Improving Students' Conceptual Understanding of Electrical and Electronics Circuits Via Computer-Based Review Sessions

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Introduction

The Funding for Result (FFR) committee at Southeast Missouri State University funded this quasi-experimental study in 1996. The study continued for two years. In 1998, the university selected the project as one of the three best projects completed.

Review of prior knowledge before introducing new knowledge enhances learners' understanding of subject matter. Verbal information learning and psychomotor skill learning seem to require the most review (Smith & Ragan, 1993). An introduction to electrical circuit analysis presents learners with verbal information and psychomotor skills from start to finish. As technology advances, the amount of information to be presented and the number of skills to be mastered increase, leaving instructors of the circuit analysis course little time for preparing and presenting a review session. However, advancement in computer software and information-presentation technologies may provide some answers to the above challenges.

Properly designed computer-based lesson outlines and lesson reviews can be used in distance education. By placing these materials in instructors' web-sites, students have the opportunity to review the lessons when they are not able to attend lectures.

Purpose

The objective of this study was to improve students' conceptual understanding of electrical circuits via computer-based review sessions. Researchers have identified that students who have a good conceptual understanding of electrical circuits will be able to troubleshoot circuit problems more effectively and efficiently (De Kleer, 1984; White & Frederiksen, 1990).

It was hypothesized that if students are exposed to interactive review sessions pertinent to previously learned concepts before new concepts are presented, the students would be able to apply their conceptual understanding to solve complex circuit problems more effectively.

Research Questions

The research questions were formulated as follows:

1. Is there a difference in the students' achievement level between an experimental group, for which computer-based review sessions are given, and a control group for which no treatment is given?

2. Is there a difference in the students' ability to identify the circuit behavior -- how circuit parameters such as voltage and current would change if the value of one component were changed (De Kleer, 1984) -- in electrical circuits between the experimental group and the control group?

Review of Literature

The difference between novices' and experts' approaches to electrical problem solving is that experts have mental models (Newell & Simon, 1972) pertinent to specific types of electrical circuits, and have the abilities to describe circuit behavior under "what if" conditions. When troubleshooting, experts are able to isolate circuit problems through logical, qualitative reasoning which requires a solid conceptual understanding of the behavior of electrical circuits (De Kleer, 1984; White & Frederiksen, 1990). Once mastered, concepts will be retained for a longer time than memorized formulas. In order for concepts to enter into a learner's long-term memory, the subject matter must be presented in a way that allows learners to develop their own concepts as well as those that are reinforced through periodical reviews (Smith & Ragan, 1993).

Educators Rohrer (1990), Jacob, Harland, Hubbard, and Reeve (1991), and Ioinovici (1991) were concerned about current textbooks' effectiveness. They pointed out that contemporary introductory textbooks are filled with more examples, drill problems, summaries, and mnemonics than similar textbooks from fifteen years ago. However, the newer texts failed to instruct students in developing their intuitive awareness of basic circuit behaviors.

The Proposed Study Vs. Other Computer-Based Instruction

Computer-based instruction and evaluations have been used for many

years in the field of electrical technology for pedagogical purposes (Pudlowski & Rados, 1987; Dobson, 1995). Most computer-based instructions are designed as stand-alone units or as tutorials that require learner-initiatives, extensive time, and dedicated computers.

The study described in this report incorporated presentation software (Microsoft PowerPointÔ) and an overhead projection system for presenting review sessions. The instructor has designed all his lecture outlines and review sessions for each lecture using Microsoft PowerPoint. Students had the chance to participate in the review sessions during the first five to ten minutes of the class. A computer was programmed to start the review sessions and the display was projected on a screen via a LCD projector. The review sessions continued in a cyclic fashion until the instructor arrived. The above process required only one computer set-up but presented the review session to all students, providing them with the resources to recall prior knowledge and prepare for the upcoming class.

Methods and Treatment

A quasi-experimental design was used for the study. Since random assignment was not possible due to the classroom environment, a research design known as the Nonequivalent Control Group Design, as suggested by Cook and Campbell (1979), was used. The population of the study consisted of students who enrolled in Electronic Circuit Design Analysis I, Electronic Circuit Design Analysis II, DC Circuit Principles, and AC Circuit Principles, offered in 1996 and 1997, by the Department of Industrial Technology, at Southeast Missouri State University. In those four courses, electronics majors learn the most important and fundamental concepts that are the pillars of the study of electronics. The classes offered in 1996 were selected as the control group and the classes offered in 1997 were used as the experimental group.

Educational research requires repetition with varying bodies of populations to verify their effectiveness

(Smith & Ragan, 1993). By conducting the study over two years including four different courses, the researcher expected to identify statistically significant outcomes.

At the beginning of the semester, a pretest was administered to both groups of each course to measure similarities between the two groups. The pretests were used to identify significant differences between the groups on their conceptual understanding of electrical and electronic circuits. A t-test was used to find significant difference between the treatment group and the control group at 0.05 alpha level. Cook and Campbell (1979) suggest that the researcher must know the initial differences between control and experimental groups in order to ascertain if differences exist between pre and post test.

The computer-based review sessions were shown only to the students in the experimental group. The equipment was purchased with the funding provided by the Funding for Results (FFR) program at Southeast Missouri State University. A laptop computer and a color projection system were among the equipment. Both groups completed the same classroom instruction pertinent to each class, received the same amount of homework and other assignments, and took the same exams pertinent to each course. The researcher tried to minimize the effects of other variables such as variation of instruction in order to identify the effects of the review sessions.

The researcher designed all lecture outlines and review sessions for each lecture using Microsoft PowerPoint. The review sessions served two purposes: a) to allow students to recall previously learned concepts and their inter-relationships; b) to activate

students' attention to prepare for the upcoming lecture (Smith and Ragan, 1993, pp.140-144). Students had the chance to participate in the review sessions during the first five to ten minutes of the class. Each review session consisted of key concepts from the previous lecture. The concepts were lined-up so that one concept tied to the preceding concept. All interrelated concepts were presented as a whole. Large font -- size 36 -- and consistent color patterns were used in slide construction. Microsoft PowerPoint was selected because: a) it is widely available; b) it generates file format that can be easily transmitted via telecommunication mediums; c) viewers do not require the same program to view presentations. The viewing software is available to any computer user at no cost. These features were important because students who choose to copy the lesson outlines or the review sessions may not own the PowerPointÔ program, and students have the option to download or view the material over internet from the instructor's homepage.

A computer was programmed to start the review session five minutes before class began. The display was projected on a screen via a LCD projector. The display time was limited to a maximum of ten minutes, while running in a cyclic fashion.

At the end of each semester, both groups were administered a posttest to examine the students' mastery level of concepts taught in that class. The control group and the experimental group of each course received the same posttest.

Results

The result of this study is presented under the title of each course. After grading and tabulating the data, a

	Mean	Variance	Observations	P(T<=t) one tail
Control	72	127.46	16	0.345
Experimental	69	273.06	10	

Table 1. t-Test Results of Pretest Given to Electronic Circuit Design Analysis I Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	60.31	1036.76	16	0.0611
Experimental	78.22	323.06	10	

Table 2. t-Test Results of Posttest Given to Electronic Circuit Design Analysis I Course

t-test was performed to identify significant difference between the control group and the experimental group.

Electronic Circuit Analysis I
Table 1 (page 3) illustrates the results of the t-test for the pretest. The test used two-samples with equal variance.

The pretest indicates that there was no statistically significant difference between the two groups at a significance level of 0.1 (p>alpha). It was concluded that both groups had a similar conceptual understanding.

Table 2 (page 3) illustrates posttest analysis for the same course. The t-test assumed two-samples with equal variance.

The above test assumed that there was no significant difference between the two groups at the beginning of the study. The results show that there is not enough evidence to support the equality assumption of the two groups at a significance level alpha of 0.1 (p = 0.06 < alpha = 0.1). Since the experimental group has a higher mean score compared to the mean score of the control group, it can be concluded that the review sessions had improved conceptual understanding of the students in the experimental group.

Overall achievement levels of both groups were examined using semester grades (percentage) of each student. Table 3 illustrates the results of that t-test.

The test shows that there was no statistically significant difference between the overall achievement level of students in both groups at alpha level of 0.1 (p>alpha). Many other factors that the researcher did not have control over may have contributed to this outcome. The overall achievement levels were computed based on test scores, lab assignments, homework assignments, and computer-simulation projects. A student with higher test scores might not have performed as well in laboratory activities, which may have resulted in lower achievement levels.

Electronic Circuit Analysis II
Table 4 illustrates the results of a t-test. The test used two-samples with equal variance.

Based on the above test, there is no statistically significant evidence to dispute the equality assumption of two groups at alpha level of 0.1. Therefore, the conceptual understandings of both groups were similar at the beginning of the study.

Table 5 illustrates statistical analysis of posttest results. The test assumes two-samples with equal variance.

At the end of the study, the two groups performed in a statistically significant manner at alpha level of 0.1. The experimental group achieved a higher mean score (mean = 79.3) compared to the control group (mean = 59.3). For this course, the review session provided a very significant contribution, because even at alpha level of 0.5 there was a statistically significant difference between the groups.

Overall semester grades are compared in Table 6. The t-test was performed under the assumption of two-samples with equal variance.

At alpha level of 0.1, there is a statistically significant difference between the two groups (p = 0.053 < alpha = 0.1). The experimental group performed excellently (mean score of 89.0) compared to of the control group (mean score of 72.6) in all activities during the semester.

DC Circuit Principles
The results of the t-test performed to examine initial differences in conceptual understanding of electrical circuits between the groups are tabulated in Table 7. It was assumed that the mean difference between the two groups was zero.

The test shows that the assumption of equality of the two groups is unacceptable even at an alpha level of 0.5. Since the groups are not similar at the begging of study, initial variations may have affected the outcome of the study.

Analysis of posttest results is shown in Table 8. The test assumes

	Mean	Variance	Observations	P(T<=t) one tail
Control	80.11	80.287	16	0.489
Experimental	118.86	451.19	10	

Table 3. t-Test Results of Semester Grades of Electronic Circuit Design Analysis I Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	74.94	136.05	17	0.1411
Experimental	80.44	169.77	9	

Table 4. t-Test Results of Pretest Given to Electronic Circuit Design Analysis II Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	59.33	589.88	18	0.0122
Experimental	79.33	56.75	9	

Table 5. t-Test Results of Posttest Given to Electronic Circuit Design Analysis II Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	72.58	837.33	18	0.0530
Experimental	89.00	20.80	9	

Table 6. t-Test Results of Grades of Electronic Circuit Design Analysis II Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	86.13	52.26	15	0.0464
Experimental	80.66	129.82	36	

Table 7. t-Test Results of Pretest Given to DC Circuit Principles Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	77.12	117.85	16	0.3299
Experimental	73.12	126.35	34	

Table 8. t-Test Results of Posttest Given to DC Circuit Principles Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	75.82	122.00	17	0.1440
Experimental	71.21	236.98	28	

Table 9. t-Test Results of Pretest Given to AC Circuit Principles Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	73.14	205.82	14	0.0092
Experimental	82.5	101.66	28	

Table 10. t-Test Results of Posttest Given to AC Circuit Principles Course

	Mean	Variance	Observations	P(T<=t) one tail
Control	74.46	557.08	16	0.3575
Experimental	76.96	454.66	31	

Table 11. t-Test Results of Grades of AC Circuit Principles Course

that the mean difference between the two groups is 5.5 points.

There is no statistically significant difference of posttest performance between two groups. The review sessions did not help in this course.

AC Circuit Principles

The test result shown in Table 9 indicates that there was no statistically significant difference between two groups at the beginning of the study (p = 1.44 > alpha = 0.1). See Table 9.

Analysis of posttest results of AC Circuit Principle course indicated that there is a statistically significant difference between the two groups (p = 0.0092 < alpha =0.1). The group which received computer-based review sessions had mean score of 82.5 while the group which did not receive the same treatment had mean score of 73.14. Since the groups were initially similar, it can be concludes that the review sessions did enhance the conceptual understanding related to electrical circuits. See Table 10.

When examined for overall achievement level of students enrolled in AC Circuit Principles (Table 11), the results indicated that there is no significant difference (p = 0.357 > alpha = 0.1). This may be due to the other factors such as lab scores and scores of other assignments were not affected by the review sessions.

Conclusions and Applications

The effectiveness of computer-based review sessions was examined in four different courses. The results show that the review sessions increased the students' conceptual understanding of electrical circuits in three out of four courses. The overall achievement level of one course improved in a statistically significant (alpha=0.1) manner. It is suggested that the review sessions could be used as lecture outlines.

An effective review session should include graphic representations of concepts whenever possible. A consistent presentation in terms of font size, highlighting colors, and design may attract and keep students' attention. It is also important to tie similar concepts together while showing the relationships among them.

Though it takes additional time and efforts to prepare computer-based lesson outlines and review sessions, the benefits clearly outweigh the seeming drawbacks. Some observed benefits are:

1. Easy to upgrade -- as the course content change, individual slides can be modified or added to the presentation. This may not be possible with regular transparency based presentations.
2. Telecommunication ready -- Students are able to download the presentations from a web-site to review missed lesson and notes. Computer-based materials are fully compatible with telecommunication mediums and can be used in distance education activities.
3. Supplement to slow-learners -- Students who have learning difficulties may be able to copy the material into their personal computers for additional review.
4. Multimedia Presentations -- The computer-based nature of this study allows easy integration of the content into multimedia presentations with sound and animation.
5. Activated attention -- The review sessions focus students' attention on the topic being discussed.

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