121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #10786

Impact of Simulation-based and Hands-on Teaching Methodologies on Students' Learning in an Engineering Technology Program

Dr. MOHAMMED TAQIUDDIN TAHER, DeVry University, Addison
Dr. Ahmed S. Khan, DeVry University, DuPage

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 years of experience in research, instruction, curricula design, development, evaluation, implementation and program 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, Application of Telecommunications Technologies in Distance Education, 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).

Impact of Simulation-based and Hands-on Teaching Methodologies On Students' Learning in an Engineering Technology Program

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, but simulation becomes effective in promoting student learning when used in conjunction with hands-on approach i.e. hybrid or combinational instructional strategy. Furthermore, the paper presents recommendations for improving student learning, viz a viz simulation-based and hands-on labs.

I. Introduction

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.

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 [5], 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 [6] 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.[7] Although the importance of hands-on labs to the technology curriculum cannot be denied, Garcia[8] 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.

Table 1: Theoretical Framework: Comparison of Traditional versus cognitive apprentice-based teaching/learning methods

Teaching/Learning based on Traditional Methods	**Teaching/Learning based on Cognitive Apprenticeship**
• Theoretical Framework of Instruction	• Physical activity based Framework of instruction
• Learning takes place by reading, writing and problems solving i.e. invisible learning processes	• Learning takes place by watching/doing physical activity based problem solving i.e. learning is visible
• Learning is based on Formulaic methods	• Learning is based on real world/complex scenarios
• Learning/Teaching strategies lack integration of skills and knowledge	• Learning/Teaching promotes integration of skills and knowledge
• Effective strategy for teaching rote tasks	• Effective strategy for teaching complex tasks
• Thinking process is invisible	• Thinking process is visible

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[9] 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. [10] 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.[11] 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. [12] According to Magnusson and Palincsar [12,13](1995), 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. Simulation: Historical Perspective

Games and simulations entered the broad educational scene in the late 1950s; however, until the early 1970s, they were not part of the instructional design movement. Instead, these exercises were primarily developed by business, medical education faculty, and sociologists who adapted instructional developments pioneered by the military services.[14]

Currently, the increased power and flexibility of computer technology is contributing to renewed interest in games and simulations. This development coincides with the current perspective of effective instruction in which meaningful learning depends on the construction of knowledge by the learner. Games and simulations, which can provide an environment for the learner's construction of new knowledge, have the potential to become a major component of this focus.[14]

Simulations have the potential to develop students' mental models of complex situations as well as their problem-solving strategies.[15] Games and simulations are often referred to as experiential exercises because they provide unique opportunities for students to interact with a knowledge domain.

V. Applications of Simulation in Education

Engineering & Engineering Technology Education

Phenomenal growth in a wide spectrum of new and emerging technologies has led to an increased demand for engineering and engineering technology graduates to deeply understand the fundamental principles behind contemporary state-of-the art technologies, but also exhibit analytical, problem solving and expert thinking skills. To address these growing industry demands, new technological tools and teaching methodologies need to be incorporated into engineering and engineering technology curricula. However, incorporation and implementation of the state-of-the-art technological tool and equipment requires a considerable investment of time and financial resources. Keeping curricula and lab resources current with respect to the fast rate of change of technological advances poses another challenge for faculty. Engineering and Engineering Technology professors all over the world can address some of the challenges by using simulation and virtual experiments.[16] In addition to cost saving, simulation offers a number of other advantages, which include the following:

- Allowing the user to modify system parameters and observe the outcomes without any harmful side effects.
- Eliminating component or equipment faults that effect outcomes.
- Supporting user pace progress in discovery and understanding of issues.
- Facilitating the presentation of 'dry concepts' in another way – by integration of theory and practice.

The present study focused on the use of simulation as an instructional method to improve student learning. Specifically scaffolding and exploration domains of cognitive apprenticeship were employed to explore their impact on student learning. Due to limitations of simulation software elements like modeling, coaching, articulation, and reflection were not addressed (See Table 2). Also Multisim features do not allow interactivity component thus modulation will not be directly studied. Since the present study primarily focused on the use of scaffold instruction to gauge the learning outcomes, thus the effect of fading of the scaffold i.e. the decrease of teacher's assistance for helping student acquire a specific skill was not gauged. The literature does not cite any applications of cognitive apprenticeship to electrical and electronics engineering curricula.

Table 2: Mapping of Cognitive Apprenticeship elements with features of Multisim-8 Software.

Cognitive Apprenticeship /elements	Definition	Multisim-8 Capabilities
Modeling	Involves an expert's performing a task so that the students can observe and emulate the desired skill.	The software functions do not allow modeling capabilities.
Coaching	Involves observing students while they carry out a task and offering hints in the forms of feedback and reminders.	The software features are not interactive in nature and thus do not allow coaching capability.
Scaffolding	Involves the support that teacher provides to help students can carry out a desired task.	The software has the capability to pinpoint the error or mistake in circuit construction and thus scaffolds student to carry out a desired task.
Articulation	Involves any method of getting students to express their acquired knowledge or problem-solving skill.	The software allows articulation in terms of letting students run the simulation feature and demonstrate the acquired learning skill.
Reflection	Involves any method adopted by student compare his/her acquired learning skill with that of others such as experts or other students.	The software lacks ability to allow students to compare their results with other in a synchronous manner.
Exploration	Involves any strategy to force students into a mode of problem solving on their own.	The software has a built–in help feature using which students can achieve their tasks and sub-tasks related to circuit construction.

VI. Methodology

In the present research study, a case study approach was employed since the student group was small in size. Yin[17] observes that the case study methods involve three roles: exploratory/descriptive, evaluation, and hypothesis testing. For the present case study, hypothesis testing was employed. Specifically, this proposed study employed a two-phase mixed-method approach as identified in Creswell's research.[18] In this research framework, investigators first conduct a quantitative study to address the research questions, and then collect and analyze the data quantitatively. Next, to further strengthen the quantitative findings, qualitative methods are used to explain the unexpected results, significant or non-significant quantitative findings, and the description of the context within which the findings are situated.

Study Context

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 Technology Accreditation Commission/Accreditation Board of Engineering and Technology (ETAC/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.

Participants

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.

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. All of the students in the participating class section were also given lab assignments that provided an equal and independent chance to build circuits using simulation software. After completing all practice labs (using Multisim-8) on each of the topic, students were given a two—hour mid-term (problem solving exercise) to assess the acquisition of domain knowledge. The grades of the students who completed the mid-term (simulated lab) were then compared to the grades of students who took the midterm (hands-on lab using breadboarding) teaching techniques (baseline reference group). The grades were then analyzed using the ANOVA test. Table 3 illustrates the implementation schedule for the case study.

Table 3: Case Study Schedule.

Date	Event/treatment	Duration	Data Collection/Measures (Group)
Week 1	Intro to Electronic Fundamentals	50 minutes	
	Ohm's Law – Problem solving	50 minutes	
	Simulation Lab#1 – Ohms Law	2 hours	Quiz 1 (Simulation)
Week 2	Series Circuit – Problem solving	2 hours	
	Simulation Lab#2 – Series circuit	2 hours	Quiz 3
Week 3	Parallel Circuit – Problem solving	2 hours	
	Simulation Lab#3 – Parallel circuit	2 hours	Quiz 4
Week 4	Combination Circuit – Problem solving	2 hours	
	Simulation Lab#4 – Combination circuit	2 hours	Quiz 5
Week 5	Practice Problem solving and circuit building	2 hours	
	Test learning gain	2 hours	Mid-Term Exam (Simulation and Hands-on, and hands-on only)
Week 6	Hands-on Lab#5 – Ohms Law	2 hours	Quiz 2(Hands-on)
Week 7	Focus group interview	2 hours	Measuring students confidence level to operate the Multisim-8 (simulation

			and Hands-on)
Week 8	Data Analysis (Quiz and Exam score). Final Exam Interview	4 hours 2 hours	ANOVA (Simulation & Hands-on (Hybrid) , and hands-on only Gauging students' attitude towards the use of Simulation Software (Simulation and Hands-0n)

Setting

Following is the description of data collection sources used in the study:

1. Simulation Software

A virtual prototype software-simulation model with the same capabilities as the hardware prototype, created the same real-world effects, ensuring that the hardware prototypes worked when built and minimized the hardware-software integration effort in later stages of the course work. The model included processors, buses, and hardware components. It allowed the students to debug their circuits long before the detailed hardware design was complete, and thus enabled true parallel development of hardware and software. Using a virtual environment of Multisim-8 as a reference allowed simultaneous verification of hardware and software, ensuring they worked together as intended. It also reduced the amount of work that hardware designers had to do to verify their circuits, since they could leverage the system-level environment rather than develop independent test benches that were likely to be inconsistent. The software simulation (Multisim-8) tool, which was an integration of hardware, software and architecture into a single development environment, had profound effects on every aspect of learning.

The students were introduced to the concept of circuits, circuit components, circuit building techniques, and measuring tools through labs. The simulation software used in this experiment was Multisim-8. Multisim-8 provided the students with a virtual environment that gave them the ability to do virtual (simulation) labs and arrive at results that were similar to results obtained through the hand-on labs. The simulation labs were designed to prepare the students to identify components, build circuits using different techniques, and connect different types of wires. In additions to circuit building, students learned how to use measuring instruments while following safety standards.

2. Problem solving activity

The students were given in-class assignments that included practice and drill type exercises to re-enforce the concepts they learned in class as a problem solving activity (class work, home work, and online assignments). After completion of the class work activities, students were given homework and online assignments to master the concepts covered in class. To further enhance the understanding of topics covered in class, simulation labs were given to foster hands-on experience. Each lab was followed by a quiz on that particular topic to assess the understanding of the concepts learned.

3. Design treatment

VII. *Data Sources*

To conduct the study, the following data collection methods were employed:

1. Quizzes and Mid-Term Exam

2. Interview

3. Focus Group Interview

VIII. 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.

Hypothesis

A hypothesis is simply a prediction of the possible outcomes of a study. It enables one to make specific prediction based on prior evidence or theoretical arguments. In the present study, the expectation was that the test results would improve significantly by using Multisim-8 in comparison to the standard bread boarding method. Test results were evaluated by comparing the scores from the breadboard method to the scores from the Multisim-8 method. The expectation was that Multisim-8 would produce better results because of the ease of using the software, elimination of mistakes by students in selecting the wrong components, and the prospect of human error in measuring values using the measuring instruments. It was also expected that the students using Multisim-8 would have higher mid-term grades. If difference of the means between the two methods was significant and in the proper direction, the hypothesis would be supported; and if not, it would be rejected.

Reliability issues

Reliability relates to demonstrating that the operations of the study can be repeated with the same results. The goal of reliability is to minimize the errors and biases in a study. According to Yin,[17] "the objective is to be sure that if a later investigator followed the same procedures as described by an earlier investigator and conducted the same case study all over again, the later investigator should arrive at the same findings and conclusions". The emphasis is on "doing the same case over again, not 'replicating' the results of one case by doing another case study." Table 4 indicates what data sources were used to answer each research question.

Table 4: Data Sources for Each Research Question

Research Question	Data Sources	Data Analysis
Q1	Quizzes Mid-term Exam Final Exam	Repeated-measure ANOVA Single-factor ANOVA Mixed-method ANOVA
Q2	Individual Interview	Faculty Feedback
Q3	Focus Group Interview Follow up	Students' Feedback Qualitative data analyses employing open and selective coding Students' Feedback

IX. Findings

Quantitative 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 & 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. Of the total sample of students, 71 (96%) were male and 3 (4%) were female. Participants ranged in age between 18 and 20 years. Additional information was obtained for students in Instructor A's class. Here, approximately one-half (52%) of the participants who completed the class had prior experience with information technology and had some electronics background, while the remaining participants (48%) had no prior technical or information technology experience. All the students in Instructor A's class were high school graduates without prior college experience.

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.

Two students (who were both female students) from the Simulation & Hands-on (Hybrid) group for Instructor A did not have both midterm and final exam scores due to absence for exams, resulting in a zero score. These two cases were not included in further analysis. Since multiple statistical tests were being conducted using the different variables in each test, more specific findings from data exploration and specific missing values and outliers in each test will be explained below. Table 5 provides a summary of groups, data collection tools, sample size and type of data analysis performed.

Table 5: Details of groups, data collection tools, sample size and data analysis

Group	Tools for Data Collection	Frequency of Data Collection	Sample size	Analysis performed
Hands-on only	Quiz 1	1	29	Repeated Measure ANOVA
	Quiz 2	1		Repeated Measure ANOVA
	Mid Term	1		Single factor ANOVA
	Final	1		Mixed Method ANOVA
Simulation and Hands-on	Quiz 1	1	24	Repeated Measure ANOVA
	Quiz 2	1		Repeated Measure ANOVA
	Mid Term	1		Single factor ANOVA
	Final	1		Mixed Method ANOVA

Research Question 1: *Does the use of simulation improve students' learning outcomes?*

Multiple tests of inference were conducted to analyze the effect of simulation on students' test scores. The first test was a single-factor ANOVA, which was conducted to assess the difference between midterm test scores of students from Instructor B who used the hands-on approach (only) with test scores of students (from Instructor A) who used simulation method (only). The criterion for statistical significance was set to alpha = .05. Two low score outliers were identified in the midterm scores of the simulation group for Instructor A and these outliers were changed to the nearest higher value within the group, (Outliers were not changed to the mean scores to retain the scoring pattern of the students in the group assuming from the scoring pattern that the students were low scorers.) Examination of histograms, Q-Q plots, and Kolmogorov-Smirnov test statistics indicated that the assumption of normality was met. Levene's test indicated that the assumption of equality of variances was met.

Table 6 shows descriptive statistics for the midterm scores. Single-factor ANOVA showed a significant difference in the mean scores ($F(1, 42) = 0.949$, $p = .336$), with the simulation intervention group showing a higher mean score ($M = 81.82$, $SD = 17.26$) than the hands-on control group ($M = 76.95$, $SD = 15.39$). The results of the ANOVA are shown in Table 7. The strength of the effect was large ($\eta^2 = .02$), which suggests that a small association was evident between the instruction method and the midterm score at the sample level. This finding further suggests that the use of simulation accounts for 2% of the variance in midterm scores.

Table 6: <u>Descriptive statistics for midterm scores by method of instruction</u>

Groups	*n*	*M*	*SD*
Intervention Group –Simulation only	22	81.82	17.26
Control Group -Hands-on only	21	76.95	15.39

Table 7: <u>ANOVA Results: Comparison of midterm scores from intervention and control groups</u>

	Sum of Squares	*df*	Mean Squares	*F*	Sig.
Between Groups	254.38	1	254.38	0.949	.336
Within Groups	10989.47	41	268.04		
Total	11243.85	42			

Among the students in the Simulation & Hands-on (Hybrid) group, there were two students who rarely attended class, and scored very low on the midterm. When these cases were omitted from the analyses, results suggested a marginally significant difference between the treatment and control groups (F (1, 40) = 4.01, p = .05), with the treatment group showing higher midterm scores than the control group. The observed effect size was moderate (eta-squared = .09).

The mixed method ANOVA additionally demonstrated a significant main effect for the within-subjects factor; i.e., between the midterm test scores and the final test scores, while disregarding treatment group distinctions (F(1, 40) = 54.95, p < .01). It appears that when disregarding treatment group distinctions, students score lower on the final exam compared to the midterm exam. The findings from this analysis are displayed in Table 8. The observed magnitude of this main effect was very large (eta-squared = .58).

Table 8: ANOVA Results: Within-subjects effect for time using midterm/final exam scores

Source	Sum of Squares	*df*	Mean Square	*F*	Sig.
time	5769.75	1	5769.75	54.95	<.01
error	4199.80	40	105.00		

The main effect for the between-subjects factor (treatment group) was found to be non-significant $F(1, 40)$ =1.87, p = .18. The findings from this analysis are displayed in Table 9. Thus, it can be concluded that the two groups show a significant difference in overall scores irrespective of the time factor. The effect size was η^2 = .08, which suggests that a moderate effect was evident.

Table .9: ANOVA Results: Between-subjects effect for group using midterm/final exam scores

Source	Sum of Squares	*df*	Mean Square	*F*	Sig.
Group	949.81	1	949.81	1.867	.18
Error	20354.01	40	508.85		

We next repeated this mixed design ANOVA, but omitting the two students from the treatment group who rarely attended class. Results again indicated no statistically significant interaction between test time and group ($F(1, 38) < 0.01$, $p = .98$). That is, the mean change in scores from midterm to final was similar for both the Simulation & Hands-on (Hybrid) group and the hands-on only group.

Finally, one-way ANOVA was carried out to assess the difference between final exam scores of Instructor B's students who used the hands-on only approach with final exam scores of Instructor A's students who used simulation and hands-on method. The criterion for statistical significance was set to alpha = .05. The sample size of the hands-on group was $n = 21$ while the sample size of the simulation and hands-on group was $n = 22$ students. The independent variable was the use of simulation in learning and the dependent variable was the final exam scores. Examination of histograms, Q-Q plots, and Kolmogorov-Smirnov test statistics indicated that the assumption of normality was met. Levene's test indicated that the assumption of equality of variances was met.

Table 10 shows descriptive statistics for the final exam scores. Single-factor ANOVA showed no significant difference in the mean scores ($F(1, 41) = 1.16$, $p = .29$). The results of the ANOVA are shown in Table 11. The strength of the effect was small ($\eta^2 = .03$), which suggests that a small association was evident between the instruction method and the final score at the sample level. This finding further suggests that the use of simulation accounts for 3% of the variance in final exam scores.

Table 10: Descriptive statistics for final exam scores by method of instruction

Groups	*n*	*M*	*SD*
Intervention Group –Simulation & Hands-on (Hybrid)	22	65.74	18.23
Control Group -Hands-on only	21	59.48	19.84

Table 11: ANOVA Results: Comparison of final exam scores from intervention and control groups

	Sum of Squares	*df*	Mean Squares	*F*	Sig.
Between Groups	420.67	1	420.67	1.16	.287
Within Groups	14851.88	41	362.24		
Total	15272.55	42			

We then repeated this analysis, but omitting the two students from the treatment group who rarely attended class. Results again showed no statistically significant difference in mean final exam scores ($F(1, 39) = 2.10$, $p = .16$). The effect size, however, was moderate (eta-squared = .05). This suggested that a moderate difference existed between the mean final exam score of the simulation group of Instructor A (*M* = 67.96, *SD* = 17.48) and the mean final exam score of the hands-on only group of Instructor B (*M* = 59.48, *SD* = 19.84), although this difference may have been due to sampling error.

X. 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 in comparison to 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.

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 & 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 $F(1, 40) = 0.16$, $p = .69$. 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 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. Banky & Wong [20] observed that use of simulation software promotes deep learning in the study of electronic circuits.

Question2. 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 promote scaffolding.

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 becomes 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.[21]

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, measure and monitor the performance of circuits. Furthermore the findings suggest that, in regards to 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 [21] that students can efficiently construct complex circuits using the Multisim simulation program.

XI. Shortcomings/limitations of Simulation and Recommendations:

Based on the findings of the current study the recommendations and suggestions for addressing the shortcomings of simulation-based instructional strategies are listed as follows:

1. Simulation should be used to re-enforce the breadboard circuit construction.
2. Simulation by itself is not very effective in teaching new concepts.
3. Simulation programs should have help features where help is provided when user places the cursor on a specific component.
4. Simulation programs lack interactivity functionality.
5. There should be a balance between simulation labs and actual hands-on lab for performing circuit construction experience and project.
6. Simulation programs should have built-in short tutorials to enable students to achieve their results effectively and efficiently.
7. In simulation, component icons should reflect reality. Instead of using symbols, actual 3-D images of components should be used. For example an image showing the color code combinations for resistor should be used to represent a resistor

The results regarding the impact of modeling element of simulation program on students learning reveal that the majority of students believe that modeling is faster, simpler and easier because it allows quick changes for circuit modification, which is beneficial in case of design of complex circuits.

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.

XII. 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 combinational 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 & 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: Students feedback suggests that simulation-based labs offer a safer environment for 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 form of circuit construction on a breadboard to complement their learning and to verify their knowledge of theory.

XIII. 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 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. The paper also presented recommendations on the effective use of simulations for teaching laboratory courses.

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. Gredler, M. (1990). Analyzing deep structure in games and simulation. *Simulation/Games for Learning, 20*(3), 329-363.
15. Dekkers, J., & Donatti, S. (1981). The integration of research studies on the use of simulation as an instructional strategy. *Journal of Educational Research 74*, 424-451.
16. Yakov, C., Karim, A., Khan, A., Rubanchik, V., & Mullett, G. (2008). *Using simulation-based hybrid and multilevel virtual labs for fiber optics, photonics, and telecom education.* Paper presented at the meeting of the National Science Foundation, Pittsburg, PA.
17. Yin, R. K. (2003). *Case study research: Design and methods* [Google books version]. Retrieved November 20, 2009, from http://books.google.com/books?hl=en&lr=&id=k0WrN3rBz sC&oi=fnd&pg=PR7&dq sage+publications&ots=IWlPqCDanK&sig =HaSHzKaI3hHUzhgZeue9Kg6qYZE#v=onepage&q=&f=false

18. Creswell, J. W. (2003). Research design: Qualitative, quantitative, and mixed methods approaches, 2nd edition, Sage Publications, Thousand Oaks, California.
19. Cohen, J. (1987). *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Eribaum.
20. Banky, G. P. & Wong, K.K. (2007). Troubleshooting exercises using circuit simulator software: upport for deep learning in the study of electronic circuits. *ICEE – International Conference on Engineering Education, Portugal*.
21. Fraga, J.R.C.P et al (2003). Using Simulation Programs to enhance learning in electrical circuits classes, Anais do XXXIV COBENGE. Passo Fundo: Ed. Universidade de Passo Fundo, Setembro de 2006.