Games and simulations

Article · July 2008

2 authors:

Nathan Balasubramanian

Brent G Wilson
University of Colorado

GAMES AND SIMULATIONS

Nathan Balasubramanian
Applied Technology Teacher
Angevine Middle School
United States
nathan.bala@bvsd.org

Brent G. Wilson
Professor, School of Education and Human Development
University of Colorado at Denver and Health Sciences Center
United States
brent.wilson@cudenver.edu

ABSTRACT

This overview examines the challenges and opportunities afforded by games and simulations to enrich teaching and learning. It presents the preliminary findings from a classroom study that used the promising educational games and simulations developed by the Nobel Foundation. Middle school students from all groups, disaggregated by gender and ethnicity, showed significant learning gains after playing these challenging Nobel games. We recommend five guidelines that are necessary for games and simulations to be meaningfully integrated into classrooms.

INTRODUCTION

> *Improving schools internationally is the greatest challenge of our generation* – Clark Aldrich (2004, p. 229)

> *Early studies show that gamers perceive the world more clearly, are more creative problem solvers, are more confident, and are more social* – Steven Johnson (2005)

We juxtaposed these two divergent comments because games and simulations offer tremendous promise to help us cope with the current challenges in education and training. The current technology-savvy generation of students are cognitively more sophisticated and want learning to be fun, engaging, hands-on, challenging, interactive, empowering, and thought provoking. However, some educators continue to think of knowledge and learning in terms of textbooks – sequential, fact-based, and immutable. Students' varied interests and habits of inquiry conflict with traditional textbook-centered classroom instruction, and often result in discipline issues in the classroom.

Simultaneously, the problems facing the world and the workplace are becoming more and more complex. Employers wonder if their employees can be better prepared at schools and universities to cope with today's unique challenges, both nationally and globally. Could simulations and gaming environments stimulate competence, creativity and problem-solving through active collaboration, interactions, dialogue, and shared interests between individuals?

The purpose of this introduction is to examine the challenges and opportunities afforded by games and simulations to enrich teaching and learning. In the latter half of the paper, we assume Nathan's voice as he provides a practitioner's perspective on classroom realities. We conclude with five guidelines that we believe are essential for educational games and simulations to be integrated into classrooms.

WHY GAMES AND SIMULATIONS?

HISTORY AND DEFINITIONS

Although the idea of using computer games to facilitate learning is being resuscitated with new technologies and fresh thinking, a visit to the library at a local university revealed a shelf-load of textbooks from the late 1950s until early 1970s, centered on using games and simulations in classrooms to facilitate learning. Klietsch's (1969) curriculum guidelines elaborate on the underlying *behavioral-learning systems theory* behind games and simulations. Klietsch details various unique characteristics of behavior-based simulations and games (Unit A, pp. 4-5), which include: goals, capabilities, resources, means, interactions, strategy, engagement, decision-making, and problem-solving requirements. The commercial gaming industry has capitalized on these characteristics and continues to design games that satiate gamers' interests world-wide. The latest snapshot study by the BBC Audience Research (BBC News, 2005) in the UK reported that 59% of the 26.5 million individuals surveyed in the age groups 6 – 65 are gamers – 48% of them women. They concluded that gaming is enjoyed by both genders across all ages in all walks of life.

With numerous genres available, the word "game" has been elusive to define and holds various denotations and connotations. Glazier (1973), Prensky (2001), and Rasmusen (2001) have described the presence of the following basic components in games: 1) Player Roles, 2) Game Rules, 3) Goals and Objectives, 4) Puzzles or Problems (Challenges), 5) Narrative or Story, 6) Players' Interactions, 7) Payoffs and Strategies, and 8) Feedback and Outcomes. We define a game as *an engaging interactive learning environment that captivates a player by offering challenges that require increasing levels of mastery*. The *Laser Challenge Game* (http://nobelprize.org/physics/educational/laser/challenge.html) designed by the Nobel Foundation exemplifies this definition.

Similarly, with wraparounds or scaffolds to advance learning outcomes, simulation-based environments also engage students and promote learning. Aldrich (2004) defines simulations as tools that facilitate learning through practice in a repeatable, focused environment. Additionally, simulations are safe, flexible, resource-efficient, globally accessible when web-based, and effective in helping students develop visual and conceptual models. *SimCity*, a popular simulation, is a good example. This simulation challenges players' strategic thinking and building abilities as they cope with resource constraints to design a harmonious city. Players can see how well their city evolves based on the decisions they make. According to Chaplin and Ruby (2005), the designer of *SimCity*, Will Wright, had deliberately left the criteria of winning and losing to the players to make their experience personal and compelling.

Even though researchers are constantly trying to define and differentiate games from simulations, there are more commonalities than differences between them. Aldrich (2004) attenuates the distinction further by recommending that educational simulations should incorporate "applied pressure situations that tap users' emotions and force them to act" (p. 9). He argues that simulations can promote full cycles of learning starting with goal, plan, experiment, feedback, update, and understanding. In a book published a year later, Aldrich (2005) prefers defining educational simulations as something that happens when simulation elements, game elements, and pedagogical elements converge. Although we are not there yet, Aldrich (2004) predicts that the development and adoption of games and simulations will have the greatest impact on teaching and learning in schools.

EDUCATIONAL STRENGTHS

When designed well, both simulations and gaming environments can facilitate students' learning of both specific domain knowledge and concepts, and several cognitive skills like pattern recognition, decision-making and problem-solving. From their review of literature covering a period of 28 years, Randel et al. (1992) concluded that gaming could be used effectively to provoke interest, teach domain knowledge, and shore up retention in math, physics, and language arts when specific instructional objectives were targeted. Funk (2002) cites studies which found that games strengthened students' engagement, information processing, problem-solving, social development, and academic abilities. Other educational strengths of using games and simulations include developing a variety of cognitive objectives, transferable process skills, student-centered learning, initiative, creative thinking, affective objectives, sense of completion, and knowledge integration (Ellington, Gordon & Fowlie, 1998).

Additionally:

- Exploratory interactive games are useful for instruction in math and science, particularly when concepts are difficult to visualize or manipulate with concrete materials (Mitchell & Savill-Smith, 2004).
- Students' dialogue and decision-making while engaged with multi-level games provokes experimentation, discovery learning, and perseverance as science, technology, engineering, mathematics (STEM) principles are distorted and explored in the games (Kirriemuir, 2002).
- Students develop expert behaviors such as pattern recognition, problem solving, qualitative thinking, and principled decision-making as their individual expertise with games increase (VanDeventer & White, 2002).
- Student effectiveness increases when they are afforded opportunities to contribute to the game design and create new games (Mitchell & Savill-Smith, 2004).
- Students' motivation, skills, and ability to explore, experiment and collaborate increased by playing computer games (BECTA, 2001).
- With realistic games, students not only become smarter and intellectually engaged but also realize their desire for hard fun, delayed gratification, rewards, making right decisions, participation, depth of understanding, challenge, and using their pattern recognition and problem-solving skills (Johnson, 2005).
- Both resource-deprived and resource-affluent students, make significant learning gains after playing well-designed games (Herselman, 1999, cited by Mitchell & Savill-Smith, 2004).
- Students' spatial abilities and cognitive development increases after playing with simulations and games among both genders (Mitchell & Savill-Smith, 2004).

POSSIBLE EXPLANATIONS

Computer games embody good principles of learning (Gee, 2003) and motivate players by providing them with appropriate levels of challenge, curiosity, control, and fantasy (Malone & Lepper, 1987). More specifically, what might make games and simulations so powerful for enhancing students learning?

1. Is it gamers' familiarity with the powerful visual media and gaming environments? Kafai (1996) noted that playing video games was often students' first interaction with technology in their homes.
2. Is it gamers' active engagement in structured learning environments? Rendel et al. (1992) observed that students' active participation during play could account for their better integrated cognitive structures, retention, and subsequent transfer.
3. Is it gamers' engaging experience as they interact with the different levels of game? Swartout and van Lent (2003) highlight the interplay of the three levels: short-term, medium-term, and long-term goals in facilitating compelling experiences for gamers during play.
4. Is it gamers' increased self-efficacy as their proficiency develops? Although temporary, Roe and Muijs (1998, cited by Mitchell & Savill-Smith, 2004) observed an increased sense of mastery, control and achievement in players as their individual gaming proficiencies improved.
5. Is it gamers' improved knowledge and conceptual understanding due to meaningful computer-based dialogue? Ravenscroft and Matheson (2002, cited by Mitchell & Savill-Smith, 2004) found that 30 minutes of collaborative learning through dialogue games (including exploratory talk, constructive conflict, and collaborative argumentation) produced significant improvements in students' knowledge and conceptual understanding about the physics of motion.
6. Is it gamers' ongoing learning from the immediate feedback, both successes and failures, embedded in games? According to Prensky (2001), individuals' learning through games is primarily due to the instant feedback gamers receive during play.

CHALLENGES

While powerful and promising, the use of games and simulations present several challenges. Aldrich (2004) discusses 17 challenges related to games and simulations, including cost, delivery, time constraints, evaluation, and extent of guidance in simulations. Both the case study by Yeo et al. (2004) and our personal experiences show that interactivity and dynamic graphics in simulations, by themselves, do not promote transfer, reflection, or understanding. Meanwhile, finding and using engaging educational games continue to remain a challenge. Is this because games' efficacy and usefulness have been suspect (Wolfe & Crookall, 1998)? Are games perceived as frivolous diversions in this era of increased accountability (Balasubramanian, 2003)? Has educational computer games' limited use of sound pedagogical principles and reliance on drill and practice resulted in their being ignored in educational research (Gredler, 1996; Reiber, 1996, cited in MIT Games-To-Teach Research Team, 2003)?

Other concerns with using computer games include: difficulty of integrating games with traditional instruction, mismatch between level of game and students' abilities or needs, fear of some students not participating or cooperating, and exposing teacher vulnerabilities amidst technology-savvy students (Ellington et al., 1998). Above all, although several studies have shown the merits of playing computer games, none has addressed the classroom challenges of matching the games to the standards-based curriculum, justifying its use during premium instructional time, aligning game activity with content understanding, customizing off-the-shelf games to the learning needs of culturally diverse populations, designing authentic open-ended learning scenarios, and furthering humane values of acceptance, trust, and citizenship.

USING GAMES AND SIMULATIONS IN THE CLASSROOM – NATHAN'S EXPERIENCE

The preceding paragraphs highlight the challenges that need to be addressed before games and simulations can become ubiquitous in classrooms. In this section, I reflect on my 16 years of teaching science and technology in middle and high schools when I have used computer games and simulations.

FOUR CRITICAL QUESTIONS

What should a classroom teacher look for in games and simulations? Malone (1980) made a compelling argument organized around challenge, fantasy, and curiosity for designing intrinsically motivating computer games. Additionally, I would examine the content, quality, usability, and age-appropriateness of the game. I believe well designed games are a great asset in helping students engage and explore the core concepts in a safe learning environment, prior to formal instruction. Egenfeldt-Nielsen (2005) makes a case for using them to introduce theory and provide some concrete experience for the students. We made a similar case for using games and simulations as the first step in our conceptual framework for promoting STEM learning (Balasubramanian, Wilson, & Cios, 2005). Whether it is learning about systems and models, or examining cause-and-effect relationships, or figuring out choices and consequences, students can be quickly exposed to the big ideas in a topic by using well-engineered simulations. For example, I use the Circuit Construction Kit designed by the *Physics Education Technology Group* (*PhET*) at the University of Colorado (http://www.colorado.edu/physics/phet/web-pages/simulations-base.html) to introduce the concepts of an electrical circuit, current, voltage, and resistance. I have students explore these concepts by posing a challenge: Can you construct an electrical circuit to light a bulb with just one wire, one battery, and one light bulb and not burn the battery or your fingers? Students have opportunities to do this both online using the simulation (and not have the battery burst into flames) and hands-on with the three objects (and not have their fingers burnt). Although students are immediately engaged because they know they should be able to do it, you will be surprised by the number of students (and adults) who find this challenging.

Where should a classroom teacher look to find useful games and simulations? This has been my major concern because there is no place teachers can go to find the different games and simulations available by topic or age-appropriateness. In this era of National Digital Libraries, it would be good to have one place where teachers can access available games and simulations resources easily. I have used the *Physics 2000* simulations (http://www.colorado.edu/physics/phet/web-pages/simulations-base.html) while teaching modern physics for the International Baccalaureate program at the Emirates International School in Dubai, United Arab Emirates. I vividly recall students' fascination with this resource for testing their ideas, for example on interference and polarization, and learn more about 20th century science and technology. I also used the *Physlets*, physics applets (http://webphysics.davidson.edu/Applets/Applets.html), which are small flexible Java simulations designed for science education as a resource. *Physlets* are used by several physics teachers around the world for classroom demonstrations, peer instruction, and media-focused homework, and just-in-time teaching of introductory and modern physics. The *PhET* website at http://phet.colorado.edu hosts over 50 sims that are designed to increase student engagement and learning (Perkins et al., 2006) on common physics topics such as motion; work, energy, and power; sound and waves; heat and thermodynamics; electricity and circuits; light and radiation; quantum phenomena; chemistry; mathematics tools; and cutting edge research.

How should a classroom teacher use games and simulations? Recently I heard a counselor chuckle about a student who whined about the social studies class, asking, "Why should we study about dead people?" Researchers have used commercial games like *SimCity* and *Civilization III* to enrich their social studies classes. For example, Squire (2004) used *Civilization III* to explore its usefulness in the classroom and found that, although useful, it led to several contradictions because of the complexity of the game, extended time commitments required, students having varied difficulty learning how to use it, and different levels of students' personal motivation.

The most promising educational games and simulations I know, based on prize-winning achievements, are those designed by the Nobel Foundation (http://nobelprize.org/games_simulations.html). Students' enthusiasm for learning and playing well-designed games is captured in their rich descriptions available at http://www.innathansworld.com/technology/GamesNSimulations.htm Students repeatedly used words like learning, figuring out, paying attention, scoring, thinking, decision-making, multiple game levels, fun, challenge, interactive, strategy, hands-on, and choices in their descriptions. In my 16-years of teaching in middle and high schools, I have not seen such widespread enthusiasm for learning and sharing.

How should a classroom teacher evaluate the use of games and simulations? I was keen on finding out the ability of these games to promote student learning with minimal teacher intervention. McDonald and Hannafin (2003) noted that web-based games promote higher-order learning outcomes because they increase meaningful dialogue. Before students played the games from a list of six, I administered a 25-question pretest electronically that provided "immediate feedback" (Balasubramanian, 2006) to students. Then students played the games for about an hour and in the last five minutes of class, I debriefed them about their experience. I gathered feedback on what they liked about these games or games in general. I consider this a brief after action review (AAR), recommended by Bonk and Dennen (2005).

In their next class, students took a post-test, with the same 25 questions. However, the order of questions was different and the tests had different titles. I analyzed their results using the Statistical Package for the Social Sciences (SPSS). The results are tabulated in Fig. 1 below.

Group	N	Pretest Mean (%)	Pretest SD (%)	Post-test Mean (%)	Post-test SD (%)	t-value	p-value
Entire Class	40	46.9	18.2	77.9	19.4	8.341	<.0001
Caucasian M.	18	51.8	19.9	80.7	16.2	6.113	<.0001
Minorities	22	42.9	16.2	75.5	21.7	5.824	<.0001
Girls	11	41.8	11.6	81.1	12.1	8.418	<.0001

Fig. 1. Summary of two-tailed, paired sample t-tests after playing the Nobel games

Clearly, despite small sample sizes and minimal teacher intervention, the two-tailed, paired sample, t-tests show that the mean test scores increased *significantly* from pretest to post-test for the entire class, even with disaggregated data by gender, ethnicity, and minority students (Girls, Hispanics, African Americans, and American Indians) classification. Clearly, my study is not a valid scientifically based research because there is no control group. However, with larger sample sizes, I could have examined whether groups of students with after action review (AAR) did better than those without AAR.

GAMES AND SIMULATIONS ARE NOT TEACHER-PROOF

Evidently, designing wraparounds can be challenging. The computer games in education project (BECTA, 2001) concluded that although the benefits of using games was clear, a teacher's role in structuring and framing activities around games was critical. In the case of games and simulations designed by the Nobel foundation, it was easier for me to personally justify their use in the classroom and design quizzes to find out what students were learning. Although the games designed by the Environmental Protection Agency, (http://www.epa.gov/OGWDW/kids/gamesandactivies.html) directly related to water and the filter design activities at that time, students were quick to point out that they liked the Nobel games better. The Nobel games were "useful, exciting, fun, active, challenging, engaging, interactive, interesting, hard, and designed with very good graphics," the students wrote.

Contrary to Schank (Green, 2000), who claims that interactive software would make teachers redundant, I would argue that even with well-designed games, a teacher's role in facilitating a meaningful learning environment will remain pivotal. I would concede though that a teacher's subject expertise, understanding of pedagogy, comfort level using technology, and easy access to technology would contribute significantly to games and simulations becoming used more often in the classroom.

RECOMMENDATIONS

The findings of numerous researchers in this article illustrate that well designed games and simulations can prepare our students to learn critical problem-solving and decision-making skills necessary for the real world. Student endorsements that the Nobel games and simulations actually "teaches you about the subject, uses harder questions and better graphics," along with results from their pretests and post-tests showing significant gains, illustrated how students are not averse to learning in the classroom. Further studies might explore what makes these Nobel games and simulations interesting.

Evidently, games are firmly entrenched among youth and adults alike, as the recent BBC Audience Research study reported. When designed well, games can truly be an important teaching tool (Shreve, 2005). They promote numerous cognitive benefits in learners, including a facilitation of increased interactions, motivation for learning, visualization, experimentation, self-efficacy, self-monitoring, pattern recognition, problem-solving and critical thinking – abilities that we want all our students to graduate with from our schools.

Yet, several educators continue to view the use of games and simulations in the classroom with apprehension. If games and simulations are to be meaningfully integrated into classrooms, the following five guidelines should inform the design of educational games in the future.

1. The design of games and simulations should be sophisticated and challenging enough for students to be cognitively engaged with the game.
2. The content of games and simulations should be aligned with the standards and viable curriculum in schools.
3. The logistics and usability of the games should reflect classroom realities and time constraints in schools.
4. The feedback and assessments embedded in the games should embody measurable learning outcomes.
5. The teacher guides accompanying the games should provide sufficient ideas, activities and resources to enhance students learning.

The papers that follow provide more examples of how games and simulations might be used to enhance learning in classrooms.

REFERENCES

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

Aldrich, C. (2005). *Learning by doing: A comprehensive guide to simulations, computer games, and pedagogy in e-learning and other educational experiences.* San Francisco: Pfeiffer.

Balasubramanian, N. (2003). Smart education: Blending subject expertise with the concept of career development for effective classroom management. University of Georgia, *Instructional Technology Forum (ITFORUM) Web site*. Retrieved from http://itech1.coe.uga.edu/itforum/paper73/paper73.html

Balasubramanian, N., Wilson, B. G., & Cios, K. J. (2005). Innovative methods of teaching and learning science and engineering in middle schools. In F. Malpica, F. Welsch, A. Tremante, & J. Lawler (Eds.), *The 3rd International Conference on Education and Information Systems: Technologies and Applications: Vol. 1.Proceedings* (pp. 174–178), Orlando, FL. July 14 – 17, 2005. Retrieved from http://www.gamestolearn.us/E898HR.pdf

Balasubramanian, N. (2006). Increasing student achievement through meaningful, authentic assessment. Manuscript accepted for presentation at the *17th International Conference of the Society for Information Technology & Teacher Education*, Orlando, FL. March 20 – 24, 2006.

BBC News (2005). *At-a-glance: State of play*. Retrieved from http://news.bbc.co.uk/1/shared/spl/hi/sci_nat/05/state_of_play/html/1.stm

BECTA. (2001). Computer games in education project. *British Educational Communications and Technology Agency* (BECTA). Retrieved from http://www.becta.org.uk/page_documents/research/cge/report.pdf

Bonk, C. J., & Dennen, V. P. (2005). *Massive multiplayer online gaming: A research framework for military education and training*. Technical Report 2005-1 of Advanced Distributed Learning. Retrieved from http://www.adlnet.org/downloads/189.cfm

Chaplin, H., & Ruby, A. (2005). *Smartbombs: The quest for art, entertainment, and big bucks in the videogame revolution.* Chapel Hill, NC: Algonquin Books.

Egenfeldt-Nielsen, S. (2005). *Beyond edutainment: Exploring the educational potential of computer games*. Unpublished doctoral dissertation. University of Copenhagen, Denmark. Retrieved from http://www.it-c.dk/people/sen/egenfeldt.pdf

Ellington, H., Gordon, M., & Fowlie, J. (1998). *Using games & simulations in the classroom*. London: Kogan Page.

Funk, J. B. (2002). Electronic Games. In V. C. Strasburger and B. J. Wilson. *Children, adolescents, & the media*. Thousand Oaks, CA: Sage Publications. 117-144.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Glazier, R. (1973). *How to design educational games* (4th ed.). Cambridge, MA: ABT Associates.

Gredler, M. E. (1996). Educational games and simulations: A technology in search of a (research) paradigm. In D. H. Jonassen, (ed.), *Handbook of Research on Educational Communications and Technology*. New York: Macmillan. 521-539.

Green, J. (2000, August 10). No lectures or teachers, just software. *New York Times*. Retrieved November 17, 2005, from http://www.nytimes.com/library/tech/00/08/circuits/articles/10prof.html

Johnson, S. (2005). *Everything bad is good for you*. New York: Riverhead Books.

Kafai, Y. B. (1996). Software by kids for kids. *Communications of the ACM, 39*(4), 38-39

Kirriemuir, J. (2002). The relevance of video games and gaming consoles to the higher and further education learning experience. In Techwatch report TSW 02-01of *The Joint Information Systems Committee*, http://www.jisc.ac.uk/uploaded_documents/tsw_02-01.rtf

Klietsch, R. G. (1969). *An introduction to learning games & instructional simulations: A curriculum guide*. Newport, MN: Instructional Simulations.

McDonald, K. K., & Hannafin, R. D. (2003). Using web-based computer games to meet the demands of today's high-stakes testing: A mixed-methods inquiry. *Journal of Research on Technology in Education*, *35*(4), 459-472.

Malone, T. W. (1980). *What makes things fun to learn? A study of intrinsically motivating computer games*. In Cognitive and Instructional Sciences Series CIS-7. Palo Alto, CA: Xerox Palo Alto Research Center.

Malone, T. W., and Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction: Cognitive and affective process analyses: Vol. 3*. Hillside, NJ: Lawrence Erlbaum Associates. 223-254.

MIT Games-to-Teach Research Team. (2003). Design principles of next-generation digital gaming for education. *Educational Technology*, *43*(5), 17-23.

Mitchell, A., & Savill-Smith, C. (2004). *The use of computer and video games for learning: A review of literature*. London: Learning and Skills Development Agency.

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. *The Physics Teacher*, *44*(1), 18-23.

Prensky, M. (2001). *Digital game-based learning*. New York: McGraw-Hill.

Randel, J. M., Morris, B. A., Wetzel, C. D., & Whitehill, B. V. (1992). The effectiveness of games for educational purposes: A review of recent research. *Simulation & Gaming*, *23*(3), 261-276.

Rasmusen, E. (2001). *Games and information: An introduction to game theory* (3rd ed.). Malden, MA: Blackwell.

Shreve, J. (2005). Let the games begin. *Edutopia*. 28-31. Retrieved from http://www.edutopia.org/magazine/ed1article.php?id=art_1268&issue=apr_05

Slavin, R. E. (2003). A reader's guide to scientifically based research. *Educational Leadership*, *60*(5), 12-16.

Squire, K. D. (2004). *Replaying history: Learning world history through playing civilization III*. Unpublished doctoral dissertation. Indiana University, Bloomington. Retrieved from http://website.education.wisc.edu/kdsquire/dissertation.html

Swartout, W., & van Lent, M. (2003). Making a game of system design. *Communications of the ACM*, *46*(7), 32-39.

VanDeventer, S. S., & White, J. A. (2002). Expert behavior in children's video game play. *Simulation and Gaming*, *33*(1), 28-48.

Wolfe, J., & Crookall, D. (1998). Developing a scientific knowledge of simulation/gaming. *Simulation and Gaming*, *29*(1), 7-19.

Yeo, S., Loss, R., Zadnik, M., Harrison, A., & Treagust, D. (2004). What do students really learn from interactive multimedia? A physics case study. *American Journal of Physics*, *72*(10), 1351-1358.