Jl. of Technology and Teacher Education (2007) **15**(1), 87-100

Assessing Higher Order Thinking in Video Games

JOHN W. RICE
University of Northern Texas
Denton, TX USA
jrice@coe.unt.edu

Computer video games have become highly interesting to educators and researchers since their sophistication has improved considerably over the last decade. Studies indicate simple video games touting educational benefits are common in classrooms. However, a need for identifying truly useful games for educational purposes exists. This article begins with an examination of lower level learning in so-called edutainment products and concludes with an example of an advanced social studies simulation that fosters higher order thinking. The article identifies characteristics of highly cognitive virtual interactive environments and offers a detailed index and scoring rubric as a tool for teachers and preservice teachers to use when evaluating the tendencies a video game demonstrates toward encouraging higher order thinking in its participants.

Gaming has been a source of interest in educational circles since at least the early 1900s. Interest in paper-based games for education surged in the 1960s and 1970s among educators, only to wane under the influence of the back to basics movement. Now that computers have increased in sophistication, there is once again renewed interest in how gaming, specifically video gaming, might affect pedagogy (Juul, 2001). The academic publishing industry has likewise taken note, with Wolf and Perron's (2003) groundbreaking *The Video Game Theory Reader* serving as a prime example.

The term *video game* covers a broad swath of applications from simple ones (e.g., *Tetris*) to complex military simulations (e.g., the U.S. military's recruitment game, *America's Army*). Many educators, when asked to name

an educational video game, may point to products falling in the "edutainment" category that have become commercial hits over the past several years. These products include, among others, Oregon Trail, SimCity, and the Math Blaster series. Following Gee's (2003b) precedent, who noted computer video games and home console video games (e.g., the Sony PlayStation) share many properties and are essentially similar, for the purposes of this article, "video games" will encompass both computer-only products and console-specific products. However, since consoles appear to be primarily relegated to the home market, and mindful that so-called educational video games finding their way into the classroom are overwhelmingly computer-based, and in light of the fact it appears there are considerably more computers in classrooms that home gaming consoles, the video game products discussed in this article will be primarily those designed for personal computers.

Evidence exists suggesting a strong predilection among teachers for simple, edutainment-style software in the classroom. One British survey indicated a higher likelihood that simpler edutainment products may be found in classrooms than more sophisticated computer simulations (Kirriemuir & McFarlane, 2003). The authors suggested simpler edutainment software required less computing power and could run on older, more widely available computers in schools. In addition, because they purport to offer some educational benefit, edutainment products are often allowed and encouraged in classrooms.

In light of the fact a wide disparity exists among products spanning from the simple to complex, and because so many educators are willing to purchase and attempt to use software promoted as "educational" within their classrooms, a need exists to more clearly define advanced video gaming products which hold potential for educational purposes. The concept of understanding beneficial cognitive aspects of video games is an important one for preservice teachers to understand. This article will define characteristics comprising advanced gaming products useful for educational purposes by identifying gaming elements leading to higher cognitive processing. Additionally, teachers and preservice teachers have a need for assessment tools to determine the cognitive benefits of educational gaming products. Toward that end, this article offers a rubric for assessing cognitive potential in video games. The score from the rubric will correspond to a cognitive viability index, giving teachers an estimate of how effective a game is in promoting higher order thinking.

AN EXAMPLE OF AN EDUTAINMENT PRODUCT FOR LOWER ORDER THINKING

The Math Blaster series is illustrative of typical edutainment software found in schools. It was listed in one survey as being among the top math-related titles used in American classrooms (Becker, Ravitz, & Wong, 1999). A more recent Australian survey indicated similar results (Forgasz & Prince, 2002). The first version of Math Blaster appeared in 1983, and several million copies have since been sold under multiple titles bearing the Math Blaster brand name.

Math Blaster titles typically include educative efforts involving simple "drill and kill" mathematical problems combined with arcade-style games, all framed by a simple story of good versus evil. The programs offer, in effect, digital worksheets for students to solve within a gaming environment. Math Blaster Ages 6-7 is ranked the most popular of all Math Blaster titles on Amazon.com at the writing of this article, ranking #112 overall in Amazon software sales at the moment. The Math Blaster series is produced by Knowledge Adventures, a subsidiary of Vivendi Universal Games Studio. Knowledge Adventures currently offers 12 products under the Math Blaster label, aimed at ages ranging from four (Math Blaster Ages 4-6) to 14 (Math Blaster Algebra).

The general premise of the Math Blaster series is to invite students into a narrative that involves defeating enemies by correctly answering math problems (in other words, filling out digital worksheets to help win the game). In a typical scenario, correctly answering problems eventually opens opportunities to play arcade games, such as a space-based shooter game. Ultimately, the Math Blaster series offers traditional worksheet practice in a "kid friendly" environment, and achieves this mainly by throwing in some mindless games along with cartoon-like graphics. Its philosophical constructs are based on positive reinforcement, in which students are rewarded (through access to the games) for completing work (electronic worksheets).

Porting drill and kill exercises to electronic gaming formats has been largely successful in educational environments and the marketplace. The interest taken by giant entertainment companies such as Vivendi-Universal is indicative of the enormous profit potential of successful edutainment game titles. Teachers and parents become interested in providing drills in electronic gaming formats when students express higher interest in doing the drills electronically rather than on paper. Educational researchers are consequently interested in studying this phenomenon. Recently, Lee, Luchini, Michael, Norris, and Soloway (2004) introduced a math drill game for the Nintendo Game Boy system into an elementary classroom environment and reported

finding teachers and students enjoying the experience, with higher motivation evident and greater work-through of problems.

COGNITIVE VIRTUAL INTERACTIVE ENVIRONMENTS

The allure of porting the easiest elements of teaching, like worksheets, into a simple gaming environment is a strong one. However, when this occurs the same limitations inherent in lower learning efforts will be replicated in the digital environment. Drill and kill has some value on lower learning levels, and this may help explain the high sales ranking of Math Blaster titles. Students weak in math indeed do need time to practice their math skills. Efforts such as those by Lee et al. (2004) empirically demonstrated a strong surge in practice efforts (at least initially) by students exposed to drills in gaming environments, making the notion of porting drill and kill exercises to an electronic format seem like a reasonable one.

However, if teachers wish to address the upper levels of Bloom's Taxonomy (1956) within computer gaming environments, more advanced products will be required. Bloom's Taxonomy includes, from lower to higher order thinking levels: knowledge, comprehension, application, analysis, synthesis, and evaluation.

The efforts by Lee et al. (2004) were aimed at second graders. The most advanced title in the Math Blaster series, Math Blaster Algebra, is aimed at students aged no older than 14 years. While the age groups these and similar products are written for might justify keeping the gaming elements and interactions simple, it will necessarily restrict the games to lower level learning such as knowledge and comprehension. Higher order thinking will need to take place within a virtual interactive environment (VIE). Cognitive VIEs are software products designed to encourage higher order thinking by users.

Virtual implies that complex three-dimensional graphics are used to create a form of Virtual Reality (VR) that McLellan (2002) defined as "through the window," or "desktop VR" (p. 465). The properties of complex three-dimensional virtual environments set apart cognitive VIEs from simpler computer games. Computer text-based games, which do not incorporate graphics at all would not be termed VIEs due to their lack of VR elements. Games which incorporate two-dimensional, or simple three-dimensional graphics with little interaction would also not be considered VIEs, or at least not cognitive VIEs. The complex nature of advanced three-dimensional environments offers multiple affordances for students to engage in higher level learning. The notion of affordances, that clues to how things work in an environment are evident through sensory cues, stem from Gibson's (1986) assertions regarding ecological psychology. According to McLellan (2002),

Gibson's theory indicated active "perception and exploration" (p. 477) may occur in virtual environments, rendering them advantageous as a teaching mechanism.

Interactive stipulates that participation requires extensive user interaction, usually involving reading, clicking on appropriate icons, appropriate mouse maneuvers, manipulating virtual objects, possibly keyboard input, and possibly speech and hearing interaction. The interaction is not simply for mechanical efforts (as in arcade games) but it stimulates mental processes, causing the user to actively learn new knowledge and synthesize existing knowledge for new purposes (Gee, 2003b). Some or most of the interaction may (but not required by definition) involve other people or programmed nonplaying characters (NPCs) also residing in the gaming environment.

Environment indicates the context within which the game takes place. Cognitive VIEs will have complex virtual environments allowing persistent interaction over long periods of time. The environments often will be virtually large, highly engaging, and will allow and encourage users to explore extensively. The environment may incorporate elements of a virtual community such as those found in persistent worlds, or massively multiplayer online role playing games (MMORPGs). Additionally, a cognitive VIE's environment will often incorporate elements of a narrative to better situate learners within the environment and assist in their suspension of disbelief (Laurel, 1991; Ryan, 2001).

Most VIEs educators will come into contact with are commercially developed software games. VIEs are sometimes billed as simulations. A simulation, as defined by Gredler (2002), is "an evolving case study of a particular social or physical reality in which the participants take on bona fide roles with well-defined responsibilities and constraints" (p. 571). The interactions within the environment often may be considered *high fidelity* simulations. Gredler defined a high fidelity simulation as "an adequate model of the complex real-world situation with which the student interacts" (p. 571), and indicated the simulation provides ample data and feedback to users, allowing multiple means of completion. However, it should be noted that although VIEs may often be considered computerized simulations, commercially developed video gaming products may often fall under the game label while nonetheless incorporating Gredler's elements of high fidelity simulations.

The distinction between simple computer games and cognitive VIEs is critical. The important distinction is that cognitive VIEs provide sufficient opportunities for complex interactions, making them suitable environments within which higher order learning may occur. Many popular titles in the video game marketplace could be considered cognitive VIEs. Teachers have found several computer games useful for classroom adoption which are

modeled after complex social or environmental structures, and allow considerable interaction and development within their artificial environments (Squire & Jenkins, 2003). Squire, for instance, based his Ph.D. dissertation on studying the use of Civilization III for social studies instruction (Squire & Jenkins).

Ample evidence suggests that complex computer games provide participants excellent participatory learning, along with opportunities to engage in higher order learning skills. Perhaps no other scholar has argued this point more effectively than James Paul Gee. Gee (2003a) stated that advanced computer games engage learners in two foundational cognitive tenets: the competence principle and the expertise principle. Successful computer games force users to work hard toward conclusion, offering opportunities for accomplishment that are difficult to attain, but not completely impossible. Simultaneously interesting and frustrating users stimulates intense engagement, and leads to increased learning opportunities. This application of the competence principle, explains Gee (2003a), is one of the ways successful computer games engage users in intense learning situations.

Commercially successful games engage users in the expertise principle by forcing them to fully absorb needed details in order to be successful. Many computer games require complete mastery of a particular level before allowing the user to proceed to a following level. Complete mastery of gaming elements, Gee (2003a) stipulated, exemplifies use of the expertise principle. Gee (2003b) maintained that successful games make extensive use of the principles of good cognitive science, otherwise they tend to fail in the marketplace.

VIDEO GAME COGNITIVE VIABILITY INDEX

Teachers wishing to incorporate video games that encourage higher order thinking in the classroom may find themselves attempting to assess new products continuously entering the marketplace. Toward that end, a rubric has been created to help assess the inherent tendency a video game may have to encourage higher order thinking in its users (Table 1). The score from the rubric will generate a number on the Video Game Cognitive Viability Index. The number will fall within a range corresponding to a scale that indicates the level of tendency a game has toward cognitive viability (Table 2). The scale is weighted against lower scoring games. Games must therefore earn more points on the index in order to achieve a high placement on the scale.

Table 1

Video Game Higher Order Thinking Evaluation Rubric

Characteristics	Y/N 1/0
Requires users to assume a role in the game, rather than simply play.	
Offers meaningful interaction such as dialogue with NPCs.	
Has a storyline.	•
Has a complex storyline with characters users care about.	
Offers simple puzzles.	
Has complex puzzles requiring effort to solve.	
Uses three-dimensional graphics.	
Allows multiple views or camera pans and the ability to zoom in and out.	
Allows different ways to complete the game.	
Simulates complex processes requiring adjustment of variables by users to obtain desired results or adjusting variables leads to different results.	
Allows interaction through use of avatars.	
Avatars are lifelike.	
Requires interaction with virtual elements within the game.	
Requires knowledge of game elements beyond mouse prompts, number entry (e.g., combining elements to create new tools, understanding complex jargon).	
Requires gathering of information in order to complete.	
Requires synthesis of knowledge in order to complete or successfully engage elements in the game.	
Environment effectively replicates real world.	
NPCs display AI characteristics.	
NPCs display effective use of AI resulting in dynamic experiences for the user.	
Offers replay ability with varying results.	
Total score: (Indicating placement on the Video Game Cognitive Viability Index)	

Table 2
Video Game Cognitive Viability Scale

20	*Perfect score*. Game displays highest elements of cognitive viability.
15-19	*Upper-range*. Game holds several positive characteristics lending itself to higher order thinking.
14-18	*Mid-range*. Game is probably acceptable for some higher order thinking opportunities.
9-13	*Lower-range*. Fewer opportunities for higher order thinking will take place in the game.
0-8	*Little or no cognitive viability*. Typical score range for arcade-style only games.

Upon evaluating a video gaming product, teachers should answer the yes/no indicators in the rubric with a 1 for yes and a 0 for no. A game earning a perfect score would earn a 20. The higher a game scores on the index, the more opportunities the game will afford users higher order thinking, while the opposite is true for lower scores. Following are more details on the components of the rubric along with an explanation of the rationale behind the evaluating factors. Note that the examples of specific games, where provided, do not necessarily indicate the game would score high on the index. Rather, the examples indicate where a game would score a particular point on the rubric, and are only included for illustrative purposes for that particular portion of the rubric.

RATIONALE FOR RUBRIC COMPONENTS IN TABLE 1

Requires users to assume a role in the game, rather than simply play. Requiring users to assume some sort of role typically offers increased opportunities for higher order thinking. Users will engage in additional cognitive processing when role play is involved because it forces them to process information outside their normal experiences. Rearranging knowledge into cognitive patterns is a key tenet of Gestalt psychology (Alberto & Troutman, 2003). Role playing often forces users to engage in analysis, in which they must interpret elements in the game according to the role they are playing; synthesis, in which they must apply concepts to a new setting (the role they

are playing within the game's environment); and evaluation, in which they must constantly evaluate whether actions taken within the role they are playing assists them in meeting the goals of the game. Video role playing games (RPGs) can be contrasted with simple arcade-style games which require no roles and little or no higher order thinking. Revolution, a complex social studies RPG developed by Massachusetts Institute of Technology's (MIT) Comparative Media Lab, would earn this point while Tetris, a simple arcade game, would not.

Offers meaningful interaction such as dialogue with NPCs. Meaningful interaction is important because it offers additional opportunities for thinking. It is possible to have a complex environment in which users wander about but have little meaningful interaction within the environment. Such an environment might be a photo-realistic representation of empty streets, in which users could roam about but not be involved in additional interactions such as chatting with NPCs or other concurrent gaming participants. Note that NPCs do not need artificial intelligence (AI) for the game to earn this point on the index. All NPC dialogue may be scripted by the programmer for this point to be earned, provided the interaction is meaningful somehow.

Has a storyline/has a complex storyline with characters users care about. Storyline is related to narrative, which is a key component of advanced games and simulations (Ryan, 2001). When users immerse themselves in a story line, opportunities for increased thought and narrative processing will take place. Storylines provide users with a reason for the gaming action to occur. Narrative study has been extended successfully to gaming environments and is considered a key means of understanding interactions within complex computer games (Ryan). Complex storylines logically lead to more opportunities for complex thoughts. While it is possible for a game to earn a point for a storyline, the game possibly may not earn a corresponding point for a complex storyline. The storyline within Math Blaster Age 6-7 would earn one point for a storyline but miss the point for a complex storyline, while an intense social studies game like Revolution would earn both points.

Offers simple puzzles/has complex puzzles requiring effort to solve. Including simple puzzles in a game offers additional opportunities for cognitive processing. Inclusion of simple puzzles will result in a point earned on the scale while complex puzzles requiring analysis and synthesis will earn an additional point. The puzzles found within games such as the *Pajama Sam*

series, where the character must infer simple visual relationships in certain areas in order to proceed would earn one point while the complex puzzles in the Myst series would earn both points.

Uses three-dimensional graphics/allows multiple views or camera pans and the ability to zoom in and out. One of the defining characteristics of cognitive VIEs is complex three-dimensional VR, described by McLellan (2002) as "desktop VR" (p. 465). Two-dimensional graphical games would not earn a point in this category and would rank lower on the Video Game Cognitive Viability Index. While research in VR environments remains a developing field (McLellan), complex three-dimensional VR affords users additional opportunities for cognitive processing. Multiple views and camera pans enhance the interaction opportunities within three-dimensional environments, and games including those features would earn an additional point on the index.

Simulates complex processes requiring adjustment of variables by users to obtain desired results or adjusting variables leads to different results. This factor of the index rests on cognitive theory in education, which emphasizes the rearranging of thought patterns in order to perceive new understandings and ways of doing things (Alberto & Troutman, 2003). Good cognitive VIEs will encourage users to adjust variables and learn how readjusting variables might lead to favorable outcomes. Readjusting variables causes users to readjust their understandings, resulting in increased cognitive functions. An example of a game featuring this characteristic might be Fable, where the choices users make to help or harm NPCs result in their character developing "good" or "evil" personas, reputations, and appearances within the game.

Allows interaction through use of avatars/avatars are lifelike. Some may debate the inclusion of avatars as necessary for higher order thinking to occur within a gaming environment. Advocates of the SimCity line of products and their ilk, for instance, would argue that other elements of higher order thinking, such as the adjustment of variables to reach positive outcomes, take place in these games. Higher order thinking may indeed be encouraged in games that do not use avatars, but a strong rationale exists for stipulating the best games for cognitively viable interactions will make use of lifelike avatars. Following Gee's (2003b) line of reasoning, these games are typically the most advanced products on the marketplace, and consequently make the most use of cognitive strategies to enhance the gaming experience. Using avatars, specifically lifelike avatars, will earn a game both points on the

index. It should be noted, however, a game could still earn a high score on the Video Game Cognitive Viability Index without the inclusion of lifelike avatars.

Requires interaction with virtual elements within the game. Games requiring a high level of interaction with virtual elements will earn this point on the index. Good cognitive VIEs will always offer users opportunities to "hold," examine, manipulate, and interact with objects in the game. Games such as Dungeon Siege allow users to buy and sell weapons, potions, pack mules, and other errata. Virtual books in the game can be opened and read by the user. An opposing example might be a maze or race game which proffers a three-dimensional environment, but seldom allows users to manipulate items within the environment.

Requires knowledge of game elements beyond mouse prompts, number entry (e.g., combining elements to create new tools, understanding complex jargon). The more elements in the game required to master it, the higher the opportunities for learning and synthesizing new knowledge. It is important for evaluators to note that this point not be reserved only for games with complex interfaces, such as realistic airplane or military vehicle simulators. Games with simple interfaces may still earn this point if knowledge of processes required in the game remains high, or knowledge for proper use of virtual elements is high. For instance, a game requiring users to understand the proper sequence and combination of certain compounds in order to develop powerful weapons or tools might earn the point, even if the interface for the game is simple and intuitive.

Requires gathering of information to complete/requires synthesis of knowledge in order to complete or successfully engage elements in the game. When a game requires simple information gathering to successfully complete portions of the game, it will earn the first point. For instance, games requiring only simple quests to gather information and report back to a particular NPC would earn the first point. One of the most basic elements of cognition is the gathering of information, while synthesizing the information is one of the elements of higher order thinking. Therefore, games that require users to not only gather information, but synthesize it as well, will earn the second point.

Environment effectively replicates real world. Some may argue the environment does not have to effectively replicate the real world in order for higher order thinking to occur. Games based on completely imagined

environments, such as Oddworld, may be pointed out as props for this argument. Others may likewise point to the SimCity games which have little or no use of human avatars. In the first instance an argument could be made that even when gaming elements are based in imaginary environments, recognizable real life (RL) elements remain in place, including the use of anthropomorphic avatar and NPC characteristics, laws of physics, and so forth. Second, in game-based simulative environments such as SimCity, the simulations are based on mathematical estimations of processes taking place within RL, rendering the argument moot. Video gaming environments which do not effectively emulate RL typically tend toward the simple and arcade-style, and would not earn this point on the index.

NPCs display AI characteristics/NPCs display effective use of AI resulting in dynamic experiences for the user. A game may earn a point on the index if its NPCs at least display characteristics of AI. Such a simple appearance of AI may in fact be only good programming on the part of the game developers. In such an instance, where the NPCs are particularly well scripted and interactions appear "real" to the player, the game would earn the first point. Such scripting frequently occurred in excellent older games such as the original Ultima series, and often continue to take place in current RPGs. Extensive use of effective AI, such as what is currently available in the game Far Cry, earns an additional point on the scale. AI as exemplified in Far Cry results in users experiencing different tactics by the game's adversarial NPCs each time they are engaged. Additionally, effective AI might allow NPCs to "learn" new tactics based on players' previous efforts within the game.

Offers replay ability with varying results. A cognitive VIE will display elements separating it from less cognitive games by allowing users to replay and obtain different results each time. Evaluators will know to award this point when the endings are different for the game when it is played multiple times and/or by different players. If the game ends with identical results each time, regardless of players or variable manipulations, the evaluator should probably not award this point. Some otherwise high index scoring games, such as Dungeon Siege, might lose this point since completing the game always requires successfully defeating the final enemy at the highest level.

RATIONALE FOR TABLE 2

Table 2 indicates the ranking of a score earned by the evaluation of a video game on the Higher Order Thinking Evaluation Rubric. Any video

game scoring 15 or higher is highly probable to encourage higher order thinking in its users. Note that for a game to be ranked in the upper range of the scale, the reviewer would need to award it a score of at least three quarters of all the points on the rubric. This is based on the assumption that a video game should have to display a lot of evidence of higher thinking characteristics to actually be a game that promotes higher thinking.

CONCLUSION

Serious research in what could be considered highly cognitive VIEs has been assisted through a long history of VR and gaming efforts by the Comparative Media Lab at MIT. The Games to Teach Project, coordinated by MIT and Microsoft Corp. has developed several education-specific gaming applications. One of the more intriguing efforts is Revolution, a role playing game set in 1770s America. Revolution is clearly a significant cognitive VIE, as users take on the roles of townspeople in a realistic environment and experience how the American Revolution fomented ideas stirring within the general populace at the time (Squire & Jenkins, 2003). Revolution was specifically designed for classroom use, and it remains a most excellent example of an educationally useful, highly cognitive VIE for teachers and students.

Revolution was created using the free modification tools available for a popular computer video game RPG. It may be possible that future examples of computer video games modified for educational use may provide additional opportunities for highly cognitive VIEs to be developed for classroom purposes. Other examples may abound in video gaming products co-opted for use in the classroom by educators. Ideally, this article's goal of providing an established means of assessing higher order thinking potential within either a commercially available, modified, or teacher-developed video game will assist educators in deciding what video games to use with their students, and spark additional cognitive research in video game development and deployment.

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Note

The author extends special thanks to Leslie Moller, University of South Dakota for his suggestions and encouragement in the writing of this article.