Content-Based Computer Simulation of a Networking Course: An Assessment

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***Abstract*— This paper presents a successful lab simulation experience to teach signal modulation and demodulation concepts in communication and computer networks to computer science and computer engineering students. 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 in order to gain some insight on students' knowledge retention. The validated Attitude Survey and qualitative study was administered at the completion of the treatment. The findings of this research indicate that conceptual simulation programs could be feasible substitute for hands-on exercises.

***Index Terms*—Network Communications, Simulation, Virtual Lab, Matlab.**

I. INTRODUCTION

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 in computer science and engineering 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 as virtual laboratory and present the results. Specifically, this study examines whether computer simulations are as effective as physical laboratory activities in teaching college-level computer science and engineering students about the concepts of signal transmission, modulation and demodulation.

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].

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. For instance, 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 have been home-kit, on-campus laboratory visits, and in some instances, computer-simulated laboratories. In engineering and computer science literature, however, despite the use of these methods, there is little evidence on their effectiveness.

The existing studies reported in the literature are small case studies and lack 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 areas, 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 and computer science, 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 and computer science 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].

One reason could be that computer science and engineering classes do not have enough students to form experimental and control groups large enough to yield statistically significant results; another is that few engineering professors are familiar with the complexities and ethical issues involved in human subject research; and still another is that control group studies must be planned in advance, whereas many innovations in computer science and engineering education seem to develop more by natural growth and change than from preplanning. Due in part to these difficulties, relatively few of the studies reported computer science and engineering literature have used rigorous quantitative methods and many of those that have done so suffer from methodological weaknesses.

On the other hand, although there is a lack of qualitative research in the fields of engineering, this type of research will undoubtedly become more common and more imperative in engineering and technology as more faculty members discover that some of the skills specified by the Accreditation Board of Engineering and Technology (ABET) can be assessed most effectively using qualitative methods.

The purpose of this study is to use both quantitative and qualitative methods to examine an alternative to the use of physical laboratory activities in a communication systems course where laboratory activities are required. 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.

The findings revealed significant differences, in favor of the simulation group, between the two groups on both the conceptual post-test and the follow-up test. The findings also revealed significant correlation between simulation groups' attitude toward the simulation program and their post-test scores. Moreover, there was a significant difference between the two groups on their attitude toward their laboratory experience in favor of the simulation group. The qualitative research uncovered several issues not explored by the quantitative research. It was concluded that incorporating the recommendations acquired from the qualitative research, especially elements of incorporating hardware experience to avoid lack of hands-on skills, into the laboratory pedagogy should help improve students' experience regardless of the environment in which the laboratory is conducted.

II. SIGNIFICANCE

The pursuit of an understanding of the potentials of simulation methods for conducting laboratory activities, (both off- and on-campus) is worthwhile for several reasons. Simulation potentially offers students opportunities to explore situations that may be impossible, too expensive, difficult or time-consuming to accomplish with actual laboratory or real-life experiences. Even if real-life experiences seem feasible, simulations offer 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 laboratory based engineering and computer science courses may be due to the fact that traditionally undergraduate engineering and some computer science courses employ lectures and laboratories as the most common method of delivering education. In many engineering courses in particular, 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 2).

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.

While there have been reports of multiple efforts to simulate engineering labs to enhance teaching pool-based electricity markets to power engineering students [9], viable design and analysis tools to achieve better productivity of 300mm wafer fabs [10], complementary computational fluid dynamics (CFD), experimental fluid dynamics (EFD), and uncertainty analysis (UA) [11], digital design instruction [12, 13], and communication networks [14], there has not been much of research addressing soft issues related to engineering labs. In other words, theory based labs dealing with vague concepts in engineering have not been simulated mainly due to the tough nature of any approach to this issue. This research has uniquely found a solution to handle one of these soft issues qualitatively and quantitatively and has tested the idea to confirm its validity.

Given the potential benefits of engineering and technology programs incorporating simulated laboratories, an investigation of such a program at the college level is desirable. Such investigation would fill a gap in engineering and computer science research and contribute considerable knowledge in the area of using simulation technology for learning and teaching enhancement in higher education.

III. RESEARCH DESIGN

This study combines both quantitative and qualitative approaches into the research methodology. Therefore, the current research effort has three 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.

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 third track was a qualitative study that uncovered issues and differences that were not shown by the quantitative study.

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?

The two main qualitative research questions were: (1) what are the perceptions of both groups on the use of laboratory experiments in general for learning the concepts? And (2) what are the students' perception toward the use of simulation in place of physical laboratory?

The initial number of enrollment in the communication network course was 87 students. Only data from 80 students were used due to the fact that three students dropped the course before the midterm, and four students did not take the midterm exam and as a result did not produce any scores for the follow-up test. Thus, the scores of those seven students were eliminated from the final study. Dropped students were evenly distributed over the two groups.

The sample included junior or senior level undergraduate engineering and computer science students. Both sections were taught by the same instructor.

Data from the demographic survey indicated that of 80 students from both sections, 57 were male and 23 were females. In terms of age, 31 of the students were less than 20 years of age, 46 were 20-30 and only 3 were 31-40. There were 55 seniors and 25 juniors. Only 10 out of 80 students reported that they had used a simulation before. In addition, six out of 80 reported that the subject of modulation and demodulation had been covered previously in some of their classes (no use of simulation) but all six reported that they did not understand the concept.

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.

IV. METHODOLOGY AND PROCEDURES

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. The subject matter for this study is the signal modulation and demodulation in the context of a course (Introduction to Communication Systems and Networking) and the associated lab. The specific topic for this research was a thorough understanding of the speech signal modulation and demodulation to give the students a perspective on how the communication systems such as radio and television work. The learning objectives are limited to the analysis, synthesis, and evaluation levels in the cognitive learning domain.

All sections met once a week on two different days for a period of four hours. The students met in the classroom as scheduled. All participants received a lecture on the topic of FM and AM modulation and demodulation. Then the research project was explained to them and they were asked to sign the consent form and were allowed to keep a copy. They were reminded again about the 5 points extra credit for participating in the study. They were also asked to take a few minutes and answer background questions. Based on the last two digits of the subject's student ID, each student was assigned to one of the two groups.

Then the physical lab group met in the hardware laboratory, and the simulation group met in the computer lab. Each group was given a pre-lab followed by two laboratory experiments specifically designed for each group. Overall treatment time was the same for both groups. The pre-lab for both groups was designed with five objectives in mind:

1. Introduce the students to the simulation program or the laboratory equipment. Allow students to get familiar with new material.
2. Alert the student to the overall nature of the process.
3. Establish the need for deeper understanding.
4. Answer questions.

The physical lab group performed the experiments in a well-equipped electronics lab. The laboratory equipments and instruments were pre-assembled for the experiments. The simulation group performed similar lab experiments using computer simulation software in a well-equipped PC lab proctored by another teaching assistant. The simulation program and MATLAB software were pre-installed on each PC in the computer lab. The simulation software was installed only in a lab that did not have open lab hours. Thus the students could only access the software during the scheduled class time. In addition, physical lab was made available to the students only during the scheduled class hour. In addition, the PC lab was equipped with LinkSys hardware, which allowed the researcher to observe the students' monitors and their activities to assure that they restrict the simulation to complete only the two lab experiments and no other extra activities on the simulation.

Both groups were given the same guidelines for completing the lab activities to help achieve a cognitively similar treatment for both groups. At the completion of the experiments, the students remained where they were and took a one-hour Conceptual Test. Then, both groups were asked to complete the attitude survey questionnaire. Finally, the physical lab group was dismissed from the physical lab but the simulation group remained in the PC lab and completed the qualitative survey questionnaire. A few days after post-test, three students from each group were randomly selected to participate in a group interview.

Three weeks after the first treatment, all 12 post-test questions were incorporated into the students' midterm exam to examine the difference between the two groups in terms of their knowledge retention.

The conceptual test was administered twice to each student in the sample: during the 5th week of the semester after the experimental treatment and at the 8th 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 ranging from the low of .96 to the high of 1 with an overall reliability of .94, indicating an acceptable consistency of grading for the instructors.

V. QUANTITATIVE RESULTS

Although, the researchers could have selected reported grades from one of the instructors/graders for analysis, it was decided to include the average of post-test scores reported by both instructors/graders as the students' final score. Table 1 outlines the mean scores and other descriptive statistics.

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. The following graph presents a visual comparison of the mean scores of the physical group and the simulation group on the conceptual test (Figure 1).

TABLE 1.
DESCRIPTIVE STATISTICS FOR BOTH POST-TEST AND FOLLOW-UP TEST

Measure	**Statistic**	**Total**	**Phy.**	**Sim.**
Learning Post test	N	80	40	40
	Minimum	11.00	11.00	26.00
	Maximum	36.50	15.50	36.50
	Mean	22.71	13.78	31.65
	Std. Deviation	9.22	1.14	2.68
	Skewness	0.10	-0.39	-0.03
	Kurtosis	-1.84	-0.52	-0.64
Follow-up Test	N	80	40	40
	Minimum	11.00	11.00	12.50
	Maximum	35.50	15.50	35.50
	Mean	19.42	13.35	25.50
	Std. Deviation	8.14	1.15	7.57
	Skewness	0.65	-0.19	-0.79
	Kurtosis	-1.39	-0.76	-0.99

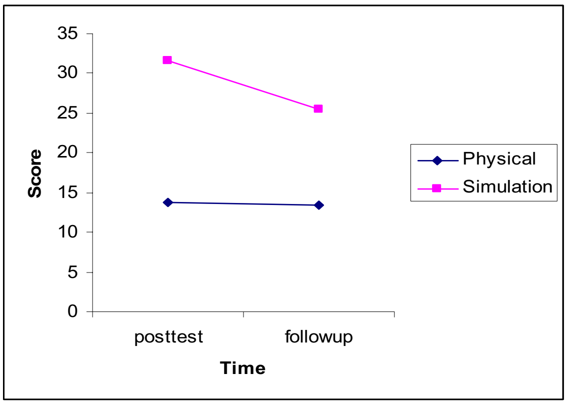

Figure 1. Comparison of Means on the Conceptual Test Over Time

This preliminary comparison hints an interesting trend with respect to the conceptual test. With respect to post-test score, the mean score for the simulation group (M = 31.65) appears to be much higher than the mean score of the physical group (M = 13.78). In other words, the simulation group did much better immediately after the treatment. On the follow-up test, during the midterm exam, the simulation group still performed better (M = 25.50) than the physical group (M =13.35), but the score for the physical group did not change significantly. The mean score on the post-test and the follow-up test for both groups still is statistically different, in favor of the simulation group. Even though the conceptual test graph (Figure 1) exhibits change over time for the simulation group, it shows very minimal change for the physical group. The results suggest that in fact the physical group initially had a lower score than the simulation group but its retention remained the same whereas the simulation group still performed better than the physical group on the follow-up test but the scores slightly decreased over time.

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 reveal that the simulation group did perform significantly higher on the post-test than the physical group. The results also indicate that the simulation group 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 follow-up scores (t = 4.85, p = .000). The findings 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 slightly 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). These results support the notion that the simulation program is more interesting, it cuts down on the time it takes to complete the laboratory assignments and it makes the subject matter less abstract.

A 13-item survey (alpha reliability of .91) was also administered only to the simulation group at the completion of the simulation program to assess their attitude toward the use of simulation program. The results indicate that 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.

VI. QUALITATIVE PROCEDURE

Qualitative research was conducted to remedy some shortcomings of quantitative measures. An interview questionnaire consisting of seven questions was designed for the simulation group. The questionnaire helped with gaining a deeper understanding of students' feelings and thoughts on the use of simulation instead of physical laboratory equipment. A panel of two experts reviewed the survey for content-related validity. These experts consisted of the director of research at a southern university and the director of grants and proposals. Both experts suggested that the questionnaire method should be replaced with a group interview, if possible. They suggested that the interview questionnaire method does not capture the true feelings of the students. As a result, both methods of survey questionnaire and group interview were employed. Group interviews were conducted on both randomly selected simulation and physical group participants few days after the completion of treatment.

The interviews were transcribed and analyzed for themes, which provided insights regarding the effectiveness of the laboratory experience and simulation groups' attitude toward the use of simulated laboratory in place of physical laboratory. Sample individual interviews included questions such as:

- In what ways do you think the simulation program was effective as a tool for conducting the laboratory experiments?
- Do you think that simulation programs could be a substitute for physical laboratory activities?
- Should the simulation program be used instead of the physical laboratory for communication systems course?

Sample group interview questions included questions such as:

- Did you think the simulation was helpful?
- What were the difficulties that you had with using the simulation?
- Did the use of the simulation help you on solving the problems on the exam?
- Do you think the simulation can be a substitute for the physical laboratory?
- If you had a choice for conducting similar experiments, which would you choose, simulation or physical laboratory?
- Did the lab experiment help you with understanding the concept of modulation/demodulation better? If yes, in what way?

VII. QUALITATIVE RESULTS

The responses to the survey questionnaire showed that, in general, the simulation group liked using the simulation program and were willing to use it again. Few of the students seemed to recognize the ease of use of the simulation program as compared to the physical lab equipments. Few students recognized that working with the simulation is less time-consuming and less frustrating.

Following is a summary of the results of survey and group interview.

- For students in both groups, the lab experiments were helpful in reinforcing their knowledge and understanding of the modulation and demodulation concepts.
- The simulated lab eliminated the frustration of a physical lab that focuses on making the equipment work, which does not contribute to their learning.
- There were many students who had never used a simulation before and felt that the simulated lab was helpful and was really a replica of the oscilloscope screen.
- Some students expressed concerns in terms of loss of hands-on skills.
- Many students appreciated the fact that the lab experiments did not involve unnecessary calculations and repetitive procedures that actually did not contribute to their learning
- Simulation students expressed the benefit of being able to see a mathematical equation in the form of a graph or the theoretical concepts beings presented visually.
- All students expressed that they understood the concept of the modulation and demodulation better after performing the laboratory experiments.
- A frequent comment was that the lab ties everything together.
- All students mentioned that the simulation lab increased the interest level in the course.
- The lab experiments gave them a chance to find answers for the what-if questions that were discussed in the class.
- There were no expressions of boredom or disinterest in any part of the interviews.
- The students found the simulation to be motivating, easy to use and less-time consuming.
- The students stated that they liked being able to translate the theoretical concepts into "real" examples on the laboratory equipment. In fact, very few students manifest meta-cognition when they stated that the laboratory helped them to "see" what was described by the mathematics.
- A concern was that direct hands-on student interaction with the experimental equipment is of absolutely paramount importance for the educational effectiveness of the experimental experience.
- Another concern that was voiced repeatedly relates to the perceived difficulties in enforcing the independence of remotely performed student work

VIII. OBSERVATION RESULTS

During the experiment, the researchers had the opportunity to briefly observe both the simulation and physical lab activities. As mentioned before in this paper, LinkSys hardware in the PC lab allowed the researchers to observe the student's monitor one at a time. An interesting observation that was made of the simulation group was realizing that students had different methods and styles of working with the simulation program. For example, before the treatment, the authors had believed that a key strategy was being systematic: varying one variable at a time. However, other styles can be productive, such as varying several variables to rapidly look for unforeseen special cases to investigate first and doubling one variable while halving another.

Another observation was that one student ran the simulation several times before even starting the simulation and when asked he indicated that the first time through he looked at values, then at variables and tried to remember the underlying formulae and understand the graphs.

A third observation was that despite the fact that the students were reminded that the experiments must be conducted individually, majority of the students in the physical group started talking to each other and sharing information whereas the students in the simulation group worked independently and did not talk or exchange any information.

Based on this observation, a concern that was obvious from the simulation lab was that despite the fact that it allowed the students to work individually and concentrate more on the interface, in a way, it was short on the student-student interaction, which sometimes is needed in a laboratory setting. But regardless, the simulation group performed better in this study. However, degree of interaction might have had an impact on the results of this study and it brings up an important question prior to making any decision on the laboratory delivery mode - how important student collaboration for any specific laboratory experiment is and how such collaboration can be accommodated in an online environment. However, at this point, this is beyond the scope of this study and should be subject to investigation in the future studies.

IX. 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 possible that the results have to do with the type of course and lab experiments. It is also 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 according to each variable on their PC screen and the physical group could see the waves on the screen of the 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

On the other hand, the qualitative results uncovered several issues not explored by the quantitative research. Incorporating the recommendations acquired from the quantitative research into the laboratory pedagogy should help improve students' experience regardless of the environment in which the laboratory is conducted.

In conclusion, 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.

X. 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.

A. 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.

B. Types of Cognitive Learning: 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.

C. 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.

XI. 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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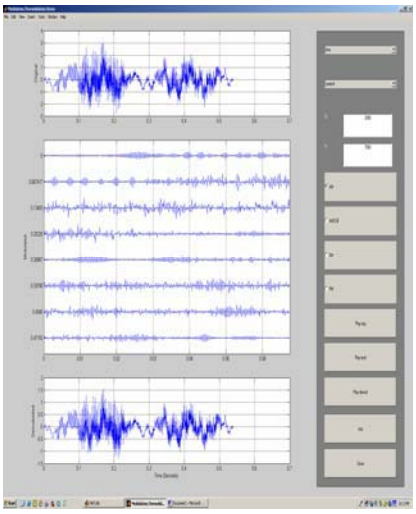

Lab Experiment II

FM Modulator

Objectives:

1. To observe the operation of an FM mod/Demodulator.
2. To observe the operation of an FM peak detector (demodulator)

A Simulated FM Modulator/Demodulator

When a relatively high frequency carrier signal is mixed in a nonlinear device with a relatively high frequency-modulating signal, frequency modulation occurs. In this experiment a MATLAB based simulator is used to generate an FM waveform. The output (modulated signal) is displayed on the screen of the computer monitor. The graphical user interface of the simulator allows you to change frequencies relevant to the operation of a mod/demodulator and display the results with the new setup. You can also change the type of mod/demodulation from a drop down menu. Confirm the operation of the simulator as discussed in lecture and plot the input, intermediate and output waveforms per following instruction:

1. Run and display the simulator program from the MATLAB interface. From the modulation type drop down menu, select FM to observe the input wave-form (modulating signal), carrier wave and demodulated signal on the monitor of your computer. Using the “Print Screen” button on the keyboard get a hard copy plot of these waveforms.
2. Using the frequency drop down menus on the screen, change the carrier and sampling frequencies and repeat step 1 above.

Figure 2. Screen shot and lab procedure of the simulated lab.