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Video and Computer Games as Grounding Experiences for Learning

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Abstract

A powerful role for games and simulations is providing rich, perceptually-grounded experience with the content being learned, which when combined with more formal learning activities, provides deeper more robust learning that transfers. Research with an historical simulation game found that grappling with historical dynamics via game play prepared students to learn more from reading a difficult chapter from a college history text. Similarly, interpreting observations in an archaeological site simulation increased students' ability to interpret and argue using such observations. Other research showed that having learners use avatars to role play historical actors and events in a virtual world simulation of the history increased learning, understanding and transfer of historical knowledge acquired from reading about the history. Further research found that increasing the perceptual richness of grounding physics experiences with a simulation game providing force feedback increased student learning and understanding of concepts in physics.

Keywords: Grounded Cognition, Embodied Cognition, Experience, Learning, Transfer

Most of learning in school is thin and shallow: it is not understood very deeply, is quickly forgotten and does not really become part of the way the learners think about the world. As Dewey (1938) pointed out, learning without experiencing what is being learned is not meaningful. Modern research in embodied and perceptually-grounded cognition (Glenberg, 1997; Barsalou, 2008) is based in a similar point: namely, that full understanding means that learners build a mental perceptual simulation of what is being learned, and doing that effectively requires as rich a perceptual experience as possible during learning (Black, Segal, Vitale, & Fadjo, 2012). We propose that computer and video games and simulations can provide these grounding experiences and can be effective when used in conjunction with other learning activities.

Advocates for the use of computer and video games in education (e.g., Gee, 2007; Prensky, 2007; Squire, 2011) view them as very effective learning environments. However, recent reviews of the relevant research (National Research Council, 2011; Tobias, Fletcher, Dai, & Wind, 2011; Young, Slota, Cutter, Jalette, Mullin, Lai, Simeoni, Trau, & Yukhymenko, 2012) have found that this evidence is at best inconsistent and mixed. Ideally, one would like controlled, experimental studies that show that computer and video games yield more learning than learning the same content in the same amount of time in an alternative way. Adams, Mayer, MacNamara, Koenig, and Wainess (2012) recently reported a pair of such studies that showed that students learned more about pathogens in one study and electromechanical devices in another from a matched slideshow presentation than they did from narrative discovery games. Similarly, Egenfeldt-Nielsen (2007) compared learning about European history from playing a history simulation game to learning the same content in a classroom, and found that

students learned more in the classroom. Despite these findings, many researchers retain the belief that computer games can be effective for learning (Gee, 2007; Squire, 2011). However, the conditions under which that might happen requires further investigation and are not as self-evident as some of the original rhetoric by advocates suggested. We share this belief and propose a different use of computer and video games in learning: namely, that they call for direct experience of what is being learned which can provide depth when combined with more formal learning experiences.

An Historical Simulation Game as Grounding for Future Learning

Civilization (Meier, 1991) is a popular simulation game with extensive historical content that students have the potential to acquire via game play (Squire, 2004).



Figure 1. Screen shot from *Civilization* History Simulation Game

In their study, Hammer, Black, and colleagues (Hammer & Black, 2009; Hammer, Black, Andrews, Zhou, & Kinzer, 2007) recruited expert *Civilization* players who were

largely high school and college students, as research participants from online discussion forums for the game, and then gave them a series of tests to see what they had learned from the game. One goal of the study was to determine whether these expert *Civilization* players knew more about the historical content in the game than expert game players who were expert in another popular, content-rich simulation game (*Sim City*; Wright, 1989). The results showed that the expert players did not know any more about the historical content contained in the game than expert players of the other unrelated game (*Sim City*). Another goal of the study was to examine how much the expert *Civilization* players would learn from reading a difficult, college textbook chapter on related historical content. Findings showed that the *Civilization* players learned much more from reading the chapter than the expert players of the *Sim City* comparison game. Table 1 shows how much historical knowledge was acquired from reading the history chapter by the two groups of game experts for the propositional, procedural, imagery, and system knowledge contained in the chapter. Propositional knowledge referred to the set of historical facts and their relationships; procedural knowledge referred to the set of strategies for reasoning about these historical facts; system knowledge pertained to the descriptions of the historical dynamics (e.g., how various historical events might change as a function of changes in other historical events); and images were the visual and spatial knowledge (e.g., historical maps). The study participants read the text then answered a series of free response questions about the content of the chapter. Multiple raters scored these responses (with high inter-rater reliability) for how many propositions, procedural if-then (production) rules, and images they contained. A 0-2 score for system complexity was awarded whereby 0 indicated that no system was described; 1 that a simple system was

described; and 2, that a complex system had been described. As shown in Table 1, the *Civilization* experts learned significantly more of all four types of knowledge from reading the history chapter than did the comparison group participants ($p < .05$).

Table 1

Mean score for type of History Knowledge acquired from Book Chapter

	<i>Civilization</i> Game Experts	Other Game Experts
Propositions	2.33	0.50
Procedures	1.43	0.22
Systems	0.42	0.07
Images	1.52	0.25

Thus, having the experience of grappling with historical issues in the game may have provided the players with a set of experiences, as Dewey (1938) had stated, that better prepared them for future learning from a more formal learning approach (Bransford & Schwartz, 2001). These results suggest that the best use of video and computer games in learning might be in providing experience with the subject matter that is to be later acquired via more formal learning settings.

Support for this contention also was obtained by Ahn (2007) who examined college undergraduates' learning in the context of an entrepreneurship simulation game (from Harvard Business School) that was incorporated into an entrepreneurship course. Findings showed that students learned more from playing the game multiple times when they also reflected on and articulated their business and game-playing strategies, and related them to background readings in textbooks for the course reminiscent of the college textbook reading in the Hammer and Black study

(2009). Notably, students did not learn nearly as much from game play if they did not reflect on how it related to their background reading.

An Archaeological Simulation Game as Grounding for Interpretation

Civilization is sometimes seen as allowing its players an opportunity to experience what it is like to be an historian. Specifically, via game play, players can grapple with the dynamics of history (e.g., change something in history to see how that alters other things). However, this activity differs from that which historians do which entails collecting and interpreting historical data (e.g., artifacts) to come up with the descriptions of events that are then taught as historical facts (Wineberg, 1991). The *Archaeotype* archaeological simulation game (Black & McClintock, 1996) is designed to allow sixth grade students to act as archeologists via the simulation of digging up artifacts (from ancient Greek, Assyrian and Roman history) and, measuring them. They then can look up related artifacts that will enable them to interpret what happened at the simulated archaeological site and to argue for their interpretation. Figure 2 shows a screenshot of the simulated archaeological site and Figure 3 shows the simulated lab where measures are taken of the artifacts that have been found at the site. The students simulate digging and sifting through sectors in the archaeological dig site (Figure 2) where they find artifacts which are then moved to the simulated lab (Figure 3). In the lab, they are examined, measured, and compared to background information about artifact characteristics of candidate ancient civilizations potentially relevant to the site.

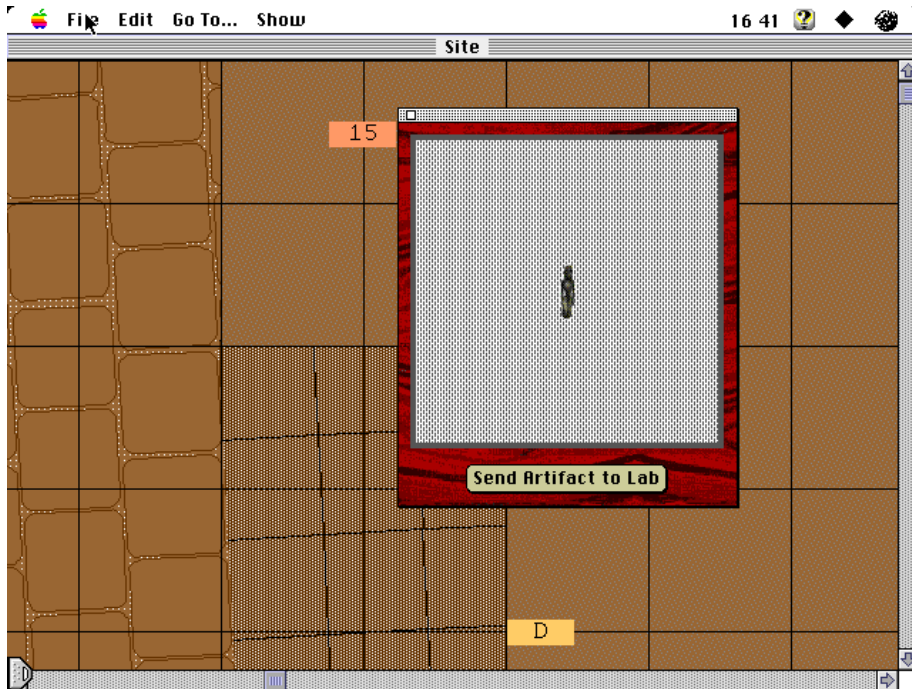


Figure 2: Screenshot of the *Archaeotype* Archaeological Simulation Site

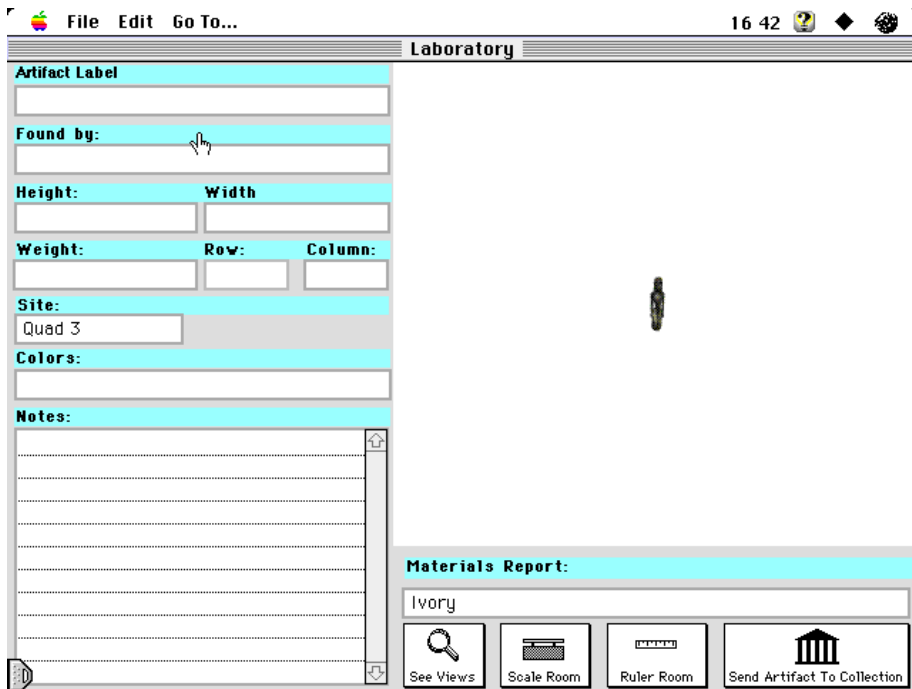


Figure 3: Screenshots of the *Archaeotype* Archaeological Simulation Lab

In the study, students were given a booklet with raw observations in an unfamiliar area accompanied by brief background readings. They then worked in pairs for four hours

to prepare a report describing and interpreting the patterns they saw in the observations, and then providing arguments for their interpretations. Experts in the field made a list of 60 points that the students could make in their reports. Students' written reports were then evaluated for the presence of these points. As shown in Table 2 the *Archaeotype* students showed significantly better pattern recognition than the control students. The largest difference was in shown for provision of those points related to explanation and argumentation whereby the *Archaeotype* students made significantly more points than the control students.

Table 2

Points by Study Group

	Pattern Recognition	Explanation and Argumentation
<i>Archaeotype</i>	42%	45%
Control	32%	26%

These findings point to the efficacy of *Archaeotype* as a vehicle for grounding ancient history for the students and for providing them with direct experience with how archaeologists devise interpretations of data, which in turn, facilitated their pattern recognition, interpretation, and explanation and argumentation skills.

Surrogate Role Playing in Second Life as Grounding for Comprehension and Learning

For students to comprehend content presented in a given text, they need to extract ideas (propositions) within the text, link them together (into a propositional network), and to imagine the situation and world that are being referred to in the text (Black, 2007; Graesser & MacNamara, 2011; Kintsch, 1998). We (Khan & Black, in press) examined these activities in the context of a study whereby college students read an illustrated text about the history of a Mughal emperor in ancient India. Students then role played the part of the emperor in an episode of his life in a computer simulation game implemented in *Second Life* (Linden Labs, 2003) as shown in Figure 4.

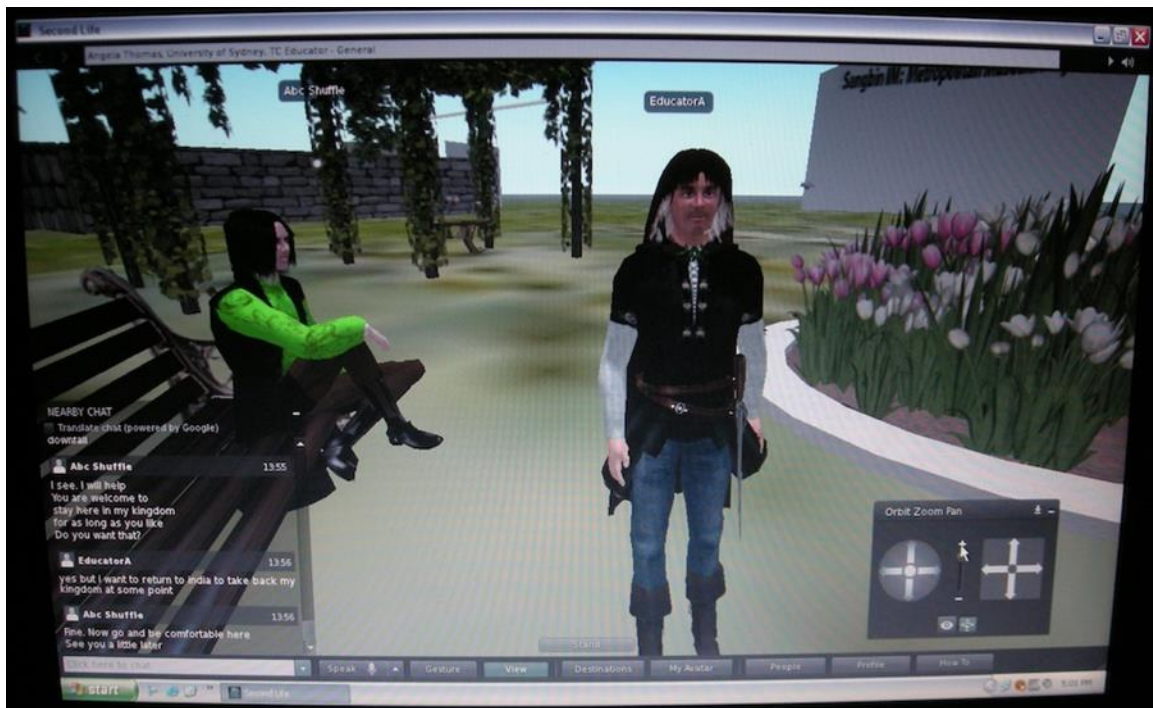


Figure 4. Screenshot from *Second Life* Surrogate Embodiment Avatars for Indian Mughal History Study

During the study, students in the No Embodiment condition read a text with pictures about a particular event in Indian history. In the Surrogate Embodiment condition, the students were also asked to role play the Mughal emperor in this event by controlling an avatar (their surrogate) in *Second Life*. In the Imagined Embodiment condition, students were told to imagine themselves as the Mughal emperor in the historical event. Student learning was assessed via a 20 item memory test (after a brief delay). Students' scores on the test are shown in Table 3. Findings showed that students in the Embodiment conditions remembered significantly more information about the historical event than control group participants (No Embodiment); students who role played with the avatar (Surrogate Embodiment) remembered the most information. Students also were administered a transfer task that entailed reading a text about another figure from the same era of Indian history and listing the similarities and differences between that figure and the emperor. Students in the Surrogate Embodiment students scored significantly higher than the Imagined Embodiment students, who in turn, scored higher than students in the No Embodiment condition. A Far Transfer task, in which students read a literary text instead of an historical one showed the same pattern of results, as did a comprehension test in a follow-up study. Thus, role playing with a surrogate avatar in a computer simulation game seemed to help students better construct an imaginary world and context for their reading and ultimately, promote better learning, memory, understanding, and transfer of the content presented in their reading .

Table 3

Second Life Findings by Condition

	Surrogate Embodiment	Imagined Embodiment	No Embodiment
Memory ¹	24	21	19
Transfer ²	6.7	5.3	4.3

¹ Highest score possible was 30. ² Highest score possible was 12.

In current work, we are exploring the effects of having different historical figures interacting in the same historical events (a multi-user virtual environment), how learning via virtual role playing with avatars as in this study, compares to physical role playing, and how physical and virtual role playing might be mixed to facilitate learning.

Force Feedback Games for Fuller Grounding

Increasing the perceptual richness of simulations, and of video and computer games, increases their effectiveness as grounding experiences for learning. Han and Black (2011) provided evidence for this contention by showing that providing force feedback in a simulation of gear ratios increased students' learning. In this situation the students were learning about work gain and its relationship to gear ratios. Using a graphic interactive simulation yielded better learning than using text and pictures. However, adding force feedback (if the gears in a certain ratio would take more force to turn then the joystick would be harder for the student to turn to control the gear simulation) yielded the greatest learning. (For the study, a simple Microsoft force feedback game joystick was used whereby feedback was provided by the difficulty involved in moving the

joystick in a circular motion.)

Huang, Vea, and Black (2011) expanded this work by using a more sophisticated three dimensional joystick (see Figure 6) that provided a much wider range of force feedback. Specifically, they used it to control the catapult game shown in Figure 5. This game provides students experience with Newton's law relating force with mass and acceleration in physics. Here, the students could vary the mass of the projectiles that they launched with the catapult and also the amount of force they used to pull back the catapult (using the joystick) then observe how far the projectile travelled.

Students' learning was assessed via a basic physics test including 10 standard multiple-choice physics problems taken from Conceptual Physics (Hewitt, 2010) and the Force Concepts Inventory (Hestenes, Wells & Swackhamer, 1992). The Advanced Physics test included another 10 standard multiple-choice problems from the same sources. The Pre-Test showed no significant differences, so Table 3 shows the Post-Test results as mean percent correct on these physics problems. For the Basic Physics Test (related to Newton's Second Law of Motion) the Force Feedback students did significantly better than the No Force Feedback students (first row of table), and also they also did significantly better on the Transfer Advanced Physics Test (related to Gravitation – second row of the table). There was no Force Feedback during the learning of the advanced topic (a Gravitation simulation without Force Feedback capability) so that better performance reflects transfer of the Force Feedback experience from the Basic Physics learning.

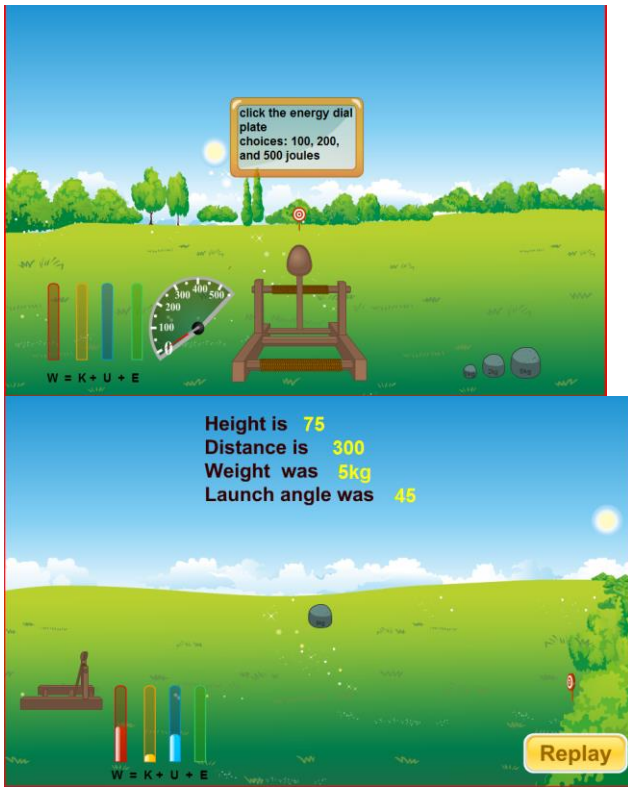


Figure 5. Screen shot from the Catapult Force Feedback Simulation Game (Behind and Side Views)



Figure 6. 3D Force Feedback Joystick Used to Control Catapult Game

The results showed better learning of both the basic physics with the catapult and then transfer to later learning with a different simulation of more advanced physics principles. Thus, increasing the richness of the grounding experience in a computer

simulation game increased learning, problem solving, and transfer to more advanced learning.

Table 3

Force Feedback Study % Correct on Basic Physics Test and Advanced Physics Transfer Test (the differences between Force and No Force Feedback were statistically significant)

	Force Feedback	No Force Feedback
Basic Physics (Law of Motion)	73%	60%
Advanced Physics (Gravitation)	57%	46%

Huang (2013) replicated these results and showed an even stronger result when a force feedback simulation was used to prime related prior experiences (e.g., experiences with sling shots) before the instruction. These results showed improvement in learning with force feedback initial priming of relevant prior experience and also with force feedback during instruction of the current content. In fact, the priming effect yielded the strongest improvement. Thus, further examination of this effect in the context of computer and video games is a promising area for future research.

Transfer of Video and Computer Game Learning

The research reported here suggests that a potentially powerful role for video and computer games and simulations in education is providing rich, perceptually-grounded experience with the content to be learned. This experience, when combined with the interpretations provided by more formal learning activities, provides deeper more robust learning that transfers to other situations, activities and content. The research with the *Civilization* historical simulation game found that becoming expert at playing that game did not seem to increase knowledge of history. However, the experience of grappling with historical dynamics by playing the game prepared students to learn more from reading a difficult college history text chapter. Similarly, efforts to interpret observations in an archaeological site simulation (*Archaeotype*) increased students' ability to interpret and argue using such observations. Others have also found that grappling with observations and phenomena before engaging in more formal learning is particularly effective for learning and transfer (Kapur, 2008; Schwartz & Bransford, 1998; Schwartz, Chase, Opezzo, & Chin, 2011;).

The research on role playing in *Second Life* showed that having learners use surrogate avatars to role play historical actors and events in a virtual world simulation increased their learning, and transfer of historical knowledge acquired from reading an illustrated text about the history (similar to the results with *Civilization* and reading a history text). Ostensibly, the grounding experience provided by this virtual role playing increased students' ability to construct and use the imaginary historical world referred to by the history text (Black, 2007; 2010). Further, this experience enhanced students'

memory, understanding, and transfer of knowledge.

The research on force feedback found that increasing the perceptual richness of grounding physics experiences with a simulation game providing force feedback in addition to the visual and auditory feedback of other simulation games, increased student learning and understanding of basic laws of motion in physics. This knowledge also transferred to improved understanding of more advanced physics.

Collectively, these findings suggest that increasing the richness of the experiences provided by video and computer games may increase the learning, understanding, and transfer of knowledge when used in conjunction with more formal learning activities that provide interpretations of these experiences. Investigating more ways of facilitating these conditions and how best to combine virtual, real world and academic experiences is an important topic for future research.

References

- Ahn, J. (2007). *Application of experiential learning cycle in learning from a business simulation game*. Doctoral Dissertation. Teachers College, Columbia University, New York, New York
- Black, J.B. (2007). Imaginary Worlds. In M.A. Gluck, J.R. Anderson and S.M. Kosslyn (Eds.) *Memory and mind*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Black, J.B. (2010). An embodied/grounded cognition perspective on educational technology. In M.S. Khine and I. Saleh (Ed.) *New science of learning: Cognition, computers and collaboration in education*. New York: Springer.
- Black, J.B. & McClintock, R.O. (1996) An interpretation construction approach to constructivist design. In B. Wilson (Ed.), *Constructivist learning environments*. Englewood Cliffs, NJ: Educational Technology Publications.
- Black, J.B., Segal, A., Vitale, J. and Fadjo, C. (2012). Embodied cognition and learning environment design. In D. Jonassen and S. Lamb (Eds.) *Theoretical foundations of student-centered learning environments*. New York: Routledge
- Bransford, J.D. & Schwartz, D.L. (2001). Rethinking transfer: A simple proposal with multiple implications. In Iran-Nejad, A. & Pearson, P. D., (Eds). *Review of Research in Education 24*, 61-100.
- Dewey, J. (1938). *Experience in Education*. New York: Touchstone.
- Egenfeldt-Nielsen, S. (2007) Third generation educational use of computer games. *Journal of Educational Multimedia and Hypermedia*, 16, 263-281.
- Gee, J. P. (2007). *What Videogames Have to Teach Us about Learning and Literacy* (. 2nd Ed.). New York: Palgrave MacMillan.
- Glenberg, A.M. (1997) What memory is for. *Behavioral and Brain Sciences*, 20, 1-55.

- Graesser, A. C., & McNamara, D. S. (2011). Computational analyses of multilevel discourse comprehension. *Topics in Cognitive Science*, *3*, 371–398.
- Hammer, J. & Black, J. B. (2009). Games and (preparation for future) learning. *Educational Technology*, *49*, 29-34.
- Hammer, J., Black, J., Andrews, G. Zhou, Z., & Kinzer, C. (2007). *Games and learning: A process/PFL approach*. Paper presented at Games Developers Conference, San Jose, CA.
- Han, I. & Black, J. (2011). Incorporating haptic feedback in simulations for learning physics. *Computers and Education*. *57*, 2281-2290.
- Hestenes, D., Wells, M., & Swackhamer, G. (1992) Force concept Inventory. *The Physics Teacher*, *11*, 502-506.
- Hewitt, P.G. (2010) *Conceptual Physics (11th Ed.)*. New York, NY; Pearson.
- Huang, S.C. D. (2013) *Grounded learning experience: Helping students learn physics through visuo-haptic priming and instruction*. Doctoral dissertation. Teachers College, Columbia University, New York, New York.
- Huang, S.C.D. Veal, T., and Black, J.B. (2011). Learning Abstract Physics System with a 3-D Force Feedback Joystick. *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2011*. (pages 1618-1624) Chesapeake, VA: AACE
- Kapur, M. (2008). Productive failure. *Cognition and Instruction*, *26*, 379-424.

- Khan, S.A. & Black, J.B. (in press). Surrogate embodied learning in MUVes: Enhancing memory and motivation through embodiment. *Journal of Immersive Education*.
- Kintsch, W. (1998) *Comprehension: A paradigm for cognition*. New York: Cambridge University Press.
- Linden Labs (2003) *Second Life*. San Francisco: Linden Labs.
- Meier, S. (1991). *Civilization*, Hunt Valley, Maryland: Microprose.
- National Research Council (2011) *Learning science through computer games, and simulations*. Washington, DC: National Academies Press.
- Prensky, M. (2007) *Digital game-based learning*. New York: Paragon House.
- Schwartz, D.L. & Bransford, J.D. (1998) A time for telling. *Cognition and Instruction*, 16, 475-522.
- Schwartz, D.L., Chase, C.C., Oppezzo, M.A., & Chin, D.B. (2011) Practicing versus inventing with contrasting cases: The effects of telling first on learning and transfer. *Journal of Educational Psychology*, 103, 759-775.
- Squire, K. (2004) *Replaying History: Learning World History through playing Civilization III*. Doctoral Dissertation, Indiana University, Bloomington, Indiana
- Squire, K. (2011) *Video games and learning*. New York, Teachers College Press.
- Tobias, S. Fletcher, J.D., Dai, D.Y. and Wind, A.P. (2011) Review of research on computer games. In S. Tobias and J.D. Fletcher (Eds.) *Computer games and instruction*. Charlotte, NC: Information Age Publishing.
- Wineberg, S.S. (1991) Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology*, 83, 73-87.
- Wright, W. (1989) *Sim City*, Emeryville, CA: Maxis.

Young, M.F., Slota, S. Cutter, A.B., Jalette, G., Mullin, G. Lai, B. Simeoni, Z. Tran, M. & Yukhymenko (2012.) Our princess is in another castle: A review of trends in serious gaming for education. *Review of Educational Research*, **82**, 61-89.