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ABSTRACT

This paper presents the results of a study on the effects of using 3 simulators with 14 computer science majors enrolled in an undergraduate computer architecture course. Three ability groups (high, medium, and low) were formed based on the students' quality point averages for prior computer science courses. Analyses of data from a pretest, a posttest, instructor-prepared achievement tests following each of the simulators, programming assignments, and survey results showed: (1) no significant differences among the three groups on the pretest and posttest scores; (2) only the low and medium ability groups showed significant performance gains from pretest to posttest; (3) the use of the simulators equalized the student performance in the three ability groups; (4) nonsignificant differences on both programming assignments for all ability groups; (5) positive student attitudes toward and perceptions of the use of simulators; and (6) student perceptions that the simulators made learning about computer architecture more concrete, and helped in writing and understanding programs and microsequences of instructions. Suggestions for further research are presented including using larger samples, different methodology for defining the ability groups, and the use of qualitative interviews to ascertain student perceptions. Six figures present the results of the various statistical analyses. (Contains 5 references.) (ALF)

The Effects Of Teaching a Hypothetical Computer Architecture with Computer Simulators

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ABSTRACT

Research indicates that computer simulations in higher education settings generally result in better or equivalent student performance. This paper presents the results of a study on the effects of using three simulators in an undergraduate computer architecture course.

Three ability groups were formed based on the subjects' quality point averages (QPA) for prior computer science courses. Analyses of the pretest and posttest showed no significant differences among the three groups. Overall, only the low and medium ability groups showed significant performance gains from pretest to posttest. This research indicates that the use of the simulators equalized student performance in the three ability groups. Additionally, student attitudes and perceptions about the use of the simulators were positive.

OBJECTIVES

Having a course which deviates from the students' norm makes for difficulty in learning. The unconventional and abstract nature of the computer architecture course material needs to be simplified for the students' comprehension without reducing the quality of the course. Clariana (1988-1989), Lunetta and Hofstein (1981), and McGuire (1976) suggest that providing students with computer-simulated learning materials will allow them to have a realistic understanding of abstract material.

Realistically, students cannot study the internal architecture of a computer system. However, computer programs to simulate the architecture are used frequently when this subject is studied. In similar situations in which actual and simulated science experiments were studied, Boblick (1972) and Cavin and Lagowski (1978) showed that students using computer simulations performed as well as or better than students who performed the actual experiments. The incorporation of computer simulated learning materials may maintain the integrity of the course content while decreasing the level of comprehension complexity.

This research was motivated by the need for supportive learning materials for the students in a computer architecture course. With the support of interactive computer learning aids, the researchers found that students had a better understanding of the course material.

Several research questions were addressed in this study:

1) To what extent do the use of computer-based simulators affect the students in low, medium, and high ability groups?

2) To what extent do the use of computer-based simulators affect student achievement in the computer architecture course?
3) How do students perceive the use of simulators in a computer architecture course?

DESIGN OF THE STUDY

Sample

Fourteen undergraduate students enrolled in a computer architecture course served as the subjects in this study. The students were computer science majors in a small state university in southwestern Pennsylvania.

Independent Variables

Blocking Variable. The students were separated into low, medium, and high ability groups based on their quality point average (QPA) for computer science courses taken prior to the study. The average QPA score for all students in the study was calculated. Those scoring at least one standard deviation above the mean were placed in the high-ability group. Those scoring at least one standard deviation below the mean were placed in the low-ability group. The remaining students were placed in the medium-ability group.

Treatment. Students from all ability groups began the semester with an introduction to the first computer architecture simulator. This simulator provided the students with an introductory instructional tutorial of a hypothetical computer architecture. Additionally, this first package included a content quiz followed by an interactive machine-code program simulator. The package presented the first 11 instructions of the hypothetical computer described in the textbook used in the course. The machine-code simulator demonstrated "canned" as well as student-written programs.

Near the midpoint of the course, the students used a second simulator demonstrating data flow at the machine level. This simulator was used to support the class lectures on microsequences; however, the students had the opportunity to operate this simulator outside the class.

Near the end of the semester, the students used a simulator containing the entire instruction set of the hypothetical computer. This simulator accepted programs written by the students and demonstrated the execution sequence for a program. Several programs were assigned to be written using this third simulator.

Dependent Measures

Pretest. At the beginning of the semester, the students were administered a pretest designed by the course instructor. A panel of experts validated the pretest. The results of the pretest were used to establish the students' initial level of computer architecture knowledge. Significant differences in achievement between the three groups were investigated.

Achievement Tests. The students were administered instructor-prepared tests after each of the simulators was used.

Programming Assignments. The students wrote and demonstrated two programs using the third simulator.

Posttest. The students were administered the posttest at the end of the course.

Surveys. The subjects completed a 13-item survey which examined the time they spent on each of the three simulators and their perceptions of the effects the simulators had on their understanding of computer architecture concepts, the instruction set of the computer, the effects of the simulators on their abilities to write programs, and on the overall effectiveness of the simulators.

RESULTS

A one-way ANOVA was used to compare the means of the pretest, examination 1, examination 2, and posttest scores for the subjects in the three ability groups. The results are represented in a chart (see Figure 1).

Significant differences were found among the groups on examination 1 and examination 2. To determine the source of the significant differences, the Scheffé's test was used. On examination 1, significant differences were found between the Low and Medium ability group means and between the Low and High ability group means. The Low ability group performed significantly lower than the Medium or High ability groups. On examination 2, significant differences were found between the Low and High ability group means, favoring the High ability group.

T-tests were performed to determine whether or not significant gains were made between the various examinations. Those results can be found in Figure 2. Significant differences were found between the pretest and examination one, examination two and the posttest, and the pretest and posttest scores.

T-tests were used to compare the gains for each of the groups. The results can be found in Figure 3, Figure 4, and Figure 5. For the Low ability group, there were significant gains pretest to examination one and pretest to posttest. For the Medium ability group, there were significant gains pretest to examination one, examination two to posttest, and pretest to posttest. There were nonsignificant gains for the High ability group.

A one-way ANOVA was used to compare the means on the two programming assignments for the subjects in the three ability groups. There were nonsignificant differences on both assignments.

Percentage changes were calculated for the three ability groups between the various examinations. These gains can be found in Figure 6. The Medium ability group made the greatest gains from pretest to examination one. The Low ability group made the greatest gains between examination one and examination two and between examination two and the posttest. The Medium ability group made the greatest percent gains between pretest to posttest.

DISCUSSION

The ANOVA performed on the pretest means for the three ability groups (F=1.52) showed no significant differences among those means. This could be expected since the content examined on the pretest consisted of information the students should not have known. Therefore, the students were relatively equal in their knowledge of computer architecture concepts at the beginning of the semester-long study.

The significant gains in performance for all students (t=8.25) from pretest to examination one were expected. Also, the increases for the Low (t=2.97) and Medium (t=9.50) groups were significant and were further reflected in the percent gains for those two groups (PG_L=191.30%, PG_M=319.34%). Although the High ability group outscored both the Low and Medium ability groups, the gain for the High ability group (from pretest to examination one) was not significant.

It would be expected that the High ability group would outscore the Low and Medium ability groups. What is important is that the gains made by the Low and Medium ability groups were significant, while the gains made by the High ability group were not. Also, the percent gain made by the Low ability group was higher than the percent gain for the High ability group (PG_H=179.75%). Perhaps the use of the first simulator helped the Low and Medium ability groups to make the significant gains in their scores.

No significant differences were found in the score changes between the first and second examinations. However, the results of the ANOVA performed on the means of the three ability groups on the second examination was significant (F=4.95). The significant difference was between the Low and High ability group means. While both the Medium and High ability groups outscored the Low ability group on the first examination, only the High ability group outscored the Low ability group on the second examination. Each of the three groups increased their means from the first examination to the second (PG_L=110.68%, PG_M=101.75%, PG_H=102.70%); however, the greatest increase was in the Low ability group. Again, it may be that the use of the first two simulators contributed to the reduction in differences between the scores of the students in the different ability groups.

A significant difference was found in the test scores between the second examination and the posttest. Overall, the scores dropped. When the ability groups were examined, the scores for the Low ability group dropped while those for the Medium and High ability groups rose. The gain for the Medium ability group was statistically significant (t=2.36). Perhaps the drop in overall scores can be explained by the nature of the examinations. The second examination tested the information covered after the first examination; the posttest was comprehensive. The all-inclusive nature of the posttest may explain the drop in scores.

A one-way ANOVA performed on the scores of the entire group on the posttest indicated no significant differences between the three group means (F=0.78). This might show that the simulators had a leveling effect on the scores. However, the Low and Medium ability groups had significant gains in average scores (t_L=4.46, t_M=6.07) while the High ability group did not (t_H=3.27). When these gains are expressed as percent changes, the Low and Medium ability groups, as expected from the t scores, outperformed the High ability group (PG_L=216.46%, PG_M=289.22%, PG_H=175.37%).

The same comprehensive examination was used as both the pretest and the posttest. The High ability group made nonsignificant changes throughout. The mean on the pretest ($\bar{x}_H$=54.17) was overshadowed by the means on the other three examinations (exam 1: $\bar{x}_H$=97.37, exam 2: $\bar{x}_H$=100.00, posttest: $\bar{x}_H$=95.00). There was not much room for improvement in the scores of the subjects in the High ability group.

However, there were significant gains in examination scores for the Low and Medium ability groups. Subjects in the Low ability group made significant gains pretest to examination one and pretest to posttest. Those in the Medium ability group made significant gains pretest to examination one, examination two to posttest, and pretest to posttest. We hypothesize that these gains were due, at least in part, to the equalizing effect the simulator had on the subjects in the Low and Medium ability groups.

There were no significant differences between the set of scores on programming assignment one ($\bar{x}_L$=96.25, $\bar{x}_M$=85.00, $\bar{x}_H$=95.00, F_{prog1}=0.26) and on programming assignment two ($\bar{x}_L$=83.75, $\bar{x}_M$=61.25, $\bar{x}_H$=95.00, F_{prog2}=1.22). These are not surprising results. The students were permitted to work on their programming assignments for a specified period of time. However, if the output of the assignment was not correct, the students were free to alter the code. Perhaps the use of the previous two simulators influenced the subjects in the Low and Medium ability groups so that their resulting programs were not significantly different from those produced by the students in the High ability group.

Another reason for the lack of statistically significant differences in the group means on the pretest and posttest may be due to the small sample size (n_L=4, n_M=8, n_H=2). With a larger sample size, the degrees of freedom would, of course, be greater and a smaller calculated F value would have been significant. If the means of the groups on the pretest ($\bar{x}_L$=35.42; $\bar{x}_M$=28.02; $\bar{x}_H$=54.12) and posttest ($\bar{x}_L$=76.67; $\bar{x}_M$=81.04; $\bar{x}_H$=95.00) are examined, it can be seen that they are different from each other; yet, the small sample size did not allow for significant differences.

Each of the 14 students in the study anonymously completed a survey. The survey asked for a self-reported indication of the time spent using the three simulators. One-half of the students used the first simulator for approximately one and one-half hours. Six other students used it more frequently. All but one of the students used the second simulator for three or fewer hours. Most students used the third simulator for two or more hours. The third simulator was probably used for more hours than the first two simulators since the students were required to write two programs using that simulator.

For the most part, the students who participated in the study indicated that the simulators helped them to understand the concepts relating to the specific machine demonstrated in the simulators. They also indicated that the use of the simulators helped them to understand the concepts relating to computer architectures. Their responses indicated that the simulators made learning about computer architecture more concrete.

Student responses were less strong concerning the use of the simulators to write or understand programs written for the hypothetical machine. However, the majority of the students agreed that the simulators helped in those areas. They also agreed that the simulators helped them to understand the instruction set and microsequences of instructions.

The students indicated that the simulators helped them better understand how other computer structures operate. And, although some students felt that they could have learned about the architecture of the hypothetical machine without the simulators, they recommended its use when the class is next taught.

CONCLUSIONS

Students, especially in the Low and Medium ability groups, benefitted from the simulators. The use of the simulators may have equalized student achievement in the three ability groups. As reported in the surveys, the students had positive attitudes about the advantages of using the simulators.

Although these first findings are encouraging, more research needs to be done in this area. Larger sample groups should be studied. Student QPAs are based, in part, on the number of courses taken. Since this varies from student to student, the pretest should be used to separate the subjects into Low, Medium, and High ability groups. We feel this would be a better determiner of ability levels at the beginning of the course. Also, a more equal distribution of the subjects into the three groups is needed.

Individual interviews with the subjects should be conducted to gain the subjects' perspectives on the use of the simulators. An interview approach would permit the researcher to gain a better perspective on student views of the architecture simulators. Additionally, other areas of the computer architecture, such as the ALU, can and should be simulated. This is an area of research which deserves further study.

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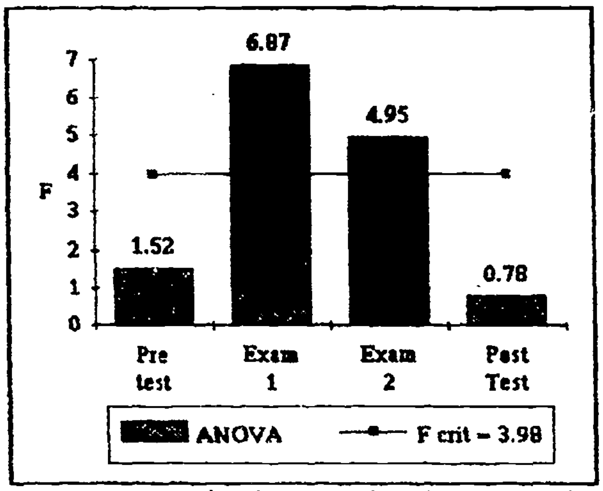

Figure 1 Analysis of Variance for Various Exams for the Low, Medium, and High Ability Groups.

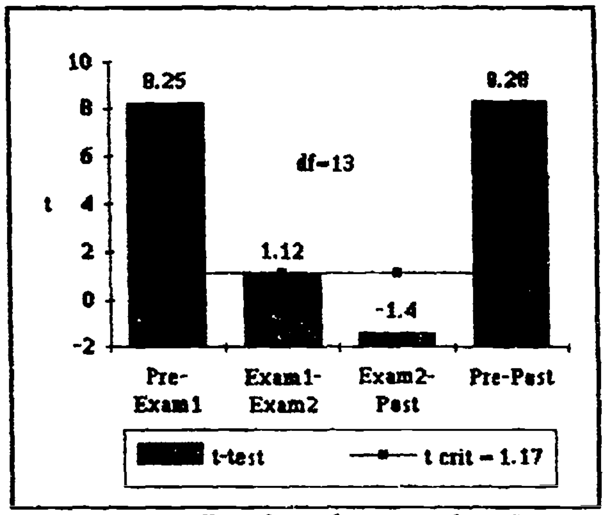

Figure 2 Results of t-tests for Various Exams for all Subjects.

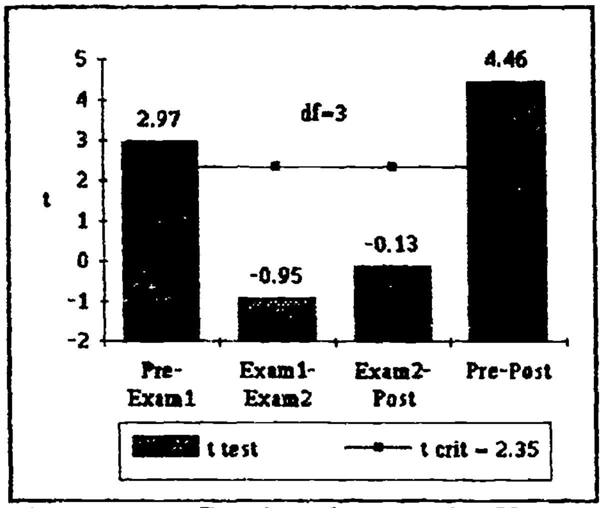

Figure 3 Results of t-tests for Various Exams for the Low Ability Group.

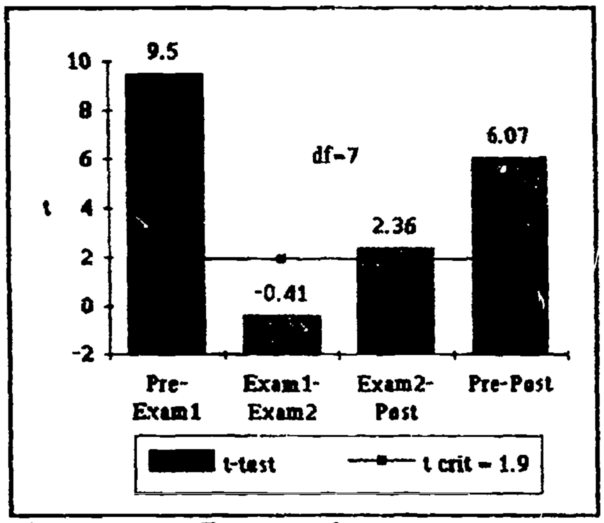

Figure 4 Results of t-tests for Various Exams fot the Medium Ability Group.

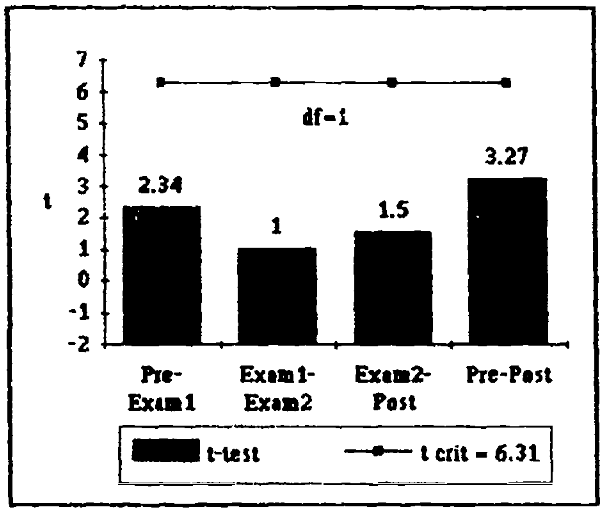

Figure 5 Results of t-tests for Various Exams for the High Ability Group.

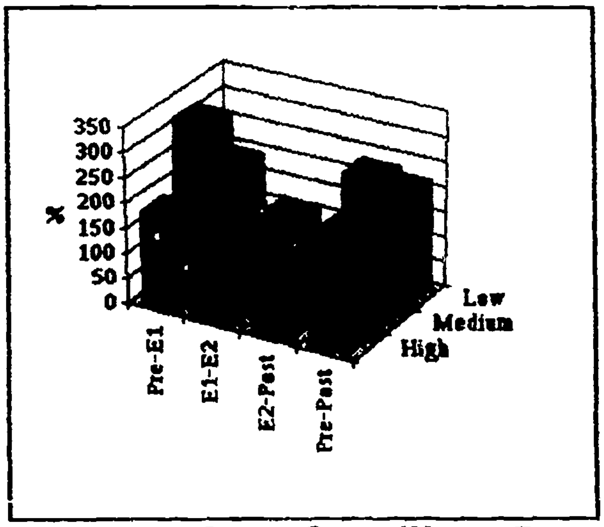

Figure 6 Percent Gains of Various Exams for the Low, Medium, and High Ability Groups