (e.g. MySQL/SQLite). An NWN persistent world server is not an MMOG-class server because the former can only support 72 players at any one time, while an MMOG server can support thousands. In this project, NWNX was used primarily to facilitate retrieval of game variables from customized NWN-Information Trails modules to a MySQL database.

Data Collection

We, the project team, began the journey by learning to mod NWN, and to perform basic queries in NWN through function calls provided by NWNX. After accomplishing simple tasks such as time-stamping and entry/exit logging, we moved on to track other players' actions, including:

(1) items received and lost by players,
(2) items equipped and unequipped,
(3) item activated (e.g. a wand),
(4) path traversed by players in the game world.

We ended up making several playable, *Information Trails* enabled modules, which we used extensively for play-testing, mock-up, data collection, and testing. Having learned what traceable events were supported in NWN (Figure 1), we discovered some functions that are not compatible with Information Trails.

The following are two examples that illustrate why Information Trails needs to be integrated at the design/ storyline level, and not be retrofitted as an afterthought.

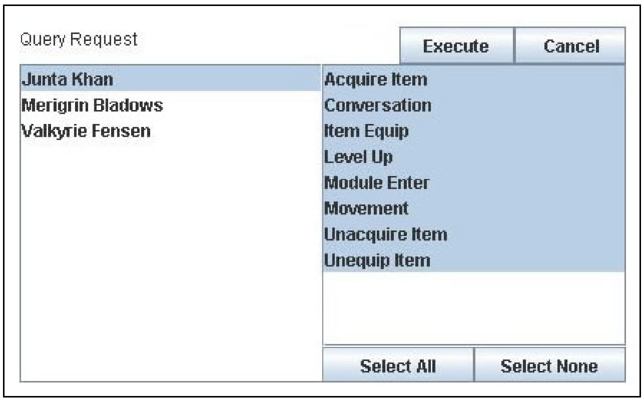

Figure 1: Category of Player's Actions in the Game

Example #1: There are only two functions for tracking items in NWN: *item_gained* and *item_lost*. This mean there is no telling how items are added or removed from the player character's inventory. For example, when player "gained" a bottle of health potion, it could have been:

(a) picked up from a treasure chest,
(b) bought from a merchant,
(c) stolen from a non-player character,
(d) looted from a body,
(e) made by combining items in the player's inventory,
(f) created by a special spell, or
(g) given to the player by a non-player character or another player in a persistent world.

Conceivably, the game programmers may have chosen to create just one function, *item_gained*, to represent all these above actions (a-g) because they are merely semantic differences as far as the NWN "program" is concerned. However, these differences may be important information in an assessment report!

Example #2: There is no way to track conversation in NWN because the conversation tree structure does not use any variables. So, until other alternatives are found, it is not possible for the prototype to track conversation threads between player characters and non-player characters.

Nevertheless, we still wish to commend the programmers of NWN and NWNX because the two programs worked amazingly well together! Pappilon is currently putting the final touches on the next version of NWNX, which extends the function of NWN2.

In time, we hope to be able to tell apart the different kinds of actions performed and identify the placement of *nodes.* Nodes are areas where players must make a choice from several available alternatives (e.g. a fork of the road with three different paths leading east, west, and north).

[3] From "*mod*ifying" – see Morris (2004) for background.

REPORTING

Readers need to bear in mind that, up till this point, all of the data captured is still of no value to teachers, trainers, and developers of serious games. In order for the information captured and analyzed to be useful to them, we need to translate the stored information into a more humanly understandable format. In other words, we need to help educators and trainers visualize the data or information.

Simple Map

Figure 2 below shows the result of a game module with three playable areas: Fern, Fernesk Mine, and an Inn. The left is a text-based panel showing the sequence of "visits" (travels) from area to area made by the player as the game progresses. In the example above, the sequence is:

> Fern » Mine » Fern » Inn » Fern » Mine » Fern » Mine » Fern (there is no telling if the player have completed the game at this point)

The right panel is a viewer displaying the path travelled by the player when s/he visited Fernesk Mine for the first time.

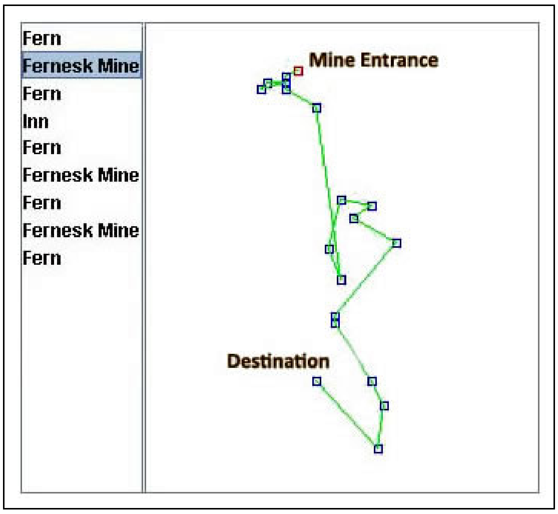

Figure 2: Path Traversed (Fernesk Mine: First Visit)

The path was drawn using coordinates provided by NWN, and is therefore, to scale. The very first box is red in color, indicating it is the "Starting Point" of the area. The rest of the blue boxes are snapshots of the player's position taken every few seconds ("Action-Markers"). The green line is merely a *connector* line joining one marker to the next one (chronologically) and by no means indicates the player travelled in a "straight" line. However, the minimalistic box-and-line drawing failed to show any side caves, or obstacles found in the mine that may have contributed to the path being chosen in this manner.

Detailed Map

In our next attempt, we tried to incorporate some "rich" data into the path viewer. In this scenario, player must find a hidden master key to open the final door and escape the maze.

Figure 3 showed the map of the "5 x 5" maze as seen in the game using the *map* function. The blue boxes represent doors, while player's position is represented by a golden triangle (top-left corner box).

Figure 3: The Maze (Viewed Using Map Function in NWN)

Figure 4 shows a much nicer "bird's-eye view" of the Maze when viewed within the Aurora Toolset. This highly detailed "map" not only revealed more details in full color; it also displayed magical effects in the area. For example, in the center of the maze is a crystal ball that was bathed in an eerie pink glow, and the teleportation portal (START) was swirling in white light.

Figure 4: Bird-eye View of Maze using "Aurora" Toolset

When used in conjunction with "path traversed," a highly detailed "map" could provide readers of the report with more (too much?) visual cues, and therefore, a greater appreciation for the players' actions.

We have also incorporated *MouseOvers* in our prototype in order to reveal even more details about player's actions (Figure 5). When a *MouseOver* was performed over an

Action Marker, additional information about the time and action performed was revealed. In the example given here, we now know the exact location (WHERE) of the master key, and the time (WHEN) it was acquired [2007-01-22 03:02:05 hr]. (We should not be surprised to find players trying to find the master key at 3:02:05AM, should we?)

Figure 5: "Mouse Over" The White Markers Will Reveal More Details About Player' Actions

Interactive Reports

So far, we have demonstrated screen captures of "map," simple box-and-line plot of "path traversed," and Action Markers, can be used to piece together what actions and paths a player has taken when playing games, and to present it as a simple "reports" for the trainers, or educators.

An even more interesting and revealing report than the one shown in Figure 5 is an animated, *time-lapsed* report. Although we are not able to include the time-lapsed report in this paper (due to the confine of the printed page), an interactive Web report using animated GIF, Flash SWF, or JAVA applet would be another natural fit (we will also show it at the conference.)

FUTURE RESEARCH

From our experience, we discovered reporting to be a big component in serious game assessment that requires further research. Because serious games can be used in so many sectors, not just education, the reporting function must to be just as useful for educators, as it is for managers, policy-makers, military officers, parents, doctors, and other stakeholders. Moreover, all these reports will likely be formatted very differently from one another; hence a lot of customization may be needed.

Although game companies may employ focus-group interviews and usability testing to ascertain the best formats to present these information, we believe the gap in knowledge can only be fully addressed by emerging research in *educational data mining*, and *information visualization* (Chen 2006).

As we have explained, because *in situ* game data is derived directly from gamers' in-game actions (hence, their decisions), the massive data sets would represent snapshots for the learners' minds. Analysis of these snapshots can reveal many things about the learners, including learners' beliefs, learning behaviors, thought processes, and problem solving strategies. However, there is not enough research in this area to offer anything conclusive. As research in the field of educational data mining continues to mature, new methodologies and technologies will not only allow for a better understanding of the data, but may even reveal obscure data unobtainable through other methods of analysis.

Research in information visualization will likely offer new ways of visualizing the data. For example, it is simply not possible to represent "star maps" in massive worlds involving space travel (e.g. E.V.E. online) using 2D images. A serious game involving space exploration and colonization may be better represented using "Arcs" (Dodge 1999). A "map" of the Internet may look like a Jellyfish (Dodge 2001), but how do one even begin to think about "maps" in "fantasy" world settings, such as journey between heaven and hell, or multi-dimensional traveling?

CONCLUSIONS

Serious games is a very young discipline, and as such, much research will need to be done to advance the field. Serious game design is different from commercial videogame design in part because the former needs to take into consideration the element of assessment. At the moment, most of the research in serious games fell into three major categories (Michael and Chen 2006): assessment of learning, cost per students (i.e. rate of return), and successful examples of classroom integration of serious games.

Our journey on the *Information Trails* has revealed that it is possibly to conduct scientific research within a social research paradigm. We have been able to capture players' actions and paths taken as quantitative data points, and be able to reconstruct what players' did in the game without using a video camcorder.

We have found *Information Trails* to be a viable means to assess what players learned when playing games by analyzing their actions and paths taken in the games. Careful implementation of the information trails will allow researchers to collect massive, *in situ*, data sets for statistical analysis. The scientific finding will provide policymakers with the much needed statistical *power* for generalization and make a compelling case to serious games. Moreover, the generalizable findings can be applied across sectors, to measure performance indexes, and rate of return in personnel training.

We would like to recommend to the serious game community that *Information Trails* be integrated early at the storyline level, and that the game design process be closely monitored so that programmers understand what needs to be done to shunt appropriate data and variables for external storage and analysis. Because the approach may seem counterproductive to current trends of computer programming, extra care will need to be exercised for the time being until programmers of serious games become familiarized with the approach.

Information Trails should be implemented at the game design level for it to work well, and it should not be retrofitted only as an afterthought. It would do well for the game development team (level designer, script writer, and programmers) to sit down with the SMEs (in the broadest sense) to, *first*, work out the details about the *Information Trails* and what data to be captured along the storyline, before discussing characters and levels design. Just like there is no way to capture conversation threads, or tell apart how items are "gained" within NWN, such mistakes may be more costly to fix after the game has been released.

Linda G. Roberts, Director of Education Technology to the U.S. Department of Education, once wrote (2003), "I believed that researchers could improve the design and collection of data. Just as new technology created new opportunities for learning, it created ways to invent new tools for research and evaluation, particularly ways to track and monitor what, how, and when learning occurred" (p. viii). That's what we hope to do.

BIOGRAPHY

Chistian S. Loh (Ph.D.) is Assistant Professor of Instructional Design Technology and Coordinator for the *Collaboratory for Interactive Learning Research* (CILR) at the Southern Illinois University Carbondale.

His research interests include assessment of learning using digital games, and educational data mining. He has spent many hours working with videogames, particularly *Neverwinter Nights* 1 & 2, to create new contents for serious play and to search for new ways to integrate videogames into education, training, and classroom instruction. He teaches instructional design and the use of open source software for online content delivery and e-Learning. His personal interests include emerging technology, music, and photography. He currently serves as Communition Officer, and will be the next President-Elect (2007-8) for the Multimedia Production Division of the Association for Educational Communications and Technology. At the moment, his pet projects are the *Information Trails*, and Creative Writing Illustrated (CWILL).

The *Information Trails* project is made possible through the funding provided by the Faculty Seed Grant of SIUC; and the hardwork by the research project team members:

- Arnond Anantachai (graduate assistant/programmer),
- JaeHwan Byun (doctoral student/game modder), and
- Joe Lenox (student help/programmer).

REFERENCES

Abt, Clark C. 1970. *Serious Games*. New York: Viking Press.

Aldrich, Clark. 2004. *Simulations and the future of learning: An innovative (and perhaps revolutionary) approach to e-learning*. San Francisco, CA: Pfeiffer.

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

Anderson, Craig A. 2003. Violent video games: Myths, facts, and unanswered questions. *Psychological Science Agenda* (5), http://www.apa.org/science/psa/sb-anderson.html.

———. 2004. An update on the effects of playing violent video games. *Journal of Adolescence* 27 (1):113-122.

Associated Press. 2005. *A generation of game boys, girls*. Wired News, September 23 2005 [cited September 26 2005]. Available from http://www.wired.com/news/culture/0,1284,68964,00.html.

Barab, Sasha, Micahel Thomas, Tyler Dodge, Robert Carteaux, and Hakan Tuzun. 2005. Making learning fun: Quest Atlantis, a game without guns. *Educational Technology, Research, and Development* 53 (1):86-107.

Bergeron, Bryan. 2006. *Developing Serious Games*. Hingham, MA Charles River Mdeia, Inc.

Carbonaro, Mike, Maria Cutumisu, Matthew McNaughton, Curtis Onuczko, Thomas Roy, Jonathan Schaeffer, Duane Szafron, Stephanie Gillis, and Sabrina Kratchmer. 2005. Interactive Story Writing in the Classroom: Using Computer Games Paper read at 2nd International Digital Games Research Conference (DiGRA 2005), June 16-20, at Vancouver, Canada.

Chen, Chaomei. 2006. *Information Visualization: Beyond the Horizon*. 2nd ed. London, UK: Springer-Verlag.

Communicare. 1996. The Manager as Teacher. *Press Release*, http://www.communicare.com/files/pdf/TheManagerAsTeacher.pdf.

Dodge, Martin. 1999. Internet Arcs Around The Globe (1996). *Mappa Mundi*, August 1.

———. 2001. What Does the Internet Look Like, Jellyfish Perhaps? . *Mappa Mundi*, March 31.

Ellington, Henry. 1981. *Games & simulations in science education* New York, NY: Nichols Pub. Co.

Feller, Ben. 2006. Scientists: Video Games Can Reshape Education. *USA Today*, http://www.usatoday.com/tech/gaming/2006-10-17-gaming-education_x.htm.

Gee, James P. 2003. *What video games have to teach us about learning and literacy*. 2nd ed. New York: Palgrave Macmillan.

Gentile, Douglas A., and J. Ronald Gentile. 2005. Violent Video Games as Exemplary Teachers In *Biennial Meeting of the Society for Research in Child Development*. Atlanta, GA.

Gorniak, Peter, and Deb Roy. 2005. Speaking with your Sidekick: Understanding Situated Speech in Computer Role Playing Games. Paper read at Artificial Intelligence and Interactive Digital Entertainment, June 1-3, at Marina del Rey, CA

Green, C. S., and D. Bavelier. 2007. Action-Video-Game Experience Alters the Spatial Resolution of Vision *Psychological Science* 18 (1):88.

Hill, Michael. 2005. *More colleges offering video game courses*. USAToday, September 25 2005 [cited September 26 2005]. Available from http://www.usatoday.com/tech/products/games/2005-09-25-video-game-colleges_x.htm.

Ivory, James D. 2004. Addictive For whom? Electronic games, the third-person effect, and contributors to attitudes toward the medium. In *Annual Conference of the International Communication Association*. New Orleans, LA.

Jackson, Peter. 2002. The Lord of the Rings: The Two Towers. USA: New Line Cinema.

Javid, Christine. 2004. Video games promoted as effective health-care training. http://wistechnology.com/article.php?id=1193.

Jones, Marshall G. 1997. Learning to play; playing to learn: Lessons learned from computer games. In *Association for Educational Communications and Technology (AECT) 1997*. Albuquerque, NM.

Kafai, Yasmin. 2001. The educational potential of electronic games: from Games-To-Teach to Games-To-Learn. In *Playing by the Rules*. Chicago, IL.

Kim, Ryan. 2006. Video dance game to be used in schools: West Virginia taps Konami's system to help fight obesity. *San Francisco Chronicle*, January 25, C-1.

Kirriemuir, J., and A. McFarlane. 2004. Literature review in games and learning. Bristol, United Kingdom: FutureLab.

Kirriemuir, John. 2005. A Survey of COTS Games Used in Education. In *Serious Games Summit/Game Developers Conference*. San Francisco, CA.

Kirriemuir, John , and A. McFarlane. 2003. Use of Computer and Video Games in the Classroom. Paper read at Level Up Digital Games Research Conference, at Universiteit Utrecht, Netherlands

Kreimer, Susan. 2004. Active Video Games Help Dance Off Pounds. *DOC News Online* (2), http://intl-docnews.diabetesjournals.org/cgi/content/full/1/2/17.

Loh, Christian Sebastian. 2006. Tracking an avatar: Designing data collection into online game. Paper read at annual conference of the Association for Educational Communications and Technology (AECT 2006), at Dallas, TX.

———. 2007. Designing Online Games Assessment as "Information Trails". In *Games and Simulation in Online Learning: Research and Development Frameworks*, edited by D. Gibson, C. Aldrich and M. Prensky. Hershey, PA: Idea Group, Inc.

Malone, Thomas. 1980. What makes things fun to learn? A study of intrinsically motivating computer games. Palo Alto, TX: Xerox.

Marriott, Michel. 2005. What makes a good surgeon? Video games. *The New York Times*, February 27.

McIntyre, Jeff J. 2004. APA Congressional Testimony on Media Violence and Children. http://www.apa.org/ppo/issues/mediavioltest504.html.

Means, Barbara, Geneva D. Haertel, and Lincoln Moses. 2003. Evaluating The Effects Of Learning Technologies. In *Evaluating Educational Technology: Effective Research Designs For Improving Learning*, edited by G. D. Haertel and B. Means. New York, NY: Teachers College Press.

Michael, David, and Sande Chen. 2006. *Serious games: Games that educate, train, and inform*. Boston, MA: Thomson Course technology PTR.

Morris, Sue. 2004. Co-Creative Media: Online Multiplayer Computer Game Culture. *Scan* 1 (1).

Prensky, Marc. 2001. *Digital game-based learning*. New York: McGraw Hill.

Rieber, Lloyd P. 1996. Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology, Research, and Development* 44 (2):43-58.

Rieber, Lloyd P., Lola Smith, and David Noah. 1998. The value of serious play. *Educational Technology* 38 (6):29-37.

Roberts, Linda G. 2003. Foreword. In *Evaluating Educational Technology: Effective Research Designs for Improving Learning*, edited by G. D. Haertel and B. Means. New York, NY: Teachers College Press.

Robertson, Judy, and Judith Good. 2005. Children's narrative development through computer game authoring. *TechTrends* 49 (5):43-58.

Rosser, Jr., James C., Paul J. Lynch, Laury A. Haskamp, Asaf Yalif, Douglas A. Gentile, and Liza Giammaria. 2004. Are Video Game Players Better at Laparoscopic Surgery? In *Medicine Meets Virtual Reality Conference*. Newport Beach, CA.

Sandford, Richard, and Ben Williamson. 2005. *Games and Learning: A handbook from Futurelab*. Bristol, United Kingdom: Futurelab.

Sasson, Dorit. 2007. The Teacher as a Classroom Manager. *Suite 101*, http://classroom-organization.suite101.com/article.cfm/the_teacher_as_a_classroom_manager.

Trochim, William M. 2006. *Qualitative Measures*. 2nd ed, *The Research Methods Knowledge Base*. Cincinnati, OH: Atomic Dog Publishing.

You, Sung H., Sung Ho Jang, Yun-Hee Kim, Mark Hallett, Sang Ho Ahn, Yong-Hyun Kwon, Joong Hwi Kim, and Mi Young Lee. 2005. Virtual Reality – Induced Cortical Reorganization and Associated Locomotor Recovery in Chronic Stroke: An Experimenter-Blind Randomized Study *Stroke* 36 (6):1166-1171.