An Ecological Description of Video Games in Education

Michael Young, Ph.D.
Learning Technology Program, Neag School of Education
University of Connecticut
249 Glenbrook Rd, Unit 2064
Storrs, CT 06269-2004
myoung@uconn.edu

ABSTRCT

To understand video games as learning envnironments, it is essential to look carefully at the qualitative descriptions of learning in video game environements and apply to it what we know from learning theory about how people think and learn. An ecological psychology view of learning from video games would highlight 9 principles focusing on the primacy of goals and intentions that guide perception-action within the constraints of the game design and user interface. From an ecological perspective, then, the task of game design becomes one of selecting goals and creating environments in which those goals can optimally be pursued, while taking into account those things that gamers tell us are keys to enjoyable, engaging experience.

1. VIDEO GAMES and LEARNING

Who would not want to play video games in their classrooms instead of listening to dry lectures or completing endless worksheets? The very mention of the word "games" evokes an anti-classroom image, running through the park or flopped on the living room floor vigorously working the game controllers. But what possible value could the use of video games add to classrooms, where the goals are often curriculum coverage of serious academic content, high stakes test performance, or simply work completion for acceditation. Further, how can playing video games be understood in terms of learning theory? For video games to play a significant role in classrooms, three things may have to change: 1) classroom goals will clearly need to change from test performance and broad curriculum coverage, to development of students' meaningful understanding of content (constructivist pedagogy); 2) games will have to be adapted so that the actions players take are more cognitive and social (like massively multiplayer online role playing games MMORPGs such as Everquest or Star Wars Galaxies, circa 2004) [1] and less purely hack & slash motor behaviors (like arcade style or dungeons and dragon style role playing games); and 3) games will need to be understood from a learning theory perspective to enable proactive instructional designs that address specific content domains.

On the first issue, much has been said about the nature of test-centered curriculum in an age of federal and state mandates for high-stakes mastery tests. For the purposes of the present paper, suffice it to assert that such high-stakes tests must continue to become more valid as measures of students' deep understanding, rather than broad samplings of primarily superficial facts. While it is reasonable for taxpayers to hold educators accountable, it is also reasonable to require that such accountability be authentic in terms of the best values and pedagogical practices available. At present this is not the case and the constraints of group-referenced measures based on the general linear model seems to underestimate students' deep understanding in some areas and preclude individual (learner-centered) choices as to what will be "mastered" in most cases. Hopefully the goals of constructivist pedagogy and educational accountability will be reconciled so that innovative classroom activities that invite students to learn some things deeply can be widely implemented and contribute to the assessment of overall school success measures.

On the second issue, Marc Prensky [2] wrote that to begin to adapt games to education, all it takes is for content experts to ask themselves, "How can the use of my unique content knowledge be considered a game?" Then it is simply a matter of constructing a gaming environment to simulate those uses and give successful applications value (e.g., points, power). For my personal field of expertise, educational resesarch, there are two easy answers to Prensky's challenge. First, research methods is a game in the sense of working toward the perfect set of conditions or series of observations that will provide indisputable evidence that my favorite learning theory (ecologocal psychology) is correct above all others. Second, academics, the world of publish or perish, is also a game. It is a balancing act between deep theoretical discussions and more mundane office work, all of which is valued in some ways by various constiuencies. To date I have not seen either of these exploited as a gaming environment, but I agree with Prensky's premise that such games would be a significant enhancement to how we currently indoctrinate graduate students into these practices.

On the third issue, how to understand video games as learning envnironments, it is essential to look carefully at the qualitative descriptions of learning in video game environements and apply to it what we know from learning theory about how people think and learn. It is in the context of this interesting challenge, to advance constructivist pedagogy with the integration of video games into education, that I would like to present an ecological description of games in education as a possible over-arching framework in which to understand and engage the challenge to adopt and adapt video games in education.

2. GOOD LEARNING AND GOOD VIDEO GAMES—WHAT HAS BEEN SAID

(Dateline 5/11/97) Man loses to Machine: Gary Kasperov loses to Big Blue chess program. He also lost a rematch to "Deep Blue" in June of 1997, which

included heuristics and rules of thumb from game theory in addition to exhaustive tree search strategies.

Games were historically the test for early computer science demonstrations of intelligence and learning, particularly Chess and the Tower of Hanoi problem. Game theory, which also underlies several economics models, has been a fruitful line of mathematical inquiry in its own right. Such research has produced neural nets that play Backgammon, Go, checkers and bridge programs, and research continues at the University of Alberta's Game-playing, Analytical methods, Minimix search, and Empirical Studies (GAMES),

Commercial video games have been shown to improve children's abilities in a range of academicly valued attributes, such as visual and motor skills (e.g., Green and Bavelier [3]). For a more detailed review see Schrader [4]. But young people are not the only ones to enjoy the pleasures and benefits of video games. Video games have been shown to have positive effects on non-institutionalized elderly people (aged 69-90 yrs), improving their reaction time (as measured by the Sternberg RT task) and their self-reported well being [5]. Some studies have also shown that simulations like "Sim City 2000" can have positive outcomes directly on academic topics such as problem solving [6]. Tetris has been the focus of several psychological studies of cognitive benefits from video games. Antoniette, Rasi, & Underwood [7] used Tetris to study expert strategies for hand-eye coordination and metacognitive monitoring, finding that the most functional patterns of moves and eye movements were associated with the highest performance scores. Sims & Mayer [8] also studied skilled Tetris players and found that their skills were very domain specific to Tetris shapes and did not transfer to other spatial tasks, suggesting that at least the physical benefits of video game do not tranfer widely. In an early attempt to use video game learning to inform cognitive science theory, Kirsh & Maglio [9] used Tetris play to argue against an information processing view of cogniton, pointing out that such games draw more directly on perception than on computational actions in the head. This points to an ecological description of video game play and its potential educational value.

Figure 1A.

1. Doing and reflecting
2. Appreciating good design
3. Seeing interrelationships
4. Mastering game language
5. Relating the game world to other worlds
6. Taking risks with reduced consequences
7. Putting out effort because they care
8. Combining multiple identities
9. Watching their own behavior
10. Getting more out than what they put in
11. Being rewarded for achievement
12. Being encouraged to practice
13. Having to master new skills at each level
14. Tasks being neither too easy nor too hard.
15. Doing, thinking and strategizing
16. Getting to do things their own way
17. Discovering meaning
18. Reading in context

Games continued to be a favorite example of contemporary learning theory related to situated learning and situated cognition. Suchman's response to Vera and Simon in the 1993 special issue of Cognitive Science [10] devoted to situated cognition, cited contrasting algorithmic solutions the Towers of Hanoi solution as an examples of how a robot's plans can emerge from perception and action, rather than rule-based systems. When considering the educational benefits of video games, one is naturally drawn away from memorization and test performance to thinking in the moment, strategizing while acting, and considering social influences, all of which are at the heart of embedded and embodied cognition [11].

Expert players (gamers) are perhaps the most aware of video game elements that engage their interests and enable them to learn and adapt within the game parameters of the virtual environment:

> "*The most important things to remember are multiplayer, creative, collaborative, challenging, and competitive*"
> --Cory (a high school gamer participating in IAETE's "Soapbox" on "What can education learn from the video game industry" online at http://www.iaete.org/soapbox/summary.cfm

From the player perspective, the ability to socially interact with pre-programmed and other human players, the experience of new and unusual circumstances beyond everyday activities, the ability to form social alliances and perform feats beyond the capabilities of any one player alone, the accommodation of a range of player abilities from novices to unlimited expert potentials in a variety of areas, and the ability to detect progress or success in a competitive sense are the keys to learning and "fun." Most preservice teachers value these powerful learning events, particularly the mental engagement, clear rules, authentic contexts and creative (roleplay) nature of video games as well as good graphics (Schrader, this volume). These are the key variables that can be adapted to educational purposes.

Figure 1B.

19. Relating information
20. Meshing information from multiple media
21. Understanding how knowledge is stored
22. Thinking intuitively
23. Practicing in a simplified setting
24. Being led from easy problems to harder ones
25. Mastering upfront things needed later
26. Repeating basic skills in many games
27. Receiving information just when it is needed
28. Trying rather than following instructions
29. Applying learning from problems to later ones
30. Thinking about the game and the real world
31. Thinking about the game and how they learn
32. Thinking about the games and their culture
33. Finding meaning in all parts of the game
34. Sharing with other players
35. Being part of the gaming world
36. Helping others and modifying games, in addition to just playing.

In trying to capture the positive benefits of video games for educational purposes, Gee [12] identified 36 principles of effective video games that he believed represented educationally relevant design ideas. Prensky [1] restated Gee's 36 principles in terms more approachable by educators and designers (see Figures 1A and 1B above).

Some of these positive attributes emerge from the design of an overall game fantasy context while others are part of game design or the user-system interface. The fantasy aspect of learning has been explored and shown to be effective in contexts like Anchored Instruction [13,14]. In their work to create videos in which to "anchor" instruction, they have drawn on a considerable body of cognitive psychology to confirm that narrative structure and story grammars can make complex phenonena approachable. CTGV argued persuasively that narratives are a fundamental way we think and learn, dating back to oral histories. The design of the fantasy context has been shown to be able to control factors such as the social value system that students bring to bear on their gaming interactions, such as in the context of Quest Atlantis [15]. This is particularly critical as games are imported from the primarily violent (slashing for points) or commerical (grabbing teasure) goals of video games to the social and academic (accumulating wisdom) goals associated with traditional curricula. Turning knowledge to a social good is a theme that has been targeted by several contemporary educational initiatives.

3. GOOD LEARNING AND GOOD VIDEO GAMES—AN ECOLOGICAL PSYCHOLOGY PERSPECTIVE

An ecological psychology view of learning from video games would highlight fewer parameters than Gee's original list, focusing on the primacy of goals and intentions that guide perception-action within the constraints of the game design and user interface. From this perspective, Prensky's [1] challenge to adapt an area of expertise into a game can be given further design constraints. First, how can an area of expertise be organized around a discernable goal or goals (possibly discovered or emergent through game play) that are attainable through actions within the game environment? Next, how can game actions (and associated game affordances) be created to allow initial simple progress toward the goal with increasing success contingent on higher and higher levels of attainment (education of intention and attention)? Finally, how can random or interrelated social variables be instantiated so that "bots" or other gamers can influence the outcome of game play?

My personal example of academics in educational psychology as a game would address these issues by targeting one or more academic goals such as numerous peer-reviewed publications (publish or perish), stature in field (being known by many other researchers), and academic leadership (controlling committees, organizations, and programs). Game parameters might include initial "graduate work" in which a game mentor assists in creation of point-scoring "publications." Repitition and social attributes would need to be represented within the game environment to enable those features such as #25 mastering upfront things early and #3 seeing interrelationships (such as status increasing opportunities for publication). These could include the value of collaborating with other players to establish their own journal, befriending government managers to increase grant opportunities, or creating a special interest group (SIG) within an organization that can sponsor its own presentations and leadership.

Rather than looking at descriptive attributes of games that can be adapted and adoped for education, an ecological approach attempts to identify the underlying learning variables that represent the power of video games to motivate and sustain interactions. This description of video game learning parameters from an ecological perspective provides common themes of video game pedagogy that can more parsimoniously describe the core perceptual learning concepts (for background see Young [16]).

The Table shows the key ecological psychology principles that can be applied to understand learning in the video game context.

Table 1. Ecological Principles for Educational Video Games

Principle	***Gee/Prensky instantiation***
Perception-Action Cycle (Dewey's learning by doing)	#1, #15
Embodied cognition (thinking for action)	#27
Social attributes of situated learning (co-labor)	#34, 35, 36
Boundary constraints on behavioral trajectories:	#6
Repetition (opportunty to show what you know)	#12, #28
Affordances (detection of functional value)	#8
Detection of the raison d'être (potential far transfer)	#2
Goal-direction action (intentionally-driven cognition)	#7, #11, #13, #24
Contextualize learning (fantasy or realistic scenarios)	#18, 19, 28

Many in the field of education have begun to consider that thinking (cognition) is not a separate stand-alone computational act of the human mind alone, as believed by most information processes theories of cognition [14] in favor or a more situated, embodied and embedded view of thinking. Such a view presumes that learners have a basic "comportment" to explore their world and learn from their senses directly [18,19], and posits an integrated agent-environment view of learners as "embodied and embedded" in everyday cognition [20]. This different way of describing thinking (cognition) as always <u>for</u> something, in service to doing, has been explored under the various titles of embodied cognition, experiential learning, situated cognition, cognition in the wild, situativity, and ecological psychology (see for example the seminal paper by Brown, Collins & Duguid, [21]). The educational implications of taking an ecological approach to situated cognition are described in detail elsewhere [16]. For current purposes, several of the key ideas from this approach to cognitive science can be directly applied to understanding learning within the video game format. As described by Young [16] the key principles of ecological psychology that direct educational design include:

- Learners are self-directed by personal goals and intentions,
- Learning improves with practice, and
- Learning improves with feedback.

Yet these are nearly universal principles, so to these are also added:

- Co-determined affordances and effectivities,
- The dynamics (ontological descent) of intentions as they drive the perception-action cycle,
- Intentional dynamics as goals are created and anihilated (achieved).
- The direct perception of invariance and change, and
- Learning as the education of attention and intention.

Video games provide a nearly ideal testbed for the ideas of situated, embodied and embedded cognition. The primary idea of embodied cognition is that thinking is done in service to action, not as a separate offline activity of itself. A classic game-related example of embodied cognition is the interplay of thinking and action that results when playing Scrabble. Players often rearrange their seven tiles physically (along a wooden stand) to make words (or partial words) that in turn provides prompts that support their further thinking. In this simple example, thinking and action take place in a dynamic interaction, iterative cycles of perception and action, that together work to achieve a goal of the game. It is in this sense that the word "ecological" can aptly be applied as thinking is not simply influenced by context, but is one tool used to adapt to a particular situation's constraints and take advantage of possibilities for action (affordances) presented by the game situations. Thinking in this Scrabble example is embodied in the hand movement of the tiles and the new word possibilities that emerge. Such examples of embodied cognition are marked by the presumptions that cognition is situated in a particular episode of space-time, cognition is time-pressured, cognitive work is interactively offloaded to the environment, the environment is an inherent part of our cognitive system, and cognition is always <u>for</u> something, in service to action.

Consider the now-classic example of situated cognition as given by Jean Lave [22] in describing the activities of a weight watcher with plenty of formal math education. The weight watcher had a daily allowance of two-thirds of a cup of cottage cheese. The problem was, he wanted most of it for lunch but wanted to reserve a little (a quarter of that allowed) for his salad at dinner:

> *…The problem solver in this example began the task muttering that he had taken a calculus course in college (an acknowledgment of the discrepancy between school math prescriptions for practice and his present circumstances). … He filled a measuring cup two-thirds full of cottage cheese, dumped it out on a cutting board, patted it into a circle, marked a cross on it, scooped away one quadrant, and served the rest. Thus, "take three-quarters of two-thirds of a cup of cottage cheese" was not just the problem statement but also the solution to the problem and the procedure for solving it. The setting was part of the calculating process and the solution was simply the problem statement, enacted with the setting.* (p. 165)

This example shows how the situation, including the cutting board and spoon, afforded thinking about the mathematics (3/4 of 2/3) as a series of enacted, embodied activites: measure 2/3 cup, cut it into quarters, scoop out 1/4 for later, serve the remaining 3/4ths. So just like the Scrabble player, body movement and activity substituted for offline thinking and problem-solving computationally. Cognition was in service to action directly, without symbolic representation or offline processing.

Learning within video game environments is perhaps best described this way, as situated (embedded in the fantasy environment of the video game) and embodied (in the actions of an avatar or game perspective as taken through the user-system interface). Ecological psychology raises questions about how cognition can be fluently used directly in service to action, rather than through processing and computation. For example, how can skilled drivers drive almost mindlessly to work, talking and thinking about other things while engaged in such a skilled performance? Such questions suggest that something other than the simple playing out of compiled schemas may be at work, perhaps direction perception in service to action. Ecological psychology looks for an answer in the direct perception of agent-environment interactions. The environment provides enough information (invariance) so perception and action can proceed directly, without the need for retrieval and other representational offline processing.

With this thought in mind, consider the ecological psychology view of learning in video games: **learning is defined as the education of intention and attention**. The education of <u>intention</u> describes how new intentions emerge as compactified fields during the pursuit of existing goals. Consider that as a video game unfolds, new subgoals and problems emerge that allow for new intentions to be adopted. The additional part of the definition, then, is the education of <u>attention</u>. Movement through a video game scenario can tune players' attention to detect information (specifying affordances) in the environment that they might not initially notice (such as SpongeBob inflating to drift from rock to rock or Sonic the Hedgehog balling up to bowl over impediments). Such "attunement" to possibilities for action (affordances) can take place as two players coordinate their activity, with a more knowledgeable gamer acting together with a more novice perceiver (scaffolding). A mathematical model of such a coupled two-person system has been described as the "intentional spring" model [23,24]

Experience can also attune peoples' attention to aspects of their social environment that have functional value for their purposes. As the perceiving-acting cycle unfolds, the environmental consequences of actions produce new experiences that can draw the attention of the perceiver to new affordances of their fellow gamers or other agents in the game. This could also happen vicariously, as one student perceives another student operating within a shared environment. The actions of one player, then, can cause another to detect an affordance, enabling the perceiver to achieve a goal and "tuning" them to be able to detect similar functional values in the environment in the future. The resultant tuning of attention, along with the induction of new goals, represent the education of attention and intention that define learning.

An ecological description of learning in video games rests on the assumption that what humans are designed to do is to detect variance and invariance. This is a whole-body achievement of a human and not simply the result of working sensory receptors. Some fundamental studies include Lee's [25] description of grasping, time-to-collision (tau), and optic flow as well as other midlevel intentional behaviors such as the perception of crawlable surfaces [26], sittable heights [27], steppable heights [28,29], passable apertures [30], center of mass and center of percussion [31], and time to contact [32, 33]. From these more basic studies we can conclude that as gamers interact with the game environment, they pick up information that specifies what is possible to "do" in the game as well as what objects in the game environment can be used for. Through experience, gamers are drawn to detect that some objects used in one context may prove useful in another. But the bottom line is, is the game learning of any real value?

This final point is an issue of game design that returns our focus to standard curricular goals and how they might be instantiated in game environments. To Prensky's question of how experts might view what they do as a game, I would like to add the question, "how can succeeding at said game be linked to the raison d'être of the expert's field?" Finding the fundamental reasons why a field of study exists represents perhaps a difficult insight to achieve, but an important one that can bridge the gap between simply fun but less socially valuable hack and slash game goals and the more educative goals of economic growth (Sim City) or cross-cultural exchange (Quest Atlantis). From an ecological perspective, then, the task of game design becomes one of selecting goals and creating environments in which those goals can optimally be pursued, while taking into account those things that gamers tell us are keys to enjoyable, engaging experience.

4. REFERENCES

[1] MMORPG online at http://www.mmorpg.net.

[0] Squire, K. (2003). Video Games In Education. Unpublished paper distributed through Comparative Media Studies Department, Massachusetts Institute of Technology.

[2] Prensky, M. (2003). Proposal for educational Software development sites: An open source tool to create the learning software we need. Downloaded from http://www.marcprensky.com/writing/ 10 Feb 2004.

[3] Green, C. S., & Bavelier, D. (2003). Video games modify visual attention. *Nature, 429*, 534-537.

[4] Schrader, P. G. (this volume), Games in education: Beyond arousal, agression and gender. Paper presented to EISTA conference, Orlando FL, July 21-25.

[5] Goldstein, J. H., Cajko, L., M., Michielsen, M., vanHouten, O, & Salverda, F. (1997). Video games and the elderly. *Social Behavior and Personality, 25*(4), 345-352.

[6] Betz, J.A. (1995-96). Computer games: Increase learning in an interactive multidisciplinary environment. *Journal of Educational Technology Systems, 24*(2), 195-205.

[7] Antoniette, A., Rasi, C. & Underwood, J. (2002). Do video games enhance strategic thinking. *Ricerche di Psicologia (Italian). 25*(1), 125-144.

[8] Sims 8 Mayer, (2002).

[9] Kirsh, D & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science, 18*(4) 513-549.

[10] Cognitive Science (1993) 17 (1), Jan-March. Special Issue: Situated Action. Norwood, NJ: Ablex.

[11] Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625-636.

[12] Gee. J. P. (2003). *What Video Games Have to Teach Us About Learning and Literacy*. New York: Palgrave/Macmillan.

[13] Cognition and Technology Group at Vanderbilt (CTGV). (1990). Anchored instruction and its relationship to situated cognition. Educational Research. 19 (6), 2-10.

[14] Cognition and Technology Group at Vanderbilt (CTGV). (1993). Anchored instruction and situated cognition revisited. Educational Technology March Issue, 52-70.

[15] Barab, S., Thomas, M., Dodge, T. Carteaux, R. Tuzun, H. (2003) Making Learning Fun: Quest Atlantis, A Game Without Guns. In Press. *Educational Technology, Research And Development.*

[16] Young, M. F. (2004). An ecological psychology of instructional design: Learning and thinking by perceiving-acting systems. In D. H. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology, 2nd Ed*. Mahwah, NJ: Erlbaum.

[18] Heidegger, M. (1927a/ 1962). Being and Time. New York: Harper and Row.

[19] Heidegger, M. (1927b). The Basic Problem of Phenomenology. New York: Harper and Row.

[20] Merleau-Ponty, M. (1962). Phenomenology of Perception. London: Routledge and Kegan Paul.

[21] Brown, J.S., Collins, A, & Duguid, P. (1989). Situated cognition and the culture of learning, Educational Researcher, Jan-Feb, 32-42.

[22] Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge, UK: Cambridge University Press.

[23] Shaw, R. E., Kadar, E, Sim, M. & Repperger, D. W. (1992). The intentional spring: A strategy for modeling systems that learn to perform intentional acts. *Journal of Motor Behavior, 24*(1), 3-28.

[24] Young, M. F., & Barab, S. A. (1999). Perception of the raison d'être in anchored instruction: An ecological psychology perspective. *J. of Educational Computing Research, 20*(2), 113-135.

[25] Lee, D. N. (1976). A theory of visual control of braking based on information about time to collision. Perception, 5, 437-459.

[26] Gibson, E. J. & Spelk, E. S. (1983). Development of perception. In P. H. Mussen (Ed.) *Handbook of Child Psychology*. New York: Wiley.

[24] Gibson, J. J. (1986) *The ecological approach to visual perception*. Hillsdale, NJ: Erlbaum.

[27] Mark, L. S., Bailliet, J. A., Craver, K. D., Douglas, S. D., & Fox, T. (1990). What an actor must do in order to perceive the affordance for sitting. Ecological Psychology, 2, 325-366.

[28] Pufall, P., & Dunbar, C. (1992). Perceiving whether or not he world affords stepping onto or over: A developmental study. Ecological Psychology, 4, 17-38.

[29] Warren, E. H. (1984). Perceiving affordances: Visual guidance of stair climbing. Journal of Experimental Psychology: Human Perception and Performance, 10, 683-703.

[31] Warren, E. H., & Wang, S. (1987). Visual guidance of walking through apertures: Body-scaled information specifying affordances. Journal of Experimental Psychology: Human Perception and Performance, 13, 371-383.

[31] Kugler, P. N., & Turvey, M. T. (1987). Information, Natural Law, and the self-assembly of rhythmic movement. Hillsdale, NJ: Erlbaum.

[32] Kim, N-G, Turvey, M. T., & Corello, C. (1993). Optical information about the severity of upcoming contacts. Journal of Experimental Psychology: Human Perception and Performance, 19, 179-193.

[33] Lee, D. N., Young, D. S., Reddish, P. E., Lough, S., & Clayton, T. M. H. (1983). Visual timing in hitting an accelerating ball. Quarterly Journal of Experimental Psychology, 35A, 333-346.