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Computer Simulation Laboratory Instruction vs. Traditional Laboratory Instruction in Digital Electronics

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Abstract

The purpose of this study was to compare and evaluate the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction for educating college students (n=22) about digital electronics circuitry. The study treated computer simulated laboratory instruction and traditional laboratory instruction as independent variables and learning outcome and attitude, based on posttest scores, as the dependent variables. The findings indicated that sequence of the laboratory instruction was a significant factor. Students learned more digital electronics circuitry concepts when they utilized the traditional method of instruction and then used computer simulated method of instruction.

Keywords: Computer simulation, laboratory instruction, digital electronics.

Introduction

The laboratory has been a central component of science instruction the early 20th century. It has been used to teach experimental methods and techniques that clarify and validate existing scientific principles and theories and has typically been considered expository in nature (Lagowski, 2002). Expository and/or traditional laboratories use scripted procedures and directions that are given to students in order to minimize potential equipment damage and injury, while maximizing potential for generating usable data.

In the case of science laboratory instruction, technology has reached a threshold where virtual or simulated approaches can formidably meet or exceed the learning outcomes of traditional approaches. And research suggests that simulation laboratories can dramatically impact learning in positive ways (Mencer, 2002; Nejad, M.A., 1997; Wieman & Perkins, 2005).

Researchers have convincingly argued that the cutting edge technology has dramatically changed the laboratory education landscape (Scanlon et al. 2002; Taghavi 2001). The nature and practices of laboratories have been changed by two new technology-intensive automations: simulated laboratory (Mcateer et al. 1996) and remote laboratory (Albu et al. 2004) as alternatives for traditional hands-on laboratory. Each type of laboratory has been discussed from different perspectives (Nedic et al. 2003; Sehati 2000; Subramanian & Marsic 2001; Wicker &

Loya 2000). However, there is no conclusive answer to the key question: Can technology promote students' learning or not? The two new forms of laboratory are seen by some as educational enablers (Raineri 2001; Striegel 2001) and by others as inhibitors (Dewhurst et al. 2000; Dibiase 2000). The relative effectiveness of the two new laboratories compared with traditional hands-on labs is seldom explored. This study was directed towards providing data to permit an evaluation of the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction in digital electronics circuitry.

Purpose of the Study

The purpose of this study was to compare and evaluate the effectiveness of computer simulated laboratory instruction versus traditional laboratory instruction for educating undergraduate college students (n = 22) about Digital Electronics Circuitry.

The study also examined the students' attitudes toward computer simulated laboratory instruction versus traditional laboratory instruction as a means of conducting laboratory activities.

Objectives of the Study

The objectives of this study were to:

1. Compare the achievement levels of college students who received computer simulated laboratory instruction with students who received traditional laboratory instruction.
2. Evaluate the effectiveness of computer simulated laboratory instruction in educating undergraduate students in Digital Electronics Circuitry.
3. Compare which instructional method helped students to better understand the underlying applied concepts of Digital Electronics Circuitry.
4. Evaluate the comparative results of effectiveness between computer simulated laboratory instruction and traditional laboratory instructions by means of pretest and posttest differential, and;
5. Assess the students' attitude toward computer simulation as a mode of instruction as opposed to the traditional laboratory approach.

These objectives were formulated into 8 null hypotheses, which are stated along with their tests in the result section.

Assumption of the Study

1. No interaction (Social, academic, or otherwise) occurred among experimental and control groups;
2. The presence of experimental and control groups in the same class had no effect on either group; and
3. Students were randomly and independently assigned in both the experimental and control groups with respect to traditional laboratory work and control laboratory work.

Limitation of the Study

The participating classes in this study were limited to those students who enrolled in TECH3337 Digital Electronics class during spring semester of 2007 and spring semester of 2008. A total of 22 subjects participated in this study.

The experimental units for this study were limited to four circuits. The circuits were:

1. AND gate circuit
2. NAND gate circuit
3. OR gate circuit
4. NOR gate circuit

Methods of Procedure

Instruments. A total of six measuring instruments were used to collect data in this study (a) pretest, (b) posttest I, (c) posttest II, (d) posttest III, (e) pretest student attitude questionnaire, and (f) posttest student attitude questionnaire.

Pretest. The pretest instrument was developed by the researchers. The pretest was administered during the first meeting before the instruction began. The pretest consisted of 20 multiple choice question items; this test was designed to be used as a covariate. The KR-20 reliability estimated this test was 0.76.

Posttest I. The test items were identical in content to the pretest. Posttest I consisted of 20 items, five items for each experimental circuit. Scores on posttest I ranged from 7 to 20 out of a total of 20 possible, with the mean score of 12.27. The KR-20 reliability estimated this test was 0.76.

Posttest II. The test items were identical in content to the pretest. Posttest II consisted of 20 items, five items for each experimental circuit. This test was identical to the pretest. Scores on posttest II ranged from 4 to 19 out of total of 20 possible, with the mean score of 13.56. The KR-20 reliability estimated this test was 0.76.

Posttest III. The posttest III instrument was also developed by the researchers. Posttest III was conducted at the end of the study. Posttest III consisted of 20 multiple choice items, 5 for each experimental circuit. This test was identical to the pretest. Scores on posttest III ranged from 4 to 19 out of total of 20 possible, with the mean score of 13.56. The KR-20 reliability estimate of this test was 0.75

Pretest Student Attitude Questionnaire. The pretest student attitude questionnaire was administered to both the experimental and control groups during the first meeting before the instruction began. This test was designed to be used as a covariate to control for initial differences in the students' attitude toward the computer simulated laboratory instruction. Of the twenty items in the instrument 10 were positively worded and 10 were negatively worded. The items used a Likert scale with 5 responses from “Strongly Agree” to “Strongly Disagree”. The reliability coefficient of this was 0.79.

Posttest Student Attitude Questionnaire. The student attitude posttest was administered to both the experimental and control groups at the end of the study. This test was similar in content to the pretest student attitude questionnaire with some appropriate changes in wording, such as the tense. The reliability coefficient of this test was 0.78.

Statistical Analysis of Data. All scores were coded by the researchers and provided as a data file for running statistical analysis by applying Statistical Package for Social Sciences (SPSS). The statistical methods used for analyzing the data in this study were Analysis of Covariance, the T-test for independent and T-test for dependent values.

Simulation Program. The computer simulation program that was used in this study was the schematics capture program which allows on-screen assembly, simulation, and analysis of electronic circuits. Microsim7 distributed by the Microsim Corporation.

Research Procedures. This study used an experimental design in order to examine the effects of the independent variables on the dependent variables. This type of design compares among groups to which subjects have been randomly assigned (Borg & Gall, 1989). Random assignments were used to make equivalency between the two groups in this study.

A pretest-posttest control group design was used in the experiment. The design is schematically presented as the following.

Group one	R	O1	T	O2	C	O3	O4
Group Two	R	O1	C	O2	T	O3	O4

R: Stands for random assignment of subjects.
O: Stands for observation O1 is the pretest, O2, O3, and O4 are the posttests.
T: Stands for traditional treatment.
C: Stands for experimental treatment.

In this study, the researchers randomly assigned subjects to particular groups. The experimental group received the pretest, experimental treatment, and posttest I, traditional treatment, posttest II, and the posttests, while the control group received the pretest, traditional treatment, posttest I, experimental treatment, posttest II, and the posttests.

Classroom Procedure. Both the experimental and control groups received theoretical instruction together from the same instructor. Also, both the experimental and control groups received the same in class tests and homework problems.

Laboratory Procedures. In order to become familiar with the use of software simulation, all subjects had three weeks of computer simulated laboratory activity before the study began. Both experimental and control groups were supervised by the same instructor at the different time. In each laboratory session the instructor first briefly reviewed the objectives or the experiment plan and made comments on special problems and safety precautions.

The treatment (experimental) group used the computer simulation as the means of conducting laboratory experiment. Students were provided instruction on the use of the computer, both through demonstration and in a written format. Students were monitored by the researchers during the computer simulation activities. The assistance given to students during laboratory activity consisted of instruction on the use of the computer, software simulation program and written laboratory procedures.

The control group used the traditional bread boarding (actual components) as laboratory experiments. The assistance given to students during laboratory activity consisted of instruction on the use of various components, equipments, and written laboratory procedures.

Data Collection Procedures. At the beginning of this study, a general information sheets was administered in order to gather demographic information on each subject. At this time students were given the opportunities participate in the study and they were requested to respond the pretest student attitude questionnaire. Prior to instruction, the twenty item pretest was administered to all subjects to assess students' background and knowledge of Digital Electronics.

After completion of the pretest and the student attitude pretest questionnaire, the subjects were randomly assigned to the experimental treatment group (computer simulation group) and the control treatment group (traditional treatment group).

After three weeks of experiments, the twenty items posttest I was administered to all subjects to measure treatment effects. Then the experimental group switched with the control group.

After three more weeks of experiments, the twenty items posttest II was administered to all subjects to measure the treatment effects.

At the end of the study, two instruments were administered to all subjects. The first was posttest III which was used to measure treatment effects. The second was the posttest student attitude questionnaire which was used to determine student attitude toward the computer simulated laboratory instruction and traditional method of laboratory instruction.

Results

The major hypotheses of the study and the results of testing these hypotheses are summarized as follows:

Null Hypothesis 1. There is no significant difference between the pretest mean scores of the experimental and control groups.

Because the calculated t-value was 0.06 which is not significant at 0.05 level, null hypothesis I was retained (Table 1). This finding implies that the random assignment of the subject produced equivalent groups.

Table 1. The T-Test Summary of Pretest Mean Scores of the Experimental and Control Groups

Pretest	N	MEAN	STD DEV	STD ERR	T	DF	R>|T|
GROUP 1	11	15.39	5.43	1.45	0.06	20	0.4713
GROUP 2	11	15.32	5.18	1.424			

Group 1: Traditional Treatment Group 2: Simulation Treatment

<u>Hypothesis 2</u>.There is no significant difference between the adjusted group mean scores of the experimental and control groups as measured by a posttest I with a pretest covariate.

There was no significant difference between the experimental and control groups as indicated by F-value of 1.087 which is not significant at 0.05 level (Table 2). Therefore, null hypothesis 2 was retained. Both methods of instruction tended to produce similar effect.

Table 2. Analysis of Covariance Summary for Posttest I Scores with Pretest Scores as a Covariate

SOURCE	DF	SS	MS	F-VALUE	F	SIG
Covariate	1	43.58	43.58	6.98	0.004	Yes
Groups	1	6.79	6.79	1.087	0.194	No
Error	20	160.23	6.41			
Total	21	210.60				

Regression Coefficient for adjusting = 0.281

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	12.39	2.76	1.54	12.37
2	13.46	13.12	3.48	13.48

Significant at 0.05 level.

<u>Hypothesis 3</u>.There is no significant difference between the mean scores of the experimental and control groups as measured by posttest II with a posttest I covariate.

There was a significant difference between the control and experimental group as indicated by an F-value of 19.23, which is significant at 0.05 level. The simulation group scored significantly higher than the control group on posttest II (Table 3). Therefore, the hypothesis 3 was not retained.

Table 3. The Analysis of Covariance for the Posttest II with a Posttest I Covariate

SOURCE	DF	SS	MS	F-VALUE	F	SIG
Covariate	1	22.43	22.43	2.853	0.085	No
Groups	1	157.95	157.95	19.23	0.0001	Yes
Error	20	190.02	9.50			
Total	21	370.40				

Regression Coefficient for adjusting = 0.528

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	11.56	16.76	4.79	11.29
2	15.69	2.61	2.32	15.96

Significant at 0.05 level.

Hypothesis 4. There is no significant difference between the mean scores of experimental and control groups as measured by a posttest III with posttest II covariate.

There was no significant difference between the two groups as indicated F-value of 1.43, which is not significant at 0.05 level (Table 4). Therefore, hypothesis 4 was retained.

Table 4. The Analysis of Covariance for the Posttest III with a Posttest II Covariate

SOURCE	DF	SS	MS	F-VALUE	F	SIG
Covariate	1	57.54	57.54	9.22	0.007	Yes
Groups	1	8.97	8.97	1.43	0.279	No
Error	20	162.08	6.47			
Total	21	228.59				

Regression Coefficient for adjusting = 0.280

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	14.89	5.90	1.78	14.19
2	14.10	6.69	1.23	14.80

Significant at 0.05 level.

Hypothesis 5. There is no significant difference between the mean scores of the experimental and control groups as measured by a posttest III with pretest covariate.

There was no significant difference between the experimental and control groups. The calculated F-value was 0.582, which is not significant at 0.05 level (Table 5). Therefore the null hypothesis 5 was not rejected. Both laboratory instructional methods contributed similar results.

Table 5. The Analysis of Covariance for the Posttest III with a Pretest Covariate

SOURCE	DF	SS	MS	F-VALUE	F	SIG
Covariate	1	57.07	57.07	3.233	0.027	Yes
Groups	1	10.28	10.28	0.582	0.412	No
Error	20	294.71	11.71			
Total	21	362.06				

Regression Coefficient for adjusting = Y = 0.453

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	15.12	3.31	1.97	15.10
2	16.19	15.79	4.29	16.21

Hypothesis 6. There is no significant difference between the combined pretest and combined posttest mean scores of the experimental and control groups.

There was a significant difference between the combined pretests and the combined posttests mean scores of the experimental and control groups. The calculated t –value was 9.09, which is significant at 0.05 level (Table6). Therefore null hypothesis 6 was rejected. Both laboratory instruction methods contributed to higher posttest III scores.

Table 6. The matched T-Test Analysis for Combined Pretest and Combined Posttest Means of the Experimental and Control Groups

Test	N	MEAN	STD DEV	STD ERR	T	DF	R>|T|
Pretest	22	8.35	2.54	0.47	9.09	20	0.0001
Posttest III	22	14.50	2.24	0.42			

Significant at 0.05 level.

Hypothesis 7.There is no significant difference between the pretest student attitude questionnaire mean scores of the experimental and control groups.

There was no significant difference between the pretest student attitude mean scores of the experimental and control groups. Therefore null hypothesis 7 was retained (Table 7). This means prior to instruction, students' attitudes toward traditional and simulation instructions were relatively equal.

Table 7. The T-Test Summary Table of the Difference Between the Pretest Student Attitude Questionnaire Mean Scores of the Experimental and Control Groups

Pretest	N	MEAN	STD DEV	STD ERR	T	DF	R>|T|
GROUP 1	11	92.45	10.08	2.69	0.02	20	0.4955
GROUP 2	11	93.18	8.86	2.36			

Group 1: Traditional Treatment Group 2: Simulation Treatment

Significant at 0.05 level.

Null Hypothesis 8. There is no significant difference between the adjusted group mean scores of experimental and control groups attitude as measured by a posttest student attitude questionnaire with the pretest as a covariate.

There was no significant difference between the two groups attitude as indicated by an F-value of 2.59, which is not significant at 0.05 level (Table 8). Therefore, null hypothesis 8 was retained. This hypothesis indicates that, after treatment both groups displayed similar attitudes toward computer simulated laboratory instruction as well as the traditional method of instruction after treatment.

Table 8. Analysis of Covariance Summary for Posttest Scores with Pretest Scores as a Covariate

SOURCE	DF	SS	MS	F-VALUE	F	SIG
Covariate	1	647.07	647.07	14.34	0.001	Yes
Groups	1	117.03	117.03	2.59	0.061	No
Error	20	886.44	35.45			
Total	21	1650.54				

Regression Coefficient for adjusting = 0.582

GROUP	MEAN	VARIANCE	STD DEV	ADJUSTED MEAN
1	97.24	71.68	8.36	97.26
2	93.32	75.68	8.62	93.30

Group 1: Traditional Treatment Group 2: Simulation Treatment

Significant at 0.05 level.

Conclusion.

From this study the researchers concluded that, the findings have implications regarding the design of simulated laboratories for secondary and post-secondary schools for the 21st century. According to Pyatt and Sims (2007), the role of the laboratory in 21st century science instruction is to (a) enhance mastery of subject matter, (b) develop scientific reasoning skills, (c) develop practical skills, (d) assist students in understanding the complexity and ambiguity of empirical work, and (e) understand the nature of science.

Findings revealed that no significant difference existed between the computer simulated laboratory instruction and the traditional method of instruction as resulted by the mean scores of posttest I with pretest as a covariate, Posttest III with the posttest III as a covariate, and posttest III with pretest as a covariate.

Findings also revealed no significant difference existed between students' attitude toward computer simulated laboratory instruction and traditional method of instruction. Results indicated that students' attitudes were similar with regard to both the simulated and traditional laboratory instruction.

Findings revealed that a significant difference did exist between the computer simulated laboratory instruction and the traditional method of instructions indicated by the mean scores of the posttest II with posttest I as a covariate. The result indicated that the simulation group scored significantly higher than the traditional group. Because the treatment groups switched after three weeks, perhaps the sequence of the instruction was an important factor. Also, a significant difference was found between the pretest and the posttest mean scores of the experimental and control groups. This indicated that both instructional methods contributed to higher posttest III scores.

The results of this study indicated that integration of the computer simulated laboratory instruction with the traditional method of instruction significantly increased the students' understanding of the digital electronics circuitry concepts.

The findings indicated that the sequence of laboratory instruction was a significant factor. Students learned more digital electronic circuitry concepts when they utilized the traditional method of instruction and then used computer simulations. Also, the findings revealed that the computer based learning program could be used in an integrating mode rather than in the experiencing mode as it was in this study.

From this study, the researchers conclude the following (1) students learned digital electronics circuitry concepts more when they utilized actual electronics components, and then used computer simulated laboratory instructions, and (2) computer simulated laboratory instruction can be used to extend the traditional methods of laboratory instruction.

Recommendation

1. This study should be replicated with a randomly selected and larger population of students. This would assist the generalizability of the findings to a broader student population.
2. More research should be conducted with a larger group of students, on the use of simulation on more complex concepts of circuitry and applications requiring actual analysis, troubleshooting, evaluation, and repair.
3. One instructor should provide all phases of instruction to groups, the treatment as well as the control group, to eliminate instructor's bias.

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