QSCIENCE PROCEEDINGS

Engineering Leaders Conference 2014

Comparison of simulation-based and hands-on teaching methodologies on students' learning in an engineering technology program

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ABSTRACT

The use of simulation-based labs has been gaining currency in the domains of engineering and technology programs. How effective is simulation-based teaching methodology in comparison to traditional hands-on activity based labs? To answer this question a study was conducted to explore the impact of the use of computer simulation design methods on students' learning for circuit construction in an undergraduate technical course.

This paper presents the findings of the research study, which tested the hypothesis by investigating three key 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?

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. Furthermore, the paper presents recommendations for improving student learning, viz a viz simulation-based and hands-on labs.

http://dx.doi.org/10.5339/qproc.2015.elc2014.58

Cite this article as: Taher M, Khan A. Comparison of simulation-based and hands-on teaching methodologies on students' learning in an engineering technology program, QScience Proceedings (Engineering Leaders Conference 2014) 2015:58
http://dx.doi.org/10.5339/qproc.2015.elc2014.58

I. INTRODUCTION

Using simulators as a teaching tool is widespread, both in academic areas and in business areas because simulations are recognized as an efficient and effective way of teaching and learning complex and dynamic systems in engineering education. 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] Therefore, it reduces practical learning time for the learners, and for schools and programs. Simulation reduces costs for practice-oriented educational methodology.

The advantage of simulation-based training includes reduction in 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.

II. PURPOSE OF THE STUDY

The present research study employed a case study approach. The purpose of this comparative case study was to explore the impact of the use of computer simulation design methods on students' problem-solving skills for circuit construction in an undergraduate ECET (Electronic Computer Engineering Technology) course. The design methods incorporated qualitative and quantitative modes of data evaluation by incorporating cognitive apprenticeship instructional methodology. The following are the research questions of this study: 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?

III. SIGNIFICANCE OF SIMULATION TO INSTRUCTIONAL TECHNOLOGY

According to Veenman, Elshout, and Busato,[3] 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. Simulations promote active learning. As experiential learning, simulations generate student interest beyond that of traditional classroom lectures[4] 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.[5] Although the importance of hands-on labs to the technology curriculum cannot be denied, Garcia[6] 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. According to Pogrow[7] 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. According to Magnusson and Palincsar,[8] 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.

IV. METHODOLOGY

In the present research study, a case study approach was employed since the student group was small in size. Yin[9] observes that the case study methods involve three roles: exploratory/descriptive, evaluation, and hypothesis testing. For the present case study, hypothesis testing was employed.

Research Procedure: The case study employed a group of 24–29 students enrolled in a technical class (with multiple sections) of a technology-based undergraduate program. Students first attended and completed the lecture part that gave them knowledge/understanding in building circuits using both techniques of breadboarding (hardware) and Multisim-8 (Simulation software). After practicing the circuits in the class, the whole group was given a simulation lab of building circuits using Multisim-8 for each of the topics covered in the class. The labs were given on a specific topic after covering the corresponding lecture component of that topic. The grades were then analyzed using the ANOVA test.

Data Sources: To conduct the study, the following data collection methods were employed: 1. *Quizzes and Mid-Term Exam, 2. Interview, and 3. Focus Group Interview.*

V. DATA ANALYSIS

Quantitative Data: The data were analyzed using statistical tool SPSS. Data analysis was performed by using the ANOVA. The average score of the mid-term exams from both of the groups (baseline reference group [hands-on only lab experience] and present case study group [simulation and hands-on based lab experience]) was calculated, the means were compared, and the standard deviation was found.

Qualitative Data: The qualitative data acquired through the interviews were first coded. These codes were then used to identify emerging patterns, recognize trends and form generalizations about the outcomes.

VI. FINDINGS

Participants: The sample consisted of 74 participants, who were each in one of three classes. The first class of students ($n = 24$) was taught by Instructor A, and these students received the simulation and hands-on (Hybrid) (Hybrid) training. The second class of students ($n = 21$) was taught by Instructor A, and these students received the hands-on only training. The third class ($n = 29$) was taught by Instructor B, and these students received hands-on only training.

Quantitative Analyses: Scores were obtained from both the intervention and control groups for four separate assessments—two quizzes, a midterm exam, and a final exam. These scores were entered into the statistical package SPSS v16.0. The scores were based on the official examinations and quizzes for the course. The raw numerical scores achieved by students on each quiz or examination were used in this analysis.

VII. DISCUSSION OF FINDINGS

Research Question 1: Does the use of simulation improve students' learning outcomes?
In order to explore the impact of simulation on student learning outcome, three tests were conducted. The hypothesis for the present study was that the test results would improve significantly by using simulation software Multisim-8 as compared to the standard breadboarding method. However, the findings revealed that there was moderate improvement in student learning with the help of simulation software Multisim-8. The hypothesis was partially supported. A repeated measures ANOVA test was conducted to analyze the relationship between the quiz scores using the simulation method and the quiz scores using the hands-on method for the same group (simulation and hands-on [hybrid]) taught by Instructor A. The results were statistically insignificant. This result may be due to the fact that the same group performed both tasks, so there was no improvement in acquiring any new skill sets, whereas the mixed design ANOVA demonstrated a significant interaction effect between the time and group factors $F(1, 40) = 0.16, p = 0.69$. These findings suggest that the two groups are behaving similarly across time with respect to their scores even though the simulation group had an advantage since they could verify their results. The hypothesis was that the use of simulation will increase student learning measured in terms of student test scores. Therefore, it is evident that simulation does in fact play a marginally significant role in improving student learning.

Question 2. How do the faculty members perceive the use and effectiveness of simulation in the delivery of technical course content?
This research question was answered using feedback collected from the course instructor.
The professors' feedback suggests that simulation scaffolds student's problem-solving skills because simulation helps students acquire news knowledge in progressive stages. The professors said that the features embedded in simulation software—like drag and drop capability, flexibility of object manipulation, easy identification of components, easy construction of circuits, observation of casual relationships, and ease of troubleshooting—promotes learning.

3a. How does the design feature of exploration embedded in the simulation program support students in learning new concepts?
The findings revealed that the program's tool panel provided a functional structure that enabled students to easily construct, troubleshoot, and monitor the performance of circuits. Another interesting finding is that simulations become easier and facilitate faster learning for beginners if they have some previous exposure with breadboarding circuit construction. Based on their responses most students believe that simulation is simpler (in identifying components, learning procedure, understanding circuits, and placing components) easier (in making circuits, accessing components, connecting components, and troubleshooting circuits) and (faster, in allowing students to learn new basic concepts quickly). The findings are supported by the similar results, reported by Fraga et al.[10]

3b. How does the design feature of scaffolding embedded in the simulation program support students in learning new concepts?
The findings revealed that the program's tool panel provided a functional structure that enabled students to easily access components, inter-connect components, learn basic formulas/concepts, and measure and monitor the performance of circuits. Furthermore the findings suggest that, regarding scaffolding, the simulation technique allows 100% agreement between circuit diagram and actual circuit, whereas in a breadboard there may be a difference between circuit construction and actual circuit diagram. Another important characteristic of simulation is that it allows efficient construction of larger and complex circuits, which are difficult to construct in a breadboard environment. The finding is similar to results reported by Fraga[10] that students can efficiently construct complex circuits using the Multisim simulation programs.

VIII. SUMMARY

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.

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.

IMPLICATIONS FOR PRACTICE/RECOMMENDATIONS

1. *Instructional design for lab activities:* The findings of the current study suggest that in order to enhance student learning the instructional design should consider three approaches. The first approach deals with using simulation based experiments in the first half of the course followed by the hands-on experiments in the second half (sequential design). The second approach deals with simultaneous use of simulation and hands-on experiments (parallel design). And the third approach deals with using simulation and hands-on in an alternating mode (mixed design). All three approaches support a combined approach or hybrid instructional delivery.

2. *Delivery mode*: The findings suggest that use of simulation is effective for onsite delivery mode or the online delivery mode; the simulation can support lower courses as well as higher-level courses in the Electronic and Computer Engineering Technology (ECET) programs and Electronics Computer Technician (ECT) programs.
3. *Faculty pedagogy*: Faculty feedback suggests that knowledge of simulation program and pedagogical skills are major factors for enhancing student learning.
4. *Learner safety*: Student feedback suggests that simulation-based labs offer a safer environment for the user. However, in a simulation environment there is no such threat.
5. *Hybrid approach*: 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 the form of circuit construction on a breadboard to complement their learning and to verify their knowledge of theory.

IX. CONCLUSION

The paper presented the results of a comparative case study conducted to explore the impact of the use of computer simulation design methods on students' problem-solving skills for circuit construction in an undergraduate engineering technology course. The study used a sample consisting of the 24–29 freshmen enrolled in an 8-week technical course at DeVry University, Addison, Illinois. Two groups were used; one was taught using simulation and hands-on instructional strategy and the other was exposed to hands-on instruction only. The findings 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 a hands-on approach, i.e., hybrid or combinational instructional strategy. 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.

REFERENCES

[1] Nahvi M. Dynamics of student-computer interaction in a simulation environment: Reflections on curricular issues. *Proceedings of the IEEE Frontiers in Education, USA*. 1996;1383–1386.
[2] Hsieh S, Hsieh PY. Integrating virtual learning system for programmable logic controller. *Journal of Engineering Education*. 2004;93(2):169–178.
[3] Veenman MV, Elshout J, Busato V. Metacognitive mediation in learning with computer-based simulations. *Computers in Human Behavior*. 1994;101(1):93–106.
[4] McKeachie WJ, Pintrich PR, Lin Y, Smith DAF. *Teaching and learning in the college classroom: A review of the research literature*. Ann Arbor, MI: Regents of The University of Michigan; 1986.
[5] Wolfe J. 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*. 1993;24:446–463.
[6] Garcia JR. Use of technology in developing problem solving/critical thinking skills. *Journal of Industrial Technology*. 1995;11(1):14–17.
[7] Pogrow S. Students who just don't understand. *Educational Leadership*. 1994;52(3):62–66.
[8] Magnusson SJ, Palincsar A. The learning environment as a site of science education reform. *Theory into Practice*. 1995;34(1):43–50.
[9] Yin RK, *Case study research: Design and methods*. [Google books version]. Retrieved November 20, 2009, from http://books.google.com/books?hl=en&lr=&id=koWrN3rBzsC&oi=fnd&pg=PR7&dq sage+publications&ots =IWlPqCDanK&sig =HaSHzKaI3hHUzhgZeue9Kg6qYZE#v=onepage&q=&f=false
[10] Fraga JRCP, Marcelo C, de Castro A F, Franchin M N. Using Simulation Programs to enhance learning in electrical circuits classes, Anais do XXXIV COBENGE. Passo Fundo: Ed. Universidade de Passo Fundo, Setembro de 2006.