Paper ID #17788

A Comparative Study for Determining the Impact of Simulation-based, Hands-on and Feedback Mechanisms on Students' Learning in Engineering Technology and Computer Networking Programs

Dr. M T Taher,
Dr. Usman Ghani, Robert Morris University

Usman Ghani Professor Robert Morris University

Usman Ghani is a senior professor of Network and Communication Management in the College of Engineering and Information Science at Robert Morris University, Chicago, Illinois. Professor Ghani's area of specialization is 'Network Infrastructure and Security'. Mr. Ghani began his career as an Electronics Engineer for Johnson Controls, Inc. in Milwaukee, Wisconsin, developing machine code for high end industrial controllers. Later he joined Illinois Technical College, Chicago, IL where he developed and taught courses in the various domains of computer communications. Dr. Ghani joined DeVry University as an assistant professor to teach engineering technology related courses but his interest in computer networking compelled him to get trained and obtained many industry certifications including CCNA (Cisco Certified Network Associate), CCNA-Security, MCP (Microsoft Certified Professional) and VCP (VMWare Certified Professional); he is also a Cisco Certified Academy Instructor (CCAI). To bring real world experience into his classroom, Professor Ghani frequently gets involved in various professional IT consulting assignments as well. He is currently teaching MIS graduate courses at Robert-Morris University.

Dr. Ghani holds MSEE from Illinois Institute of Technology, MBA from Keller Graduate School of Management and Doctorate from Northern Illinois University.

Dr. Ahmed S. Khan, DeVry University, Addison

Dr. Ahmed S. Khan is a Senior Professor in the College of Engineering and Information Sciences at DeVry University, Addison, Illinois. Dr. Khan has more than thirty-two years of experience in research, instruction, curricula design and development, program evaluation and accreditation, management and supervision.

Dr. Khan received an MSEE from Michigan Technological University, an MBA from Keller Graduate School of Management, and his Ph.D. from Colorado State University. His research interests are in the areas of Nanotechnology, Fiber Optic Communications, Faculty Development, and Social and Ethical Implications of Technology. He is the author of many educational papers and presentations. He has authored/coauthored the following books:

• Nanotechnology: Ethical and Social Implications (2012) • Technology and Society: Issues for the 21st Century and Beyond 3E, (2008) • The Telecommunications Fact Book and Illustrated Dictionary 2E (2006) • Fiber Optic Communication: An Applied Approach, Prentice Hall, N.J. (2002) • Technology and Society: A Bridge to the 21st Century (2002) • Technology and Society: Crossroads to the 21st Century (1996) • Technology and Society: A Spectrum of Issues for the 21st Century (1994) • The Telecommunications Fact Book and Illustrated Dictionary (1992)

Dr. Khan is a senior member of the Institute of Electrical and Electronics Engineering (IEEE), and a member of American Society of Engineering Education (ASEE), and has been listed in Who's Who among America's Teachers. Dr. Khan also serves as a program evaluator for the Accreditation Board for Engineering and Technology (ABET).

A Comparative Study for determining the Impact of Simulation-based, Hands-on and Feedback Mechanisms on Students' Learning in Engineering Technology and Computer Networking Programs

Abstract

The use of Simulation-based labs has been gaining currency in the domains of engineering technology and IT programs. In Simulation-based teaching, various feedback mechanism play a vital role for improving student learning as it guides and refines learning through scaffolding. A number of studies in literature have shown that students' learning is enhanced in Simulation context when feedback is incorporated How effective is simulation-based teaching methodology in comparison to traditional hands-on activity based labs? This paper compares the findings of two studies conducted to determine the effectiveness of simulation-based, hands-on and feedback mechanism on students learning by answering the following questions: 1). Does the use of simulation improve students'learning outcomes? 2). How do faculty members perceive the use and effectiveness of simulation in the delivery of technical course content? 3). How do students perceive the instructional design features embedded in the simulation program such as exploration and scaffolding support in learning new concepts? 4.) What is the effect of feedback mechanisms on students' learning in the use of simulation-based labs?

The paper also discusses the other aspects of findings which reveal that simulation by itself is not very effective in promoting student learning. Simulation becomes effective when it is followed by hands-on activity and feedback mechanisms. Furthermore, the paper presents recommendations for improving student learning through the use of simulation-based, hands-on, and feedback-based teaching methodologies.

I. Introduction

A. What is the purpose of Comparative Study?

The purpose of this comparative study was to explore the impact of the use of computer simulation design methodologies on student learning. The comparative study is composed of two case studies; the first study investigated the effect of simulation-based instruction with hands-on based teaching and learning methodologies. The design methods included cognitive apprenticeship domains of Modeling, Scaffolding, Articulation, and Exploration in traditional lecture-lab activities on students' problem-solving skills for circuit construction in an undergraduate ECET (Electronic Computer Engineering Technology) course. The second case study explored the impact of the use of computer simulation's feedbacks i.e. knowledge-of-correct-response (KCR) feedback and answer-until-correct (AUC) feedback on students' declarative knowledge in the area of information technology i.e., computer networking and Infrastructure. Hence, the proposed research is to study the effects of simulation feedbacks on computer engineering students' declarative knowledge.

B. What is the importance of Simulation?

Widely used in both academia and business, simulations are recognized as an efficient and effective way of teaching complex and dynamic engineering systems. A simulation-based teaching environment enables students to acquire experience and consider their previous results [1]. In particular, the gaming approach utilizing interactive media and/or simulation has been shown to be effective in improving teaching and learning of various subjects [2]. By reducing practical learning time for students, and for schools and programs, simulation reduces costs for practice oriented educational methodology.

The simulation-based training reduces the gap between learning environment and “real" environment, and making available training of “real world” situations that are difficult to simulate in a hands-on lab environment. Traditionally for teaching technology-based courses, laboratory experiments were offered using a hands-on approach. With the miniaturization of integrated circuits, it is becoming very difficult to construct a PC board or assemble surface mount chips in a lab environment. This shortcoming of the hands-on approach has led professors and teachers to incorporate simulation in place of hands-on in technology-based lab courses.

In spite of the advantages of simulations, hands-on labs remain tremendously important in the technology curriculum, which is based on Dewey’s experiential learning theory. The basic premise of this theory is that students learn as a result of doing or experiencing things in the world, and learning occurs when mental activity is suffused with physical activity [3].The professional success of a technologist is directly related to her/his ability to transfer knowledge gained in the academic environment to real-world situations. Acquisition of manipulative skills is only possible through the use of real instruments and real experimental data. Therefore, to enhance student learning, the technology curriculum must integrate the effective characteristics of both computer simulations and hands-on lab activities.

The fundamental building blocks of a simulation comprise the real-world problem being simulated, its conceptual model, and computer model implementation. Simulation models speed product development and reduce physical testing as well as production costs. Designers are finding that virtual product development using simulation is the preferred tool for testing, is more cost-effective and repeatable than physical testing, and is resulting in better products. With simulations, one can analyze results more thoroughly than with test results. Software simulation tools are becoming both more sophisticated and easier to use. Even though software simulation provides an enhanced learning platform for engineering students, it has its some limitations:

- Faculty and students need special training in using the new simulation tool.
- Student learning and teaching styles must match. If they do not, learning may not take place.
- Students need to be trained in basic computer skills, breadboarding, component identification, running simulations, and understanding the different elements of the simulation platform before they start the course.
- Faculty teaching the course should also have good teaching skills to deliver information using electronic media and be proficient in hardware.

According to Veenman, Elshout, and Busato 4], problem-oriented simulations help develop higher-order thinking strategies and improve the students' cognitive abilities employed in the service of recall, problem-solving, and creativity. Computer-based simulation software enables the students to experiment interactively with the fundamental theories and applications of electronic devices. It provides instant and reliable feedback and, thus, gives students an opportunity to try out different options and evaluate their ideas for accuracy almost instantly. Lab students often assume that lab equipment is not always accurate and reliable, and they sometimes make the mistake of attributing their design errors to experimental errors. By focusing mainly on the mental activity that takes place within the learner, simulation can direct students' attention to their own designs.

Simulations promote active learning. As experiential learning, simulations generate student interest beyond that of traditional classroom lectures [5] and thereby provide insight. Additionally, simulations develop critical and strategic thinking skills. The skills of strategic planning and thinking are not easy to develop, and the advantage of simulation is that they provide a strong tool for dealing with this problem [6] Although the importance of hands-on labs to the technology curriculum cannot be denied, Garcia [7]) cites several advantages of computer simulations compared to laboratory activities. First, there appear to be important pedagogical advantages of using computer simulations in the classroom. Second, the purchase, maintenance, and update of lab equipment is often more expensive than computer hardware and software. Also, there is no concern for students' physical safety in the simulation learning environment.

For the present case study, two elements (exploration and scaffolding) of cognitive apprenticeship phases were used. Exploration considers those features of simulation software which allow students to construct circuits using by selecting and connecting components & devices. Whereas scaffolding involves those features of the simulation software that allows students to access components, construct circuits, troubleshoot and monitor circuit performance.

The primary goal of simulation is to help students understand the basic concepts of a given construct. Additional simulation goals focus upon encouraging student-to-student contact outside the classroom and promoting student research beyond classroom assignment. The simulation software used in this study was Electronic Workbench (Multisim-8). As its name suggests, the program models a workbench for electronics. The large central area on the screen acts as a breadboard for circuit assembly. On the top is a shelf of test instruments and program controls and on the left is a bin of parts. A click of a mouse button allows a user to causes an action to occur such as selecting & connecting components to make a circuit and to run the simulation to observe the circuit behavior and performance.

According to Pogrow [8] a learning strategy based on the higher order thinking skills project (HOTS) involves three principles:

1. Creating an intriguing learning environment.
2. Combining visual and interactive learning experiences that help students to form mental representations,
3. Developing cognitive architecture that unifies their learning experiences.

Interactive computer simulations based on this strategy help students to create explanations for the events and argue for the validity of those explanations using a mixture of their own ideas and technical concepts in the simulation. In addition, simulations that employ an array of media will help bridge the gap between the learning styles of students and the teaching styles of instructors.

Computer simulations were found to be very effective in stimulating environmental problem solving by community college students [9]. In particular, computer simulation exercises based on the guided discovery learning theory can be designed to provide motivation, integrate information, and enhance transfer of learning [10]. By implementing properly designed simulation activities, the role of a teacher changes from a mere transmitter of information to a facilitator of higher-order thinking skills [11]. According to Magnusson and Palincsar, simulations are seen as a powerful tool to teach not only the content, but also thinking or reasoning skills that are necessary to solve problems in the real world [12-13].

The use of feedback is a critically important attribute in computer-based instruction (CBI) such as multimedia simulations, as it promotes learning by providing students with information about their responses [14]. Especially when it comes to novice learners, research has demonstrated that novices do not learn as well when they are placed in unguided training environments [15]. Novices need to be given some degree of guidance when learning new information, especially those involving complex tasks. The content of the feedback should help the novice develop accurate knowledge structures and build schema in order to better learn the information and eventually become an expert [16]. Even though the effects of multiple types and forms of feedback have been investigated in a large variety of instructional contexts, some of the widely used feedback types in a multimedia learning environment are: 1. Knowledge-of-response (KOR), which indicates that the learner's response is correct or incorrect, 2. Knowledge-of-correct-response (KCR), which identifies the correct response, 3. Elaborative feedback, a complex form of feedback that explains, monitors, and directs, such as answer-until-correct (AUC).

C. What are the Research Questions?

The research questions for the first case study are:

1. Does the use of simulation improve students' learning outcomes?
2. How do faculty members perceive the use and effectiveness of simulation in the delivery of technical course content?
3. How do students perceive the instructional design features (IDF) in simulation that support their knowledge comprehension?

   3a. How does the design feature of exploration embedded in the simulation program support learning new concepts?

   3b. How does the design feature of scaffolding embedded in the simulation program support students in learning new concepts?

The second case study investigated the following research questions:

1. Do pure discovery-based (no feedback) simulated labs improve students' declarative knowledge?"
2. Do KCR (knowledge-of-correct-response) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts?

3. Do AUC (answer-until-correct) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts?
4. Do KCR (knowledge-of-correct-response) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts as compared to no-feedback (pure discovery) based simulation?
5. Do AUC (answer-until-correct) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts as compared to no-feedback (pure discovery) based simulation?

D. What is the research methodology?

For the first case study, the sample for this study was drawn from the freshman class of engineering technology students at a midsized university who enrolled in an eight-week Electronics and Computer and Engineering Technology (ECET) course. The primary objective of this course was to prepare students to acquire skills in building or constructing basic DC circuits and to develop an understanding of electronic fundamentals. This course was a pre-requisite for all of the advanced electronic courses in the three-year degree program. The students came from varied educational backgrounds and experience, mostly recent high school graduates, or with no college experience yet they all received the same instruction using the same instructional strategies and the same content. This course, designed by the university's technical faculty, is taught in the ECET (Electronic Computer Engineering Technology) program. The program was accredited by the Engineering Technology Accreditation Commission (ETAC) of ABET, the leading accreditation agency in the United States. The course consisted of a lecture part, a lab part, and an online part; all three parts were supported by a prescribed text. The curriculum focused solely on hands-on training using the breadboard during the lab assignments. The teaching approach did not require simulation as a part of the curriculum and did not include any Multisim-8 (software simulation tool in this study) as a part of the curriculum materials.

Students were selected from the ECET-110 (Electronic-I) course taken during their first semester in the ECET program. The group consisted of 24-29 students from a wide range of demographic attributes: their age ranged from 18 to 30 years; their educational background varied from as little as a recent high school education to 3-5 years of work experience or having completed an undergraduate degree prior to enrolling in the technical program; 96% were males and 4% were females; and majority were whites and rest belonged to various minority groups including Asian, African American, and Latino.

For the second case study, the sample for the study comprised of 80 students enrolled in four sections of Cisco Routing Fundamentals (NETW205) course offered during the winter session of 2012, at DeVry University, Addison, Illinois 60101. All 80 participants involved in the study were enrolled to complete their CCNA certification. Classes were randomly selected and assigned to one of the four groups: simulation- lab with AUC (AUC), simulation lab with KCR (KCR), simulation lab with no feedback (NFB), and traditional hands-on lab (HON) group. Even though all four groups were given the same lab work to complete, the AUC group was required to complete the lab using the simulation software with AUC feedback, the KCR group was required to complete the lab using simulation with KCR feedback, and the NFB group was required to complete the lab using simulation with no feedback. The hands-on HON group was asked to complete the same experiment using physical equipment in the traditional hands-on lab environment; irrespective of the class size and the level of students' prior technical knowledge.

II. Findings

For the first case study, the findings based on quantitative analyses reveal that in the initial phase of course delivery, simulation based instructional strategy had a marginal effect on student learning compared to hands-on teaching strategy. In the second phase of course delivery, the data analyses reveal that the instructional strategy based on a combination of simulation and hands-on (Hybrid) had a moderate effect on student learning compared to a hands-on only instructional strategy Since the two strategies complement each other, they enable students to enhance their understanding of the basics of circuit design and application.

Qualitative Analysis**:** The qualitative analysis involved student interviews in form of focus groups and individual interviews of faculty. First, all students taking ECET-110 (DC Circuit Analysis) were informed about the purpose of the comparative case study. They were also informed that design methods include cognitive apprenticeship domains of modeling, scaffolding, articulation and exploration. All students were given an introduction letter and a consent form. Ten out of 24 students volunteered to participate in the study. Ten student volunteers were randomly divided into two groups. The first focus group (FG-1) had 6 members and the second focus group (FG-2) had 4 members. The first focus group was interviewed and responses were transcribed using MS-Word and also voice recorded using an audio voice recorder and a digital voice recorder. After one week, the second focus group was interviewed in a similar manner. Questioning was proceeded by a follow up meeting with the participants to seek additional feedback. Group members (from both groups) were males with diverse backgrounds, some of whom who had exposure to the electronic/information technology field, while others did not. All participants were from the same original group. To analyze the student response data the qualitative analysis software NVivo-8 and Microsoft Word were employed. The open coding results are displayed in Figure 1.

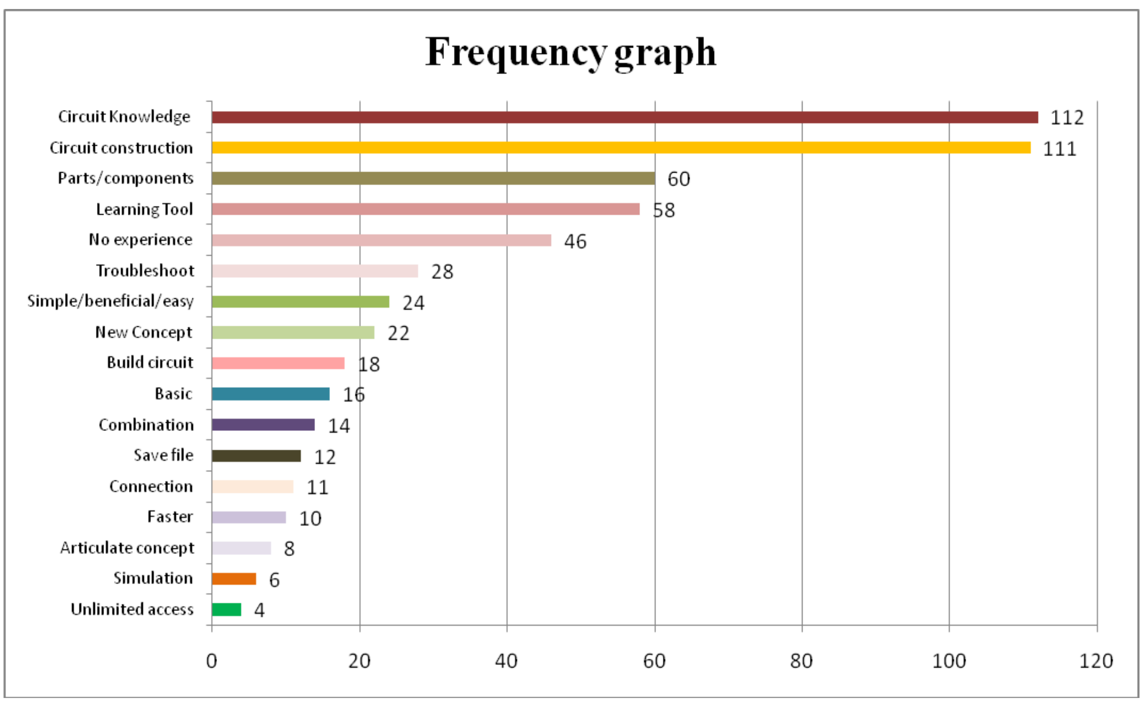

Figure 1: Frequency count of open coding process.

The open code frequency count analysis revealed that participants' most frequently used words or phrases were (frequency of 40+) were: "Circuit knowledge" (112) and "Circuit construction" (111), followed by "selection of parts/components" (60), "good learning tool" (58), and "no prior experience" (46). In the second phase of qualitative analysis, axial coding was used, and in the third and final phase selective coding was employed. The findings based on the qualitative analyses reveal that students perceive that simulation scaffolds the learning process. However, students also perceive that simulation fails to replicate the real world scenarios and applications. The majority of students perceive that a hybrid approach, i.e. a combination of hand-on and simulation is the best instructional strategy for learning circuit design and applications. The implications of these findings for the practice of instructional technology vis-à-vis cognitive learning (scaffolding and exploration), in the context of past and future research endeavors is discussed in the following section.

The second case study looked at role of feedback in simulation-based training. Laboratory exercises play a key role in the education of future scientists and engineers, yet there exists disagreement among science and engineering educators about the effectiveness and types of technology-enabled laboratory exercises to be used. The present study was designed to address this concern. The first three hypotheses involved a comparison of the hands-on experiment and simulation labs with or without any feedback type such as KCR and AUC. It is interesting to note that the study showed no advantage for simulated labs under any feedback condition over hands-on experiments. The finding was similar to the observation made by Corter et al. "There was no significant difference in lab test scores when experimenting with either simulation or hands-on physical equipment." The following is a summary of findings after running repeated measures analysis of variance (ANOVA) followed by Kruskal-Wallis and Mann-Whitney U tests for cross validation:

- Simulated labs with no feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with KCR feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with AUC feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with KCR feedback statistically do not produce better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with AUC feedback statistically do produce better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.

III. Implications for Practice/Recommendations

The findings of the comparative study suggest that in order to enhance student learning, the instructional designers should consider the following recommendations for incorporating simulation and feedback in the design of curricula:

a. The findings suggest that use of simulation is effective for onsite delivery mode or the onsite delivery mode; the simulation can support lower courses as well as higher level courses in the Electronic & Computer Engineering Technology (ECET) programs and Electronics Computer Technician (ECT) programs.
b. Faculty feedback suggests that knowledge of simulation program and pedagogical skills are major factors for enhancing student learning.
c. Students' feedback suggests that simulation-based labs offer a safer environment for user. However, in a simulation environment there is no such threat.
d. Simulation is effective when it is followed by the hands-on activity to reduce the gap between theoretical knowledge and practical expertise. Students should be first exposed to circuit construction in the simulation environment, and then required to perform actual hands-on activity in form of circuit construction on a breadboard to complement their learning and to verify their knowledge of theory.
e. The use of simulation is at least as effective as hands-on labs in the learning of basic information technology concepts; therefore, when and where appropriate, traditional hands-on laboratories can be replaced with the simulated labs.
f. Simulation with AUC feedback proved to be more effective than traditional hands-on labs; using such methodology will not only improve students' learning but will also offer a low-cost and a flexible training platform.
g. Even though AUC is a preferable type of feedback compared to KCR, it is more complex and therefore expensive to develop.
h. Instructional designers are often interested in efficiency. It might be expected that the additional steps necessary for AUC would require more study time.
i. Simulation-based teaching methodology offers a cost reduction by replacing expensive physical lab equipment such as routers, switches, and firewalls. By incorporating simulation-based laboratory experiments in place of physical laboratories, institutions can save a tremendous amount of expenditure.
j. Simulation based labs offer a safe working environment for learners. In a traditional lab, a typical station has high voltage connections and outlets to run IT equipment such as routers and switches, potentially creating a hazardous environment. Simulation, on the other hand, has no such threats.

Conclusion

The findings presented in this paper reveal that simulation by itself is not very effective in promoting student learning. However, simulation becomes effective in promoting student learning when used in conjunction with hands-on approach i.e. hybrid or combinational instructional strategy. The findings of current study are affected and limited by its: smaller sample size, shorter student soak-in time (8-weeks), limited interactivity and capabilities of simulation software. Based on findings it is suggested that first students be exposed to theoretical knowledge in traditional lecture mode followed by simulation-based lab activities, and finally required to do hands-on lab experiments. It is recommended that future studies be conducted to validate the findings of the current study by incorporating: a larger sample size, a diversified ethnic group, a longer soak-in period (15 weeks), and other forms of instructional strategies.

The findings also reveal that simulation with AUC feedback proved to be more effective than traditional hands-on labs; using such methodology will not only improve students' learning but will also offer low-cost and flexible training platform necessary for 21st century students. Even though AUC is a preferable type of feedback compared to KCR, it is more complex and therefore expensive to develop. Instructional designers are often interested in efficiency. It might be expected that the additional steps necessary for AUC would require more study time.

References

[1] Nahvi, M. (1996). Dynamics of student-computer interaction in a simulation environment: Reflections on curricular issues. *Proceedings of the IEEE Frontiers in Education, USA*, 1383-1386.

[2] Hsieh, S., & Hsieh, P.Y. (2004). Integrating virtual learning system for programmable logic controller. *Journal of Engineering Education*, *93*(2), 169-178.

[3] Dewey, J. (1938). *Democracy and education*. New York: Macmillan.

[4] Sevgi, L. (2006). Electrical and computer engineering education in 21st century: Issues, perspectives and challenges, Paper presented at the meeting, Istanbul, Turkey.

[5] Veenman, M. V., Elshout, J., & Busato, V. (1994). Metacognitive mediation in learning with computer based simulations. *Computers in Human Behavior*, *101*(1), 93-106.

[6] McKeachie, W. J., Pintrich, P. R., Lin, Y., & Smith, D. A. F. (1986). *Teaching and learning in the college classroom: A review of the research literature*. Ann Arbor, MI: Regents of The University of Michigan.

[7] Wolfe, J. (1993). A history of business teaching games in English-speaking and post-socialist countries: The origination and diffusion of a management education and development technology. *Simulation & Gaming*, *24*, 446-463.

[8] Garcia, J. R. (1995). Use of technology in developing problem solving/critical thinking skills. *Journal of Industrial Technology*, *11*(1), 14-17.

[9] Pogrow, S. (1994). Students who just don't understand. *Educational Leadership*, *52*(3), 62-66.

[10] Faryniarz, J. V., & Lockwood, L. G. (1992). Effectiveness of microcomputer simulations in simulating strategy in a Logo microworld. *Journal of Educational Psychology*, *86*(3), 368-379.

[11] Mayes, R. L. (1992). The effects of using software tools on mathematical problem: Solving in secondary schools. *School Science and Mathematics*, *92*(5), 243-248.

[12] Woolf, B., & Hall, W. (1995). Multimedia pedagogues: Interactive systems for teaching and learning. *IEEE Multimedia*, 74-80.

[13] Magnusson, S. J., & Palincsar, A. (1995). The learning environment as a site of science education reform. *Theory into Practice*, *34*(1), 43-50.

[14] Clariana, R. B., Ross, S. M., & Morrison, G. R. (1991). The effects of different feedback strategies using computer-administered multiple-choice questions as instruction. *Educational Technology Research and Development, 39*(2), 5-17.

[15] Institute for Creative Technologies. (2009). Intelligent guided experiential learning: Tutoring for practice. Retrieved from http://ict.usc.edu/projects

[16] Cuevas, H. M., Fiore, S. M., Bowers, C. A., & Salas, E. (2004). Fostering constructive cognitive and metacognitive activity in computer-based complex task training environments. *Computers in Human Behavior, 20*(2), 225-241.