International Journal of Engineering Education Vol. 28, No. 3, pp. 724–733, 2012
Printed in Great Britain

0949-149X/91 $3.00+0.00

Student Attitude and Achievement with Computer-based Instrumentation*

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This quasi-experimental research studied the cognitive and affective domains of achievement in engineering laboratories while employing computer-based and traditional oscilloscopes. 61 students from two courses, electrical engineering for non-majors and electronic fundamentals, were randomly assigned into treatment and comparison groups. The students' knowledge and attitudes were gauged using assessment instruments and an attitudinal survey. These results were statistically analyzed and conclusions are discussed. The results suggest that computer-based instruments are viable in engineering laboratories.

Keywords: educational technology; engineering education; laboratories, user-interface; human factors

1. Introduction

Distance education has the ability to transcend the confines of location and schedules, reaching students anywhere at any time [1]. With an open environment and widely accessible resources, distance courses and learning activities become available to a diverse population of asynchronous learners: single parents, those limited by travel or access to a campus, working professionals, secondary educators, and those with disabilities [2]. Distance education has potential benefits for engineering education by mitigating the barriers of geography and costs and reaching underrepresented demographics such as, rural and minority students [3, 4].

Although engineering education could benefit from distance delivery, there are obstacles to overcome. Two major obstacles are costs and hands-on interactions in laboratory activities [5]. Engineering is a practice-oriented discipline requiring students to couple the mastery of scientific and mathematical theories with practical skills. Kolb described the complementing relationship of concrete activities and abstract reflection as part of the total learning experience [6]. Laboratory experiences have the potential to cement theoretical understanding, augment analytical reasoning, enhance troubleshooting ability, and strengthen psychomotor skills by employing a variety of the students' senses and aptitudes [5]. These experiences also aid in student motivation by engaging students in stimulating, collaborative, and real-world activities [7].

Engineers use a variety of tools to approach and solve problems, ranging from theoretical scientific analysis to using physical instruments to collect raw data. Laboratory instruments are one of the tools used by engineers. Two of the eleven outcomes in the ABET criteria outcomes, b and k, emphasize the importance of laboratory instrumentation: 'an ability to design and conduct experiments, as well as to analyze and interpret data' and 'an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice' [8]. Thus, educational laboratories are integral to an engineer's education.

As previously noted, there are great potential benefits in delivering educational laboratories in a distance format. Since instruments are an important component of engineering laboratories, the methods for their implementation in distance education are an important issue that needs to be addressed. The prevalence of computer interface for distance laboratories [9–12] make computer-based instruments a logical choice. However, few studies have systematically investigated the impact of student achievement and attitude in engineering laboratories with computer-based instrumentation [5, 7]. The objective of this research study was to examine student learning and attitude with respect to the human-computer interface in an educational engineering laboratory. This objective was accomplished by evaluating student achievement and affective characteristics in engineering laboratory activities utilizing a computer-based oscilloscope.

An oscilloscope was the instrument chosen for investigation in this research study, as it is a fundamental measurement instrument used in the measurement of electronics and their accompanying phenomena. In addition to providing a window into the abstract world of electronics, the oscilloscope can lend to further understanding of engineer-

* Accepted 20 August 2011.

ing math and science concepts such as trigonometry and the periodic nature of signals.

2. Research Questions

Within this study, student achievement was a measure of learning reflected by the extent to which students attained a specific objective or goal. In addition, a number of affective traits were examined including, values, attitudes, self-concept, interests, and opinions. Two research questions were asked:

1. Were there differences in student achievement and student affective traits in engineering laboratories utilizing traditional (stand-alone instruments commonly used in engineering laboratories) versus software-based instrumentation?
2. If differences existed between achievement and affective traits using traditional and software-based instrumentation, how did they compare?

3. Pedagogical Motivation

3.1 Role of Educational Laboratories in Engineering

There is a consensus for the need of laboratories in engineering curriculum [5, 7, 12, 13]. However, there is not a consensus regarding the roles and expectations of educational laboratories in engineering, which hinders the progress of research in this area [5, 7]. To further clarify and establish the role of engineering laboratories, ABET, Inc., along with engineering education professionals, convened to address the matter in 2002 [14]. The result was the list of 13 objectives for successful engineering laboratories shown in Table 1 [15]. Although these objectives have not been formally validated, they assist in developing sound laboratory objectives and activities. The objectives spread across the three domains, cognitive, psychomotor, and affective, in Bloom's Taxonomy [16] ranging from simple to complex outcomes. Included in the affective domain is the motivational aspect of engineering laboratories [17]. An educational laboratory may also introduce the student to experiences drawn from engineering practice, lending further relevance to the learning activity. Students benefit from practical examples, authentic applications, and hands-on activities often found in laboratories, increasing motivation and mitigating apathy [18].

3.2 Software-based instrumentation in distance laboratories

The operation of instruments and manipulation of components is important in hands-on engineering laboratories [1, 8, 14]. The first objective listed in Table 1 was instrumentation and the ability to apply appropriate tools [15]. However, one of the primary impediments to distance engineering laboratories is the failure to meet the objective of 'applying appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities' [1, 14]. The primary objective of this study was to further understand software-based instrumentation as an essential component to distance laboratories.

Table 1. Objectives of Engineering Laboratories [15]

Objective	Description
1	Instrumentation: Apply appropriate tools to make measurements.
2	Models: Identify the strengths and limitations of models.
3	Experiment: Devise an experimental approach.
4	Data analysis: Demonstrate the ability to collect, analyze, and interpret data.
5	Design.
6	Learn from failure.
7	Creativity.
8	Psychomotor: Demonstrate competence with engineering tools and resources.
9	Safety: Identify health, safety, and environmental issues.
10	Communication.
11	Teamwork.
12	Ethics in the laboratory.
13	Sensory awareness: Use the human senses to gather information.

Simulations address the limitations of costs and wide spread availability, however, they commonly lack: noise or the inherent variation found in the physical world [5], presence [19], and realistic problem solving skills [20]. Software-based instruments may help mitigate these problems. Software-based instruments are those instruments that incorporate computer hardware and software to acquire data.

Software-based instruments have the advantage of reduced costs when compared to traditional instrumentation, a common and familiar platform (the computer), and near-ubiquitous availability through the Internet. Furthermore, when software-based instruments are coupled with hands-on laboratory delivery methods, the laboratories can maintain the variability inherent in the natural world.

Software-based instruments should not detract or distract from the laboratory objectives. With traditional, as well as software-based instrumentation, students' learning will be diminished if too much attention is given to instrument training. Software-based instruments do offer the advantage of being mediated by a personal computer, as computer literacy is high amongst college students [21]. The software-based instrument should also relate to the traditional instrument by giving the end user a similar experience to a traditional laboratory. To ensure broad application, the time to deploy the software-based instruments should be kept to a minimum, reducing the demand on instructors' resources. Regardless of the tool's effectiveness, it will not be widely adopted if the training is overly cumbersome.

3.3 Student achievement assessment in engineering laboratories

Student achievement is an important measure of success for most educational studies and is part of the ABET engineering accreditation process [8, 17, 22–24]. However, few studies of engineering and scientific laboratories have produced empirical data of student cognition. In a September 2006 review of literature, Ma and Nickerson found that only 5% (n = 3 of 60) of articles were based on empirical data [7].

Ninety-five percent of the articles were only opinion-based or descriptive. The literature review search included three electronic databases: ACM, IEEE, and ScienceDirectd and keywords included 'remote laboratory or remote experiment,' 'virtual laboratory or virtual experiment,' 'real laboratory or real experiment,' and 'hands-on laboratory or hands-on experiment.' The number of empirical studies has increased since 2006 [25, 26].

3.4 Affective traits assessment in engineering laboratories

While student achievement is not the sole measure of success in engineering laboratories, affective traits like attitude, satisfaction, and motivation are integral, if not foundational, to a successful education experience [8, 16]. Student cognition is only one component necessary for proficient problem solving skills [27]. These traits are not easily measured employing a cognitive assessment instrument like a written test, but are more effectively assessed by an instrument such as a self-report survey. In addition to providing insight into the affective domain, affective traits may also correlate with other variables in the cognitive and psychomotor domains. Certain affective traits, such as motivation and preference, may directly impact how well a student performs on an achievement test or performance evaluation [28].

Affective traits have been measured in various studies throughout the distance education domain [11, 29, 22]. These studies included self-report questions regarding preferences, satisfaction, and effectiveness of the control and treatment methods. Nickerson, et al. [10] measured ease of use, overall satisfaction with the delivery methods, instructor support, teamwork, and reliability of the software-based instruments. Campbell, et al. [22] included questions regarding ease of use, overall satisfaction with the laboratory modules, and instructor support. Rutherford [30] included demographics in his study to further analyze the study participants' responses. Variables such as age, gender, socio-economic status (SES), and city size may play a significant role in either cognitive or affective outcomes [31]. Engineering laboratory assessments of affective traits allow the researcher not only to see a change in knowledge, but possibly, the reasoning behind the scores.

4. Methods and Procedures

4.1 Research design

This study involved two courses at Utah State University (USU): ETE 2210—Electrical Engineering for Non-majors and ETE 2300—Electronic Fundamentals. ETE 2210 is a course offered to engineering students outside the electrical engineering discipline with an introduction to fundamental electrical engineering concepts. ETE 2300 is a general education course offered to all students, but taken primarily by students in the Engineering and Technology Education (ETE) department.

Relevant learning objectives for the electrical engineering laboratory activities in the corresponding courses were stated and defined. The achievement instrument was derived from these learning objectives. A software oscilloscope was identified and implemented in the laboratories [34]. Three laboratory modules were updated to incorporate either the traditional or software-based oscilloscope with the students randomly assigned into software-based oscilloscope and traditional oscilloscope groups.

Students' knowledge and attitudes were gauged using an achievement assessment instrument and an attitudinal self-report survey and were analyzed with descriptive and inferential statistics.

4.2 Sample description

The sample was comprised of 61 students enrolled during the spring semester of 2008. There were 31 students in the computer-based oscilloscope group and 30 students in the traditional oscilloscope group. Ninety-seven percent of the students were under the age of 30 with a median age of 22. The computer-based and traditional groups were similar across the demographics with no statistical significance found on any component of the demographics. The same instructor taught both courses. All students in the different laboratory sections received the same laboratory activities. During the intervention, all students had access to the same laboratory instructor, demonstrations, instructor guidance, readings, and handouts.

The genders of the study participants were less

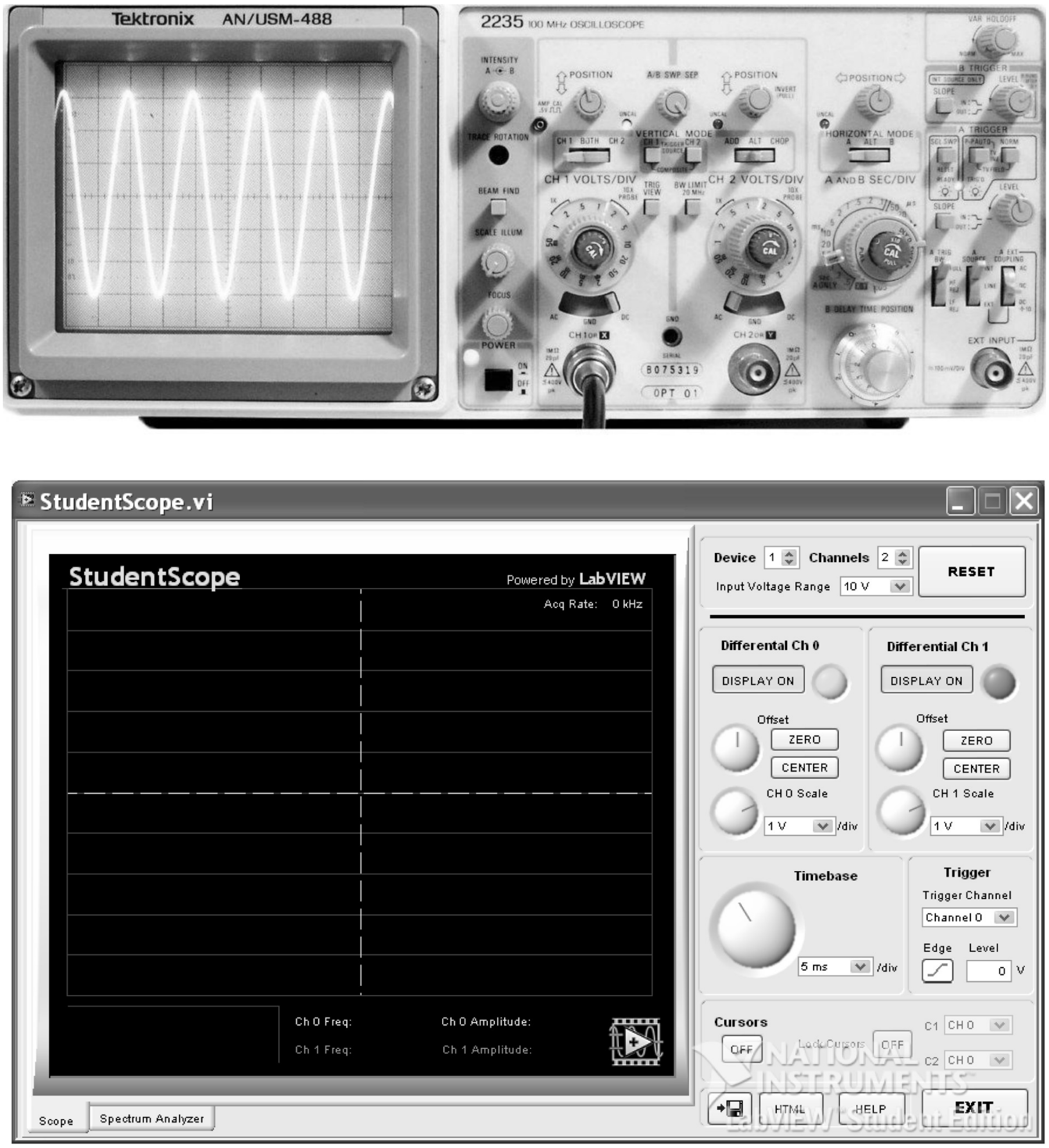

Fig. 1. Traditional and software oscilloscope user interfaces (Test Equipment Depot, 2008). Both oscilloscopes have two inputs, variable voltage and time scales, a basic trigger function, and offsets. The software oscilloscope also has digital voltage and frequency displays and a cursor. The traditional oscilloscope has more complex mathematical functions, an advanced trigger function, and a frequency range up to 100 MHz versus 25 KHz for the 6009 software oscilloscope.

than 2% different from the national percentage of graduating engineering students. The ethnicity of the sample was predominantly white (88.5%) versus the national average of 67.3%. Although there may be a high number of white students in this study, the sample ethnicities more closely followed those of the state of Utah ethnicities since the sample was drawn from a state run university [32].

4.3 Laboratory modules

Schulz [18] recommended showing relevance to the students' particular field to incite student motivation. The three laboratory modules were chosen due to their wide applicability and broad scope. The laboratory activities were identical across courses and sections. The learning objectives of the laboratories were:

1. Introduction to AC measurements—gain familiarity with the oscilloscope and measure electrical signals with respect to time.
2. Frequency Response of RC and RL Networks—plot the voltage/current versus frequency, calculate phase angles, and calculate the critical frequency of the network.
3. Resonances of an RLC Circuit—plot voltage/current versus frequency, demonstrate how input impedance varies with frequency, under-

stand the quality factor and bandwidth, and validate the equations for the resonant frequency of a series resonant circuit.

4.4 Independent variable

The independent variable in this study was the type of oscilloscope used in the laboratory, traditional or software-based. Student achievement was measured depending on the type of oscilloscope used. The laboratory activities in this research required an oscilloscope with a peak-to-peak input voltage range of 20 Volts, a 10 kS/s sampling rate, and variable voltages and time per division. The 'traditional' oscilloscope was a Tektronix model 2235 100 MHz oscilloscope. The software oscilloscope had a graphical user interface (GUI) that closely mimicked a traditional oscilloscope. The software oscilloscope used in this study was based on a National Instrument data acquisition unit NI USB6008 DAQ and LabVIEW software.

The DAQ was chosen due to its flexibility, ease of implementation, low cost, and its compliance with the requirements of the laboratory activities. The software routines were developed by Spexarth and can be found on the Internet as freeware [33]. The oscilloscope interfaces and specifications are shown in Fig. 1 and Table 2, respectively. Both oscilloscopes' capabilities surpassed the needs of the laboratory activities in this study. Although not within the scope of this study, these and additional laboratory activities could be performed at a distance by incorporating this and other computer-based instrumentation. These low-cost instruments would include a multimeter and a function generator based on a computer's sound card.

4.5 Methods used in research question one

Student achievement was the dependent variable in this portion of the study. Within this study, student achievement was a measure of cognition reflected by the extent to which students attained a specific learning objective or goal.

4.5.1 Achievement assessment instrument—pretest

The students' achievement was measured using a pretest-posttest design. The pretest was administered during a lecture period to all the study participants prior to covering the specific topics and before the laboratory activities. The pretest established a baseline that was later compared against the posttests. The pretest consisted of 30 items randomly ordered covering three topic areas in electrical engineering: alternating current (AC) measurements, the frequency response of resistive-capacitive (RC) and resistive-inductive (RL) circuits, and resonance in a resistive-inductive-capacitive (RLC) circuit. The items on the pretest were drawn from multiple sources: Boylestad's *Introductory Circuit Analysis*, 11th edition [34], Floyd's *Electronics Fundamentals*, 7th edition [35], Boylestad's test item generator, and Lindburg's 2002 FE Exam preparation book [36]. The items were chosen if equivalent items were found in more than one source, well written, and germane to the topic. Although the questions were not identical, they were similar in scope and purpose. The items consisted of 26 multiple-choice questions and four true/false questions. The students were assured that the pretest had no bearing on their grade.

4.5.2 Achievement assessment instrument—posttest

The posttest was given as three separate quizzes consisting of ten items each. The posttest quizzes were administered during a lecture period within three days of completing each laboratory activity. The total score on the three quizzes was combined and compared to the pretest scores for later analysis.

4.6 Methods used in research question two

An additional assessment included a survey of student affective traits. The survey collected demographics and measured the students' attitudes and preferences relevant to the laboratory. The survey consisted of questions that were answered on a 5-point Likert scale: with strongly agree, agree, neu-

Table 2. Oscilloscope Comparison Table

Oscilloscope	Tektronix	Computer-based	Laboratory Requirements
Number of inputs	2	2	2
Voltage range (V)	100	20	20
Voltage resolution	2mV sensitivity	5 mV sensitivity	10 mV sensitivity
Bandwidth	DC to 100 MHz	DC to 25 kHz	DC to 10 kHz
Trigger function	Yes	Yes	No
Offset function	Yes	Yes	Yes
Digital voltage readout	No	Yes	No
Cursors	No	Yes	No
Mathematical functions	Yes	No	No
Digital frequency readout	No	Yes	No
Appearance	35 knobs/switches	21 knobs/switches	N/A

Table 3. Engineering Laboratory Objective Alignment with the Survey

Topic	Survey item	ABET [2007]	Feisel & Rosa [2005]
Collaborative Work	2.5	D	11
Data analysis	2.2	B	4
Design	2.3	B, C	5
Engineering problems	1, 6	E	–
Engineering tools	1, 4	K	1
Experimentation	2	B	3

tral, disagree, and strongly disagree and very satisfied, satisfied, neutral, unsatisfied, and very unsatisfied, for agreement and satisfaction respectively. There were also open-ended questions included in the survey.

The first section collected student demographics such as age, gender, and year in school. These demographic data were later included in the data analyses of general applicability. The second section related to the students' preferences toward laboratories, in general, comfort level with software, rating of the laboratory activities, and the perception of support from the instructors and their laboratory partners.

This controlled for the confounding variable of the laboratory activities themselves and if the student had previous dispositions for laboratory work. The last sections address the students' satisfaction and preferences for the computer-based and traditional oscilloscopes.

The survey was broad and drew from existing surveys that analyzed students' perceptions of course delivery and pedagogy in engineering [10, 29, 30]. The survey was offered in the laboratory after all the laboratory modules were completed. The data was then transcribed into a computer database for later analysis. The items in this portion of the survey were well aligned with the objectives put forward by Feisel and Rosa [5] and ABET, Inc. [8]. The survey items spanned at least five objectives found in each of the aforementioned authors' objectives. Table 8 displays which of the objectives were matched with the survey items.

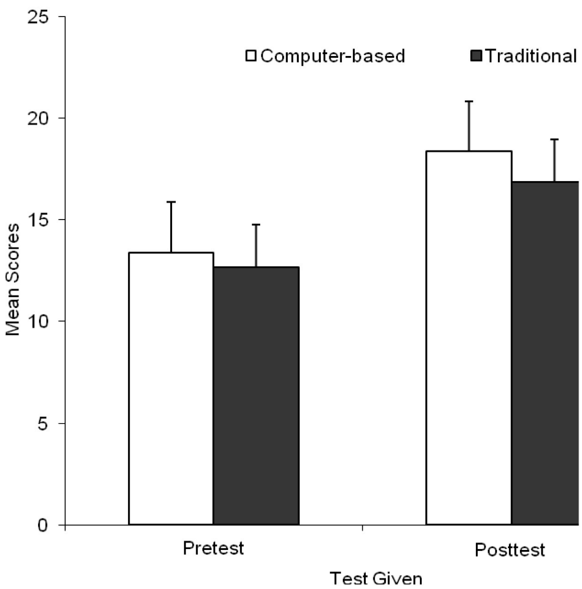

Fig. 2. Means scores on the pretest and posttest for both the computer-based and traditional groups. No statistical significance was found between groups. Statistical difference was found between pretest and posttest within each group at $p < 0.001$. Error bars represent standard error of the mean.

5. Results

5.1 Results relevant to research question one

The first research question sought to discover if there were differences in student achievement in engineering laboratories utilizing traditional versus software-based instrumentation. There was no statistical difference found between groups in student achievement. The mean score for the pretest for the computer-based group were higher (M = 13.40 SEM = ± 0.44) than the traditional group (M = 12.65 SEM = ± 0.61). The mean score for the posttest was also higher for the computer-based group (M = 18.35 SEM = ± 0.69) than for the traditional group (M = 16.87 SEM = ± 0.87). The effect sizes for the pretest ($d = 0.16$) and the posttest ($d = 0.22$) were small. Fig. 5 displays the mean scores of the pretest and posttest for both the computer-based and traditional groups. Fig. 5 indicates that the computer-based group achieved higher mean scores for both the pretest and posttest. Tests for kurtosis and skew were not significant for the achievement data.

A one-way ANCOVA was performed on the achievement data and no statistical differences were found. The independent variable was the oscilloscope used, traditional or software-based. The dependent variable was the difference score between the posttest and the pretest. A preliminary analysis evaluating the homogeneity-of-slopes assumption indicated that the relationship between the covariates and the dependent variable did not differ significantly as a function of the independent variable. The covariate 'course' was the course in which the participant was enrolled with an $F(1, 56) = 1.80$, $MSE = 25.39$, $p = 0.18$, partial $\eta^2 = 0.03$. The covariate 'overall experience' was taken from the participants' response to their overall experience with the distinct type of oscilloscopes and had an $F(1, 56) = 0.89$, $MSE = 25.39$, $p = 0.35$, partial $\eta^2 = 0.02$. The covariate 'laboratory propensity' is a subscale derived from the self-report survey that described the attitude towards engineering laboratories had an $F(1, 56) = 0.75$, $MSE = 25.39$, $p = 0.39$,

Table 4. One-Way ANCOVA Summary Table for Achievement Tests

Descriptor	*SS*	*df*	*MS*	*F*	Sig.	Partial η^2
Course	45.73	1	45.73	1.80	0.18	0.03
Overall experience	22.58	1	22.58	0.89	0.35	0.02
English lab propensity	18.91	1	18.91	0.75	0.39	0.01
Treatment	2.08	1	2.08	0.08	0.78	0.001
Error	1421.68	56	25.39			
Total	3468.00	61				
Corrected total	1528.07	60				

Note. No statistical significance was found for any covariate or main factors.

partial η^2 = 0.01. The two groups did not significantly vary statistically even while holding variables constant. The ANCOVA was not significant, $F(1, 56) = 0.08$, $MSE = 25.39$, $p = 0.78$, partial $\eta^2 = 0.001$.

5.2 Results relevant to research question two

The second research question was addressed by a self-report pencil and paper survey given to the participants during a class period. The survey was divided into three sections: demographics, attitudes toward engineering laboratories, and experience with the oscilloscopes. All 61 study participants completed the survey.

5.3 Engineering laboratory propensity subscale

There were six questions included in a subcategory to assess students' propensity for and comfort with engineering laboratories. The participants answered the questions using a 5-point Likert scale based on agreement. These questions were taken from an engineering education survey conducted by Rutherford [30]. The results found in Table 5 suggest that the students were comfortable with laboratories and the associated tasks. The engineering laboratory propensity subscale was analyzed using an independent samples t test with an alpha level of $p < 0.05$. The results of the analysis were not significant $t(59) = 1.55$, $p = 0.126$, failing to reject the null hypothesis. The 95% confidence interval ranged from –0.35 to 2.76.

5.4 Laboratory experiences

There were five questions included in this subcategory to assess students' attitudes towards the laboratory activities and their experiences (Table 6). Four of the questions were answered using a 5-point Likert scale based on satisfaction and there was one open-ended question. The results in Table 6 suggest that the students were satisfied with their laboratory experiences. Mann-Whitney U-tests were performed on the satisfaction of the laboratory experiences between the treatment and comparison groups. The results of the analysis did not show significance, $U = 368.5$, $p = 0.159$.

5.5 Satisfaction with the oscilloscopes

The participants were asked to rate their satisfaction on five items pertaining to the software-based and traditional oscilloscopes. There was also an open-ended question for both oscilloscopes. The final question of the survey asked the participants who used the software-based oscilloscope which oscilloscope they preferred since the treatment group was also able to use the traditional oscilloscope in other laboratory activities.

Both oscilloscopes were rated on five separate items using the satisfaction scale. The items with their mean scores are listed in Table 7 for both oscilloscopes. The highest mean score for the software-based oscilloscope was that for the overall experience ($M = 3.94$). The highest mean score the traditional oscilloscope was for the instruction and

Table 5. Students' Propensities and Comfort with Engineering Laboratories

		Computer-based		Traditional	
Item	**Description**	***M***	**SEM**	***M***	**SEM**
2.1	Learning and solving problems using a computer.	4.12	0.14	4.26	0.11
2.2	Performing experiments and analyzing the resulting data.	3.90	0.13	4.16	0.09
2.3	Designing new things.	3.77	0.13	3.76	0.14
2.4	Learning new laboratory skills and working in a laboratory.	3.90	0.12	4.23	0.11
2.5	Taking a leadership role in groups.	3.74	0.13	4.00	0.13
2.6	Identifying, formulating, and solving engineering problems.	3.67	0.15	3.90	0.16
	Total Propensity and Comfort Subscale	3.77	0.15	3.93	0.15
2.7	Solving problems and working on projects alone.	3.16	0.16	3.13	0.17

Note. Based on a 5-point Likert scale with a higher mean score representing a more positive student response. There was no significant difference on any item between groups.

Table 6. Students' Satisfaction with the Laboratory Experience

Item	Description	Computer-based		Traditional	
		M	SEM	*M*	SEM
2.8a	Overall experience with the laboratory activities.	3.72	0.15	3.97	0.13
2.8b	Support from the instructor.	4.03	0.14	3.93	0.17
2.8c	Your lab partner's teamwork.	4.39	0.14	4.43	0.13
2.8d	How well the laboratory activities met the objectives.	3.74	0.12	4.00	0.14

Note. There was no statistical difference on any item between groups.

Table 7. Satisfaction with the Software-based and Traditional Oscilloscopes

Item	Computer-based		Traditional	
	M	SEM	*M*	SEM
Overall experience	3.94	0.13	3.96	0.11
Reliability	3.71	0.14	3.93	0.15
Ease of use	3.87	0.15	3.61	0.14
Sensation of reality	3.84	0.14	3.71	0.15
Instruction/training	3.90	0.13	4.00	0.11

training (M = 4.00). Both groups had similar experiences and satisfaction with their oscilloscopes.

The results from Fig. 3 suggest that the students were satisfied with both oscilloscopes. The participants were also asked to respond to an open-ended question regarding how the oscilloscopes could be improved.

The response rate was 33% (n = 20). Over 33% of the responses stated 'nothing' or 'not much.' The final question answered by the treatment group was if they preferred the software-based or traditional oscilloscope. Eleven participants from the treatment group preferred the software-based oscilloscope, whereas eight participants from the treatment group preferred the traditional oscilloscope. The number of responses was too small to make any statistical inferences.

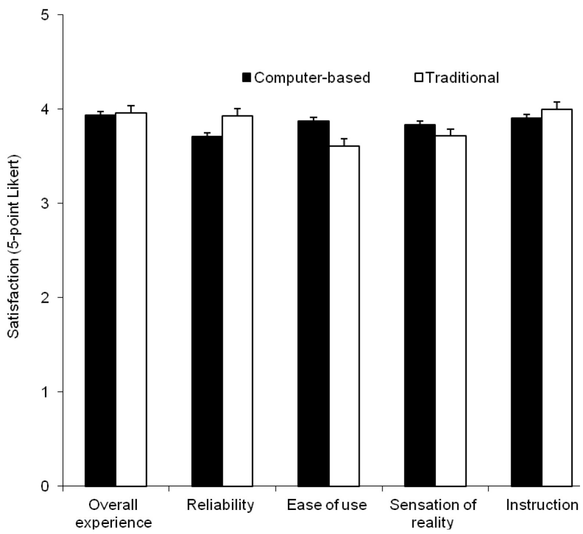

Fig. 3. Satisfaction with the computer-based and traditional oscilloscopes. *Note.* No statistical significance was found. Error bars represent standard error of the mean.

6. Discussion

6.1 Discussion relevant to research question one

The mean scores for the pretest of both groups were similar. Both groups had similar gains from their difference scores. The ANCOVA results were not statistically significant for the difference scores between the treatment and comparison groups. Three covariates were introduced and held constant in the ANCOVA analysis. None of the covariates were statistically significant.

6.1.1 ANCOVA Covariates

The results were not significantly different for experience, achievement, and satisfaction with the computer-based oscilloscope and the traditional oscilloscope. Previous studies have found similar results with distance delivery and computer-based instrumentation, showing computer-based distance experiences to be at least equivalent to traditional delivery [11, 12, 22, 29].

6.2 Discussion relevant to research question two

6.2.1 Engineering laboratory propensity and comfort

The results of the independent samples t test were not significant when comparing the treatment and comparison group. According to the results of items 2.1 to 2.7, the participants ranged from comfortable to very comfortable with learning new computer skills and solving problems with a computer.

The students' comfort with computers and laboratories was a potential confound in determining the students' experience with a computer-based oscilloscope. The participants were comfortable with using laboratory equipment, performing experiments, analyzing data, and learning new laboratory skills. Students were slightly less comfortable in taking leadership roles in groups. Overall, the subscale mean suggests that students were comfortable with engineering laboratories and their associated tasks.

6.3 Laboratory experience

This section of the instrument included five questions: four multiple choice and one open-ended. The overall experience of the laboratories was rated as 'satisfied'. The open-ended question was completed by 62% of the participants. The responses varied between open suggestion of what might be further included in the laboratories to criticism of the lack of instruction. Most responses suggested that the laboratory activities and equipment needed better explanations. The traditional and software-based oscilloscopes were introduced to the students at the same time as alternating current AC theory. The topic of AC theory has traditionally been a challenging concept to the students. Not surprisingly, the participants rated their laboratory partner's teamwork quite high between satisfied and very satisfied as they were allowed to choose their laboratory partners for each activity.

6.4 Satisfaction with oscilloscopes

The participants were asked to rate specific aspects of and the overall experience with the oscilloscopes. The study participants rated both oscilloscopes as satisfactory. The difference of the overall rating means was less than 1%. The results of the Mann-Whitney U-test were not statistically significant. All responses for each of the questions were rated close to or above satisfactory.

The software-based oscilloscope was rated lowest on reliability. One of the eight software-based oscilloscopes frequently encountered problems and forced the students to move to another station. The problem was later resolved. Therefore, it was not surprising that the software-based oscilloscope mean was rated 6% lower than the traditional scope mean respective to reliability. The software-based oscilloscope was rated higher by 7% on ease of use than the traditional oscilloscope. The traditional oscilloscope was intended to meet much greater needs than the software-based oscilloscope. The software-based oscilloscope had less complexity and the students were already familiar with a 'software' interface mediated by a computer. Further, prior to the laboratory activities, most students did not have experience with an oscilloscope. Interestingly, the software-based oscilloscope was rated higher by 4% for sensation of reality.

The training for the traditional oscilloscope was rated higher by 3% than the software-based oscilloscope. The results from the survey suggest that students found the oscilloscopes to be equivalent. The students rated both oscilloscopes favorably in each of the questions. Like Campbell et al. and Corter et al., the results found the students did not have a significant preference for either instruments or methods [22, 29].

6.5 Summary

The intent of this study was to find if there were differences in student achievement and affective traits while using a computer-based and traditional oscilloscope. The results infer that the two types of oscilloscopes were equivalent for the laboratory activities in this study. Student gain scores were similar as were the student attitudes toward the oscilloscopes.

7. Conclusions and Implications

7.1 Conclusions

One of the purposes of this study was to assess the viability of software-based instrumentation in an educational electrical engineering laboratory. Although there was no statistical significance found between the traditional and software-based oscilloscope, the results of the study were promising. The results suggest that neither the computer-based oscilloscopes nor the traditional oscilloscopes are better for electrical engineering courses delivered to non-majors.

In addition to distance laboratories, the on-site engineering laboratories could also benefit from computer-based instrumentation. If the software-based oscilloscope were intended to be an improvement solely to the laboratory, the results would suggest that all else being equal, neither scope would be preferred. However, it is important to note that the software-based oscilloscope costs a fraction $\sim$ (1/10th) of the traditional oscilloscope. Furthermore, the size of the software-based oscilloscope is smaller than the traditional oscilloscope. The computer-based instrumentation could be a promising and viable option in current laboratory settings.

7.2 Implications

Distance engineering courses are often mediated by a computer and are typically limited to lecture and theory. In order to introduce distance engineering laboratory experiences, the computer should and can be exploited. Computer-based instruments are becoming more available to students and educators and at lower costs. The students in this study used a computer-based instrument, an oscilloscope, with success and personal satisfaction. This study has shown for an electrical engineering service course and a fundamentals electronics course that software-based instrumentation is a viable alternative. Not only would a software-based oscilloscope fit well within distance education, but also for programs that are limited by costs, such as rural and urban schools.

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