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COMPUTER GAMING AND INTERACTIVE SIMULATIONS FOR LEARNING: A META-ANALYSIS

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ABSTRACT

Substantial disagreement exists in the literature regarding which educational technology results in the highest cognitive gain for learners. In an attempt to resolve this dispute, we conducted a meta-analysis to decipher which teaching method, games and interactive simulations or traditional, truly dominates and under what circumstances. It was found that across people and situations, games and interactive simulations are more dominant for cognitive gain outcomes. However, consideration of specific moderator variables yielded a more complex picture. For example, males showed no preference while females showed a preference for the game and interactive simulation programs. Also, when students navigated through the programs themselves, there was a significant preference for games and interactive simulations. However, when teachers controlled the programs, no significant advantage was found. Further, when the computer dictated the sequence of the program, results favored those in the traditional teaching method over the games and interactive simulations. These findings are discussed in terms of their implications for exiting theoretical positions as well as future empirical research.

INTRODUCTION

Understanding the specific nature of the relationship between educational gaming and simulation computer programs and how they affect learning is important for several reasons. First, due to society's reliance on computers, children and adults alike are now being required to interact with computers in all settings, including educational ones. Second, schools, universities, and even job training settings are now finding that computer programs are effective in reducing educational and training costs (Rifkin, 1994). There is also some evidence to suggest that using these computer games or simulations may actually "teach" people more effectively than traditional methods (Cassidy, 2003; Jenkins, 2002). For these reasons, it is imperative that research investigates this effectiveness to more properly utilize these programs.

The role of computers in education has changed drastically over the last several decades. These advances stem largely from the increased power, accessibility, and graphical capabilities of current computers (Kirriemuir, 2002; Naps et al., 1997; Rifkin, 1994). Initially, computers were used for business, mathematical computations, and then for leisure games. However, several reviews of computer-assisted-instruction (CAI) covering articles from the last four decades have shown that computers can also be used for learning (Bangert-Drowns, Kulik, & Kulik, 1986; Kirriemuir, 2002; Ryan, 1991). While this viewpoint is generally accepted, teachers rarely incorporate computers into their daily teaching routines (Murphy, Blaha, VanDeGrift, Wolfman, & Zander, 2002; Soloway, 1998). Some reasons for this may involve pragmatic issues such as funding and access (Murphy, Blaha, VanDeGrift, Wolfman, & Zander, 2002; Soloway, 1998). However, one might hypothesize that teachers do not use computers because they require more effort by the teacher for little perceived cognitive gain. This is not intended to place blame on teachers for this situation. Rather, it is the job of researchers to find a way to help already overworked teachers by creating computer systems that reduce the children's time-on-task and increase their cognitive gains. Stated another way, computer programs need to teach people better and faster. They must also teach in accordance with the state mandated curriculum requirements to be directly useful for teachers (Soloway, 1998).

The difficulties described above impose a special challenge for scientists and software developers in this area. First, we must develop a research base so that we know how best to create positive learning outcomes. We must then translate those results into a product that is attractive to the learner while being practical for the teacher. Obviously, software designers will not wait for a program of scientific research before responding to this need in the market. Indeed, educational software is a fast-growing genre. However, several of these products have been developed using "seat-of-the-pants" approaches rather than validated scientific principles. We seek to contribute to this area by one type of computer-based training that has only recently attracted the attention of scientists. Our goal is to arrive at an impartial assessment of these data along with some guidance about how the learning strategy can best be deployed.

We have chosen to focus on the effectiveness of games and interactive simulations. There are several factors that point to this type of computer-assisted learning as an area worthy of study. First, there is the practical reality that this type of software is easily available, and that development costs are being reduced seemingly every day. Thus, there is an exciting opportunity for the educational user. It should be noted that current theory supports the notion that playing games allows the brain to work more efficiently and thus take in more cognitive material than it would in a more traditional setting (Baltra, 1990; Pange, 2003; Perry & Ballou, 1997). Further motivation is a main focus for teachers based on the premise that motivated and interested students will learn more and will do it faster (Lardinois, 1989, cited in Siemer & Angelides, 1995; Rieber, 1996; Romme, 2003). Game theory, and video game theory specifically, support the belief that computer games are highly engaging, motivating, and interactive (Ju & Wagner, 1997; Kafai, 2001; Rieber, 1996).

This range of how a game or interactive simulation is defined varies widely (Manninen, 2002). The Society for the Advancement of Games and Simulation in Education and Training (Saunders, 1987, cited in Galvao, Martins, & Gomes, 2000) defines "simulation" as, "a working representation of reality . . . [that[may be an abstracted, simplified, or accelerated model of process." While "game" is defined as, "one or more players compete or cooperate for pay-off according to a set of rules or . . . a setting in which participants make choices, implement those options and receive consequences of those decisions as an effort to achieve given objective," (VanSickle, 1978, cited in Galvao, Martins, & Gomes, 2000). Siemer and Angelides (1995) define the hybrid gaming-situations as, "a sequential decision-making exercise, with the basic function of providing an artificial but realistic environment that enables players to experience the consequences of their decisions through immediate response." Whatever the nuances of each individual definition, one common thread must be included. Interactivity is the key factor in creating better educational outcomes (Stoney & Wild, 1998). It is based on this premise that the definitions of games and interactive simulations were created for this analysis. They are defined as follows. A *computer* game is defined as such by the author, or inferred by the reader because the activity has *goals*, is *interactive*, and is *rewarding* (gives feedback). Interactive simulation activities must *interact* with the user by offering the options to *choose or define parameters* of the simulation then observe the newly created sequence rather than simply selecting a prerecorded simulation.

As mentioned previously, numerous meta-analyses and review articles have been published showing small but positive effect sizes supporting CAI over other teaching methods (Bayrakter, 2001; Chambers, 2002; Christmann & Badgett, 2003; Cohen & Decanay, 1992; Fletcher-Flynn & Gravatt, 1995; Kulik, 1994; Kulik & Kulik, 1986; Lowe, 2001). The primary focus of these reviews is on CAI defined as any program that augments, teaches, or simulates the learning environment used in the traditional classroom (Quyang, 1993). Such programs include, but are not limited to drill-and-practice programs, multimedia classrooms, web-based instruction, and previously created simulations (Murphy et al., 2002).

A few additional meta-analyses have examined simulations and games. Lee (1999) focused on the comparison of pure and hybrid simulations finding that hybrid simulations had a significant advantage over pure simulations in learning outcomes. VanSickle (1986) found that there was a slight advantage in gaming simulations to produce positive attitudes toward the subject matter being studied compared to other teaching methods. Additionally, the analysis revealed that using gaming simulations for learning resulted in higher cognitive gains when compared to other teaching methods, but not to traditional, lecture methods. A more recent review article about games (Randel, Morris, Wetzel, & Whitehill, 1992) covering the years 1984 to 1991 reported that of the 67 articles included, 38 found no differences between computer games and traditional teaching methods, 22 favored games, an additional five with questionable control groups also favored games, and only three favored traditional methods. Additionally, results of individual studies from 1986 to the present are equivocal (Brewster, 1996; Costabile, De Angeli, Roselli, Lanzilotti, & Plantamura, 2003; Kim, Kim, Min, Yang, & Nam, 2002; Laffey, Espinosa, Moore, & Lodree, 2003; McGarvey, 1986; Rosas et al., 2003). While some studies showed significant differences favoring games or interactive simulations over traditional teaching methods (Laffey, Espinosa, Moore, & Lodree, 2003; McGarvey, 1986), other studies found the opposite result (Costabile, De Angeli, Roselli, Lanzilotti, & Plantamura, 2003; Kim et al., 2002). Still others showed no significant differences between the two types of teaching (Brewster, 1996; McGarvey, 1986; Rosas et al., 2003).

Based on the differences of results, it is difficult for researchers to determine the true nature of the relationship between gaming and interactive simulations with learning. The differences may have arisen due to various differences that exist among the articles. Each of these studies focused on different skills to learn, used the computers differently, and used different subject populations. All of these differences potentially account for the conflicting study results. We believe that a meta-analysis will more accurately synthesize the results of the existing studies thus providing more information about the state-of-the-art in this area.

The main object of this analysis is to control for each of these issues and make an accurate determination of how games and interactive simulations relate to learning.

METHOD

Potential studies were selected from computerized databases (PsycInfo, ERIC, ACM, and Google), dissertation abstracts, and back-searches from gathered articles' reference lists. In order to be included in the analysis, each study must have identified cognitive gains or attitudinal changes as one of its main hypotheses. Also, it was required that each study report statistics assessing traditional classroom teaching versus computer gaming or interactive simulation teaching. Studies were assessed using three moderator variables: Type of Activity

[(1) Interactive simulation (user must interact with the simulation by either *choosing or defining parameters* of the simulation then observe its execution), (2) Game (Any *computer* game that is *interactive* and defined as such by the author, or inferred by the reader because the activity has *goals*, is *interactive*, and is *rewarding* (gives feedback)), (3) Unknown/unspecified]; Population [AGE – Age (1, 2, 3, 4, 5, 6, 7—preschool (less than five years of age), elementary (grades K-5, ages 6-11), middle (grades 6-8, ages 11-14), high (grades 9-12, ages 14-18), college (undergraduate study, ages 18-24), adult (25 years of age and older), unknown/unspecified), GNR—Gender (1, 2, 3, 4—male, female, both, unspecified), U.S.—User (1, 2, 3, 4—individual, group, both, unspecified)]; and Computer Characteristics [RL—Realism (1, 2, 3, 4—photo-realistic, high-quality cartoon-like pictures, low-quality programmed pictures, unknown/unspecified), LC—Learner Control (1, 2, 3, 4—game is controlled by the: student, teacher, computer, unspecified)]. A total of 248 studies were evaluated for inclusion. However, after review, only 32 studies actually met the requirements and were used for the analysis. Two raters were used to assess each study in the analysis. The actual reliability found was 84% with a Cohen's Kappa of .74.

All statistics used in each study were converted to the effect size index *r* using the following formulas:

$$F \text{ to } r = \text{sq. root of } F/F + df \tag{1}$$

$$t \text{ to } r = \text{sq. root of } t2/t2 + df \tag{2}$$

$$z \text{ to } r = \text{sq. root of } z2/n \tag{3}$$

$$x2 \text{ to } r = \text{sq. root of } x2(1)/n1 + n2 \tag{4}$$

The *n* in equation 3 represents the overall sample size in each study. The *n* used in equation 4 represents the sum of sample sizes for the two groups compared. Next, we computed the overall Confidence Interval (CI) of *r*. And finally, a dot plot graph was made using the correlation coefficient estimates and CIs of each study.

RESULTS

Two effect sizes were compiled for the overall results. The data suggest that, overall, significantly higher cognitive gains were observed in subjects utilizing interactive simulations or games versus traditional teaching methods ($z = 6.051$, $p < .0001$ ($N = 8549$)). The fail-safe number (*Nf*s), or the number of undiscovered studies with opposing results needed to change this conclusion, was 1465. Thus, this finding was reliable. A main effect for attitude was also found ($z = 13.74$, $p < .0001$) ($N = 2378$), *Nf*s = 117) reliably suggesting that subjects' attitudes toward learning when using the computers were significantly better than those utilizing traditional teaching methods.

Gender

When evenly distributed across genders or when gender was unreported in the study, significant results for cognitive gains in the game and interactive simulation group were found ($z = 8.073$, $p < .0001$ ($N = 2347$), $Nfs = 288$) and ($z = 4.190$, $p < .0001$ ($N = 6102$), $Nfs = 348$) respectively. Consistent with this, females showed significant cognitive gains favoring the interactive simulation and game method ($z = 2.583$, $p = .0049$ ($N = 80$), $Nfs = 3$). There was an insufficient number of studies using only males to allow for a reasonable conclusion. However, those studies that reported statistics comparing males and females found no significant differences ($z = .9910$, $p = .1594$ ($N = 394$), $Nfs = 0$). Again, due to the low fail-safe number, these results should be considered with caution.

Learner Control

Programs that were designed to automatically navigate students through the system based on techniques such as decision trees or artificial intelligence, were less effective than traditional classroom education in creating cognitive gains ($z = –2.099$, $p = .018$ ($N = 94$), $Nfs = 0$). However, there is not a sufficient sample size to draw this conclusion with confidence. Studies that used programs where the learner controlled their navigation through the system showed opposite results. Significant cognitive gains in the game and interaction simulation groups were observed compared to the traditional teaching methods ($z = 7.038$, $p < .0001$ ($N = 3656$), $Nfs = 1233$).

Type of Activity

The type of activity does not appear to be influential. Studies using interactive simulations, games, or a method that involved both had highly significant results, similar to the overall effect, in the directions of higher cognitive gains compared to traditional teaching methods ($z = 9.147$, $p < .0001$ ($N = 2179$), $Nfs = 963$); ($z = 3.706$, $p = .0001$ ($N = 2165$), $Nfs = 24$); and ($z = 3.209$, $p = .0007$ ($N = 4205$), $Nfs = 0$) respectively. The low fail-safe numbers in the game and combination groups indicate low reliability for these results.

Age

Age groups were combined in order to attain an acceptable level of power. Preschool, elementary, middle, and high school children showed significant results ($z = 4.111$, $p < .0001$ ($N = 6138$), $Nfs = 86$) favoring game and interactive simulations. Similar results were obtained for College and Adult populations ($z = 7.434$, $p < .0001$ ($N = 2336$), $Nfs = 494$).

Realism

Level of picture realism in the computer programs did not alter the results. All levels showed strong interactive simulation and game preferences, similar to the overall effects. Results are summarized in Table 1.

User

Both user types (individual and group) showed significant results favoring the interactive simulation and game methods ($z = 7.352$, $p < .0001$, ($N = 3413$), Nfs = 1048) and ($z = 2.222$, $p = .0131$ ($N = 931$), Nfs = 11) respectively.

DISCUSSION

Not surprisingly, the overall results yielded significantly higher cognitive gains and better attitudes toward learning for subjects utilizing interactive games or simulations compared to those using traditional teaching methods for instruction. This conclusion is based on a number of studies making it extremely unlikely to be due to chance. These increased cognitive gains and improved attitudes were consistently found (Boyd & Murphrey, 2002; Cowen, 1993; Laffey, Espinosa, Moore, & Lodree, 2003; Ronen & Eliahu, 2000) yielding a very significant effect strength. Basically, this means that across all situations and variables, interactive simulations or games will most likely instruct subjects with better cognitive outcomes and attitudes toward learning when compared to traditional teaching methods. It has been previously argued (Schramm, 1977 cited in Clark, 1994) that games will show increased cognitive gains due to the increased attention paid to the curriculum used rather than due to the mode of presentation to the learner. It is thus noted that many of the studies directly reported that the curriculums used in both the control and experimental groups was identical

Table 1. Cognitive Gains Moderated by Realism

	z-Score	*p*-Value	*N*	*Nf*s observed	*Nf*s needed
Photo-realistic	4.105	<.0001*	842	120	50
High-quality cartoons	3.992	<.0001	474	17	25
Low-quality pictures	3.425	.0003*	1617	100	50
Unrealistic (numbers, lines, graphs)	5.447	<.0001*	1148	104	55

*Reliable result.

(Brewster, 1996; Marcum-Dietrich & Ford, 2002; Ronen & Eliahu, 2000; Shute & Glaser, 1990; Watkins, 1998) thus reducing the likelihood of this occurring and adding further to the validity of these findings.

Gender

However, when this finding was broken down into several categories using different moderator variables, other results were occasionally found. In the case of gender, when studies used an even distribution of both genders or used only females, the results mirrored those found in the overall results (Andrews, Schwartz, & Helme, 1992; Farrell, Arnold, Pettifer, Adams, Graham, & MacManamon, 2003; Reis, Riley, Lokman, & Baer, 2000). Further, studies comparing males and females yielded no significant differences between the two suggesting that they perform similar to each other under both teaching situations (Akpan & Andres, 2000; Choi & Grennaro, 1987; Laffey, Espinosa, Moore, & Lodree, 2003). There were an insufficient number of studies to evaluate results for males alone, but we are unaware of a theoretical position that suggests that males might be disadvantaged in this regard. Thus, it seems that the observed benefits of games and simulations can be reasonably expected in both genders.

Learner Control

The vast majority of studies utilized interactive simulations or games that required the subject to navigate through the computer program based upon their own preferences. These results, not surprisingly, yielded an effect size similar to the overall effect size. There is little data to draw meaningful conclusions about other control options, although the existing studies certainly suggest that other types of control might mitigate the game advantage. Potentially, this translates to the idea that self-direction is necessary for increased learning outcomes to occur. Clearly, this is an area that requires further study before we can provide meaningful guidance to the development community.

Type of Activity

Two main types of activities using the computer were explored. Subjects using interactive simulations or games both significantly outperformed their peers instructed using traditional classroom methods. The results of the interactive simulation programs had a large fail-safe number suggesting that in fact, interactive simulations are truly beneficial. However, the analysis of the gaming programs yielded a low fail-safe number and thus should be considered with caution. Considerably more studies comparing game usage for learning to traditional methods need to be conducted before these results can be considered reliable.

Age

Across all age groups, significant results were found in favor of interactive simulations and games. In other words, regardless of age, subjects increased their knowledge more when taught using the computer than when learning in the traditional format. This finding is somewhat counterintuitive since it is a common assumption that children, due to shorter attention-spans, higher interest in play activities, and lower intrinsic motivation to learn, enjoy and thus learn better using computer games and interactive simulations compared to adults (Kafai, 2001; McGrenere, 1996; Rieber, 1996).

Realism

Significant results in all levels of picture realism were found favoring interactive simulations or games. As most effects sizes met their fail-safe numbers, these findings can be considered reliable. Only the high-quality cartoon pictures failed to meet their fail-safe number, likely due to the small number of studies involved in the analysis. These results indicate that subjects will learn more using games or interactive simulations at any level. It is not necessary for programs to contain a high level of fidelity in order to see results. However, when comparing those studies that used pictures (excluding those studies that used words, lines, or graphs), a positive correlation in effect size is seen. Meaning, as the realism of the program increases, the amount of knowledge gained during the "teaching time" also increased.

User

Finally, studies were separated according to the user. Both user groups, individual and group, reported significantly higher cognitive gains in the interactive simulation and game groups versus the traditional teaching method groups. This finding suggests that whether subjects work alone with a computer or with a group of peers, they will learn more using the computer compared to listening to an instructor. However, it is noteworthy, that the effect sizes of the groups were quite different. Specifically, those who used the computers alone yielded a much higher effect size than those using the computers with a group of peers. This suggests that while an increase in cognitive gains can be observed whenever an interactive simulation or game is used, those allowed to work alone will likely outperform those working in groups.

Summary

The overall result of the meta-analysis, then, was that those using interactive simulations or games report higher cognitive gains and better attitudes toward learning compared to those using traditional teaching methods. This result agrees with the current overall theory stating that interactive experiential activities that increase motivation also show increased learning outcomes (Baltra, 1990; Montgomery & Fogler, 1996, cited in Cassidy, 2003; Prensky, 2002). For the most part, this conclusion seems robust to the several potential moderators that we considered, but the research base is insufficient to draw this conclusion with much confidence.

Further hindering our ability to draw accurate conclusions was the fact that too many articles were unable to be used. Methodological and reporting flaws are rampant in the unused articles. No control group was the most frequently found methodological flaw in the literature (Bills, 1998; Garg, Norman, Spero, & Maheshwari, 1999; Hakkarainen, Lipponen, Jarvela, & Niemivirta, 1999; Jackson, 1997; Ju & Wagner, 1997; Yildiz & Atkins, 1996). Without this comparison, it is impossible to conclude that the given intervention accounted for the change in results. Comparisons to traditional teaching methods can also not be made. Additional problems exist in the literature further reducing the number of studies able to be used in the analysis. Multiple studies failed to include any statistical data in their reports (Decortis & Rizzo, 2002; Haidet, Hunt, & Coverdale, 2002; Hammond, McKendree, & Scott, 1996; Najjar, Thompson, & Ockerman, 1999; Parker, Cheatham, & Milling, 2000). In absence of data, the research is left unusable. Many of the studies also left out important demographic details (Cowen, 1993; Kim et al., 2002; Ronen & Eliahu, 2000; Rosas et al., 2003; Shifroni & Ginat, 1997) or did not describe the programs and activities they used as interventions in sufficient depth for us to categorize them with confidence (George & Sleeth, 1996; Jantz, Anderson, & Gould, 2002; Jollicoeur & Berger, 1988; Klassen & Willoughby, 2003; Predavec, 2001). Thus, the literature often fails to provide the information necessary to determine if games and interactive simulations are indeed helpful. We hope that this article will draw attention to this emerging and important area of instruction, and will motivate studies that will allow us to more finely analyze the effects of this teaching approach.

REFERENCES

References marked with an asterisk indicate studies included in the meta-analysis.

*Akpan, J. P., & Andres, T. (2000). Using a computer simulation before dissection to help students learn anatomy. *Journal of Computers in Mathematics & Science Teaching*, *19*(3), 297-313.

*Andrews, P. V., Schwartz, J., & Helme, R. D. (1992). Students can learn medicine with computers: Evaluation of an interactive computer learning package in geriatric medicine. *Medical Journal of Australia*, *157*, 693-695.

Baltra, A. (1990). Language learning through computer adventure games. *Simulation and Gaming*, *21*(4), 445-452.

Bangert-Drowns, R. L., Kulik, J. A., & Kulik, C. C. (1986). Effectiveness of computer-based education in secondary schools. *Journal of Computer-Based Instruction*, *12*(3), 59-68.

*Baxter, J. H., & Preece, P. F. W. (1999). Interactive multimedia and concrete three-dimensional modeling. *Journal of Computer Assisted Learning*, *15*(4), 323-331.

Bayraktar, S. (2001-2002). A meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research on Technology in Education*, *34*(2), 173-188.

Bills, C. G. (1998). Effects of structure and interactivity on internet-based instruction. *Dissertation Abstracts International Section A: Humanities & Social Sciences University Microfilms International*, *58*(12-A), 4451.

*Blank, G. D., Roy, S., Sahasrabudhe, S., Pottenger, W., & Kessler, G. D. (2003). Adapting multimedia for diverse student learning styles. *JCSC*, *18*(3), 45-58.

*Bliss, J. P., Tidwell, P. D., & Guest, M. A. (1997). The effectiveness of virtual reality for administering spatial training in firefighters. *Presence: Teleoperators and Virtual Environments*, *6*, 73-86.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain*. New York: Longmans, Green.

*Bone, R., & Lintern, G. (1999). Rehearsal versus map study as preparation for a flight navigation exercise. *Human Factors*, *41*(3), 467-473.

*Boyd, B. L., & Murphrey, T. P. (2002). Evaluation of a computer-based, asynchronous activity on student learning of leadership concepts. *Journal of Agricultural Education*, *43*(1), 36-45.

*Brewster, J. (1996). Teaching abnormal psychology in a multimedia classroom. *Teaching of Psychology*, *23*(4), 249-252.

Cassidy, O. (2003). I try it—Utilizing multimedia simulation as a vehicle to aid experiential learning. Available online at: http://www.cs.tcd.ie/Oliver.Cassidy/Meta/meta.pdf

Chambers, E. A. (2002). *Efficacy of educational technology in elementary and secondary classrooms: A meta-analysis of the research literature from 1992-2002.* Unpublished doctoral dissertation, Southern Illinois University, Carbondale.

*Choi, B., & Grennaro, E. (1987). The effectiveness of using computer simulated experiments on junior high students' understandings of the volume displacement concept. *Journal of Research in Science Teaching*, *24*(6), 539-552.

Christmann, E. P., & Badgett, J. L. (2003). A meta-analytic comparison of the effects of computer-assisted instruction on elementary students' academic achievement. *Information Technology in Childhood Education Annual*, 91-104.

Clark, R. E. (1994). Media will never influence learning. *ETR&D*, *42*(2), 1042-1629.

Cohen, P. A., & Decanay, L. S. (1992). Computer-based instruction and health professions education: A meta-analysis of outcomes. *Evaluation and the Health Professionals*, *15*(3), 259-281.

*Costabile, M., De Angeli, A., Roselli, T., Lanzilotti, R., & Plantamura, P. (2003). Evaluating the educational impact of a tutoring hypermedia for children. *Information Technology in Childhood Education Annual*, *15*(1), 289-308.

*Cowen, M. B. (1993). Designing an instructional simulation for a program entry panel. *Simulation & Gaming*, *24*(4), 500-506.

Decortis, F., & Rizzo, A. (2002). New active tools for supporting narrative structures. *Personal and Ubiquitous Computing*, *6*(5-6), 416-429.

*Engum, S. A., Jeffries, P., & Fisher, L. (2003). Intravenous catheter training system: Computer-based education versus traditional learning methods. *American Journal of Surgery*, *186*(1), 67-75.

*Farrell, M. J., Arnold, P., Pettifer, S., Adams, J., Graham, T., & MacManamon, M. (2003). Transfer of route learning from virtual to real environments. *Journal of Experimental Psychology: Applied*, *9*(4), 219-227.

*Faulkner, D., Joiner, R., Littleton, K., Miell, D., & Thompson, L. (2000). The mediating effect of task presentation on collaboration and children's acquisition of scientific reasoning. *European Journal of Psychology of Education*, *15*(45), 417-430.

Fletcher-Flynn, C. M., & Gravatt, B. (1995). The efficacy of computer-assisted instruction (CAI): A meta-analysis. *Journal of Educational Computing Research*, *12*(3), 219-242.

*Frear, V., & Hirschbuhl, J. J. (1999). Does interactive multimedia promote achievement and higher level thinking skills for today's science students? *British Journal of Educational Technology*, *30*(4), 323-329.

Galvao, J. R., Martins, P. G., & Gomes, M. R. (2000). Modeling reality with simulation games for a cooperative learning. *Proceedings of the 2000 Winter Simulation Conference*, 1692-1698.

Garg, A., Norman, G. R., Spero, L., & Maheshwari, P. (1999). Evaluation of technology-enhanced education. *Academic Medicine 75*(10), 87-89.

George, G., & Sleeth, R. G. (1996). Technology-assisted instruction in business schools: Measured effects on student attitudes, expectations, and performance. *International Journal of Instructional Media*, *23*(3), 6p.

Haidet, P., Hunt, D., & Coverdale, J. (2002). Learning by doing: Teaching critical appraisal of randomized trials by performing an in-class randomized trial. *Academic Medicine*, *77*(11), 1161-1162.

Hakkarainen, K., Lipponen, L., Jarvela, S., Niemivirta, M. (1999). The interaction of motivational orientation and knowledge-seeking inquiry in computer-supported collaborative learning. *Journal of Educational Computing Research*, *21*(3), 263-281.

Hammond, N., McKendree, J., & Scott, P. (1996). The PSYCLE project: Developing a psychology computer-based learning environment. *Behavior Research Methods, Instruments, & Computers*, *28*(2), 336-340.

*Hess, R. D., & McGarvey, L. J. (1987). School-relevant effects of educational use of microcomputers in kindergarten classrooms and homes. *Journal of Educational Computing Research*, *3*, 269-287.

Jackson, D. F. (1997). Case studies of microcomputer and interactive video simulations in middle school earth science teaching. *Journal of Science Education and Technology*, *6*(2), 127-141.

Jantz, C., Anderson, J., & Gould, S. M. (2002). Using computer-based assessments to evaluate interactive multimedia nutrition education among low-income predominantly Hispanic participants. *Journal of Nutrition Education and Behavior*, *34*(5), 252-260.

Jenkins, H. (2002, March). Game theory. *Technology review*.

Jollicoeur, K., & Berger, D. E. (1988). Implementing educational software and evaluating its academic effectiveness: Part II. *Educational Technology*, *28*(10), 13-19.

Ju, E., & Wagner, C. (1997). Personal computer adventure games: Their structure, principles, and applicability for training. *The Database for Advances in Information Systems*, *28*(2), 78-92.

Kafai, Y. (2001). The educational potential of electronic games: From games-to-teach to games-to-learn. Paper presented at the Cultural Policy Center, Los Angeles.

*Kekkonen-Moneta, S., & Moneta, G. B. (2002). E-Learning in Hong Kong: Comparing learning outcomes in online multimedia and lecture versions of an introductory computing course. *Journal of Computers in Mathematics & Science Teaching*, *21*(4), 361-379.

*Kim, J. H., Kim, W. O., Min, K. T., Yang, J. Y., & Nam, Y. T. (2002). Learning by computer simulation does not lead to better test performance on advanced cardiac life support than textbook study. *JEPM*, *14*, 395-400.

Kirriemuir, J. (2002). The relevance of video games and gaming consoles to the higher and further education learning experience, *JISC*, *3*(1). Available at: http://scholar.google.com/scholar?hl=en&lr=&client=safari&q=cache:MHPs2N6Kb RoJ:technologiaedu.us.es/bibliovir/pdf/301.pdf+

Klassen, K. J., & Willoughby, K. A. (2003). In-class simulation games: Assessing student learning. *Journal of Information Technology Education*, *2*, 1-13.

Kulik, C. C., & Kulik, J. A. (1986). Effectiveness of computer-based education in colleges. *AEDS Journal, 19*(2-3), 81-108.

Kulik, J. A. (1994). Meta-analytic studies of findings on computer-based instruction. In H. F. O'Neil, Jr. & E. L. Baker (Eds.), *Technology assessment in education and training* (pp. 9-33). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

*Laffey, J. M., Espinosa, L., Moore, J., & Lodree, A. (2003). Supporting learning and behavior of at-risk youth children: Computers in urban education. *Journal of Research on Technology in Education*, *35*(4), 423-439.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media*, *26*(1), 71-85.

*Levine, T., & Donitsa-Schmidt, S. (1996). Classroom environment in computer-integrated science classes: Effects of gender and computer ownership. *Research in Science and Technological Education*, *14*(2), 163-178.

Lowe, J. (2001-2002). Computer-based education: Is it panacea? *Journal of Research on Technology and Education*, *34*(2), 163-171.

Manninen, T. (2002). Contextual virtual interaction as part of ubiquitous game design and development. *Personal and Ubiquitous Computing*, *6*(5), 390-406.

*Marcum-Dietrich, N. I., & Ford, D. J. (2002). The place for the computer is in the laboratory: An investigation of the effect of computer probeware on student learning. *Journal of Computers in Mathematics & Science Teaching*, *21*(4), 361-379.

*McGarvey, L. (1986). *Microcomputer use in kindergarten and a home: Design of the study effects of computer use on school readiness*. (Report No. PS-015-905) (ERIC Document Reproduction Service No. ED 272 275).

McGrenere, J. (1996). Design: Educational electronic multi-player games—A literature review. *Technical Report 96-12.* Department of Computer Science, University of British Columbia, Vancouver, BC.

Murphy, L., Blaha, K., VanDeGrift, T., Wolfman, S., & Zander, C. (2002). Active and cooperative learning techniques for the computer science classroom. *Journal of Computing Sciences in Colleges, 18*(2), 92-94.

Najjar, L. J., Thompson, C., & Ockerman, J. J. (1999). Using a wearable computer for continuous learning and support. *Mobile Networks and Applications*, *4*, 69-74.

Naps, T., Bergin, J., Jiménez-Peris, R., McNally, M. F., Patiño-Martínez, M., Proulx, V. K., & Tarhio, J. (1997). Using the www as the delivery mechanism for interactive, visualization-based instructional modules. *Report of the ITICSE '97 Working Group on Visualization*, 13-26.

Niemiec, R. P., Sikorski, C., & Walberg, H. J. (1996). Learner-control effects: A review of reviews and a meta-analysis. *Journal of Educational Computing Research*, *15*(2), 157-174.

*North, M. M., Sessum, J., & Zakalev, A. (2003). Immersive visualization tool for pedagogical practices of computer science concepts: A pilot study. *JCSC*, *19*(3), 207-215.

*Office of Social and Economic Data Analysis (2003, January). Analysis of 2002 MAP Results for EMINTS Students. Retrieved from http://emints.more.net/evaluations/reports/map2002.pdf

Pange, J. (2003). Teaching probabilities and statistics to preschool children. *Information Technology in Childhood Education Annual*, 163-173.

Papert, S. (1995). Games to be played—games to be made. In Y. B. Kafai (Ed.), *Minds in play: Computer game design as a context for children's learning* (pp. ix-xii). Hillsdale, NJ: Erlbaum.

Parker, B. C., Cheatham, T. J., & Milling (2002). Using technology to teach technology. *The Journal of Computing in Small Colleges*, *17*(4), 133-141.

Perry, E. L., & Ballou, D. J. (1997). The role of work, play, and fun in microcomputer software training. *ACM SIGMIS Database, 28*(2), 93-112.

Predavec, M. (2001). Evaluation of e-rat, a computer-based rat dissection, in terms of student learning outcomes. *Journal of Biological Education*, *35*(2).

Prensky, M. (2002). The motivation of gameplay or, the real 21st century learning revolution. *On the Horizon*, *10*(1).

Quyang, R. (1993). *A meta-analysis: Effectiveness of computer-assisted instruction at the level of elementary education (K-6).* Unpublished doctoral dissertation, Indiana University of Pennsylvania.

Randel, J. M., Morris, B. A., Wetzel, C. D., & Whitehill, B. V. (1991). The effectiveness of games for educational purposes: A review of recent research. *Simulation and Gaming*, *23*(3), 261-276.

*Reis, J., Riley, W., Lokman, L., & Baer, J. (2000). Interactive multimedia preventive alcohol education: A technology application in higher education. *Journal of Drug Education*, *30*(4), 399-421.

Rieber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *ETR&D*, *44*(2), 43-58.

Rifkin, A (1994). eText: An interactive environment for learning parallel programming. *ACM SIGCSE Bulletin*, *26*(1).

Romme, A. G. L. (2003). Learning outcomes of microworlds for management education. *Management Learning*, *34*(1), 51-61.

*Ronen, M., & Eliahu, M. (2000). Simulation—A bridge between theory and reality: The case of electric circuits. *Journal of Computer Assisted Learning*, *16*(1), 14-26.

*Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., Grau, V., Lagos, F. L., Ximena, L. V., Rodriguez, P., & Salinas, M. (2003). Beyond Nintendo: Design and assessment of educational video games for first and second grade students. *Computers & Education*, *40*(1), 71-95.

Ryan, A. W. (1991). Meta-analysis of achievement effects of microcomputer applications in elementary schools. *Educational Administration Quarterly*, *27*(2), 161-184.

*Schwid, H. A., Rooke, G. A., Ross, B. K., & Sivaragan, M. (1999). Use of computerized advanced cardiac life support simulator improves retention of advanced cardiac life support guidelines better than a textbook review. *Critical Care Medicine*, *27*, 821-824.

Shifroni, E., & Ginat, D. (1997). Simulation game for teaching communication protocols. *ACM SIGCSE Bulletin, Proceedings of the Twenty-Eighth SIGCSE Technical Symposium on Computer Science Education*, *29*(1), 184-188.

*Shute, V. J., & Glaser, R. (1990). A large-scale evaluation of an intelligent discovery world: SMITHTOWN. *Interactive Learning Environments*, *1*, 51-77.

Siemer, J., & Angelides, M. C. (1995). Evaluating intelligent tutoring with gaming-simulations. *Proceedings of the 1995 Winter Simulation Conference*, 1376-1382.

Soloway, E. (1998). No one is making money in educational software. *Communication of the ACM*, *41*(2), 11-15.

SRI, International. (2002). E-desk: *A review of recent evidence on the effectiveness of discrete educational software* (DHHS Contract # 282-00-008-Task 3). Washington, DC: Murphy, R. F., et al.

*Stasko, J., Badre, A., & Lewis, C. (1993). Do algorithm animations assist learning? An empirical study and analysis. *ACM, Proceedings of the Conference on Human Factors in Computing Systems*, USA, 61-66.

Stoney, S., & Wild, M. (1998). Motivation and interface design: Maximizing learning opportunities. *Journal of Computer Assisted Learning*, *14*, 40-50.

TEEM. (2002). Report on the educational use of games. Little Shelford, Cambridge: McFarlane, A., Sparrowhawk, A., & Heald, Y. Retrieved March 5, 2004 from http://www.teem.org.uk/publications/teem_gamesined_full.pdf

*Tompson, G. H., & Das, P. (2000). Improving students' self-efficacy in strategic management: The relative impact of cases and simulations. *Simulation & Gaming*, *31*(1), 22-41.

VanSickle, R. L. (1986). A quantitative review of research on instructional simulation gaming: A twenty-year perspective. *Theory and Research in Social Education*, *14*(3), 245-264.

Watkins, G. L. (1998). Achievement and attitudes with CD-ROM instruction. *College Student Journal, 32*(2), 293-301.

*Weir, C. G., McManns, I. C., & Kiely, B. (1991). Evaluation of the teaching of statistical concepts by interactive experience with Monte Carlo simulations. *British Journal of Educational Psychology*, *61*(2), 240-247.

Yildiz, R., & Atkins, M. (1996). The cognitive impact of multimedia simulations on 14-year-old students. *British Journal of Educational Technology*, *27*(2), 106-115.

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