# AC 2005-1034: VIRTUAL LAB IN ENGINEERING CURRICULUM

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## Session XXXX

#### Virtual Lab in Engineering Curriculum

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#### Abstract

The World Wide Web (WWW) provides alternative means for delivery of the courses and services, providing learners with an extraordinary range of options. There are few, if any, studies that have attempted to evaluate the learning achieved through the use of simulated laboratories in virtual environments, perhaps because of the difficulties in designing tight experiments for such studies. The purpose of this study would be to investigate the effectiveness of simulated labs in engineering and present the results. Specifically, this study examines whether computer simulations are as effective as physical laboratory activities in teaching college-level electronics engineering students about the concepts of signal transmission, modulation and demodulation.

Two sections of the same college course with a total of 80 subjects participated in this study. After receiving the same lecture at the same time, the subjects in each course were randomly split into two treatment groups. One group completed two laboratory experiments using the computerized simulation program, while the other completed the same two laboratory experiments using the traditional physical laboratory equipments. Upon the completion of the laboratory assignments, the performance instrument was individually administered to each student.

The groups were compared on understanding the concepts, remembering the concepts, and displaying a positive attitude toward the treatment tools. Scores on a validated Concepts Test were collected once after the treatment and another time after three weeks of the study. The validated Attitude Survey and qualitative study was administered at the completion of the treatment.

#### Introduction

Engineering education is under considerable pressure to include additional and novel material, to accommodate ABET 2000 criteria and to restructure content using new approaches and technologies. All of these are to be achieved within a nominal four-year format. Many engineering educators and administrators anticipate that new learning/teaching technologies can relieve some pressure without loss of learning or added costs.

In addition, many colleges and universities are witnessing challenges associated with offering online academic opportunities to those who are unable to attend traditional classrooms [1]. Research indicates that at this time, three-quarters of two- and four-year colleges offer distance-learning opportunities. A third of these offer accredited degree programs online [2]. Soon most colleges across the country will be offering some of their courses online, and by the completion of 2004, a hundred million Americans are expected to take part in continuing education using some form of the new communication technology [2].

Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition Copyright 2005, American Society for Engineering Education Despite the tremendous success in the development and marketing of online learning and its anticipated future, one major challenge remains that leaves several specialized fields of education far from being ready to go online. In engineering programs where laboratory sessions are indispensable, students would not be able to complete degree requirements without attending real campuses that provide real lab facilities. The primary solutions to this challenge, specifically to engineering, have been home-kit, on-campus laboratory visits, and in some instances, computer-simulated laboratories. In engineering literature, however, despite the use of these methods, there is little evidence on their effectiveness.

The existing studies reported in the engineering literature are small case studies and lack different control groups to isolate the effect on learning derived from the simulation. Such evidence can be found in a study [3], which provides an exhaustive overview of findings and trends in research over the last 15 years. Reviewing 760 reports, evidence was established that information technologies are capable of enhancing learning when pedagogy is sound and when there is a good match of technology, techniques and objectives. However, the authors could not restrict their reviews to only engineering and related subjects, for there were too few studies that met their criteria. One criterion in particular was notable; provide quantitative results on an outcome variable measured in the same way as with a technology-taught group and a conventionally instructed group. In the area of engineering, despite the need, it is rare to see a controlled study involving the comparison of student performance and satisfaction in different types of learning experiences [4, 5].

In addition despite the efforts to enhance engineering education, there appear to be few studies derived from a statistically significant data set on which to base an evaluation of the effectiveness of the presently available tools, including simulation [5].

Therefore, the purpose of this study is to examine an alternative to the use of physical laboratory activities in a communication systems laboratory. Specifically, this study examines whether computer simulation is as effective as physical laboratory activities in teaching college-level electronics engineering education students about the concepts of signal transmission, modulation and demodulation. Also of interest are the effects that computer simulations have on a) students' knowledge retention after a period of time and b) students' attitudes towards the use of the simulation as a substitute for the physical activities.

#### Significance

The pursuit of an understanding of the potentials of simulation methods for conducting laboratory activities, (both off- and on-campus) in an engineering education context is worthwhile for several reasons. Simulation potentially offers students opportunities to explore situations that may be impossible, too expensive, difficult or timeconsuming to accomplish with actual laboratory or real-life experiences. Even if real-life experiences seem feasible, simulation offers students the opportunity to explore a wide range of variables more rapidly can supplement such experimentations. In addition to being safe, convenient and controllable, the simulation-based laboratories can be made available to anyone, anywhere, anytime.

A report [6] indicates that, of the schools offering online learning programs, only 12 percent offered courses in engineering. The low percentage of online engineering courses may be due to the fact that traditionally undergraduate engineering courses employ lectures and laboratories as the most common method of delivering education. In many engineering courses, physical laboratory activities are an inseparable part of the curriculum. But delivery

of laboratory experiments beyond laboratory walls, where conducting physical experiments is not possible, has always been the greatest challenge of online engineering education. Despite the challenge, researchers argue that there is a great need for delivering online engineering courses and laboratories due to changing demographics and growing competition [7].

In response to the need for resources that provide practical experience to online engineering students, this study has been designed to investigate the effects of simulation for conducting laboratory experiments on the topic of communication systems (shown in Figure 1). By demonstrating that simulation-based laboratory methods can provide comparable outcomes to traditional physical laboratory methods, the cost of providing engineering laboratories can be dramatically reduced. By reducing the costs, specialized materials and equipment needs and facility requirements, engineering laboratory training would be more accessible for current engineering students as well as those individuals who are unable to attend traditional classrooms.

The value of this study lies in the fact that despite considerable research in using simulation software with science laboratory instruction, there is very little quantitative and qualitative research on the effectiveness of simulation for conducting engineering laboratory experiments and its potential as a substitute for physical laboratory activities at the college level engineering technology/education. Given the potential benefits of engineering programs incorporating simulated laboratories, an investigation of such a program at the college level is desirable. Such investigation would fill a gap in engineering education research and contribute considerable knowledge in the area of using simulation technology for learning and teaching enhancement in engineering higher education.

#### Methodology

The current research effort has two complementary tracks. The first of these is a quantitative study to examine the differences between the two groups on their scores on post-test as well as follow-up measure. In addition, the quantitative section examines the difference in terms of lab completion time. The physical lab group performed communication systems laboratory exercises using traditional hardware laboratory and the simulation group used simulation software for performing similar laboratory exercises on the subject of modulation and demodulation. The second track is also a quantitative study using an attitude survey questionnaire to examine the attitudes of the students toward the simulation as well as the attitude of both groups toward the use of a laboratory in general.

The sample included 80 of the students enrolled in the course during the data collection period. Students enrolled in the course were junior- or senior-level undergraduate students pursuing four-year degree in electronics or computer engineering technology. All three sections were taught by the same instructor, which included 2 hours of lecture and 2 hours of lab for each section.

The students in each section were randomly assigned either to the simulation or the physical laboratory group that signifies that the research design is true experiment. To ensure that the students were motivated to participate in the study, they were reminded that their test score would count in the course grade and they would also earn 5 extra credit points on their final grade by participating in the study.

The independent variable in this study is the method of instruction, a variable with two categories: computer simulation and physical laboratory. The dependent variables are the post-test score, follow-up scores, attitude scores and laboratory completion time scores. The post-test was made up of problem-oriented type of items and a few multiple-choice questions.

### **Research Questions**

The main research question for this research project is: "Can simulation-based laboratory replace physical laboratory methods?" Specifically,

- 1. In terms of student conceptual learning, how do simulation-based laboratory experiences compare to physical laboratory experiences?
- 2. How does the students' attitude toward the use of the simulation affect their post-test score?
- 3. How does the simulation group attitude toward the laboratory experience differ from the physical group?
- 4. In terms of completion time of the assigned laboratory experiments, how do simulation-based laboratory experiences compare to physical laboratory experiences?
- 5. In terms of student knowledge retention, how do simulation-based laboratory experiences compare to physical laboratory experiences?

### Results

A conceptual test was administered twice to each student in the sample: during the 5<sup>th</sup> week of the semester after the experimental treatment and at the 8<sup>th</sup> week of the semester during the mid-term exam week. All the 12 post-test questions were embedded into the midterm exam to assess the students' retention level. Each student test was graded by two independent instructors: first, the instructor of the course and second an instructor who was not familiar with the study and its methodology. Additionally, each instructor was unaware that another instructor would be grading the same test. Alpha reliability was computed for the scores reported by the two instructors for each student to examine the internal consistency in grading. The calculations revealed an alpha reliability of .94, indicating an acceptable consistency of grading for the instructors. For the conceptual post-test, skewness for the simulation group was more positive than the physical group. However, this was reversed during the follow-up test.

This preliminary comparison hints an interesting trend with respect to the conceptual test. The two groups significantly differ on post-test scores (p = .00; t = .38, p = .00, df = .78). The simulation group (M = 31.65) performed significantly higher the physical group (M = 13.77). The results support the notion that simulation treatment appears to improve the conceptual understanding of the students. Initially, it was perceived that the simulation group would perform as well as the physical group or slightly better. But to the author's surprise, the simulation group performed much better than the physical group. There was no surprise, however, by the scores obtained from the physical group considering the levels of the students who participated in the study. The scores of the post-test for the physical group were consistent with history of the institution where this research took place. However, the simulation program seemed to have helped the simulation group considerably since their scores improved significantly.

In addition, the results from independent t-test revealed the two groups significantly differ on the follow-up test scores (p = .00; t = -18.93, p = .00, df = 78). The simulation group (M = 27.81) performed significantly higher than the physical group (M = 13.17). The results

of  $H_02$  reveal that the simulation group did perform significantly higher on the post-test than the physical group. In addition, results of  $H_03$  indicate that the simulation group also performed significantly higher than the physical group. However, it is interesting to note that, on the follow-up test, the scores for the simulation group dropped, whereas the scores for the physical group remained. Post hoc analysis using paired sample t-test examined the significant differences within groups. Results revealed no significant difference in the physical group's scores between the post-test and the follow-up test (t = 2.80, p = .008). The simulation group's scores at the post-test were, however, significantly higher than the followup scores (t = 4.85, p = .000). These results clearly support the fact that even though the follow-up scores for both group dropped slightly, the simulation group's follow-up scores were still significantly higher than those obtained by the physical group as discussed above.

Furthermore, the two groups significantly differ on laboratory completion time (p = .001; t = 8.67, p = .00, df = 78). The simulation group (M = 71.68) utilized significantly less laboratory time than the physical group (M = 90.28).

A 9-item attitude survey questions (alpha reliability of .89) was also administered at the completion of the treatment to both groups (physical and simulation) to assess their attitudes towards the laboratory experience. The results indicate that the two groups significantly differ on attitudes toward the laboratory experience as measured by attitude survey (F = 10.55, p = .002). The simulation group reported a more positive attitude (M =3.20) than the physical group (M = 3.07). More specifically, on the individual attitudes questions, the simulation group found lab experience significantly more interesting (F = 4.27, p = .042), less abstract (F = 26.36, p = .000) and less time-consuming (F = 40.2, p = .000).

In addition to this, a 13-item survey (alpha reliability of .91) was also administered at the completion of the simulation program to assess the simulation groups' attitude toward the use of simulation program. There is a significant positive relationship between the attitudes of the simulation group's toward the use of the simulation and their post-test performance (r = .69, p = .00) at the 0.01 level.

#### Discussion

An interesting finding of this study was that the simulation groups' conceptual test scores slightly decreased from post-test to follow-up but still remained higher than the physical group. The results however suggest lower knowledge retention for the simulation group over time. On the other hand, the physical groups' score dropped very little, which may suggest that physical group's knowledge retention remained constant. But as the same time, initially, the physical group did not start with high scores on the post-test and much knowledge to begin with. Therefore, it is unreasonable to declare that those students had higher knowledge retention than simulation group.

It is very difficult to declare with certainty from this study the reasons that simulation group did much better on both post-test and the follow-up test, but one can speculate. It is entirely possible that the simulation program gave the simulation group a more secure notion of the concepts involved. It would appear that they understood the aspects of the modulation and demodulation and graphing the related waves better which was a notion on every question. They could also see the relationship between the carrier wave and the modulated wave more clearly. It is also important to note that both simulation and physical group could visualize the waves. Simulation group could see the change in the waves on the screen of the

Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition Copyright 2005, American Society for Engineering Education oscilloscope. However, since the simulation program provides more details on each displayed wave, it might have provided a better mental image of possible waves under various conditions and as a result a better understanding of the concept in general. In addition, the physical students had to deal with additional content (manipulating of the apparatus), which was not tested. Such factors might have contributed to an increase in the cognitive load, which likely interfered with physical group's learning

As a result, it is not unreasonable to assume that conceptual simulation programs could be feasible substitute for hands-on exercises when the purpose of the experiments is to understand the concepts and not manipulate the equipments since it helps reduce the unnecessary cognitive overload.

### Implications

One might ask what makes this study different than the previous ones, which found no significant difference between the two groups and/or significant difference in favor of the physical group. Based on the observations made from past literature, the author believes that some missing links are evident in previous studies reported in the literature. For instance, the author has identified few factors, which have contributed to the results of this study namely simulation design and quality, experimental design and type of learning.

Simulation Quality and Design: One contributing factor to the result of this study could be the alignment between the course objectives, the assessment procedures, the lectures, and the selection of a simulation program. Based on the result of this study, it is not unreasonable to suspect that the design of computer simulation selected for this study must have met the specific learning objectives of the laboratory experiments. In fact this was a very important factor at the initial stages of this study. For instance, simplicity and ease of use of the simulation program were few factors that were pointed out during the interview. Another contributing factor could be the quality of the simulation software in terms of *"realism"* of the simulation model.

Relevance of the simulation to the topic could also be an important factor. It can be argued that simulations should be used as a tool to advance a clear set of learning objectives, rather than as a game or classroom activity that is fun but has little relevance to the larger curriculum.

<u>Types of Cognitive Learning</u>: Previous studies have attempted to assess cognitive learning at a lower level of Boom's taxonomy whereas in this study, effects of simulated laboratory at learning at higher level (analysis, synthesis and evaluation) were the subject of investigation. Thus, it could be concluded that the use of simulation programs for laboratory purposes might prove more effective at higher levels of cognitive learning.

Experimental Design: Many empirical studies in engineering have poor statistical design [8]. In addition, the author believes that controlled comparisons of randomly allocated groups to students, taught by the same instructor, represents the ideal research design which previous studies lack. Thus experimental design employed in this study could be a contributing factor to the higher learning of the simulation group.

### Summary

The results of this research support the conclusion that whether the laboratory exercises are conducted in the traditional hardware laboratory or in the computer laboratory using simulation software, students will learn their lessons. But such conclusion can only be

made for laboratory experiments, which are not hands-on intensive. In those cases, students who cannot attend laboratory classes on campus could take the same courses using computer simulation without fear that their experience or achievement would be somehow less than it would have been attending classes on campus.

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### Biography

GITI JAVIDI earned B.S. and MS degrees in Computer Science from the University of Oklahoma and University of South Florida, respectively. Her research areas were user interface design and consistency issues. She earned a Ph.D. in Instructional technology from USF working on multimedia and virtual reality user interface design and development. She has contributed many publications and won several research awards in user interface design.

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EHSAN SHEYBANI earned B.S., MS, and Ph.D. degrees in Electrical Engineering from the University of Florida, Florida State University, and University of South Florida, respectively. His research areas were laser signal processing, ocean behavior modeling, and biomedical networks with diagnostic capabilities. He has contributed many publications and won several research awards in digital signal processing and high-speed networking.



Figure 1. Screen shot and lab procedure of the simulated lab.