1984

# Computer Assisted Instruction (CAI) Effect on Strategic Electronic Troubleshooting Performance

Virginia T. White
*University of Central Florida*

## STARS Citation

White, Virginia T., "Computer Assisted Instruction (CAI) Effect on Strategic Electronic Troubleshooting Performance" (1984). *Retrospective Theses and Dissertations*. 4668.
https://stars.library.ucf.edu/rtd/4668

# COMPUTER ASSISTED INSTRUCTION (CAI) EFFECT ON STRATEGIC ELECTRONIC TROUBLESHOOTING PERFORMANCE

BY

VIRGINIA TEDDER WHITE
B. A., University of Central Florida, 1980

THESIS

Submitted in partial fulfillment of the requirements
for the Master of Science degree in Industrial/Organizational Psychology
in the Graduate Studies Program of the College of Arts and Sciences
University of Central Florida
Orlando, Florida

Spring Term
1984

# ACKNOWLEDGMENTS

The assistance and encouragement of Dr. Janet J. Turnage throughout the masters program is gratefully acknowledged, as well as the time and effort put forth by Dr. Wayne A. Burroughs and Dr. Richard E. Reynolds.

The author also wishes to extend a special acknowledgment to Jon E. White for his continued support and encouragement throughout the years.

# TABLE OF CONTENTS

Appendixes

# LIST OF TABLES

## LIST OF FIGURES

FIGURE PAGE

# INTRODUCTION

Industrial and military settings alike are experiencing a general state of reduced worker productivity, growing maintenance costs, and reduced system readiness (Frazier, 1981). Due to the growing complexity of the in-the-field hardware and the ever increasing costs associated with the training of maintenance technicians, technical training has become a major concern of both private and military settings. The purpose of this research is to examine the training effectiveness of an off-the-shelf computer assisted instructional (CAI) program, with an attendant interactive video, on the electronic troubleshooting performance of students enrolled in a course ultimately leading to an Electronic Technician rating in the U.S. Navy.

The 1970's represent a period of exploration in the use of computer based instruction. One of the first systems put into use was the Navy's Memphis Computer Managed Instruction system, based on the existing time sharing hardware technology of the day. Early computer based instructional systems like this demonstrated that computers could be utilized to score tests and direct students through a self-paced curriculum. In computer managed instruction (CMI), students complete lessons in a learning carrel or laboratory setting. Tests taken at the end of each lesson are scored by the computer, which assigns the next lesson, remediation exercises, and maintains a record of the number of hours spent in the various modules of instruction (Service School Command, 1982).

Many training settings have employed computer managed instruction, (computer management of off-line instructional material), because of the systems ability to support a large number of students, utilizing only a few computer management terminals. However, the costs associated with acquiring and maintaining each management terminal (optical mark reader, printer, and minicomputer) along with all the off-line forms and instructional material (programmed texts, performance labs, videotapes, and cassettes) are considerable. The Basic Electricity and Electronics (BE&E) School, located at the Naval Training Center in Orlando, Florida utilizes the Memphis CMI system, employing actual equipment trainers (AET's) to provide troubleshooting training on the component level.

Using actual equipment poses several problems. Actual equipment is not designed for training, but for operational purposes. This often results in shortages in both parts and equipment, since actual field use has priority over using the same equipment for training purposes.

Usually only minor changes are made in actual equipment for training purposes, this makes AET's very system specific, allowing training only on one system or part of a system. Students are sometimes exposed to high voltages using AET's. Faulting actual equipment for student fault diagnosis sometimes damages the equipment, e.g. faulting equipment protection circuitry. Some faults cannot be feasibly demonstrated, such as those exposing students to extremely high voltages. Actual equipment trainers do not provide feedback and reinforcement on student performance, and they do not have the capability of measuring a response in relation to other options available. As operational equipment in the field is updated and replaced, AET's in the training setting should be replaced.

The many problems associated with AET's, and the surge in computer technology has caused a renewed interest in maintenance training, and how it is presented to the student. Group-paced, conventional classrooms in military settings have become "learning centers" that utilize various topics and techniques simultaneously, allowing students to proceed at their own pace. These include: CMI programmed instruction, media devices operated by students, and more recently, computer assisted instruction (Kirby & Gardner, 1976). Computer assisted instruction has the ability to teach interdependent skills and knowledge in various temporal arrangements. In computer assisted instruction, instructional material is stored in the computer and presented on a cathode-ray tube or visual aid device. Students interact with the instructional material presented by using a screen sensitive to touch or an interactive keyboard. Computer assisted instruction ranges from programmed text, with specific questions, correct and incorrect answers, key words, and predictable alternatives dependent on the student's answers, to dynamic CAI systems that use complex data bases to generate instructional material and questions (Carbonell, 1970).

Computer managed instructional systems may be more cost effective if supplemented with CAI, allowing a direct interactive interchange between the student and instructional material using low-cost microcomputers. B.F. Skinner believes computer assisted instruction could cut the amount of time needed to teach what is now being taught in American classrooms by one-half (Bales, 1983). Orlansky and String (1979) found a median of 30% of conventional instructional course completion time saved using CAI and CMI instructional methods. Current studies (Orlansky & String, 1981) revealed a time savings ranging from -32% to 59%, with a median of 28% using either computer assisted or computer managed instruction.

Computer assisted instruction can optimize costs and time associated with maintenance skills training, by furnishing each student with the appropriate practice, review, and performance tests, thus, freeing the Learning Supervisor (LS) to perform other instructional functions. Computer assisted instruction also allows the timing, evaluation, and remediation of each students performance by computer. Computer models that simulate actual equipment trainers reduce the number of AET's and circuit boards required by the school, thus, reducing actual equipment costs. Assignment of faulty circuits and test point probing are all done by computer, eliminating deadtime due to the servicing of actual equipment and circuit boards. Additionally, CAI can standardize instruction that in the past was subject to the diverse backgrounds and skill levels of various Learning Supervisors, due to turnover. Computer assisted instruction also allows the constant update of instructional information without costly text rewrites. Computer assisted instruction has the potential to provide optimum individualized maintenance training instruction, as well as to make the instructional program more cost effective.

An intermediate level maintenance system known as Automated Electronic Maintenance Training was developed for the Navy using a computer assisted instructional program with no operational equipment, only appropriate computer displays to achieve training objectives. It was generally agreed by command and staff personnel that the automated electronic maintenance training provided as good, if not better, training effectiveness than the actual equipment in use (Daniels, Datta, Gardner & Modrick, 1975). However, a comparison study looking at the automated training versus conventional instruction was not conducted.

A computerized maintenance and fault isolation training aid concept has been extensively tested by the Air Force and validated as an effective troubleshooting aid (DePaul, 1981). Subjects preferred the system over conventional paper-pencil troubleshooting aids. Kottenstette, Steffen & Lamos (1980) found that the majority of students preferred using microterminals to the marking of the paper-pencil forms used in computer managed instructional programs. Students also stated that the terminals facilitated concentration when answering test items. Utilizing computer assisted instruction on subjects with no prior knowledge of powerplant engine lube oil systems, Stevens et al. (1982) found subjects easily ran the computer assisted instructional program within minutes, and were able to observe and understand the operation of the simulated lube oil system itself. Wilper and Eschenbrenner, Jr. (1983) examining whether maintenance technicians could perform troubleshooting tasks using computer generated multiframe schematic diagrams, found 36 correct fault diagnoses out of 48 possible, indicating that maintenance technicians can effectively troubleshoot using electronically generated schematics.

There is a need to develop multiple levels of computer assisted instruction, while maintaining the support of computer managed systems presently in use by the military and private sector (Lamos, 1982). Computer assisted instruction offers an interactivity between subjects and instructional material that printed material and computer managed instruction systems do not offer. A computer assisted instructional format allows random, nonlinear access to information, allowing control over information sequence and feedback.

Reviewing fleet supervisory ratings on 1,229 graduates of conventional instruction (group-paced), and 1,186 graduates of individualized instruction (self-paced and computer managed), computer managed instruction was found to be equally effective in preparing students for operational fleet jobs. However, a combination of instructional methods would probably be more effective than using one or two methods in teaching a course (Hall & Freda, 1982).

Using computer based instruction in conjunction with a standard maintenance training program, Johnson and Fath (1983) concluded that computer assisted instruction can be used to effectively supplement or partially replace hands-on practice with actual equipment. However, no significant difference was found between the control group receiving conventional troubleshooting training on actual equipment and the computer assisted group with regard to the basic knowledge and understanding of the equipment.

Rouse (1979a) examined the transfer of skills developed during a computer assisted task to an unaided second task and found that subjects who had performed 3 computer assisted trials and transferred to an unaided second task were slower than those subjects trained without computer assistance. All subjects improved on an additional trial on the second task, computer assisted subjects improved 47%, while unaided subjects only improved 24%. Negative transfer initially occurred for the computer assisted subjects, but ended in eventual positive transfer.

A study examining maintenance trainees performing fault diagnoses with and without computer assisted instruction, found a positive transfer of training from computer assisted to unassisted displays, in terms of number of tests taken before correct fault diagnosis as problems became larger (Rouse, 1979b).

In a study looking at computer assisted fault diagnoses, computer assisted instruction resulted in a statistically greater percentage of correct responses, and subjects transferring from computer assisted to unassisted instruction maintained their level of performance (Rouse, Rouse, Hunt, Johnson & Pelligrino, 1980). Hall and Blaisdell (1975) examined a military instructor prepared CAI course on electronic troubleshooting, and discovered that 100% of the CAI subjects diagnosed subsequent faults without computer assistance, while only 83% of the conventionally trained subjects found the fault in the allotted time. Both groups displayed considerable variation in applying a proper sequence of troubleshooting steps.

Maintenance tasks are primarily decision tasks. Maintenance technicians using knowledge regarding parts and functions make decisions on what symptoms to search for, manuals to reference, and what action to be taken. Computer assisted instruction centered around the various components of a student's decisions, e.g. usefulness, alternatives, and results, cause the subject to evaluate possible decisions (Freedy & Crooks, 1975).

In a survey conducted by Martin, Stanford, Carlson, and Mann (1975), of 9 military and 11 civilian experts in computer assisted instruction, all rated innovative software as having a higher potential payoff than investment in terminal hardware or large-scale use of existing systems. The feature felt most necessary in software was tailoring interaction sequences to each students needs and prior learning experience.

An individual's prior learning experience provides a mixture of responses that can both hinder and benefit maintenance training, as well as any learning situation. A response is learned to a class of stimuli. The response may then manifest itself in other similar situations, without any specific training to those situations. Response strength, however, varies with different situations, even to the point of not being displayed at all in situations that appear to be similar to the original situation (Moore, Manning & Smith, 1978).

Training and education rely on this basic assumption that people have the ability to transfer what they have learned from one situation to another. An "identical elements theory" approach to the study of transfer of training would propose that transfer occurs more readily when technique and content of tasks are similar (context-specific). Generalization theory places emphasis on the transfer of principles (context-free). However, the transfer of principles may not be that different from the transfer of technique, since using various techniques may involve utilizing principles.

Formation of learning sets involves subjects developing generalizations regarding problem solving. Subjects learn from prior experience causing the solving of new problems to occur with more ease. Learning sets represent being ready to respond to a situation in a specific way (Hill, 1971). Certain distinguishing cues become associated with a situation. Learning sets provide the individual with the ability to apply prior experience in the development of new problem solving procedures. Prior experience (learning sets) are reflected in the educated behaviors used in developing solutions to the various problems that may arise subsequent to the subject's training.

Positive transfer of training occurs when learning a task facilitates the learning of a new task. Positive transfer is facilitated by 2 effects: proactive facilitation and retroactive facilitation. Retroactive facilitation is where newly learned responses are facilitated by previously learned responses, and proactive facilitation is where retention of previously learned responses are facilitated by newly learned responses (Vernon, 1976).

There are 2 types of negative transfer effects that may influence learning, retroactive inhibition, where newly learned responses interfere with the retention of older responses, and proactive inhibition, where older responses interfere with the learning of new responses. Osgood's transfer model proposes that stimulus similarity is directly responsible for the amount of transfer of training, high similarity leading to a large amount of transfer and no similarity leading to no transfer of training. The direction of transfer, positive or negative is determined by response similarity. Response patterns can be identical (positive transfer), dissimilar or different ("0" transfer), and opposite (negative transfer [Vernon, 1976]). Osgood's model suggests CAI examples should be context-specific and highly similar to actual hands-on equipment problems, in order to have a large amount of transfer of training. It further suggests that CAI must elicit identical responses to those actual equipment elicit, to have a positive transfer of training to subsequent tasks, used in troubleshooting actual equipment.

The purpose of context-free instruction is to force students to use the structure of a problem to make inferences about the state of various components, forcing the student to use logical problem solving strategies to determine the correct fault diagnosis. Troubleshooting trainers focus on the student learning facts rather than general troubleshooting strategies.

Hunt and Rouse (1981) conducted a study looking at context-free CAI's transfer to context-specific tasks using 4th semester aircraft powerplant maintenance students. Those receiving computer assisted, context-free training exhibited significant positive transfer of training to context-specific tasks when measured by costs associated with utilization of inefficient strategies, and information gained from each action. Costs due to inefficient strategies were lowered and information gain per action was greater. First semester, computer assisted, context-free students, however, had positive transfer of training when measuring costs associated with inefficient strategies, but a negative transfer on information gain from actions.

Johnson and Rouse (1980) found a high correlation between context-free computer simulated fault diagnosis task time and actual system performance, suggesting that context-free CAI may be a good predictor of actual troubleshooting performance. Johnson (1981) found evidence that computer assisted fault diagnosis training facilitates development of general skills in maintenance trainees that are applicable to successful troubleshooting in unfamiliar simulated contexts.

Troubleshooting performance in context-free troubleshooting simulations was a good predictor of subsequent troubleshooting performance.

The context-free studies discussed seem to indicate high fidelity (context-specific) CAI is not necessary to positively affect troubleshooting performance. Low fidelity (context-free) CAI has demonstrated a positive affect on subsequent student troubleshooting performance on both actual and simulated equipment. There are pros and cons to using high fidelity, contextually-based CAI versus lower fidelity, context-free CAI. In a context-free situation problems may arise when the subject tries to apply the general diagnostic procedures to actual equipment. On the other hand, a high degree of contextual information may be restricted in its ability to generalize to novel equipment. Examining computer assisted fault diagnosis tasks, Johnson and Rouse (1982) found that appropriate combinations of low and moderate fidelity (context-free and context-specific) computer simulation can compete with the traditional lecture/demonstration.

Fink and Shriver (1978), and Towne (1981) believe computer assisted instructional programs will eventually serve both as training information systems and subsequent job performance aids, since most troubleshooting situations rely both on prior training and job performance aiding.

In a recent study conducted by McDonald & Associates, Inc. (McDonald, Waldrop & White, 1982) at the Basic Electricity and

Electronics School, it became apparent students did not always utilize optimum electronic troubleshooting procedures. Efficient electronic troubleshooting requires isolation of the faulty component by taking readings at logical test points and using the information from those readings to determine the next logical test point. Students adopted many different combinations of troubleshooting strategy in observed hands-on performance tests. This did not always lead to optimum troubleshooting performance and often led to many inefficient test point probes being taken.

To test the applicability of using CAI to improve BE&E School student troubleshooting proficiency, a pilot study was conducted using an off-the-shelf computer/video assisted instructional program on strategic troubleshooting. The CAI course stressed taking a logical sequence of test probes, based on good and bad inputs and outputs to localize the faulty component with the least number of probes. Four experimental and 8 control subjects participated in the study. Each experimental subject was matched with a male and female control subject. Results from the pilot study were encouraging but difficult to generalize to the overall school population due to the small sample size. In order to determine whether or not the course was effective, further research was required with a larger sample size and appropriate control conditions met.

The current research used similar methods to those used in the pilot study to implement a CAI troubleshooting course just prior to students entering the Electronic Technician (ET) training modules of BE&E School. The purpose of the study was to examine the effectiveness of the troubleshooting CAI course on troubleshooting behavior during performance tests in the ET phase of instruction. Hypotheses to be tested were:

- Students participating in the troubleshooting CAI will troubleshoot more efficiently than control students.
- High proficiency students will troubleshoot more efficiently than medium and low proficiency students, and medium proficiency students will perform more efficiently than low proficiency students.
- High proficiency students will complete the ET curriculum in fewer hours than medium and low proficiency students, and medium proficiency students will complete the ET curriculum in fewer hours than low proficiency students.
- Students participating in the troubleshooting CAI will complete the ET curriculum in fewer hours than control students.

## METHOD

### Subjects

Subjects were selected from students enrolled in the Electronic Technician curriculum, modules 30 to 34 at the Basic Electricity and Electronics School located at the Naval Training Center in Orlando, Florida. Modules 30 to 34 are preparatory courses for an Electronic Technician rating in the U.S. Navy. Students were male, E3 Seamen, ranging in age from 17 to 35, with an average age of 19 years old. Education level ranged from completion of high school to 1 year of college.

All students were tracked prior to entering the ET curriculum using the school's computer managed instruction system. allowed the researcher to predict when students would be entering the ET curriculum and ready to be assigned to 1 of 3 treatment conditions.

Each student was assigned a proficiency level of high, medium or low based on their actual elapsed time listed on the daily CMI printouts. This time represented each student's contact time, accumulated from the time the student entered the BE&E curriculum, to just prior to entering the ET curriculum. High proficiency students had the lowest elapsed computer time with medium and low proficiency students following respectively.

A total of 77 ET Students were randomly selected after being tracked through the CMI data and classified in 1 of the 3 proficiency levels. Twenty-three of the students were lost due to attrition (i.e. mandatory doubleshifting in order to meet an assigned transfer date, reclassified out of the ET program, or faulty equipment causing performance tests to be voided). Six remaining students from each of the 3 proficiency levels were then assigned to 1 of 3 treatment conditions (18 troubleshooting CAI, 18 control CAI, and 18 no-treatment controls), totaling to 54 subjects used in repeated measures across 3 circuit board types.

## Apparatus

The experimental treatment (troubleshooting CAI) consisted of an off-the-shelf strategic troubleshooting course. The course combined videotape presentations, workbook exercises and computer-assisted instruction materials. The computer graphically presented hypothetical circuits with bad outputs and allowed students to select test points and visually see the results of the tests. The computer provided feedback on whether or not a proper troubleshooting strategy was being used. The principal troubleshooting strategy taught by the CAI course was the half-split technique, which involves successive testing of the midpoint between known good and bad signals until the fault is isolated. The CAI presentation took a minimum of 9 hours, with additional time required when students repeated units, reviewed practice problems or when they required additional clarification of the material.

The control CAI/video program (a computer programming course) was designed to be similar in length and instructional characteristics to the experimental treatment to give the course face validity to the control subjects, while avoiding instructional material directly applicable to troubleshooting. The video portion entitled "Computer Programming: BASIC for Microcomputers" was made available from Educational Activities, Inc. and was integrated with a TRS-80 Model III BASIC computer interactive course.

Equipment consisted of 2 TRS-80 Model III computers and 2 Betamax video playback units with video monitors to present the video portions of the CAI. Headphones were utilized to prevent interference during simultaneous operation of 2 separate testing stations. The control CAI (BASIC course) utilized the same equipment as the troubleshooting CAI.

Since complexity of the troubleshooting criterion task was certain to affect student performance, 3 different printed circuit board types were utilized in the collection of actual troubleshooting performance data: a simple 205-5 Second Intermediate Frequency Amplifier (Second IF), a medium complexity 205-4 First Intermediate Frequency Amplifier (First IF) and a highly complex Power Supply (Power Supply) board with feedback loops. The boards were contained in a NIDA Model 205 Transceiver Trainer and a NIDA Model 201 Power Supply Trainer which are utilized as a normal part of the ET curriculum.

The study utilized 9 prefaulted boards for each of the 3 printed circuit board types, totaling to 27 prefaulted circuit boards. Boards were prefaulted by the manufacturer. Each of the 9 faulted boards for each board type were divided into 3 fault groups, based on fault difficulty. This allowed random assignment of faults to each student, preventing the possibility of prior student knowledge of fault location and reduced performance variance due to fault difficulty differences.

A total of 4 trainers (2 201 Power Supply Trainers and 2 205 Transceivers) were made available, thus allowing any combination for 2 separate performance tests to be observed at one time. Additional troubleshooting equipment included: 2 sweep generators, 2 oscilloscopes, 2 Simpson Multimeters, and various probes. Any additional equipment needed was supplied by the school. Equipment and circuit boards were maintained by the school.

## Procedures

Equipment for the presentation of the troubleshooting CAI and control CAI conditions was set up at the Orlando Naval Training Equipment Center's Human Factors Laboratory. Two instruction stations were available with only 1 type of treatment condition run at one time, i.e. 2 treatment control students or 2 experimental treatment students. Headphones were used to prevent the 2 stations from interfering with one another. Two stations were also set up at the Basic Electricity and Electronics School for the collection of criterion performance data.

Proficiency levels were hypothesized to significantly influence troubleshooting performance. Student proficiency categories had been determined during previous research (McDonald et al., 1982) by looking at a random sample of 225 student BE&E School completion times. Proficiency categories were determined by dividing completion times into 3 equal groups of 75 each. This resulted in the following proficiency levels: high proficiency 0-224.99 hours to complete BE&E School, medium proficiency 225-289.99 hours, and low proficiency 290-365.99 hours. All students participating in the research were assigned to 1 of the 3 proficiency levels before being assigned to a treatment condition.

Students assigned to the troubleshooting CAI or control CAI were sent to the Human Factors Laboratory and told to report there for the next few days instead of reporting to the BE&E School. These students were put on a temporary hold on the school's CMI system so that the 2 to 3 class days spent participating in the CAI treatment conditions would not affect their class standing. After students completed their assigned CAI condition, they returned to the BE&E School and proceeded with their normal ET curriculum.

The LSs sent all ET Splice students to the research station set up at the School when they were ready for performance tests on Module 30-2 (Power Supply) or Module 31-3 (Transceiver). This allowed the researcher to observe performance tests from the students who participated in the CAI courses as well as select no-treatment control students matched by proficiency level with the troubleshooting CAI students. Eighteen troubleshooting CAI students, 18 control CAI, and 18 no-treatment control students were observed at the researcher's station. Three performance tests were observed for every student, 1 on the Power Supply, 1 on the First IF Amplifier, and 1 on the Second IF Amplifier. Fifty-four students took a total of 162 performance tests across all 3 boards. A total of 54 performance tests (6 at each of the 3 proficiency levels on each of the 3 types of circuit boards) were observed for each of the treatment conditions. A prefaulted circuit board was randomly selected from the appropriate fault difficulty group for each student by the researcher before each performance test. Experimental matrices were used to assure that all treatment conditions were balanced and completely randomized.

The Electronic Technician curriculum is a self-paced instructional system. Students participating in the research took their performance tests in normal sequence, without affecting their normal course workload or hours. The only modification was that 3 of their performance tests were taken at the research station using circuit boards assigned by the researcher, rather than an LS. The ET curriculum utilizes 3 different trainers, administering 7 practice exercises and 7 performance tests, on 7 different printed circuit boards. The research data represents 3 performance tests on 2 of the 3 trainers. The average ET Splice course completion time is 60-80 classroom hours, and the typical class day runs 6 hours.

Before taking performance tests, students were advised that they had been randomly selected to be observed while troubleshooting various trainers and that any information collected would be confidential and used only for the purpose of this study. Students were further informed that participation in the study would in no way affect their class standing at the school and that they would be observed taking 3 graded performance tests (1 on the 201 trainer and 2 on the 205 trainer). They were told they would be timed, and that there were no set time limits on the tests. Students were also advised that if they had any questions during the performance tests they could consult with an LS, at which time the timer would be stopped until they returned to the research station to continue their performance test. Students consented to the publication of the results of the study providing their anonymity and confidentiality be maintained. Students were informed they could conclude participation in the study at any time without penalty or prejudice. They were encouraged to ask any questions they might have concerning the research, at which time the researcher clarified any misconceptions the student might have had regarding the research.

Students used the school's Troubleshooting Performance Response Sheets (see Appendix A for complete proof) when taking performance tests. Each student informed the researcher when the fault was diagnosed. The student then took the response sheet to the LS for feedback on whether or not the diagnosis was correct or not. If incorrect, the student returned to the research station to continue troubleshooting the same fault until the fault was correctly diagnosed. After diagnosing the correct fault, the student returned the completed response sheet to the researcher. If the performance test was on the Power Supply, the student returned to the regular BE&E curriculum until Module 31-3 when they again were referred by the LS to the research station. Prefaulted circuit boards on the NIDA 205 trainer were issued in random sequence, thus, students received either a faulty First IF Amplifier or a faulty Second IF Amplifier as their first 205 trainer fault card and received the remaining one as their second performance test measure. Students filled out response sheets for every performance test taken and went to the LS for feedback on their fault diagnosis. All response sheets were returned to the researcher after the correct fault was diagnosed.

After students completed all 3 performance tests at the researcher's testing area, their daily progress at the school was monitored on the CMI to obtain student response histories after they completed the final BE&E School test. Student response histories provided the researcher with each student's total BE&E School completion time.

During the 3 performance tests taken at the research station by each of the 54 students, the researcher recorded the dependent performance measures of: total number of test points probed, and total troubleshooting time. These measures were recorded on Data Collection

Appendix B for complete proof) while the student utilized the troubleshooting response sheet (see Appendix B for complete proof) to record troubleshooting information. The 162 performance tests represent the criterion measure used to determine any transfer of training effects from the experimental treatment to the actual hands-on performance tests, and any effect on troubleshooting behavior due to proficiency level. In addition, each student's overall BE&E course completion time was analyzed to determine any effect due to treatment or proficiency level.

# RESULTS

The primary objective of the research was to determine if students exhibited any change in electronic troubleshooting proficiency after having participated in a troubleshooting CAI course. The 3 levels of the independent variable were the troubleshooting CAI, control CAI, and no-treatment control. Proficiency levels were used as a blocking variable, assigning students to 1 of 3 predetermined categories (blocks) determined by each student's total number of hours in the BE&E School curriculum prior to entering the ET Splice curriculum. Dependent variables include: total troubleshooting time, total number of test points probed, and overall BE&E course completion time.

The experimental design is a 3 X 3 randomized block, replicated across 3 different circuit boards. The design consists of 3 levels of 1 independent variable (CAI treatment and no-treatment conditions) and 3 proficiency levels (see Figure 1). A specific number of students were assigned to each of the treatment and no-treatment conditions from each proficiency level to eliminate a potential source of variance due to randomly assigning students to treatments. The 3 fault groups (fault categories of the circuit boards) were matched across the 3 treatment conditions.

The treatment control group was used to control for any Hawthorne effect due to changes in the student's regular curriculum, by closely

| THREE LEVELS OF THE INDEPENDENT VARIABLE | PROFICIENCY LEVELS | | |
|---|---|---|---|
| | HIGH | MEDIUM | LOW |
| Troubleshooting CAI | | | |
| Control CAI | | | |
| Control No-Treatment | | | |

Figure 1. 3 X 3 randomized block replicated across 3 circuit boards

resembling the troubleshooting CAI, and then comparing that group's performance with the no-treatment control group's performance. The no-treatment control also allowed a comparison of the troubleshooting CAI groups performance to the performance of students completing the regular ET curriculum without having received a treatment condition (computer assisted instruction).

Two-way Analysis of Variance (ANOVA) procedures were used to analyze each circuit board type separately, to determine if there were any differences between independent variables. Circuit boards were examined independently since board differences were not being researched. Fisher Least Significant Difference (LSD) post hoc tests were performed on significant ANOVA F tests to determine exactly where the significance differences were occurring (between which variables).

## Power Supply Board

Analysis of Variance procedures conducted on the Power Supply board data indicate a significant ($p < .05$) difference in the number of points probed between the treatment and no-treatment conditions, $F(2, 25) = 3.29$. However, student proficiency level had no significant effect on number of points probed. The ANOVA Summary and descriptive statistics for number of points probed on the Power Supply Board are presented in Tables 1 and 2.

### TABLE 1
### POWER SUPPLY BOARD - ANOVA SUMMARY
### NUMBER OF POINTS PROBED

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 1652.18 | 2 | 826.09 | .54 |
| Treatment | 9997.06 | 2 | 4998.53 | 3.29* |
| Interaction | 10803.16 | 4 | 2700.79 | 1.78 |
| Error | 68310.90 | 45 | 1518.02 | |
| TOTAL | 90763.56 | 53 | | |

*p<.05

### TABLE 2
### POWER SUPPLY BOARD
### MEAN POINTS PROBED BY TREATMENT CONDITION

| TREATMENT CONDITION | MEAN POINTS PROBED |
|---|---|
| Troubleshooting CAI | 57.44 |
| Control CAI | 48.06 |
| Control No-Treatment | 25.06 |

A Fisher Least Significant Difference post hoc test was performed to determine exactly where the significant difference in treatments (treatment and no-treatment) was occurring. The LSD procedure revealed a significant difference at $\underline{p}<.05$ between the control no-treatment group (mean number of probes 25.06)and the troubleshooting CAI group (mean number of probes 57.44), with the control no-treatment group taking significantly fewer probes on the Power Supply board.

The ANOVA Summary and descriptive statistics on Tables 3 and 4 demonstrate a significant effect due to treatment condition on total time taken to troubleshoot the Power Supply board, at $\underline{p}<.05$, $\underline{F}(2, 45) = 3.78$. The LSD post hoc procedure indicated that the control no-treatment students took significantly less time (mean time 34.22 minutes) to troubleshoot the Power Supply board than the troubleshooting CAI students, with a mean troubleshooting time of 63.06 minutes at $\underline{p}<.05$. There was no significant effect in troubleshooting time for the control CAI students. Again, student proficiency level had no significant affect.

## First IF Board

ANOVA results on the First IF board indicate a significant effect due to student proficiency level on number of points probed. Table 5 reflects a significant $\underline{F}$ value of 3.72 with 2, 45 degrees of freedom, at $\underline{p}<.05$. An LSD test ($\underline{p}<.05$) disclosed that the significant difference in number of points probed on the First IF board was occurring

TABLE 3
POWER SUPPLY BOARD - ANOVA SUMMARY
TROUBLESHOOTING TIME (MINUTES)

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 1350.52 | 2 | 675.26 | .64 |
| Treatment | 7967.82 | 2 | 3983.91 | 3.78* |
| Interaction | 571.36 | 4 | 142.84 | .14 |
| Error | 47432.25 | 45 | 1054.04 | |
| TOTAL | 57322.15 | 53 | | |

*$p < .05$

TABLE 4
POWER SUPPLY BOARD
MEAN TROUBLESHOOTING TIME (MINUTES) BY TREATMENT CONDITION

| TREATMENT CONDITION | MEAN TROUBLESHOOTING TIME |
|---|---|
| Troubleshooting CAI | 63.06 |
| Control CAI | 55.00 |
| Control No-Treatment | 34.22 |

TABLE 5
FIRST IF BOARD - ANOVA SUMMARY
NUMBER OF POINTS PROBED

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 4666.00 | 2 | 2233.00 | 3.72* |
| Treatment | 2380.58 | 2 | 1190.29 | 1.98 |
| Interaction | 656.00 | 4 | 164.00 | .27 |
| Error | 26984.70 | 45 | 599.66 | |
| TOTAL | 34487.63 | 53 | | |

$*p < .05$

between the high (mean points probed 20.72) and medium proficiency (mean points probed 40.89) students, and also between the high and low (mean points probed 39.00). The data indicate high proficiency students probed significantly fewer points on the First IF board than either the medium or low proficiency students. Mean total points probed by proficiency level is presented in Table 6. Treatment and no-treatment conditions did not exhibit a significant effect on total number of points probed on the First IF board.

No significant effects on total troubleshooting time were found for the First IF board due to either treatment or proficiency level. The ANOVA Summary data are presented in Table 7.

## Second IF Board

Analysis of Variance procedures revealed no significant differences in total points probed on the Second IF board, due to treatment condition or proficiency level. Table 8 contains the ANOVA Summary of total points probed on the Second IF board.

A significant effect at $\underline{p}<.05$ due to treatment condition on total troubleshooting time was revealed on the Second IF board data, $\underline{F}(2, 45) = 3.05$. Table 9 contains the ANOVA Summary of Second IF total troubleshooting time. Table 10 lists each treatment groups mean troubleshooting time. An LSD post hoc test demonstrated that the troubleshooting CAI students (mean troubleshooting time 25.39 minutes) and the control no-treatment group (mean troubleshooting time 26.00

### TABLE 6
### FIRST IF BOARD
### MEAN POINTS PROBED BY PROFICIENCY LEVEL

| PROFICIENCY LEVEL | MEAN POINTS PROBED |
|---|---|
| High | 20.72 |
| Medium | 40.89 |
| Low | 39.00 |

### TABLE 7
### FIRST IF BOARD - ANOVA SUMMARY
### TROUBLESHOOTING TIME (MINUTES)

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 3599.96 | 2 | 1799.98 | 2.25 |
| Treatment | 1418.44 | 2 | 709.22 | .89 |
| Interaction | 715.24 | 4 | 178.81 | .22 |
| Error | 35920.80 | 45 | 798.24 | |
| **TOTAL** | 41654.29 | 53 | | |

No Significant Effects

### TABLE 8
### SECOND IF BOARD - ANOVA SUMMARY
### NUMBER OF POINTS PROBED

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 234.38 | 2 | 117.19 | .28 |
| Treatment | 1958.12 | 2 | 979.06 | 2.38 |
| Interaction | 478.88 | 4 | 119.72 | .29 |
| Error | 18438.65 | 45 | 411.97 | |
| **TOTAL** | 21210.07 | 53 | | |

No Significant Effects

### TABLE 9
### SECOND IF BOARD - ANOVA SUMMARY
### TROUBLESHOOTING TIME (MINUTES)

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 1020.30 | 2 | 510.15 | 1.05 |
| Treatment | 2980.08 | 2 | 1490.04 | 3.05* |
| Interaction | 1972.92 | 4 | 493.23 | 1.01 |
| Error | 21949.65 | 45 | 487.77 | |
| TOTAL | 27923.05 | 53 | | |

*$p < .05$

### TABLE 10
### SECOND IF BOARD
### MEAN TROUBLESHOOTING TIME (MINUTES) BY TREATMENT CONDITION

| TREATMENT CONDITION | MEAN TROUBLESHOOTING TIME |
|---|---|
| Troubleshooting CAI | 25.39 |
| Control CAI | 41.44 |
| Control No-Treatment | 26.00 |

minutes) required significantly ($p < .05$) less time to isolate faults on the Second IF board than the control CAI group (mean troubleshooting time 41.44 minutes).

## BE&E School Completion Time

The Basic Electricity and Electronics School is comprised of 3 units of instruction, Basic Electricity, Splice (introduction to electronics), and ET Splice (basic electronics). After participating in the research conducted on Modules 30-2 (Power Supply) and 31-3 (Transceiver) students have approximately 50-65 hours left in the ET Splice curriculum. One of the hypothesized effects was that students participating in the troubleshooting CAI would complete the self-paced ET Splice curriculum in fewer hours than either the control CAI or control no-treatment students. Additionally, it was predicted that high proficiency students would take less time to complete the self-paced ET Splice instruction than the medium and low proficiency students and that high proficiency students participating in the troubleshooting CAI should finish the ET Splice curriculum in fewer hours than all other students.

Each student's overall BE&E School completion time was analyzed using Analysis of Variance procedures. Results show that both treatment condition, $F(2, 45) = 4.45$ at $p < .05$, and proficiency level $F(2, 45) = 94.72$ at $p < .01$ had a significant effect on curriculum completion time. However, there was not a significant interaction between the two variables. ANOVA Summary results are presented in Table 11. LSD post hoc procedures at $\underline{p}<.01$ revealed that the control no-treatment students completed the curriculum in significantly fewer hours (358.63 hours) than students participating in the control CAI course (404.97 hours). There was no significant difference in curriculum completion time for the troubleshooting CAI students or the control no-treatment group. Descriptive statistics by treatment condition are listed in Table 12.

Further LSD testing at $\underline{p}<.01$ indicates significant differences in curriculum completion times across all 3 proficiency levels. High proficiency students completed the curriculum in significantly fewer hours (275.14 hours) than the medium (378.24 hours) and low proficiency students (489.26 hours). The medium proficiency students completed the curriculum and in significantly fewer hours than the low proficiency students. Table 13 presents curriculum completion time descriptive statistics by proficiency level. The greatest difference in curriculum completion time occurred between the high versus low proficiency students, with medium versus low, and high versus medium proficiencies following respectively.

### TABLE 11
### BE&E SCHOOL COMPLETION TIME (HOURS) - ANOVA SUMMARY

| VARIATION SOURCE | SUM OF SQUARES | DEGREES FREEDOM | VARIANCE ESTIMATE | F |
|---|---|---|---|---|
| Proficiency Level | 412774.00 | 2 | 206387.00 | 94.72* |
| Treatment | 19409.76 | 2 | 9704.88 | 4.45* |
| Interaction | 9823.52 | 4 | 2455.88 | 1.13 |
| Error | 98053.20 | 45 | 2178.96 | |
| **TOTAL** | 540059.40 | 53 | | |

*p<.01

### TABLE 12
### BE&E SCHOOL MEAN COMPLETION TIME (HOURS) BY TREATMENT CONDITION

| TREATMENT CONDITION | MEAN COMPLETION TIME |
|---|---|
| Troubleshooting CAI | 379.03 |
| Control CAI | 404.97 |
| Control No-Treatment | 358.63 |

### TABLE 13
### BE&E SCHOOL MEAN COMPLETION TIME (HOURS) BY PROFICIENCY LEVEL

| PROFICIENCY LEVEL | MEAN COMPLETION TIME |
|---|---|
| High | 275.14 |
| Medium | 378.24 |
| Low | 489.26 |

## DISCUSSION

After conducting the research utilizing a strict experimental methodology, research results indicate that the troubleshooting CAI did not improve troubleshooting performance at the BE&E School. Statistical test results reveal that the control no-treatment group performed as well, and in some instances better than the troubleshooting CAI or control CAI students. If the off-the-shelf troubleshooting CAI course used in this research had facilitated more efficient electronic troubleshooting at the BE&E School the students who received the troubleshooting CAI should have significantly shorter troubleshooting times on performance tests, probe significantly fewer test points, and have lower overall BE&E School completion times than both the control CAI group and the no-treatment control group.

Previous research (McDonald et al., 1982) at the BE&E School found that students used various troubleshooting techniques, often taking many unnecessary probes and thus taking longer to troubleshoot. The school was aware of this problem and prior to the present research were trying to find ways to remedy the situation. During this time the troubleshooting CAI resulted in encouraging results in a pilot study conducted at the school, by providing additional instruction in the utilization of half-split troubleshooting techniques. However, small sample size limited the generalization of the data to the entire

BE&E population. Subsequent to the pilot study, and prior to implementing this research, the BE&E School curriculum was modified. A separate testing area was set up with an LS assigned to instruct students prior to job programs (hands-on practice sessions) and performance tests. This resulted in a greater emphasis on completion of all hands-on practice sessions and a greater emphasis on half-split troubleshooting techniques. The troubleshooting CAI should have been able to provide the additional instruction needed to facilitate more efficient troubleshooting, but the problem of troubleshooting efficiency was now also being addressed by a stronger emphasis on half-split training and hands-on practice sessions at the School. As a result, the troubleshooting CAI did not lead to significantly improved troubleshooting performance over the control no-treatment students.

Analysis of Variance results on the Power Supply board indicate that the troubleshooting CAI resulted in negative training effects in both number of probes taken to troubleshoot the board and amount of time spent troubleshooting. The Power Supply board is the only printed circuit board of the 3 boards used in this research with feedback loops and it was noted that all troubleshooting CAI students concurred that the CAI unit on feedback loops was the most difficult. Troubleshooting efficiency on the Power Supply board may have been hampered by interference from troubleshooting CAI training if students were not fully aware of its application to a hands-on situation.

Results also indicate that in troubleshooting the Second IF board the control CAI students performed less efficiently than either the troubleshooting CAI or control no-treatment students. This may be due to having been removed from the highly competitive self-paced electronic training and placed in a totally unrelated CAI course for 2-3 days. However, this effect was not exhibited on either of the other 2 boards used in the study. Both CAI groups should have experienced interference from being taken out of their curriculum, however, the control CAI group's interference may have been greater due to the unrelatedness of the BASIC CAI they participated in.

Proficiency level effects were supported by significant differences in overall BE&E curriculum completion times. High proficiency students finished the overall curriculum in fewer hours than medium and low proficiency students, and medium level proficiency students finished in significantly less time than the low proficiency students. Proficiency levels assigned to students prior to entering ET Splice, based on total time spent in the BE&E School (Basic Electricity and Splice combined) were a valid predictor of overall BE&E School completion time. However, proficiency level effects were not found on number of points probed or troubleshooting time indicating proficiency level may be merely a good indicator of test taking ability and not necessarily hands-on troubleshooting ability measured by number of points probed and time spent troubleshooting.

# CONCLUSIONS

The CAI troubleshooting course did not improve student troubleshooting performance at the BE&E School. The school's curriculum should be analyzed to determine if the CAI might have been implemented earlier or later in the curriculum with greater results.

The BE&E School has several incentives that encourage students to try to finish the curriculum in a minimum number of hours. Students enrolled at the school are assigned a projected number of hours to complete various segments of the curriculum. If students can get 30 hours ahead of their projected time in the school they are rewarded with an academic day off. Upon finishing BE&E School, students go on leave before going on to the next school, as a result students try to finish the curriculum as soon as possible in order to be able to go on leave sooner or receive academic days off. In spite of students being taken off the CMI system and put on temporary hold so that the 2 to 3 days spent participating in the CAI treatments would not affect their class standing, losing 2 to 3 days of class time from the BE&E School may have caused negative feelings toward the research that may have affected performance tests taken upon their return to the BE&E curriculum.

The various training mediums used with the troubleshooting CAI may have had negative effects on the troubleshooting CAI group's overall learning. The interaction with the computer was very well received by the students, however the video and workbook that accompany the troubleshooting CAI were not. They were criticized as not always being easy to follow and understand.

An area not addressed by the troubleshooting CAI is how to operate the actual electronic equipment. This seems to be a genuine area of concern, as many comments were made reflecting a lack of understanding on how to operate the various types of equipment used in troubleshooting and the trainers themselves. Future research should consider the possibility of addressing this problem.

A troubleshooting CAI specifically tailored to the BE&E curriculum (context-specific) may produce more significant results, rather than using an off-the-shelf troubleshooting program. Osgood's theory (Vernon, 1976) suggests the results of this study are due to the troubleshooting CAI not being context-specific to the BE&E curriculum and eliciting responses dissimilar to those required on actual equipment troubleshooting, causing no transfer of training.

The troubleshooting CAI provides no voltage readings when components are checked, only good versus bad indications. This may have had a significant effect on the amount of transfer of training to actual hands-on troubleshooting where students have to make decisions based on voltage readings. Additional research needs to be done addressing these questions before a true evaluation can be done of the possible effect CAI can have on strategic electronic troubleshooting performance.

# APPENDIX A

# TROUBLESHOOTING PERFORMANCE RESPONSE SHEET

## TROUBLESHOOTING PERFORMANCE RESPONSE SHEET

NAME ________________ CARREL # ____________ P.T.# ____________ DATE ____________

YOU HAVE BEEN ISSUED EQUIPMENT IN WHICH A TROUBLE HAS BEEN INSERTED. YOU WILL BE OBSERVED ON YOUR ABILITY TO TROUBLESHOOT USING THE SIX-STEP TROUBLESHOOTING PROCEDURE. DO NOT OBTAIN A MULTIMETER UNTIL YOU HAVE COMPLETED STEP #5 AND YOUR PROCEDURE HAS BEEN CHECKED BY THE PERFORMANCE TEST SUPERVISOR.

### STEP 1. SYMPTOM RECOGNITION

Determine that a trouble exists. What are the symptoms of trouble/failure in your equipment?

________________________________________________________________

________________________________________________________________

________________________________________________________________

### STEP 2. SYMPTOM ELABORATION

Use built-in test features (panel meters and indications) for a more detailed determination of equipment failure symptoms. What are your findings?

________________________________________________________________

________________________________________________________________

________________________________________________________________

### STEP 3. LIST THE PROBABLE FAULTY FUNCTIONS

Use the functional block diagram and the test data obtained in steps 1 & 2 to determine the functions which could cause the problem. What are your conclusions?

________________________________________________________________

________________________________________________________________

________________________________________________________________

### STEP 4. LOCALIZING THE FAULTY FUNCTION/CIRCUIT BOARD

Select the order in which you will take readings to isolate the faulty function or circuit board. Take your readings and record your results.

| POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS | POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

FAULTY FUNCTION ________________________________________________

(OVER)

**STEP 5.** LOCALIZING THE FAULTY CIRCUIT

Bracket or half-split to isolate the circuit. Take and record your readings.

| POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS | POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

FAULTY CIRCUIT ______________________________

NOTE: OBTAIN MULTIMETER FROM SUPERVISOR, LCI Initials ______

**STEP 6.** FAILURE ANALYSIS

Use resistance readings to determine the faulty component. Determine the cause of the malfunction to prevent reoccurrence. Record your readings.

| POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS | POINT OF CHECK | REFERENCE READINGS | ACTUAL READINGS |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

FAULTY COMPONENT/PROBLEM ______________________________

CIRCUIT SYMBOL AND/OR MANUFACTURER'S PART NUMBER

EXPLAIN WHY THE FAULTY COMPONENT WOULD GIVE YOU THE TROUBLE SYMPTOMS YOU LISTED IN STEPS 1 & 2.

______________________________

______________________________

______________________________

______________________________

SUPERVISOR'S SIGNATURE ______________________________

# APPENDIX B

# DATA COLLECTION SHEET

DATA COLLECTION SHEET

SUBJECT NO ________

JOB PROGRAM? ________

SSN ________

CARD/FAULT # ____ ____

RECORDER ________

DATE ________

CATEGORY ________

TIME START ________

TIME ________

<u>TOTAL:</u>

POINTS ________

FAULT ________

COMMENTS: ________

________

________

________

1. ____ ____
2. ____ ____
3. ____ ____
4. ____ ____
5. ____ ____
6. ____ ____
7. ____ ____
8. ____ ____
9. ____ ____
10. ____ ____
11. ____ ____
12. ____ ____
13. ____ ____
14. ____ ____
15. ____ ____
16. ____ ____
17. ____ ____
18. ____ ____
19. ____ ____
20. ____ ____
21. ____ ____
22. ____ ____
23. ____ ____
24. ____ ____
25. ____ ____
26. ____ ____
27. ____ ____
28. ____ ____
29. ____ ____
30. ____ ____
31. ____ ____
32. ____ ____
33. ____ ____
34. ____ ____
35. ____ ____
36. ____ ____
37. ____ ____
38. ____ ____
39. ____ ____
40. ____ ____
41. ____ ____
42. ____ ____
43. ____ ____
44. ____ ____
45. ____ ____

46. ____ ____
47. ____ ____
48. ____ ____
49. ____ ____
50. ____ ____
51. ____ ____
52. ____ ____
53. ____ ____
54. ____ ____
55. ____ ____
56. ____ ____
57. ____ ____
58. ____ ____
59. ____ ____
60. ____ ____
61. ____ ____
62. ____ ____
63. ____ ____
64. ____ ____
65. ____ ____
66. ____ ____
67. ____ ____
68. ____ ____
69. ____ ____
70. ____ ____
71. ____ ____
72. ____ ____
73. ____ ____
74. ____ ____
75. ____ ____
76. ____ ____
77. ____ ____
78. ____ ____
79. ____ ____
80. ____ ____
81. ____ ____
82. ____ ____
83. ____ ____
84. ____ ____
85. ____ ____
86. ____ ____
87. ____ ____
88. ____ ____
89. ____ ____
90. ____ ____
91. ____ ____
92. ____ ____
93. ____ ____
94. ____ ____
95. ____ ____
96. ____ ____
97. ____ ____
98. ____ ____
99. ____ ____
100. ____ ____
101. ____ ____
102. ____ ____
103. ____ ____
104. ____ ____
105. ____ ____
106. ____ ____
107. ____ ____
108. ____ ____
109. ____ ____
110. ____ ____
111. ____ ____
112. ____ ____
113. ____ ____
114. ____ ____
115. ____ ____
116. ____ ____
117. ____ ____
118. ____ ____
119. ____ ____
120. ____ ____
121. ____ ____
122. ____ ____
123. ____ ____
124. ____ ____
125. ____ ____
126. ____ ____
127. ____ ____
128. ____ ____
129. ____ ____
130. ____ ____
131. ____ ____
132. ____ ____
133. ____ ____
134. ____ ____
135. ____ ____

## REFERENCES

Bales, J. (1983, October). Skinner: Use computer as teacher. APA Monitor, p. 2.

Carbonell, J. R. (1970). AI in CAI: An artificial-intelligence approach to computer-assisted instruction. IEEE Transactions on Man-Machine Systems, 11, 190-202.

Daniels, R. W., Datta, J. R., Gardner, J. A., & Modrich, J. A. (1975). Feasibility of automated electronic maintenance training (AEMT): Vol. 1. Design development and evaluation of an AEMT/ACQ-100 demonstration facility (NADC No. 75176-40). Warminster, PA: Naval Air Development Center. (NTIS No. AD-A020 873)

DePaul, R. A., Jr. (1981). Do automated maintenance dependency charts make paper-covered JPA's obsolete? In W. J. King & P. E. Van Hemel (Eds.), Toward improved maintenance training programs: The potentials for training and aiding the technician (pp. 25-32). Orlando, FL: Naval Training Equipment Center. (NTIS No. AD-A103 476)

Fink, C. D., & Shriver, E. L. (1978). Simulators for maintenance training: Some issues, problems and areas for future research (Report No. AFHRL-TR-78-27). San Antonio, TX: Brooks Air Force Base, HQ Air Force Human Resources Laboratory (AFSC).

Frazier, T. W. (1981). Assessment of automated aiding technology. In W. J. King & P. E. Van Hemel (Eds.), Toward improved maintenance training programs: The potentials for training and aiding the technician (pp. 49-54). Orlando, FL: Naval Training Equipment Center. (NTIS No. AD-A103 476)

Freedy, A., & Crooks, W. H. (1975). Use of an adaptive decision model in computer-assisted training of electronic troubleshooting. In W. J. King & J. S. Duva (Eds.), New concepts in maintenance trainers and performance aids (Report No. NAVTRAEQUIPCEN IH-255, pp. 71-80). Orlando, FL: Naval Training Equipment Center.

Hall, E. R., & Freda, J. S. (1982). A comparison of individualized and conventional instruction in Navy technical training (Tech. Rep. No. 117). Orlando, FL: Training Analysis and Evaluation Group, Department of the Navy (NTIS No. AD-A115 319).

Hall, R. I., & Blaisdell, F. J. (1975). Experience with instructor-prepared CAI troubleshooting lessons. In W. J. King & J. S. Duva (Eds.), New concepts in maintenance trainers and performance aids (Report No. NAVTRAEQUIPCEN IH-255, pp. 81-90). Orlando, FL: Naval Training Equipment Center.

Hill, W. F. (1971). Learning a survey of psychological interpretations (2nd ed.). Scranton, PA: Chandler.

Hunt, R. M., & Rouse, W. B. (1981). Problem-solving skills of maintenance trainees in diagnosing faults in simulated powerplants. Human Factors, 23, 317-328.

Johnson, W. B. (1981). Computer simulations in fault diagnosis training: An empirical study of learning transfer from simulation to live system performance (Doctoral dissertation, University of Illinois at Urbana-Champaign, 1980). Dissertation Abstracts International, 41, 4625A.

Johnson, W. B., & Fath, J. L. (1983). Design and initial evaluation of mixed-fidelity courseware for maintenance training. In A. T. Pope & L. D. Haugh (Eds.), Proceedings of the Human Factors Society 27th Annual Meeting (Vol. 2, pp. 1017-1021). Santa Monica, CA: Human Factors Society.

Johnson, W. B., & Rouse, W. B. (1982). Training maintenance technicians for troubleshooting: Two experiments with computer simulations. Human Factors, 24, 271-276.

Johnson, W. B., & Rouse, W. B. (1980). Computer simulations for faults diagnosis training: From simulation to live system performance. In G. E. Corrick, E. C. Haseltine, & R. T. Durst, Jr. (Eds.), Proceedings of the Human Factors Society 24th Annual Meeting (pp. 69-73). Los Angeles: Human Factors Society.

Kirby, P. J., & Gardner, E. M. (1976). Microcomputer controlled, interactive testing terminal development (Report No. AFHRL-TR-76-66). San Antonio, TX: Brooks Air Force Base, HQ Air Force Human Resource Laboratory (AFSC). (NTIS No. AD-A035 731)

Kottenstette, J. P., Steffen, D. A., & Lamos, J. P. (1980). Microterminal/microfiche system for computer-based instruction: Hardware and software development (Report No. AFHRL-TR-80-17). San Antonio, TX: Brooks Air Force Base, HQ Air Force Human Resources Laboratory (AFSC). (NTIS No. AD-A090 974)

Lamos, J. P. (1982). Microterminal/microfiche system for computer assisted testing and interactive instruction (Report No. AFHRL-TR-81- 37). Brooks Air Force Base, TX: Air Force Human Resources Laboratory (AFSC). (NTIS No. AD-A110 507)

Martin, T. H., Stanford, M. C., Carlson, R., & Mann, W. C. (1975). A policy assessment of priorities and functional needs for the military computer-assisted instruction terminal (Report No. ISI/RR-75 44). Arlington, VA: Human Resources Research Office. (NTIS No. AD-A019 398)

McDonald, L. B., Waldrop, G. P., & White, V. T. (1982). Analysis of fidelity requirements for electronic equipment maintenance (Tech. Rep. No. NAVTRAEQUIPCEN 81-C-0065-1). Orlando, FL: Naval Training Equipment Center.

Moore, J. W., Manning, S. A., & Smith, W. I. (1978). Conditioning and instrumental learning (2nd ed.). New York: McGraw-Hill.

Orlansky, J., & String, J. (1981). Cost-effectiveness of maintenance simulators for military training (IDA Paper P-1568). Washington, DC: Office of the Under Secretary of Defense for Research and Engineering (NTIS No. AD-A108 717)

Orlansky, J., & String, J. (1979). Cost-effectiveness of computer-based instruction in military training (IDA Paper P-1375). Washington, DC: Office of the Under Secretary of Defense for Research and Engineering. (NTIS No. AD-A073 400)

Rouse, W. B. (1979a). Problem solving performance of first semester maintenance trainees with two fault diagnosis tasks. Human Factors, 21, 611-618.

Rouse, W. B. (1979b). Problem solving performance of maintenance trainees in a fault diagnosis task. Human Factors, 21, 195-203.

Rouse, W. B., Rouse, S. H., Hunt, R. M., Johnson, W. B., & Pellegrino, S. J. (1980). Human decision-making in computer aided fault diagnosis (Tech. Rep. No. 434). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-OK). (NTIS No. AD-A086 457)

Stevens, A., Roberts, B., Stead, L., Forbus, K., Steinberg, C., & Smith, B. (1982). Project steamer: VI. Advanced computer aided instruction in propulsion engineering--an interim report (Report No. NPRDC TR 82-28). San Diego, CA: Naval Personnel Research and Development Center. (NTIS No. AD-A110 797)

Towne, D. M. (1981). The automated integration of training and aiding information for the operator/technician. In W. J. King & P. E. Van Hemel (Eds.), Towards improved maintenance training programs: The potentials for training and aiding the technician (pp. 63-72). Orlando, FL: Naval Training Equipment Center. (NTIS No. AD-A103 476)

U. S. Navy Service School Command. (1982). Instructional procedures manual: Basic Electricity and Electronics School. Orlando, FL: Chief of Navy Technical Training, Department of the Navy.

Vernon, W. M. (1976). Introductory psychology a personalized textbook (3rd ed.). Chicago: Rand McNally College Publishing Company.

Wilper, B. L., & Eschenbrenner, A. J. (1983). Formats for electronic display of maintenance illustrations: A preliminary evaluation (Report No. AFHRL-TP-83-5). San Antonio, TX: Brooks Air Force Base, HQ Air Force Human Resources Laboratory (AFSC). (NTIS No. AD-A129 408)