AD 752 999



AD

# NAVAL PERSONNEL AND TRAINING RESEARCH LABORATORY

SAN DIEGO, CALIFORNIA 92152

RESEARCH REPORT SRR 73-13

NOVEMBER 1972

## COMPUTER ASSISTED INSTRUCTION IN NAVY TECHNICAL TRAINING USING A SMALL DEDICATED COMPUTER SYSTEM: FINAL REPORT

John D. Ford, Jr.
Dewey A. Slough
Richard E. Hurlock

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

NPTRL
NAVAL PERSONNEL AND TRAINING RESEARCH LABORATORY
SAN DIEGO CALIFORNIA

DEPARTMENT OF THE NAVY
NAVAL PERSONNEL AND TRAINING
RESEARCH LABORATORY
SAN DIEGO, CALIFORNIA 92152

IN REPLY REFER TO:
90:rd
43-03X.03a
Ser 781
13 DEC 1972

From: Commanding Officer
To: Distribution List

Subj: Research Report SRR 73-13, Computer Assisted Instruction in Navy Technical Training Using a Small Dedicated Computer System: Final Report

Encl: (1) Subject Report with Summary attached

1. Under the direction of the Chief of Naval Personnel (Pers-A3), this Laboratory has conducted advanced development concerned with application of computer assisted instruction techniques to enlisted training and is distributing as enclosure (1) copies of the final report to addressees for information and retention. The Summary attached to the report gives a brief overview and the final conclusions and recommendations which should be of use to those not having the time or need to read the entire report.

2. Distribution of enclosure (1) to cognizant offices within BUPERS has already been accomplished.

F L Nelson
F. L. NELSON

Distribution:
Chief of Naval Operations (OP-964)
(OP-39)
(OP-099)
(OP-29)
(OP-59)
Chief of Naval Technical Training (Code 34)
Office of Naval Research (Code 458) (2)
Commanding Officer, Service School Command, Naval Training Center, SDiego
Commanding Officer, Naval Training Equipment Center, Orlando
Commanding Officer, Naval Personnel Research and Development Laboratory
Superintendent, Naval Academy, Annapolis
Technical Director, CAI project, U. S. Army Signal Center and School, Fort Monmouth
Air Force Human Resources Laboratory, Brooks Air Force Base, Texas
Office of Assistant Secretary of Defense (Manpower and Reserve Affairs)
Defense Documentation Center (12)
Air Training Command, Randolph Air Force Base, Texas (3)

90:rd
43-03X.03a
Ser 781

Subj: Research Report SRR 73-13, Computer Assisted Instruction in Navy Technical Training Using a Small Dedicated Computer System: Final Report

---

Human Resources Research Organization (HumRRO)
COMASWFORLANT (Code 711)
U. S. Army Behavior and Systems Research Laboratory
Chief of Naval Training (Code 017)
Chief of Naval Training (CNT-N5)
Navy Education and Training Support Center, SDiego
Department of the Navy, Navy Recruiting Command, Washington, D. C.
Center for Naval Analyses, Arlington, Virginia
Chief of Naval Training Support
Commanding Officer, Service School Command, Naval Training Center, GLakes
Commanding Officer, Service School Command, Naval Training Center, Orlando
Commanding Officer, Navy Schools Command, Treasure Island, SFrancisco
Superintendent, Naval Post Graduate School, Monterey
Commandant, Marine Corps Headquarters, Washington, D. C.
Commanding General, Marine Corps Development and Education Command, Quantico
President, Naval War College, Newport, R. I.

Naval Personnel and Training Research Laboratory, San Diego, California 92152
"Computer Assisted Instruction in Navy Technical Training Using a Small Dedicated Computer System: Final Report," SRR 73-13 of November 1973, 43-03X.03a.


SUMMARY

Problem

This project is part of Advanced Development Objective P43-03X, Education and Training. The objectives of the project are to develop computer assisted instruction (CAI) techniques and methods, to test CAI training modules derived from these techniques and to investigate the feasibility of integrating CAI into Navy training. This is the final report on the development and evaluation of CAI techniques which were derived for a small dedicated computer system. The computer system used was the IBM 1500 Instructional System and the curriculum was taken from Basic Electricity/Electronics (BE/E) School. The project included three major development and evaluation areas: (1) instructional strategies for CAI, (2) computer based evaluation and revision methods, and (3) empirical evaluation of the effectiveness of CAI.

Approach

The development of CAI lessons consisted of a series of steps beginning with identification of training objectives and construction of criterion tests and continuing with planning of instructional sequences and strategies, preparation of lesson materials, review and revision of lessons, coding and checkout, student tryouts, analysis of lesson deficiencies, revision of lessons, and operational tests. In the process of developing CAI materials a number of special branching strategies were developed to provide pretest branching, branched remediation, student control of instructional sequences, dual control of practice by both student and program, and optional reviews.

The analysis of student performance to identify lesson deficiencies required the development of a new student performance data management system. A complete revision methodology was also developed to assist in the revision process.

For the experimental evaluation of CAI training, students from the BE/E School were randomly selected and received a segment of their training by means of CAI. They then returned to class for the remainder of their training. A total of 760 students were used during student tryouts and operational tests. These students used more than 10,197 terminal hours of CAI.

Findings and Conclusions

Computer assisted instruction provided a very effective method of training. CAI students scored higher than class instructed students on both the School Examinations and the Supplemental Tests. CAI required 39% to 54% less training time than class instruction. Students gave high ratings to their CAI instruction and would prefer to have about 70% to 80% of their instruction via CAI.

Extended experience with CAI did not have a detrimental effect. On the contrary, long term CAI was found to produce a small improvement in training time and an increase in the students' preference for CAI. Posttest performance was not affected.

Computer based training methods are ideally suited to the development of good instruction because the computer performance recording and processing capabilities make it possible to improve instruction to any required level. Data analysis and summary programs were developed in this project which allowed lesson designers to identify specific course weaknesses. Course revisions based on these analyses resulted in marked improvements in instruction.

Although CAI showed about a 45% time savings over group instruction, there is reason to believe that the efficiency of CAI can be improved even further. To do this, increased use must be made of branching technology in order to provide instruction which is maximally adaptive to individual differences. A number of advances in branching technology were made in this project and incorporated into the later lessons. The result was an improvement in student performance over the previous less adaptable CAI. In addition, it was found that student option was just as effective as control of training by means of pretests. The use of student option simplifies course preparation. Finally, it was found that dual control of drill and practice using a combination of program control and student option was superior to strict program control.

The most costly and time consuming part of CAI course development was the initial preparation of basic instruction -- computer coding and programming of these materials took far less effort. CAI shares this materials development problem with all forms of individualized instruction.

The evaluation of CAI using the IBM 1500 system was made in terms of technical and economic feasibility. These included such factors as training effectiveness, software and hardware limitations, operational limitations and cost data. CAI using the 1500 system was found to be highly effective. Serious hardware and software limitations occurred in programming of advanced instructional logics in COURSEWRITER II, using graphic displays, storing sufficient lesson material on-line, obtaining short system response times with complex instructional materials, and using the random access audio. A major operational limitation is the maximum of 32 terminals for a single 1500 system. Capital costs for the system are several times higher on a per terminal basis than newer CAI systems with larger terminal capacities.

Systems such as the IBM 1500 system can compete costwise with classroom instruction in some applications. However they are generally not cost effective in comparison to individualized instruction. The newer CAI systems, such as TICCET and PLATO IV, will be cost effective compared to off-line individualized instruction, and will provide greatly improved computer based training capabilities.

UNCLASSIFIED
Security Classification

## DOCUMENT CONTROL DATA - R & D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

1 ORIGINATING ACTIVITY (Corporate author)
Naval Personnel and Training Research Laboratory
San Diego, California 92152

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3 REPORT TITLE
COMPUTER ASSISTED INSTRUCTION IN NAVY TECHNICAL TRAINING USING A SMALL DEDICATED COMPUTER SYSTEM: FINAL REPORT

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (First name, middle initial, last name)
John D. Ford, Jr., Dewey A. Slough, and Richard E. Hurlock

| 6 REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| November 1972 | 69 | 10 |

8a CONTRACT OR GRANT NO

b. PROJECT NO ADO 43-03X.03a

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
SRR 73-13

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11 SUPPLEMENTARY NOTES

12 SPONSORING MILITARY ACTIVITY
Chief of Naval Personnel (Pers-A3)
Department of the Navy
Washington, D. C. 20370

13 ABSTRACT
This project investigated the feasibility of CAI for Navy technical training. The computer system used was the IBM 1500 system. The curriculum was taken from Basic Electricity/Electronics School. Five CAI modules were developed which could replace 92 hours of the class curriculum.

CAI provided very effective and efficient instruction. CAI students scored higher than class-instructed students on School Examinations as well as Supplemental tests, and required about 45% less training time. Student attitudes were quite favorable to CAI.

A complete CAI data management and course revision methodology was developed in this project. Revisions using this methodology resulted in marked improvements in instruction.

A number of new developments were made in branching technology for use in remediation, training, drill and practice, and review. Incorporation of these developments into CAI lessons was shown to produce substantial reductions in training time.

Although the CAI training was very effective, the 1500 system is not economically feasible for training in basic electronics because of the limitation of 32 terminals and its relatively high cost. Newer systems will be cost effective for such applications.

| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Computer assisted instruction | | | | | | |
| Computer based training | | | | | | |
| Educational technology | | | | | | |
| Instructional methodology | | | | | | |
| Individualized training | | | | | | |
| Branching Techniques | | | | | | |
| Course revision methodology | | | | | | |

AD

# COMPUTER ASSISTED INSTRUCTION IN NAVY TECHNICAL TRAINING USING A SMALL DEDICATED COMPUTER SYSTEM: FINAL REPORT

by

John D. Ford, Jr.
Dewey A. Slough
Richard E. Hurlock

November 1972

ADO 43-03X.03a
Research Report SRR 73-13

Submitted by

John D. Ford, Jr., Ed.D., Director, Computer Based Training and Simulation Research Department

Approved by

E. I. Jones, Ph.D., Technical Director
F. L. Nelson, Captain, USN
Commanding Officer



Navy Training Research Laboratory
Naval Personnel and Training Research Laboratory
San Diego, California 92152

A LABORATORY OF THE BUREAU OF NAVAL PERSONNEL

# SUMMARY

## Problem

This project is part of Advanced Development Objective P43-03X, Education and Training. The objectives of the project are to develop computer assisted instruction (CAI) techniques and methods, to test CAI training modules derived from these techniques and to investigate the feasibility of integrating CAI into Navy training. This is the final report on the development and evaluation of CAI techniques which were derived for a small dedicated computer system. The computer system used was the IBM 1500 Instructional System and the curriculum was taken from Basic Electricity/Electronics (BE/E) School. The project included three major development and evaluation areas: (1) instructional strategies for CAI, (2) computer based evaluation and revision methods, and (3) empirical evaluation of the effectiveness of CAI.

## Approach

The development of CAI lessons consisted of a series of steps beginning with identification of training objectives and construction of criterion tests and continuing with planning of instructional sequences and strategies, preparation of lesson materials, review and revision of lessons, coding and checkout, student tryouts, analysis of lesson deficiencies, revision of lessons, and operational tests. In the process of developing CAI materials a number of special branching strategies were developed to provide pretest branching, branched remediation, student control of instructional sequences, dual control of practice by both student and program, and optional reviews.

The analysis of student performance to identify lesson deficiencies required the development of a new student performance data management system. A complete revision methodology was also developed to assist in the revision process.

For the experimental evaluation of CAI training, students from the BE/E School were randomly selected and received a segment of their training by means of CAI. They then returned to class for the remainder of their training. A total of 760 students were used during student tryouts and operational tests. These students used more than 10,197 terminal hours of CAI.

## Findings and Conclusions

Computer assisted instruction provided a very effective method of training. CAI students scored higher than class instructed students on both the School Examinations and the Supplemental Tests. CAI required 39% to 54% less training time than class instruction. Students gave high ratings to their CAI instruction and would prefer to have about 70% to 80% of their instruction via CAI.

Extended experience with CAI did not have a detrimental effect. On the contrary, long term CAI was found to produce a small improvement in training time and an increase in the students' preference for CAI. Posttest performance was not affected.

Computer based training methods are ideally suited to the development of good instruction because the computer performance recording and processing capabilities make it possible to improve instruction to any required level. Data analysis and summary programs were developed in this project which allowed lesson designers to identify specific course weaknesses. Course revisions based on these analyses resulted in marked improvements in instruction.

Although CAI showed about a 45% time savings over group instruction, there is reason to believe that the efficiency of CAI can be improved even further. To do this, increased use must be made of branching technology in order to provide instruction which is maximally adaptive to individual differences. A number of advances in branching technology were made in this project and incorporated into the later lessons. The result was an improvement in student performance over the previous less adaptable CAI. In addition, it was found that student option was just as effective as control of training by means of pretests. The use of student option simplifies course preparation. Finally, it was found that dual control of drill and practice using a combination of program control and student option was superior to strict program control.

The most costly and time consuming part of CAI course development was the initial preparation of basic instruction -- computer coding and programming of these materials took far less effort. CAI shares this materials development problem with all forms of individualized instruction.

The evaluation of CAI using the IBM 1500 system was made in terms of technical and economic feasibility. These included such factors as training effectiveness, software and hardware limitations, operational limitations and cost data. CAI using the 1500 system was found to be highly effective. Serious hardware and software limitations occurred in programming of advanced instructional logics in COURSEWRITER II, using graphic displays, storing sufficient lesson material on-line, obtaining short system response times with complex instructional materials, and using the random access audio. A major operational limitation is the maximum of 32 terminals for a single 1500 system. Capital costs for the system are several times higher on a per terminal basis than newer CAI systems with larger terminal capacities.

Systems such as the IBM 1500 system can compete costwise with classroom instruction in some applications. However they are generally not cost effective in comparison to individualized instruction. The newer CAI systems, such as TICCET and PLATO IV, will be cost effective compared to off-line individualized instruction, and will provide greatly improved computer based training capabilities.

## REPORT USE AND EVALUATION

Feedback from consumers is a vital element in improving products so that they better respond to specific needs. To assist the Chief of Naval Personnel in future planning, it is requested that the use and evaluation form on the reverse of this page be completed and returned. The page is preaddressed and franked; fold in thirds, seal with tape, and mail.

---

Department of the Navy

Postage and Fees Paid
Navy Department

Official Business

Commanding Officer
Naval Personnel and Training Research Laboratory
San Diego, California 92152

---

Report Title & No: COMPUTER ASSISTED INSTRUCTION IN NAVY TECHNICAL TRAINING USING A SMALL DEDICATED COMPUTER SYSTEM: FINAL REPORT, SRR 73-13

1. Evaluation of Report. Please check appropriate column.

| FACTORS | RATING | | | COMMENTS |
| --- | --- | --- | --- | --- |
| | LOW | AVE | HIGH | |
| Usefulness of Data | | | | |
| Timeliness | | | | |
| Completeness | | | | |
| Technical Accuracy | | | | |
| Validity of Recommendations | | | | |
| Soundness of Approach | | | | |
| Presentation and Style | | | | |
| Other | | | | |

2. Use of Report. Please fill in answers as appropriate.

a. What are your main uses for the material contained in the report?

b. What changes would you recommend in report format to make it more useful?

c. What types of research would be most useful to you for the Chief of Naval Personnel to conduct?

d. Do you wish to remain on our distribution list?

e. Please make any general comments you feel would be helpful to us in planning our research program.

NAME: ______________________ CODE: ________

ORGANIZATION: ______________________

ADDRESS: ______________________

CONTENTS

CONTENTS (Continued)

## TABLES



## FIGURES

## Acknowledgments

Appreciation is expressed to the Commanding Officer, Service School Command, Naval Training Center, San Diego, and to the Director and instructional staff of the Basic Electricity/Electronics School of that Command for their cooperation and assistance. The support provided was an important factor in the successful completion of the project.

Also, appreciation is expressed to the project staff for their dedicated efforts. These include: B. D. Ellis, Mrs. Patricia S. Fredericks, W. A. King, G. F. Lahey, P. H. McCann, A. Sassano, W. L. Sarati, and Mrs. Betty S. Whitehill. The following staff members assisted during part of the project: J. A. Fey, EMCS, USN, H. E. Hash, RMC, USN, Mrs. Robin Overholt, Dr. Josephine Randel, Mrs. Doris J. Slough, L. C. Walter, ICC (SS), USN, J. H. Wilson, RMC, USN, and the late A. L. Wright, ETCS, USN.

COMPUTER ASSISTED INSTRUCTION IN NAVY TECHNICAL TRAINING USING A SMALL DEDICATED COMPUTER SYSTEM: FINAL REPORT

## I. Description of the Project

### A. Mission

The objectives of this project are to develop computer assisted instruction (CAI) techniques and methods, to test CAI training modules derived from these techniques and to investigate the feasibility of integrating CAI into Navy training. This is the final report on the development and evaluation of CAI techniques which were derived for a small dedicated computer system. The computer system used was the IBM 1500 Instructional System and the curriculum was taken from Basic Electricity/Electronics (BE/E) School.

This project is part of Advanced Development Objective P43-03X, Education and Training. Other projects in that ADO which test applications of computers to instruction include the CAI project at the Naval Academy (Final Report, 1971) and the computer managed instruction (CMI) project at the Naval Technical Training Command, Memphis.

The objective of ADO P43-03X is to test the feasibility of available new advances in training technology, performance standards, proficiency measurement, and training equipment as a means for providing and maintaining increased personnel capability. The Navy faces increasing demands for highly skilled personnel to operate and maintain complex electronic equipment. There is a need to provide training which is more job related, can be accomplished in a shorter period of time, and is adaptive to a wide range of backgrounds and aptitudes in the recruit population.

Much of Navy training uses classroom instruction. There are inherent limitations in this type of training, including the following: (1) inadequate mastery of all of the training objectives by some of the students, (2) waste of student time due to inefficient learning sequences and pacing of class to average or below average learning rate, (3) variation in quality of instruction both across instructors and by the same instructor from day-to-day, and (4) patterning instruction to some hypothetical average rather than to the needs of individuals in rate and type of learning required to achieve training objectives. Conventional classroom methods critically limit, or render nearly impossible, efforts to individualize instruction. Furthermore, classroom effectiveness is subject to variation because of instructor differences and stressful conditions such as time pressure and large class size. A high turnover rate among instructors aggravates these problems by constantly eroding experience, instructional competency, and knowledge of local classroom innovations. Without drastic changes in the technology of classroom operation, it seems highly unlikely that little more than minor improvement can be expected.

The application of computer technology to the individualizing of instruction provides a promising means of overcoming the deficiencies of classroom instruction. Computer assisted instruction permits: (1) precise control of presentation of information to the student, (2) immediate processing of student responses combined with presentation of appropriate "feedback" information, (3) branching or altering of sequence of training contingent upon student's progress, and (4) collection and processing of highly detailed student response data.

## B. CAI Problems Investigated

As the project progressed three major development areas became defined more precisely: (1) instructional strategies for CAI, (2) computer based evaluation and revision methods, and (3) development, evaluation and revision of CAI course materials for the target application. A general evaluation of CAI was made in two ways. First, a comparison was made of CAI with standard classroom instruction. These results are described in the first two parts of Section III. Second, and more important from a research and development standpoint, was the development and evaluation of new CAI technologies. These new technologies are described in Section II and results of evaluation are described in Section III. An evaluation of the 1500 system is given in Section IV. Such an evaluation must include the entire matrix of instructional technologies developed for the system and not solely the technical or engineering characteristics of the computer and terminals. Thus, other sections of the report also relate to the evaluation of CAI which employ the 1500 system as the materials development and delivery system.

## C. Staff Resources and Organization

To conduct a CAI project a mix of staff skills and resources is needed. One set of resources involves skills in research methods, research design, conducting experiments, analyzing and interpreting results, and developing new instructional techniques and strategies. Staff persons having these skills were research psychologists and education specialists. At maximum, there were ten persons on the project having these skills but by the conclusion of the 1500 evaluation project there were eight, because not all vacancies created by turnover were filled. A second set of skills were those related to computer programming and operation. System and application programming as well as computer operation and computer aid skills were represented in this group. Early in the project there were four persons in this group but later the number was reduced to three. Subject matter skills were provided by two military instructors assigned from the Basic Electricity/Electronics School, Service School Command, Naval Training Center, San Diego. Later this number was reduced to one billet. Finally, on-line coding and debugging of lessons, which had been designed by the professional and technical staff, was provided by four part time California State University students. They also assisted in the tryout and evaluation of CAI materials.

The staff was organized into two CAI design and evaluation groups, each under the direction of a Program Director. Each group was responsible for the entire cycle of design and experimental evaluation of CAI course modules including the development of experimental CAI techniques. The two groups operated in parallel and were in different stages of the design process at any given time. This prevented peak loads or demands from building up on limited resources, such as terminal capacity, student performance data processing using the 1500 system, and the availability of students from the school.

## D. 1500 System and Instructional Facilities

The IBM 1500 Computer System was installed April 1968 and remained operational continuously until removed on 30 June 1972. Computer hardware as first installed consisted of an IBM 1130 Computer with 32K memory and the following on-line equipment: a line printer (80 lines per minute) and five disk drives with removable single cartridge disks. A multiplexing station control unit was the connecting link to the eight terminal stations. The terminals were equipped with both an image projector and a cathode ray tube (CRT) display unit with keyboard and light pen (Figure 1). The image projector utilized a film cartridge that allowed random access to 1000 images. In addition, three of the terminals had typewriters which could produce hard copy for special requirements. In 1969 the system was enlarged to 16 terminals and two tape drives were added to the system. Random access audio units were installed at 12 of the terminals.

The equipment was installed in two converted classrooms and a small storage room. Air conditioning was installed to provide the environment necessary for the computer hardware. The IBM 1130 computer and on-line peripheral equipment plus two terminal stations occupied one room. The 14 remaining terminal stations were assigned to two rooms (see Figure 1). Each student carrel was designed to allow room for both computer controlled equipment and auxiliary equipment. Auxiliary laboratory equipment consisted of audio signal generators, simple oscilloscopes, vaccuum tube voltmeters, multimeters, NEAT boards (Navy Electronics Application Trainers), capacitor displays, and lamp boards. Auxiliary laboratory equipment, except for the capacitor displays and lamp boards, was furnished by the Basic Electricity/Electronics School and was the same type used by the school. In some lessons, the auxiliary equipment was used by students under guidance of the computer. The computer provided help options and evaluated student measurements.

The 1500 operating system included an executive program for both time sharing and data processing modes. The 1130 system monitor also provided additional data processing capabilities. A number of utilities were supplied with the system, such as disk-to-card, card-to-disk, tape-to-disk, and disk-to-tape. Data processing programs were not supplied by IBM but were developed as part of this project. These included a student performance data extraction program and several sort and data summary programs to provide student performance data to authors for lesson evaluation and revision.

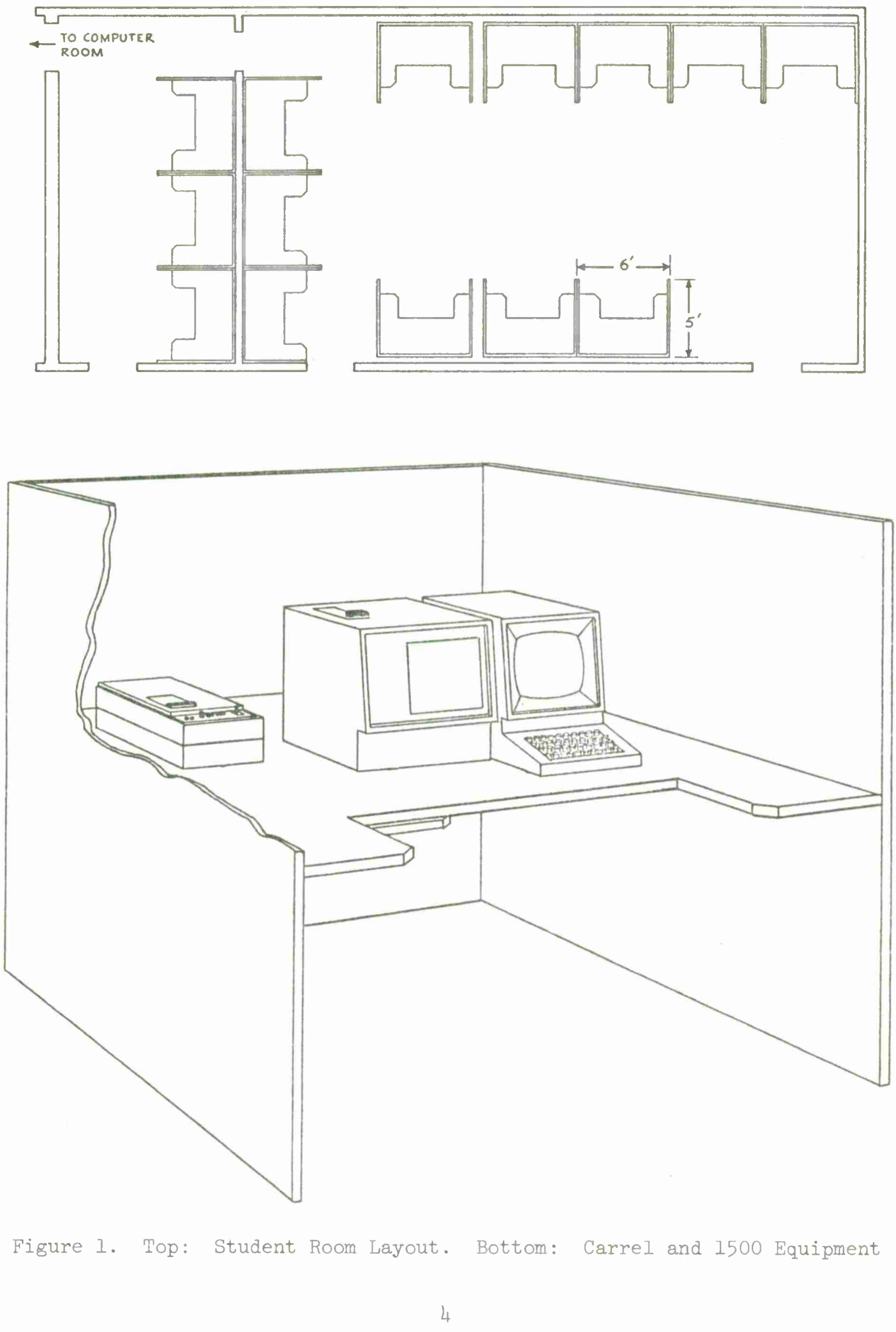



Figure 1. Top: Student Room Layout. Bottom: Carrel and 1500 Equipment

## E. Basic Electricity/Electronics School

The curriculum of the Basic Electricity/Electronics School represents a common core of knowledges and skills in the fundamentals of electricity and electronics as needed for subsequent training in a number of Navy ratings. Thus, the school is a feeder school for "A" schools for a variety of ratings: Aviation Electrician's Mate, Aviation Electronics Technician, Communications Technician, Data Processing Technician, Data Systems Technician, Electrician's Mate, Electronics Technician, Fire Control Technician, Interior Communications Electrician, Sonar Technician (Surface), Sonar Technician (Submarines), Torpedoman, and Electronics Warfare Technician.

A large percentage of the students enter the school following recruit training. The remaining students are assigned from the fleet. The recruits selected are middle to high aptitude individuals as measured by classification tests.

The selection criteria vary for the "A" schools. Different combinations of two or three aptitude tests are used by the schools and the minimum entrance scores vary. In addition, interviewers for recruits, and commanding officers for students from the fleet, can recommend exceptions to the qualification requirements. There is wide variation also in previous background in or knowledge of electronics. The range is from no high school related experience to two or more years of college.

The student load fluctuates during the year. Student aptitude varies on a seasonal basis, probably reflecting school graduation schedules. The on board count averages 300 to 500 students.

Originally, the school had three tracks of seven, eight, and nine weeks, with the lower aptitude students on the longer tracks. In 1968 the tracks were shortened to six, seven, and eight weeks. At the time the CAI AC Module was tested, there were seven or eight new classes convening each week. Students were divided into four different ability tracks and the time to complete the class instructed course was six to eight weeks, depending on the track.

In 1969 all students were put on a single six-week class instructed track. This arrangement existed during the operational testing of the CAI Inductance Module, Capacitance Module, DC Module and the AC Series Circuits and Resonance Module. The last classes of six-week track students, before full operation of the new individualized training curriculum, were used in the Long Term CAI Study.

The School curriculum during the above period was divided into eight topic areas of instruction given over a six week period. Class instruction consisted primarily of lectures, question and answer discussion periods, drill and practice sessions, assignment sheets, and demonstrations and short laboratory exercises. Course credit for each area was determined by an Area Examination. A summary outline of each area and the scheduled training time is shown below:

| BE/E School Curriculum | | Allotted Class Time |
|---|---|---|
| Area 1 | Matter/Electrostatics/Magnetism | 12 hours |
| Area 2 | Voltage/Current/Resistance | 20 hours |
| Area 3 | DC Circuits | 34 hours |
| Area 4 | AC Theory | 14 hours |
| Area 5 | Inductance/Capacitance | 34 hours |
| Area 6 | AC Series Circuits | 34 hours |
| Area 7 | AC Parallel Circuits | 34 hours |
| Area 8 | Power Transformers | 8 hours |

During 1970 and 1971 the classroom curriculum was replaced with an individualized learning program, called Basic Electricity/Electronics Individualized Learning System (BEEINLES). There were enough changes in the objectives, and hence the content of training, such that the classroom and individualized curricula were not compatible or interchangeable. Separate tests were used for the two programs. The BEEINLES curriculum was divided into 15 units called modules. Each module consisted of a Module Booklet divided into self instructional lessons. Each lesson contained a list of training objectives, an overview, a narrative, summary, programmed instructional materials, and a self administered progress test. Supplemental materials included audio instruction via cassette and film strip cartridges. Each student was free to use any part or all of the available materials and to choose when he would take the Module Examination which required a passing score before continuing. This change in curriculum and training objectives made it necessary to revise the CAI AC Series Circuits and Resonance Module into a new module, CAI AC Series Circuits, for the experimental evaluation of student option versus program controlled branching methods.

## II. Development of CAI Technology

### A. CAI Development and Revision Process

#### 1. Module Development

The steps in design and evaluation of each CAI module are flowcharted in Figure 2. Development of each CAI module began by using a team approach to determine and specify the course training objectives. The CAI training objectives were locked into the training objectives of the Basic Electricity/Electronics School curriculum. This was necessary because the students who were used in this project were taken from regular classes and had to be trained on the same training objectives as all other students.

There were three major sources for the training objectives: (1) Preliminary Instructor's Guide (August 1967), (2) Trainee's Textbook, Fundamentals of Electronics, (NAVPERS 93400A-1b), and (3) Trainee's Guide, (NAVPERS 93518-2b). In addition, the School Area Examinations were checked to cross reference all objectives actually tested. Because most of the school objectives were stated in general terms, it was necessary to rewrite them into behavioral statements which specifically defined the desired terminal criterion behavior of the student. A behaviorally stated CAI training objective specified the exact stimulus conditions to which the student would respond, the required response and sometimes the level of performance required. The purpose of behavioral CAI training objectives was to provide CAI authors with a clear statement of the material to be taught and to assist in the development of criterion questions to evaluate CAI training. This also allowed the authors to select appropriate training strategies and to save training time by eliminating irrelevant instruction.

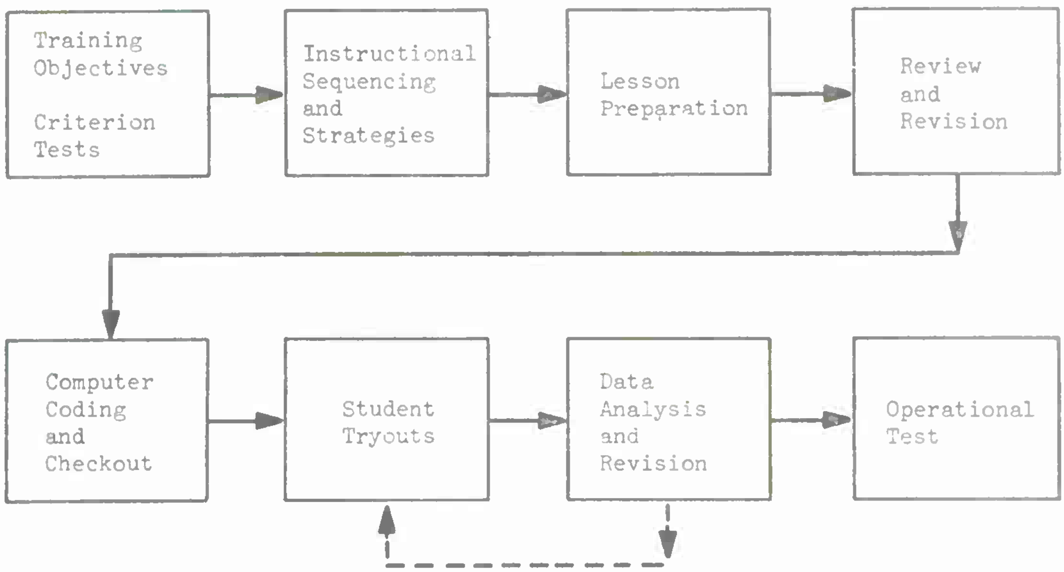



Figure 2. Steps in design and evaluation of CAI course module.

After all behaviorally stated training objectives were completed the second step consisted of grouping them into meaningful content units. Each content unit was then designated to become one or more individual CAI lessons. Finally the CAI lessons were assigned into a tentative sequence within the module. The school curriculum prescribed a sequence of training objectives and lesson plans. Because of the way students were shunted to CAI modules for training and then returned to the class for the remainder of their training, the overall sequence of topics or areas in the school curriculum had to be followed. However, sequencing within each area was under control of lesson designers who planned and wrote the CAI lessons. In this sequencing, the hierarchical arrangement of concepts within the subject matter was emphasized. Because of the progressive building of concepts and principles in electronics, attention was given to sequencing which would facilitate transfer to the learning of higher order concepts and principles. The initial sequencing which was decided upon was subject to evaluation and revision based upon empirical data from student tryouts.

2. Lesson Development

Individual authors of the team were responsible for detailed development of their assigned lessons. After lessons were assigned to individual authors, steps in the development of the lessons consisted of: (1) background familiarization with subject matter and determining instructional sequence and strategy; (2) writing criterion questions for each training objective; (3) writing the instructional sequences for each training objective; (4) team leader and subject matter specialist's critical review of drafted CAI lessons followed by corresponding corrections and changes by the author; (5) on-line coding of course materials and author checkout and debugging; (6) module tryouts for revision evaluation; and (7) revisions.

a. Criterion test items. An integral part of developing CAI lessons was the writing of criterion test items to be used to measure and evaluate training effectiveness. The actual writing of criterion test items also served to emphasize to authors the desired terminal behavior required by the training objectives.

A set of parallel criterion questions was written for each behavioral objective and used at three specific points during and after training:

(1) Immediately after a sequence of training frames at a point where the author could adequately determine the effectiveness of the training strategy and often at the end of the lesson as part of a drill and practice review;

(2) Within the Lesson Test to evaluate short-term memory and retention; and

(3) Within the Supplemental Test at the completion of the module to measure long-term memory.

There were usually four forms of each School Area Examination. Item analyses of these forms showed that 46 to 64% of the CAI behavioral training objectives were either untested or tested on less than two forms of an Examination. The School Examinations were, therefore, "norm-referenced" and designed to evaluate a student's performance relative to other students and not to the training criteria. For this reason Supplemental Tests were developed to evaluate performance on the "under tested" training objectives. Thus together, any form of the School Examination plus the corresponding Supplemental Test evaluated approximately 95% of the total training objectives and provided a "criterion-referenced" measurement for comparing training methods.

b. Instructional sequencing and strategies. Derivation of training objectives and criterion test items focused upon the content of behaviors and skills to be learned. Sequencing of objectives required consideration of both the content organization inherent in the subject matter and the types of learning which were required by the objectives. Instructional strategies focused upon the types of learning required by the training objectives, the conditions of learning, and types of learning difficulties encountered by the population of students who receive the training.

Individual authors were allowed to develop individual lesson styles during the first generation CAI modules, AC Theory and Inductance. These modules were developed concurrently by two different CAI course development teams. The resulting CAI course materials followed a fixed sequence instructional design which required all students to receive training across all training objectives. Individualization of instruction was limited to giving differential response feedback, within frame branching, some back branching within training and practice sequences, and optional student branching review. In other words, except for variations in the instruction just described, all students were given fixed sequence training on all training objectives in every CAI lesson.

At the onset of planning the second generation CAI modules, Capacitance, Direct Current, and Series Circuits and Resonance, the authoring teams began examining the possibilities of making greater usage of computer capabilities to adapt CAI to meet the training needs of individual students. Although fixed sequence CAI proved to be superior to classroom instruction in previous modules, it still retained the inherent disadvantage of providing either too little training for the slow learning or low aptitude student or too much training for the sophisticated, fast learning, or high aptitude student. It was concluded that the lesson programing logics controlling the flow of instruction would have to be highly sensitive to the response history and learning characteristics of each student in order to achieve the goal of adaptive CAI training. A major approach to this problem was the use of branching logics which would allow either the program or the student to determine the amount of instruction and/or practice received on each behavioral training objective. These strategies included pretest branching, student controlled training, optional practice, dual-control practice, and optional review. Section II.B. discusses details of these instructional strategies.

c. Lesson material preparation. Lesson preparation is the most difficult of all the steps in CAI course development. There is a strong tendency for lesson designers who have had teaching experience to write "lecture frames." Only after these habits are unlearned do lesson designers become effective in writing instructional CAI materials.

The preparation of lesson material included the writing of the actual training content, determining when and what kinds of responses were to be required of students, specifying the conditions of branching and student data to be used for making branching decisions, preparing drafts of all visual presentations and where appropriate writing audio scripts to be used in conjunction with the lessons. Authors made extensive use of flow charts as an aid whenever complex branching logics were employed in a lesson.

When all training sequences, optional reviews and special branching sequences were written, the next step for the author was to transpose each frame onto a special frame-planning form. In summary, the "Author-Coder Frame Planning Guide" was a form, developed within this project, which enabled lesson designers to plan the layout of each frame of a lesson. In addition to the instructional content and visual stimulus format, all control information necessary for computer programing was also entered on this form. This method greatly facilitated the preparation and editing of lesson material. It was also an efficient way to document and transmit the lesson to the person responsible for the next step of coding and program checkout.

d. Author-coder frame planning guide. An example of use of the frame planning guide is shown in Figure 3. Notations on the frame planning

AUTHOR-CODER FRAME PLANNING GUIDE

PRR X  PR __

FRAME IDENTIFIER

| | |
|---|---|
| m300 | (1-4 : Label) |
| 6c | (5-6 : Lesson-objective) |
| 3p | (7-8 : Frame type-consequence) |
| ib | ( 9 : Learning task; 10: |

SPECIAL IDENTIFIERS/ADDRESSES

| | (Author) | (Coder) |
|---|---|---|
| Film | 1.6.11 | |
| Audio | | |
| Graphic | | |

SHUTTER: Open X  Close ___
(CRT Text + feedback: 11 3-row lines; max 16 2-row lines)

0 5 10 20 30 39

47. Figure A shows the maximum possible phase difference. It is

(1) 0 degrees
(2) 90 degrees
(3) 180 degrees
(4) 360 degrees

(P-K-C)

| RESPONSE TYPE/RESPONSE/(Special Instructions) FEEDBACK (0 5 10 20 30 39) | | BRANCH TO |
|---|---|---|
| 13/(3) Very good. | C | nf [next frame] |
| bl/(1)/ (Add 1 to counter 5) No, zero would be in phase. Let's review why. | C | d310 [branch] |
| p2/(2) No, notice that the curves are one half cycle apart. Try again. | | re [retry] |
| p4/(4) No, 360 = zero = in phase, as in Figure B. Try again. | | re |

Figure 3. Example of Frame Planning Guide

form indicated the types of control and flow of the program which the author wished implemented. Detailed explanation of coding used for the Frame Identifier and Response Type are given in Section II. C., Data Management System. In summary, the 10 digit Frame Identifier Code served to: (1) uniquely identify each frame in the lesson, (2) identify frame as to lesson and training objective, (3) classify the type of frame (instructionally) and identify the consequence of answering incorrectly, and (4) provide for special author code use. The two digit Response Type Identifier served to: (1) indicate the exact answer selected, (2) identify the correctness of the answer, and (3) specify the exact student feedback for selection of particular answers. Other information presented on the form included the actual text and its format on the screen as seen by the student, whether or not an image would be shown on the projector, the code name of the image, and branching instructions as a consequence of student responses.

e. Team leader and subject matter specialist's review. It was a standard procedure for the team leader to review each author's lesson materials for pedagogical adequacy and adherance to project conventions of format, response made, and identification coding. A subject matter specialist also reviewed the material for technical correctness. Before turning the lesson over to coders, the author made appropriate revisions to the lesson materials.

### 3. Coding and Programming

Once the CAI lessons were designed they were coded in COURSEWRITER II, an authoring language developed by IBM. Initially, this was done by preparing coding sheets from which keypunched lesson decks were prepared and read into computer storage. This method proved to be both time consuming and error prone. Also, updating of lesson decks as lessons were modified became a major problem.

Early in the project a transition was made to direct on-line coding instead of punched card input. Students from California State University, San Diego, who worked on a part time basis, were trained to code on-line at terminals using the lesson planning guides. Once coded, the lesson material could be executed in the same manner in which a student would see the lesson. This capability permitted prompt, on-line debugging of lessons. It is estimated that the shift to on-line coding and debugging reduced the time of the coding step by at least 30 percent.

Instructional requirements often revealed the need for capabilities not available in COURSEWRITER. The language had a provision which permitted the writing of special functions which could be added to the lesson code. These functions added capabilities for answer analysis, special lesson controls and data manipulation.

### 4. Film and Audio Preparation

a. Film preparation. Preparation of film involved the following steps: (1) Authors prepared rough sketches of required illustrations; (2) Laboratory technical illustrators prepared finished art; (3) Art was photographed with a 16mm camera (Bolex H16) (averaged eight man hours of time/module); (4) Film was processed and examined for quality and correct matching of image and address code (one day); (5) Copies were made from master (averaged 10 days); (6) Special leaders and trailers were placed on student copies and mounted into special cartridges (one day).

Due to problems in camera equipment and long film processing schedules, film preparation often delayed tryout and operational CAI student testing. The camera, in unknown mechanical condition, had to be borrowed from other Navy facilities for each filming. Preaddressed coded film was unavailable during the first two years of the project; raw film required an extra processing step of two weeks. Preaddressed film demanded accurate calibration in camera during filming. Errors in filming, addressing, or calibration were undetectable until the finished master was available. Errors could only be corrected by refilming. Preparation times from photographing to final correct copies of four to eight weeks were not uncommon.

b. Audio preparation. The random access audio device allowed authors to present audio instructions and directions in combination with the visual displays: the CRT, image projector and off-line equipment.

Actual preparation of audio materials required three major steps: preprocessing, assembly, and postprocessing. Preprocessing included writing actual audio messages, making a narrative tape, and a master addressed cartridge containing an addressed digital track. Assembly involved the process of transcribing the narrative messages onto a master addressed cartridge. Finally postprocessing consisted of substituting the actual location of each message into the COURSEWRITER II program. Any change in the audio messages or addresses required repeating the entire audio preparation process. Student cartridges could be reproduced from the master cartridge for operational use.

Aside from the multiple-step preparation process for production and revision of audio materials, difficulties in audio tape preparations were minimal.

## B. Instructional Strategies

### 1. Module Organization and Sequencing

In all modules, three principles were emphasized in organizing the instruction into lessons. (1) Heirarchical sequencing. Principles and information considered necessary or useful for later learning were taught first. (2) Transfer. Sequencing was designed to facilitate transfer to the learning of higher order concepts and principles. (3) Self-pacing. CAI students were allowed to work completely at their own rate of speed and could take breaks whenever they wished. In order to provide convenient points for lesson tests and for taking breaks, lessons were designed to be less than one hour in length for the typical student.

Two other sequencing principles were frequently found to be appropriate. (1) Spacing of difficult discriminations. The most difficult parts of the course were often those in which the students had to learn to discriminate between a number of complex, highly similar concepts. For instance all the types of magnitude measurements, and their alternate names and uses, were traditionally taught at the same time. For the CAI training on AC Theory, only part of these concepts were introduced in the early lessons. Then when related concepts were taught in later lessons, the new concepts could be contrasted with ones the student already knew. The aim of this procedure was to reduce the amount of interference among the concepts introduced early. (2) Concrete to abstract sequencing. This type of sequencing was frequently used to provide a useful frame of reference for the student for learning the more theoretical parts of the course. Thus, "hands-on" lab work occurred in the first lessons of both the DC and AC Theory modules. Alternator uses and construction were taught in the second lesson of AC Theory. Demonstration of the time constant and identification of types of capacitors were introduced as early as possible in the capacitance module.

2. Lesson Organization and Frame Construction

Most of the sequencing principles discussed above were also applied to each lesson. In addition each lesson was organized into a student "self-evaluation sequence" as follows:

a. Reads brief overview (in Study Guide)
b. Does part A
    (1) reads objective(s) for part A (in guide)
    (2) does training frames
    (3) takes criterion frame(s)
c. Does parts B, C, etc.
d. Reviews
e. Takes lesson test

The objectives and overview were in a Study Guide which the student could keep and could refer to at any time except when taking tests. In some lessons the training could be skipped, either by passing a pretest or by taking advantage of student options. In some lessons an on-line optional review was available in step d. The student could review any of the topics covered in the lesson. This review always consisted of criterion type problems in which the student received no help unless he missed the question.

The CAI training generally followed a tutorial model designed to take maximum advantage of the information retrieval and response processing capabilities of the computer. Almost all of the training frames required an active response on the part of the student. After each response the computer analyzed the response and immediately provided feedback. This feedback was usually appropriate to the particular response made by the student. Both internal branching within a frame and external branching to new material were frequently employed.

Four basic types of training frames were used:

a. Lecture frame: A statement or series of statements containing one or more important facts which did not require the student to make a response.

b. Prompted frame: A statement which (1) introduced only one new fact, (2) required the student to make a relevant response to a critical feature of the new fact and (3) employed stimulus control to increase the probability of a correct response.

c. Practice frame: A frame designed to enable a student to drill or practice a terminal or criterion response without the aid of a formal prompt. On some of these frames help options were available which provided on-line assistance at the request of the student.

d. Criterion frame: A frame designed to test the effectiveness of the training sequence for an objective.

There were very few "lecture" frames in which no response was required of the student. Even the few lecture frames which did occur were usually constructed to produce a particular response by the student.

Several types of feedback and retry procedures were used in conjunction with frames requiring a response.

a. Fixed feedback: The answer or solution, given regardless of whether the student responded correctly or incorrectly.

b. Confirmation: A simple "Yes" or "No", "Correct" or "Wrong" type feedback.

c. Explanation: The correct solution to finding the answer or the reason a response was incorrect.

d. Simple retry: "Try again."

e. Prompted retry: Student was given a hint or cue as to the correct answer and told to try again.

Although errors are infrequent in a good frame, it is important to correct them when they do occur. Thus the most common type of frame used was a "prompted retry" frame. If the student missed the question he was given a "prompt" (a hint or explanation) and allowed to try again. When possible, this feedback was designed to correct the specific mistake made by the student. In many cases such feedback was added when student tryouts disclosed common errors.

### 3. Use of Training Media and Off-Line Equipment

Information was presented to the student in four principal ways. A random access image projector provided relatively fixed information such as schematic circuit diagrams. Short messages and questions were presented on the screen of a cathode ray tube (CRT). In general, the CRT was reserved for information which could be revised easily and quickly if needed, as judged by student tryouts. The combination of the CRT and image projector allowed precise control of input information to the student, as well as rapid branching appropriate to the student's progress.

The third source of information to the student was a Study Guide booklet. The Study Guide contained useful material for the student to keep permanently. This material typically included lesson overviews, lesson objectives, application problems, guidance on how to review, and references. The Study Guide performed several important functions for the student: knowledge of the exact objectives which the student was required to achieve, a handy source of job aids such as math tables, elimination of the necessity of taking notes, and brief but complete reference materials needed for self review.

The fourth source of information was random access audio instructions. These messages freed the student to view and examine related information on the CRT, image projector and Study Guide, or to receive help while operating off-line lab equipment. Audio was also used as an alternative method of presenting new material, reviewing, or providing feedback for errors on the Self Tests. During the research on Long Term CAI (See Section III.D), instruction was made optional via the CRT or via audio at a number of points in the modules. It was found that half of the students chose audio and the other half chose visual instruction.

Off-line training (operation of multimeter and oscilloscope, identification of capacitors, etc.) was controlled in two ways. Some of the training was done at the CAI carrel. The CAI media provided optional help in operating the equipment. When the student completed an exercise, he entered his result in the computer and the computer provided tutorial feedback and instructions. The other type of training was done away from the CAI carrel. Here training was controlled by requiring the student to respond in his Study Guide and check his results by turning the page or by going to the instructor in critical cases.

4. Branching Techniques for Remedial Training.

Remedial methods were developed to handle either specific instances of deficient entering behaviors or a broad spectrum of deficiencies in prerequisite skills. Specific deficiencies were usually corrected at the point where they were important in a lesson. In cases where it was difficult to determine the nature of the student's deficiency, he could be given optional review by means of a review index and allowed to correct his weakness himself. The illustration shown here is an example of optional remedial branching for students with deficiencies in mathematics.

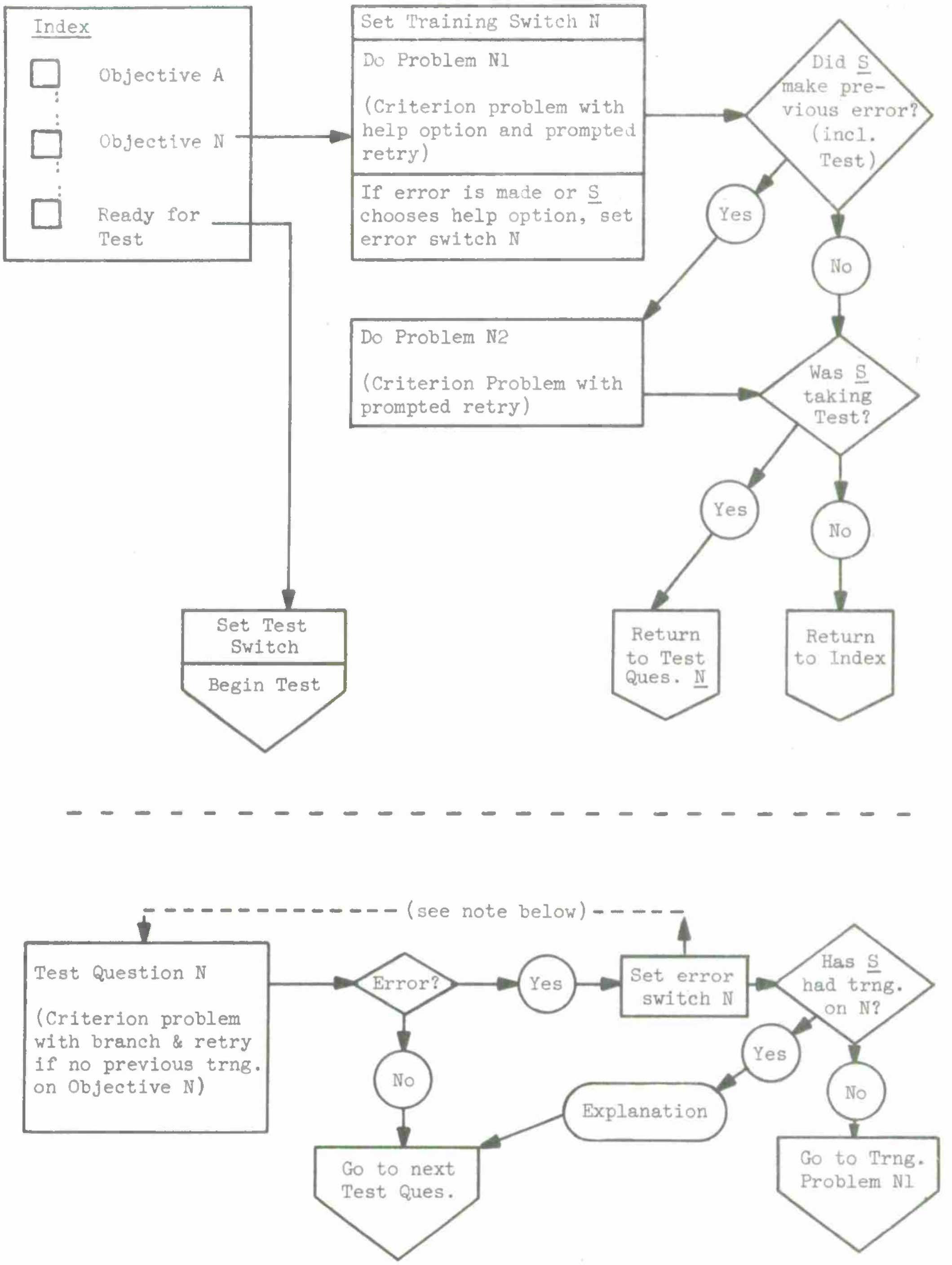
Index for reviewing:

| Rule | Practice | |
|---|---|---|
| ☐ | ☐ | Transpose formulas |
| ☐ | ☐ | Change prefixes to powers of 10 |
| ☐ | ☐ | Use powers of 10 in formulas |
| ☐ | ☐ | Use checks for correctness |
| ☐ | | I'm ready for an application problem |

The DC module on series-parallel circuits provided a case where massive remediation was required. The material was highly heirarchical and students entering the module were often unable to analyze simpler circuits or operate a multimeter correctly or test a circuit. Three branched remedial pretraining lessons were developed for this module. The pretraining was designed to accomplish three things: allow students to complete the pretraining in the minimum possible time needed, insure adequate performance on the prerequisites, and minimize the authoring time required to develop the materials.

The structure of the remedial lessons is shown in Figure 4. The student had the option of reviewing any or all of the objectives before taking the lesson test. The lesson test was arranged in a heirarchical sequence from basic to most complex items. If the student made an error he was sent back to the corresponding lesson instruction before continuing with the lesson test. Thus a student could be presumed to be competent on the prerequisites to an objective before taking the lesson test item on that objective. The reason for this procedure was that terminal performance was quite complex in this remediation, and testing the final objectives first would make it very difficult to isolate the reasons for student errors.

The effectiveness of this remedial technique was experimentally evaluated. See Section III.F.1.




Note: Computation items are normally completion, to prevent guessing. If error is merely in decimal point, student may be given prompted retry.

Figure 4. Typical structure of DC remedial lessons

5. Control of Training with Pretest Branching

Two types of pretests were developed. In Type I, pretest items were given before each objective to determine if the student could skip that objective. In Type II, the pretest items with their associated feedback constituted a minimal training sequence. If the student failed to meet certain criteria at any point, he was branched to a maximum (detailed) training sequence. Both of these types were empirically evaluated. (See Section III.F.2.)

a. Pretest Design I -- Skip ahead branching. This design called for the student to be pretested on each training objective, one at a time, with one or more criterion frames. Based on the student's performance on each pretest frame and sometimes on his performance on an interrelated training objective pretest, branching decision rules determined whether he was (1) branched ahead to the next training objective pretest or (2) branched to an instructional training sequence before being returned to the next training objective pretest. In other words, the lesson was arranged so as to determine in advance the degree of familiarity of the student on each training objective. If a student did not demonstrate the terminal behavior demanded by a training objective, the program branched him to a set of instructional frames designed to teach that objective before he could continue with the lesson. If the student's performance demonstrated that he "knew" the training objective, he was branched to the pretest for the next training objective. A flow chart model for this pretest design is shown in Figure 5.

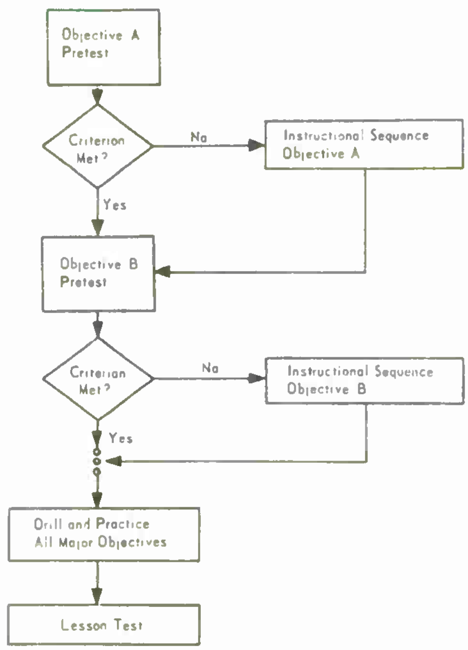



Figure 5. Flow chart model of Pretest Design I

The writing of CAI lessons to fit this instructional design was simpler, if not more systematic, than writing fixed sequence course material. The basic procedure was to write a separate sequence of instructional frames for each training objective and to conclude the sequence with one or more criterion frames.

All students were required to take a short review over all major training objectives before completing the lesson (see Figure 5). This was a safeguard against false-positive branching (skipping one or more training sequences when in fact the student did not really know the lesson objectives) and provided drill and practice repetition for over-learning and longer term memory.

b. Pretest Design II -- Mimimum vs maximum training. The pretest in this design consisted of a series of criterion questions testing all major lesson objectives. The questions were arranged in a hierarchial learning sequence and programmed to provide confirmation feedback as a consequence of correct and wrong answers. At the end of each pretest question, branching decision logics determined whether the student continued with the pretest or branched to the lesson's maximum training sequence, fixed sequence instructional frames covering all objectives. Branch decisions were based on the student's cumulative pretest performance, both quantitative and qualitative. It was possible for a student to progress through the pretest if he did not make too many errors and if he avoided distractors that were prejudged to be indicative of poor learning progress. In other words, a student was told whether his answer to each pretest question was right or wrong. Wrong answers were weighted as to the degree or type of error. Decision branching logics depended upon error weight total. The criterion for branching increased as the student progressed through the pretest. Too many errors or the wrong type of error resulted in branching the student to the instructional frame sequence for all lesson objectives. The student who missed only a few pretest questions and avoided making certain types of errors was able to complete the pretest. Minimal training occurred if a student avoided branches to the maximum training sequence and completed the entire pretest. In this case he either already knew the lesson objectives before starting the pretest or learned the objectives while taking the pretest.

A flow chart model of Pretest Design II is presented in Figure 6. Notice that branching decision logics determined whether the student continued with minimal training (pretest questions plus confirmation feedback) or branched to the maximum training sequence after almost every pretest question. All students received an optional review of selected major objectives at the end of the lesson. A unique feature incorporated into this design was "Student Self Evaluation." It was a pretest/no pretest branch decision based on the student's response to the question "Do you think you can solve for total capacitance in series and in parallel circuits?" employed at the beginning of the lesson. Selection of the answer "Yes" or "Maybe" resulted in branching to the first pretest question, a "No" answer branched the student immediately to the maximum training sequence.

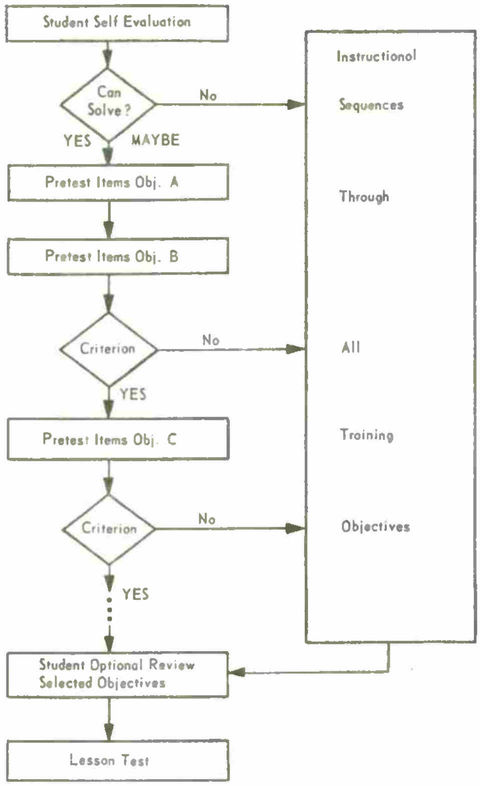



Figure 6. Flow chart model of Pretest Design II

6. <u>Student Control of Instructional Sequencing</u>

The student was given the option of skipping certain parts of the instruction in a number of training situations. These included remediation of entering behaviors, original training, drill and practice, review, and posttest remediation. These option methods seemed to work well provided the student had a clear knowledge of the objectives he was required to achieve.

Two important problems concerning optional branching were experimentally investigated. The first problem was whether extensive use of optional branching would result in a useful time savings as compared to relatively linear CAI. An example of extensive optional branching used in Lesson C of the Series Circuits module is shown in Figure 7. The student had separate options to skip remediation, training, practice, and review. Experimental results for such training are reported in Section III.F.3.

The second problem was whether student option works as well as program control for bypassing of instruction and for posttest remediation. If so, it would be preferred to program control because instruction which utilizes student option is much simpler to prepare. Experimental findings are given in Sections III.F.5 and III.F.6.

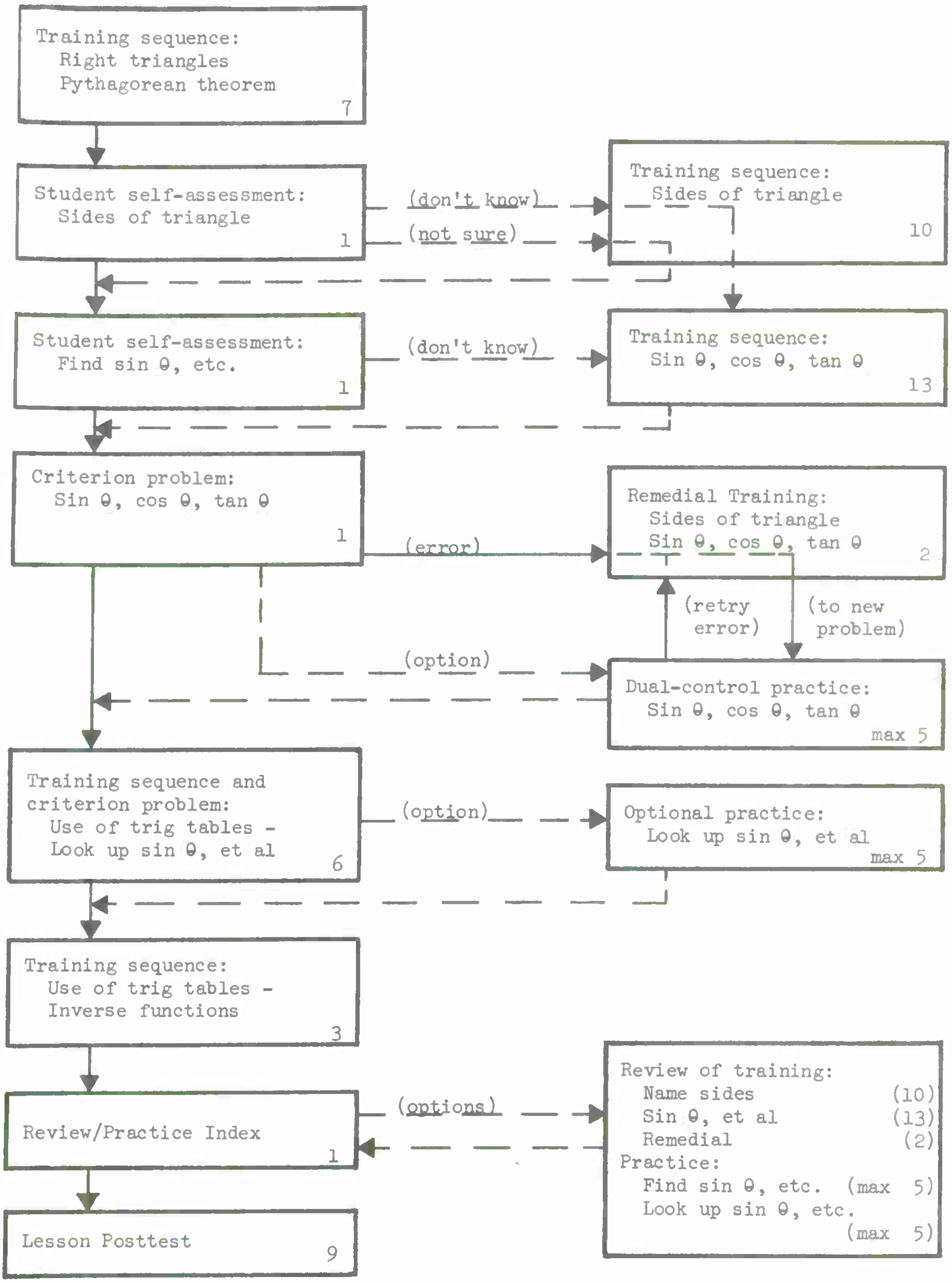



Figure 7. An example of multiple branching

7. Control of Drill, Practice, and Review

Four branching methods were successfully used for determining the appropriate amount of practice or review for each individual student. One type was strict program control. This was used for drill on skills in which the student had to demonstrate a predetermined level of competence. Computer programs were developed which randomly presented new sets of problems. Drill was continued until the student met the criterion. An example was drill on the use of the resistor color code.

A second type was complete student option. This was widely used for review at the end of lessons. It was also used in a number of lessons to provide practice in the middle of the lesson. Examples of these uses are shown in Figure 7 in the previous section.

Two kinds of dual control practice were developed. The first kind began with a required criterion problem. If the student missed the problem he was required to do another. If he got the problem correct, he was given the option of doing further practice problems. An example from Lesson E of the Series Circuits module is shown in Figure 8. The second

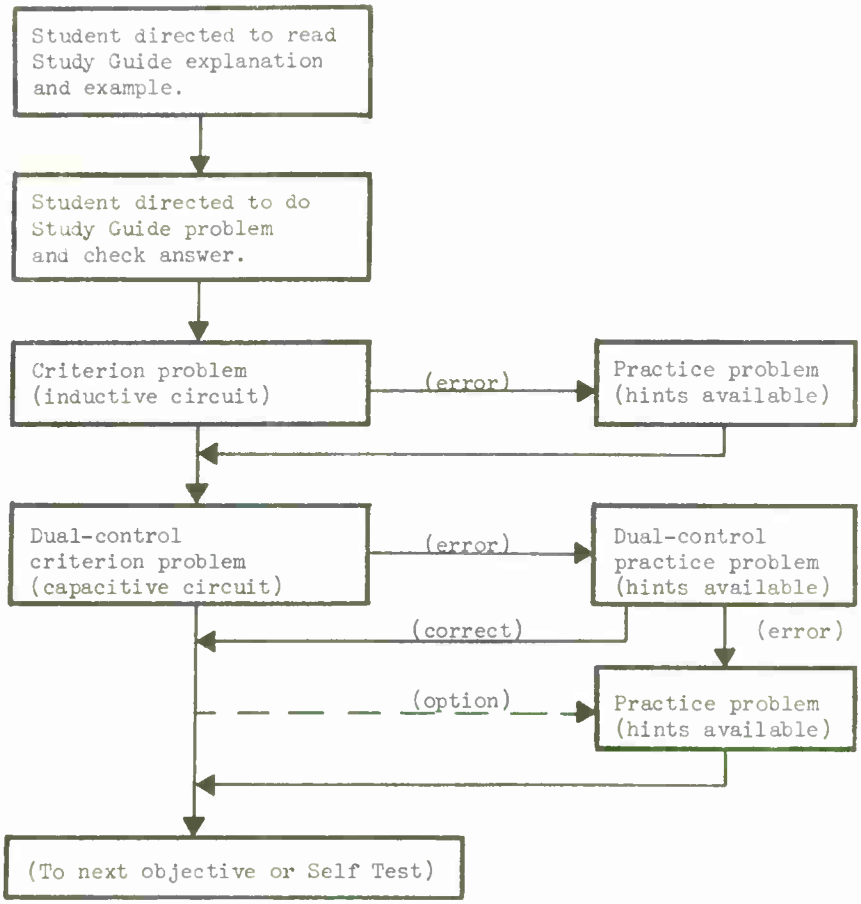



Figure 8. An example of dual control practice.

type of dual control practice occurred in a review lesson covering a number of objectives. Each objective began with optional practice problems followed by a required criterion frame. If the student missed the criterion frame and had skipped the practice, he was required to go back and do the practice. Both of these methods of dual control were experimentally compared to fixed sequence practice. See Sections III.F.3. and III.F.4.

## C. Data Management System

During the course of the project, a complete data management system was developed and evaluated. The system performed three main functions: (1) identification and classification of frames and student responses, (2) monitoring of student progress and achievement, and (3) data analyses and summaries useful for evaluation and revision of CAI courses. Components of the system were revised several times on the basis of experience with course operation and revision. Details of the final versions are given below.

### 1. Frame and Response Identifiers

The frame identifier was a 10 digit code which provided a unique frame label for branching and documentation, identified the lesson and exact objective, and classified the type of instruction used in the frame. A description of the frame identification code is given in Table 1 and an example of use of the code in a frame is given in Figure 9.

The first four digits provided a label for the frame. The first digit was a letter indicating mainline ("m"), branch sequence ("a," "b," "c," etc.), pretest ("p") or lesson test ("t") frame. The next three digits indicated numerical sequence of the frame within the lesson and was unique to each frame. The last six digits were used to identify the frame as to lesson, training objective, frame type, principal consequence of a wrong answer, special usage and branching, respectively.

The frame in Figure 9 is from branch sequence "a" of lesson "1," objective "e." It is frame type "4" (optional hint available). The principal consequence of a wrong response is a prompted retry "p": Notice that under response type "p9" (the first unanticipated response) the student is given a prompt before retrying.

TABLE 1

Frame Identifiers and Descriptions

| Column | Identifier Description |
|---|---|
| 1 | Mainline, Branch Sequence, Pretest or Test Frame |
| 2-4 | Three digit unique number (sequence based) |
| 5-6 | Lesson and Training Objective |
| 7-8 | Frame Type and Consequence of WA |
| 9-10 | Special Author Usage |

Column 2-4: Unique Frame Number. Assigned to each frame and based on sequence or position in lesson, i.e., 000, 001, 002, ..., 356, ..., 999.

Column 5: Lesson Identifier. A single letter or number to uniquely identify each lesson within a module. Usually based on sequence, i.e., A, B, C, ... or 1, 2, 3, ...

Column 6: Training Objective. A single letter or number used to uniquely identify each lesson training objective, i.e., A, B, C, ... or 1, 2, 3, ...

Column 7: Frame Type. Code and types shown below:

| | | | |
|---|---|---|---|
| 0 | Information/Directions | 8 | Practice |
| 1 | Pretest | 5 | Criterion |
| 2 | Lecture | 6 | Review criterion |
| 3 | Prompted | 7 | Lesson test |
| 4 | Optional hint | 9 | Supplemental test |

Column 8: Consequence of Wrong Answer. One digit code to identify the principal behavioral consequence (retrys, feedback, or branch) for a student making a wrong answer to a frame. Code and consequence listed below:

| | |
|---|---|
| r simple retry | t thematic |
| p prompted retry | d delayed (frame type 7 or 9) |
| e explanation | u unspecified (frame type 0 or 2) |
| a answer | b branch (frame type 1) |
| c confirmation | |

Column 9 and 10: Special Author Usage. These columns were available for special author usage. Commonly used for a code "B" to indicate frame programmed for conditional or unconditional branch.

AUTHOR-CODER FRAME PLANNING GUIDE

PRR___ PR X

FRAME IDENTIFIER

| | |
|---|---|
| a360 | (1-4 : Label) |
| 1e | (5-6 : Lesson-objective) |
| 4p | (7-8 : Frame type-consequence) |
| p0 | ( 9 : Learning task; 10: |

SPECIAL IDENTIFIERS/ADDRESSES

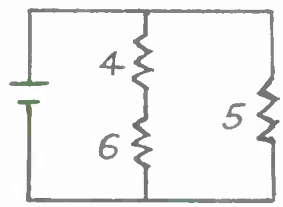
| | (Author) | (Coder) |
|---|---|---|
| Film | | |
| Audio | | |
| Graphic | | |

SHUTTER: Open___ Close X

(CRT Text + feedback: 11 3-row lines; max 16 2-row lines)

0 5 10 20 30 39

37. Type h if you need a hint.




$R_t$ = ____

(P-K-C)

RESPONSE TYPE/RESPONSE/(Special Instructions) — BRANCH TO

FEEDBACK

0 5 10 20 30 39

| | | Branch to |
|---|---|---|
| h1/h<br>Reduce it to a simple parallel circuit by finding the total resistance in the left leg. | | re [retry] |
| 21/3.33<br>On the button. | C | nf [next frame] |
| p9/un1<br>The 4 and 6 ohm resistors are in series so their resistance is 4 + 6 = 10. Now you have a simple parallel circuit. | | re |
| e9/un2<br>$R_t = \frac{1}{1/10+1/5} = \frac{1}{.3} = 3.33$ | C | nf |

Figure 9. Example of frame and response identification

Actual student responses and their consequences were identified by a two digit code. A list of codes for each digit are shown in Table 2. The first digit indicated whether the response was judged as correct (a number from 1 to 7) or wrong (a letter). The particular number or letter indicated the type of feedback programmed to be a consequence to that particular response. A special category of zero ("0") was used to indicate special frame usage. The second digit of the response identifier could be used to indicate: (1) type of special frame response to "0" first digit code, (2) position of a correct or wrong penlight answer, (3) keyboard answer choice "1" to "6" or (4) unrecognized keyboard answer "9". Examples of use of the response identifiers are given in Figure 9.

TABLE 2

Response Type Identifiers

1. Special Response Types

| Column 1 | Column 2 | Identification Description |
|---|---|---|
| 0 | 0 | Unspecified response, latency recorded |
| 0 | 1-6 | Student option choice (position) |
| 0 | 7 | Backup option |
| 0 | 8 | Light pen mismatch |

2. Correct or Wrong Responses - Column 1 Identifier Codes

| Column 1 CA | | Column 1 WA | Consequence Identification |
|---|---|---|---|
| 1 | or | a | Answer |
| 2 | or | c | Confirmation |
| 3 | or | e | Explanation |
| 4 | or | t | Thematic |
| 5 | or | u | Unspecified |
| 6 | or | b | Branch |
| 7 | or | d | Delayed Feedback |
| | | r | Retry |
| | | p | Prompted retry |

3. Correct or Wrong Responses - Column 2 Identifier Codes

| Column 2 | |
|---|---|
| "1" to "6" | Lightpen or objective constructed response position |
| "9" | Unrecognized (wrong) constructed response |

## 2. Monitoring of Student Progress and Achievement

Special proctor messages were developed which enabled the instructional proctor to continuously monitor the student while he was on-line. These messages could be used to determine if the student was progressing too slowly, to determine if his test performance was unsatisfactory, or to provide personal tutoring if necessary on the particular objectives with which the student was having difficulties.

Examples of Proctor messages are given in Figure 10. For each student the messages contained beginning times for lessons, remediation, and lesson (self) tests; time on lessons, remediation and self test; self test scores and particular wrong items on self test.

```
Station  06  mp06dc     proctor message
Begin lesson DC-13, 1435 hr.

Station  14  ma04act    proctor message
ACT6    wrong answers    3  4  11
ACT-6 lesson time 56     begin self test 840hr    self test time 6    self test score 81

Station  08  sn66scr    proctor message
SCR-41A  wrong answers   2  4
SCR-41   Beg Rem 1226   End 1236   On 10   Beg altst 1237   End 1245   On 8   Score 80%

Station  12  ma12act    message code  10    [sign off]
```

Figure 10. Examples of proctor messages used for monitoring of student progress and achievement

## 3. Student Data Analysis and Summaries

The purpose of the data programs was to make it possible for course authors to quickly and accurately pinpoint specific weaknesses in lesson material and identify the reasons for these weaknesses. Five types of programs were developed which allowed the author to probe each lesson to the level of detail needed to revise it:

a. Lesson summary. This was the most general type of analysis. It showed average performance by each student on each type of frame as well as the average for all students. An example is shown in Figure 11. Average performance on the lesson (self) test was somewhat low (78% in col. 7). One reason appears to be that the low scoring students (MP26 and MP28) were not helped by the optional review (col. 6).

b. Summary by objective. This was similar to the Lesson Summary except that the analysis was made for each separate objective. See Figure 12. From this summary the author could immediately determine the effectiveness of instruction on each objective.

LESSON SUMMARY (COURSE/STUDENT/FRAMETYPE)

CODE-
T=TOTAL RESPONSES ON FIRST TRY(00-99)
P=PERCENT CORRECT ON FIRST TRY(000-100)
L=RESPONSE AVERAGE LATENCY IN SECONDS(000-999)
X=FIELD OVERFLOW

PAGE 02

| COR-SEG | USER | 0 CHOICE | | | 1 PRETEST | | | 2 LECTURE | | | 3 PROMPT | | | 4 OPT-HINT | | | 5 CRITERION | | | 6 REVIEW | | | 7 SELF TEST | | | 8 PRACTICE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DC 013 | NO | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L |
| | MP23 | 06 | 100 | 080 | 11 | 063 | 042 | | | | | | | 10 | 020 | 026 | 02 | 100 | 018 | 03 | 066 | 008 | 10 | 090 | 026 | 01 | 100 | 041 |
| | MP24 | 07 | 071 | 043 | 11 | 063 | 032 | | | | | | | 01 | 100 | 123 | 01 | 100 | 008 | | | | 10 | 100 | 041 | 01 | 100 | 007 |
| | MP25 | 06 | 100 | 037 | 12 | 058 | 021 | | | | | | | 12 | 050 | 019 | 01 | 100 | 008 | | | | 10 | 090 | 026 | 01 | 100 | 011 |
| | MP26 | 06 | 100 | 067 | 13 | 030 | 072 | | | | | | | | | | 03 | 100 | 035 | 03 | 066 | 058 | 10 | 060 | 077 | 01 | 000 | 030 |
| | MP28 | 06 | 100 | 056 | 11 | 054 | 042 | | | | | | | 15 | 020 | 069 | 02 | 100 | 035 | 03 | 066 | 022 | 10 | 070 | 037 | 01 | 100 | C14 |
| | MEAN | 06 | 091 | 014 | 11 | 057 | 004 | | | | | | | 08 | 027 | 003 | 01 | 087 | 028 | 03 | 060 | 029 | 10 | 078 | 004 | 01 | 068 | 020 |

Figure 11. Summary of individual and mean performance on each type of frame

SUMMARY BY OBJECTIVE (STUDENT/OBJECTIVE/FRAME TYPE)

CODE-
T=TOTAL RESPONSES ON FIRST TRY(00-99)
P=PERCENT CORRECT ON FIRST TRY(000-100)
L=RESPONSE AVERAGE LATENCY IN SECONDS(000-999)
X=FIELD OVERFLOW

PAGE 11

| COR-SEG | USER | 0 CHOICE | | | 1 PRETEST | | | 2 LECTURE | | | 3 PROMPT | | | 4 OPT-HINT | | | 5 CRITERION | | | 6 REVIEW | | | 7 SELF TEST | | | 8 PRACTICE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L | T | P | L |
| | XP16 | | | | | | | | | | | | | | | | 02 | 100 | 012 | 01 | 100 | 008 | 01 | 100 | 009 | | | |
| | XP17 | | | | | | | | | | | | | | | | 02 | 050 | 006 | 01 | 100 | 005 | 01 | 100 | 006 | | | |
| | XP18 | | | | | | | | | | | | | | | | 02 | 100 | 011 | 01 | 100 | 007 | 01 | 100 | 013 | | | |
| SCP 005 OBJ- H | MEAN | | | | | | | | | | | | | | | | 02 | 087 | 008 | 01 | 091 | 007 | 01 | 091 | 010 | | | |
| | NP01 | 01 | 100 | 018 | 01 | 000 | 015 | 03 | 100 | 024 | 02 | 100 | 022 | | | | 05 | 080 | 013 | 02 | 050 | 013 | 01 | 100 | 038 | | | |
| | NP02 | 01 | 100 | 037 | 01 | 000 | 018 | 03 | 100 | 026 | 02 | 100 | 015 | | | | 05 | 100 | 010 | 02 | 100 | 014 | 01 | 100 | 010 | | | |
| | NP03 | 01 | 100 | 010 | 01 | 000 | 017 | 03 | 100 | 009 | 02 | 100 | 018 | | | | 05 | 080 | 018 | 02 | 000 | 018 | 01 | 000 | 040 | | | |
| | NP04 | 01 | 100 | 014 | 01 | 000 | 043 | 03 | 100 | 040 | 02 | 100 | 028 | | | | 05 | 100 | 010 | 02 | 100 | 012 | 01 | 100 | 016 | | | |
| | NP05 | 01 | 100 | 052 | 01 | 000 | 182 | 03 | 100 | 026 | 02 | 100 | 022 | | | | 05 | 080 | 016 | 02 | 100 | 030 | 01 | 100 | 021 | | | |
| | NP06 | 01 | 100 | 027 | 02 | 050 | 024 | 01 | 100 | 064 | 01 | 100 | 062 | | | | 04 | 100 | 012 | 02 | 050 | 030 | 01 | 100 | 042 | | | |
| | XP13 | 01 | 100 | 011 | 01 | 000 | 025 | 03 | 100 | 039 | 02 | 100 | 019 | | | | 05 | 080 | 015 | 02 | 100 | 011 | 01 | 100 | 026 | | | |
| | XP14 | 01 | 100 | 013 | 01 | 000 | 009 | 03 | 100 | 025 | 02 | 100 | 013 | | | | 05 | 100 | 010 | 02 | 100 | 018 | 01 | 100 | 018 | | | |
| | XP15 | 01 | 100 | 037 | 01 | 000 | 042 | 03 | 100 | 025 | 02 | 050 | 029 | | | | 05 | 080 | 013 | 02 | 100 | 019 | 01 | 100 | 104 | | | |
| | XP16 | 01 | 100 | 034 | 01 | 000 | 036 | 03 | 100 | 032 | 02 | 100 | 024 | | | | 05 | 100 | 014 | 02 | 100 | 010 | 01 | 100 | 016 | | | |
| | XP17 | 01 | 100 | 010 | 01 | 000 | 010 | 03 | 100 | 061 | 02 | 100 | 022 | | | | 05 | 100 | 011 | 02 | 100 | 013 | 01 | 100 | 015 | | | |
| | XP18 | 01 | 100 | 028 | 02 | 100 | 031 | 01 | 100 | 074 | 01 | 100 | 040 | | | | 04 | 100 | 032 | 02 | 050 | 022 | 01 | 100 | 022 | | | |
| SCP 005 OBJ- I | MEAN | 01 | 100 | 024 | 01 | 021 | 036 | 02 | 100 | 033 | 01 | 095 | 024 | | | | 04 | 091 | 014 | 02 | 079 | 017 | 01 | 091 | 030 | | | |

Figure 12. Summary of individual and mean performance on each objective, sorted by frame type

c. Detailed frame analysis. If an objective was not being taught properly, the author could examine performance of individual students on each frame. Two types of analysis were used. The example in Figure 13 shows frames sorted by objective so that the frames pertinent to each objective could be found quickly and compared. Notice that five students made errors (letter in col. 1 of response type) on the pretest frame, P315, and were given further training. Three of these five students made errors on their first try on criterion frame M320 but all were correct on criterion frame M330.

SCP 0009 (OBJECTIVE-FRAME TYPE SEQUENCE) 11 10 71 PAGE 47

| FRAME | STUDENT | RESPONSE TYPE | REC SEQ | LATENCY (SEC) | RESPONSE | TIME 24HR |
|---|---|---|---|---|---|---|
| H-OBJECTIVE 1-FRAME TYPE | | | | | | |
| P315TH18 | | | | | | |
| | NP02 | B5 | 39 | 17.6 | ROW 13 COL 6 | 1453 |
| | NP04 | 24 | 41 | 67.1 | ROW 10 COL 29 | 1709 |
| | NP05 | 24 | 19 | 145.2 | ROW 10 COL 29 | 1252 |
| | NP06 | B5 | 11 | 28.9 | ROW 13 COL 6 | 1335 |
| | NP03 | C3 | 66 | 6.3 | ROW 11 COL 20 | 1337 |
| | NP01 | 24 | 58 | 18.0 | ROW 10 COL 29 | 755 |
| | XP14 | C2 | 46 | 12.4 | ROW 11 COL 10 | 1009 |
| | XP17 | 24 | 19 | 34.8 | ROW 11 COL 29 | 1053 |
| | XP13 | 24 | 45 | 33.1 | ROW 10 COL 29 | 1138 |
| | XP16 | 24 | 19 | 19.8 | ROW 10 COL 29 | 656 |
| | XP15 | 24 | 18 | 14.5 | ROW 10 COL 29 | 915 |
| | XP18 | C3 | 19 | 68.9 | ROW 10 COL 20 | 1002 |
| | 12 STUDENTS--AVERAGE LATENCY -FIRST TRY 38.8 | | | | | |
| 5-FRAME TYPE | | | | | | |
| M320JH5P | | | | | | |
| | NP02 | P1 | 40 | 18.0 | ROW 12 COL 8 | 1453 |
| | NP02 | 22 | 41 | 139.0 | ROW 12 COL 14 | 1453 |
| | NP06 | 22 | 12 | 10.9 | ROW 12 COL 14 | 1335 |
| | NP03 | P3 | 67 | 6.2 | ROW 12 COL 20 | 1337 |
| | NP03 | 22 | 68 | 15.0 | ROW 12 COL 14 | 1337 |
| | XP14 | P1 | 47 | 9.8 | ROW 12 COL 8 | 1009 |
| | XP14 | 22 | 48 | 85.0 | ROW 13 COL 14 | 1009 |
| | XP18 | 22 | 20 | 48.2 | ROW 12 COL 14 | 1003 |
| | 5 STUDENTS--AVERAGE LATENCY -FIRST TRY 18.6 | | | | | |
| M330JH5P | | | | | | |
| | NP02 | 22 | 42 | 5.4 | ROW 12 COL 14 | 1454 |
| | NP06 | 22 | 13 | 5.4 | ROW 12 COL 14 | 1335 |
| | NP03 | 22 | 69 | 1.8 | ROW 12 COL 14 | 1337 |
| | XP14 | 22 | 49 | 1.0 | ROW 12 COL 14 | 1009 |
| | XP18 | 22 | 21 | 20.3 | ROW 12 COL 14 | 1003 |
| | 5 STUDENTS--AVERAGE LATENCY -FIRST TRY 6.7 | | | | | |

Figure 13. Detailed performance of each student on each frame, sorted by objective and frame type

The second type of detailed frame analysis, preferred by some authors, simply listed the frames in numerical sequence, rather than by objective and frame type.

d. Student trail. This listed all the responses of the student in the order in which they occurred (see "rec seq" in Figure 13) so that the path of the student through the lesson could be easily followed. Information included for each response was the same as for the frame analyses (frame, response type, latency, etc.).

D. Course Revision Methodology

1. Student Tryouts

Student tryout runs were made on each CAI module before it was operationally tested. During the student tryout phase, selection of students was made to insure coverage of the aptitude range, but no formal sampling procedures were used. Generally, more information was obtained from the intermediate or lower achieving students than from the high achieving students.

Tryouts provided data to evaluate training effectiveness and to act as a guide for revision: (1) performance on CAI lessons and lesson test; (2) performance on CAI supplemental test, and (3) performance on School Area Examination.

One of the major advantages of a CAI system is its ability to process large amounts of student data. Thus it is possible to make very effective revisions of a course because defects in the instruction can be exactly pinpointed. The computer keeps a continuous record of all student responses during training as well as performance on the posttests. If students perform poorly on particular posttest questions, the trouble can be isolated to such things as inadequate early training, insufficient practice, or poor retention because of insufficient spacing of practice.

2. Use of Tryout Performance Data

Responses made by each student on each frame of a lesson were recorded, and a printout of these data provided the major guide for all revisions.

The revision analysis began with the terminal performance on each training objective tested on the School Area Examination and the Supplemental Test, because these tests measured long term retention and were used for evaluating training methods (see Figure 14).

If the error rate on a particular training objective was found to be greater than 10-15%, a step-by-step backward analysis was performed to isolate the lesson and specific frames responsible for the training: (1) performance on lesson test, (2) performance on criterion frames within the lesson, and (3) performance on individual training frames of the objective. Analyzing backwards enabled authors to determine whether or not a trainee had ever demonstrated satisfactory performance on a training objective in the lesson test or criterion frames. If not, extensive revision was necessary to improve the instructional content of the lesson. On the other hand, if the trainee passed the lesson test items or criterion frames, it showed the need to include additional drill and practice in order to promote long-term memory and success on the Area Examination. Another critical analysis was to examine failed test items or frames for proper wording, adequacy of distractors, and format of presentation.

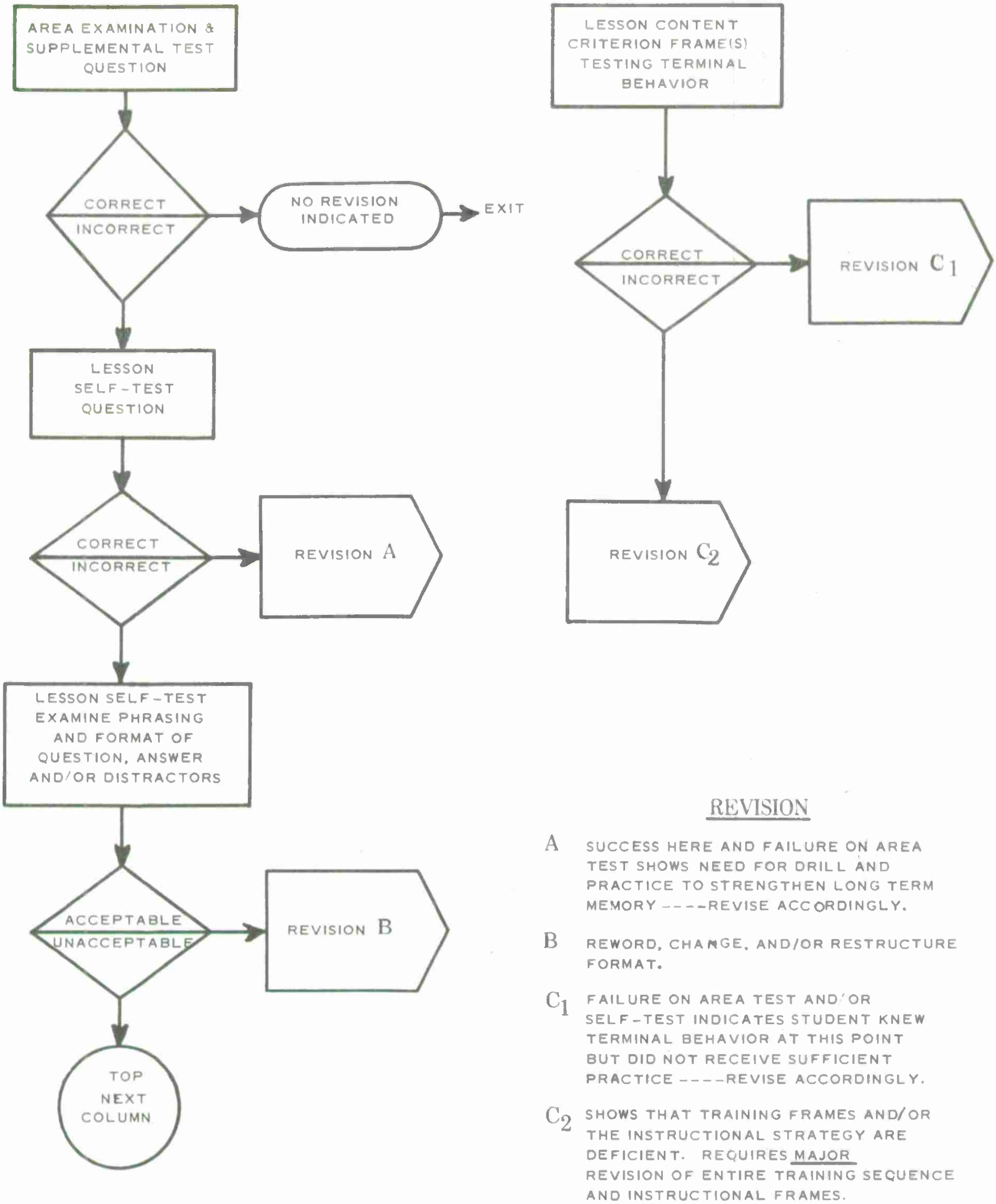



Figure 14. Flow chart of sources of data and types of revisions indicated

Team leaders often assisted authors by recommending or suggesting revisions based on performance data analysis. Examples of analysis of tryout data and suggested revisions are shown in Figure 15.

Example 1. REVISIONS OF MAJOR TOPICS

| Difficulty | | |
|---|---|---|
| 1. Low scores on particular area test questions | 1. Not taught (discrepancy between CAI and school objectives) | 1. Add new objectives; delete 1 objective |
| 2. Many students take lesson 7 over; low scores on pertinent criterion and area test questions | 2. Interference between highly similar concepts | 2. Teach average value before RMS value to take advantage of students previous experience; add discrimination frames in which student compares various concepts |

Example 2. ANALYSIS OF A POORLY TAUGHT OBJECTIVE
Objective: Select from a list the definition of angular velocity

| Data | % Error | Errors | Analysis |
|---|---|---|---|
| Area Test Q. | | | |
| A15 | 28 | a,d | Confusion with flux lines cut per unit time; |
| C15 | 60 | a,a,d | question refers to angular velocity of |
| D15 | 57 | b,b,b,d | sinewave. |
| Crit Test Q. | | | |
| 4. | 50 | c,c,c,c, c,c,c,c, a,a,a | Confusion with number of radians in one cycle; question refers to angular velocity of rotating object. |
| Training Frames | | | |
| m060X | — | | m060x and m060X1 are reading frames; m060 |
| m060X1 | — | | is only response frame and deals with rotation |
| m060 | 10 | b,b | |
| m070 | — | | m070 deals only indirectly with def. of angular velocity of sinewave. |

Suggested revisions: Need response frames on definition of angular velocity for rotation and also for sinewave. Need discrimination frame re flux lines cut per unit time, radians per cycle, and angular velocity.

Figure 15. Examples of data analysis and suggested revisions

An effective revision process makes it possible to solve two important training problems. One problem is determining the amount of training and practice required. For instance, excessive practice merely wastes the time of the brighter students. Furthermore, if a program is too long to begin with, it is often difficult to find out if it could be shortened effectively. A second problem is determining the remedial branching sequences which should be included. It is clearly not worthwhile to prepare branching materials which students never use. For example, the method of solving the above problems for the AC CAI Theory Module was to prepare an initial version of the course consisting of a minimal instructional sequence. The module was then given several student tryouts. After each tryout, the lessons were revised and additional training added as needed. Most of the remedial branching and optional student review used in the AC module were added as a result of student tryouts.

## III. Experimental Evaluation of CAI Training

### A. General Procedures

#### 1. Selection of Students

A form of systematic randomization was used to select students for the tryout and revision steps during the development of the CAI modules. Because only a few students, 10 to 20, were used for each tryout, a restriction in selection was imposed to insure that aptitude levels were proportional to that of the school population.

All students who participated in the final operational evaluation of CAI materials were randomly selected from class rolls provided by the Basic Electricity/Electronics School. The only restriction was that students had to have completed all classroom instruction immediately proceeding the CAI materials.

#### 2. Number of Students Used in Project

A total of 760 students were used during the tryout and revision stages of CAI module development, operational tests of individual modules, evaluation of effects of long term CAI, and special studies of branching techniques and paired student training (see Table 3).

TABLE 3

Number of Students Used in Project

| Use Category | Number of Students |
|---|---|
| Module Tryouts | 246 |
| Operational Tests | 175 |
| Special Studies | |
| Long Term CAI | 50 |
| Student Option/Program Controlled Training | 96 |
| Student Controlled Remediation | 108 |
| Paired Student Training | 75 |
| Total | 760 |

3. Student Terminal Hours Used

A total of 760 different students received CAI training during the project and used more than 10,197 student hours of terminal time. Table 4 presents a breakdown of these data.

TABLE 4

Student Terminal Hours

| Category | Students | Total Student Terminal Hours |
|---|---|---|
| Student Tryouts | 246 | 3,277 |
| Operational Tests | 175 | 1,894 |
| Special Studies | 339 | 5,026 |
| Grand Totals | 760 | 10,197 |

4. Data Collection and Analysis

Three types of data were collected, recorded and used in the experimental evaluation of CAI training.

a. Background measures. School records were the source of aptitude test scores--Electronics Technician Selection Test, General Classification Test, and Arithmetic Test--on each student for use in correlational, predictive analyses and for potential covariants in analysis of variance between CAI and classroom controls performance measures. School records also provided data on previous school performance. During the project, previous school performance proved to be the best predictor of CAI performance ($\underline{r}$ = .53 to .76).

b. CAI time measures. Three major time measures were recorded for each student on each CAI module. Training time, computer recorded, was the total time required for a student to complete each lesson and lesson tests. Module time consisted of total time on the system from sign-on until sign-off, i.e., cumulative attendance time for each student each day on the module. Time in other activities, obtained by subtracting training time from module time, was the time spent by a student reviewing for lesson tests and on rest breaks between lessons.

c. CAI test performance measures. Three kinds of test scores were recorded during CAI training: (1) Lesson Test Scores, (2) Supplemental Test Score, and (3) School Area Test Score.

d. Statistical analyses. The standard procedure for summarizing student data descriptively and for inferential comparisons with control groups was to record all data for experimental and control students on computer punch cards. These cards were then run on various programs to obtain descriptive statistics, multiple correlations and inferential comparisons (analysis of variance and analysis of covariance).

## B. Effectiveness of Course Revision Methodology

The process of student tryouts and revisions proved to be an extremely important step in developing effective instruction. First, and most critical, tryouts provided data to evaluate general, as well as specific, training effectiveness of the CAI course materials. Data analysis pinpointed weaknesses in the instruction of each training objective and indicated both the location and type of revisions needed. Second, it was not possible to anticipate student deficiencies in prerequisite skills and knowledges assumed in the original development of CAI materials. Student tryouts were used to determine points in the instruction where remediation was needed. Third, the tryout and revision cycle provided a useful way to aid inexperienced authors in learning how to prepare good instructional materials. Finally, even experienced instructors made oversights and other minor errors when preparing the highly detailed material required for individually adaptive instruction. These mistakes were easily discovered by testing the lesson with a few students. This part of the report is devoted to presenting the results of revisions on the CAI modules of AC Theory, Inductance, Capacitance and Series Circuits to illustrate the effects of revisions on lesson times and scores as well as on total module training times and examination scores.

### 1. Revisions of AC Theory Lessons

The effectiveness of the revision process is illustrated in Table 5. These were lessons which were excessively long in comparison to the other five lessons in the module. Training time was reduced by more than one-third from the second to the third tryout of AC Theory.

TABLE 5

Median Performance on Three "Slow" Lessons

| Tryout | N | Lesson Time (Min.) | Test Score (%) |
|---|---|---|---|
| Second | 15 | 59 | 91 |
| Third | 22 | 37 | 95 |

2. Revisions of Inductance Lessons

Revision effects in lesson time and lesson test scores, between the first student tryout and the Final Evaluation, are shown in the last column of Table 6. These changes reflect an average of three revisions per lesson. Note that revisions did not always result in both a savings in lesson time and an increase in test score (Lessons 1 and 7). It is also important to point out that the effects of certain kinds of revisions are not always reflected in either lesson time or score measurements (Lesson 5). In the case of Lesson 5, the last revision included planning a new instructional strategy, rewriting almost all the lessons instructional content and drastically changing the lesson test because of an original failure to place the proper emphasis in the lesson and lesson test upon the more important, if not difficult, training. This meant that previous measures became inappropriate for evaluating the true effect of the final revision effort on this lesson.

TABLE 6

Revision of Inductance Module Lessons

| Lesson | Measure | First Tryout | Final Eval. | Changes Between First and Final Revision |
|---|---|---|---|---|
| 1 | mean time (min.) | 100 | 62 | 38% savings |
| | mean score (%) | 85 | 88 | 4% increase |
| 2 | mean time | 101 | 77 | 23% savings |
| | mean score | 81 | 90 | 11% increase |
| 3 | mean time | 89 | 54 | 38% savings |
| | mean score | 80 | 86 | 8% increase |
| 4 | mean time | 65 | 77 | Not applicable |
| | mean score | 80 | 79 | Not applicable |
| 7 | mean time | 16 | 16 | No change |
| | mean score | 80 | 96 | 20% increase |

3. Revisions of Capacitance Lessons

Significant changes in several sample lessons between the first student tryout and the Capacitance Module operational test are shown in Table 7. Dramatic changes on Lesson 7 measures were due to major revisions of the entire instructional content; the lesson test was not revised.

TABLE 7

Revision of Capacitance Module Lessons

| Lesson | Measure | First Tryout | Cap. Op-test | Revision Results |
|---|---|---|---|---|
| 1 | mean time (min.) | 27 | 18 | 40% savings |
| | mean score (%) | 97 | 98 | No change |
| 2 | mean time | 46 | 36 | 21% savings |
| | mean score | 97 | 93 | 4% increase |
| 5 | mean time | 73 | 56 | 22% savings |
| | mean score | 86 | 84 | 2% increase |
| 7 | mean time | 91 | 48 | 47% savings |
| | mean score | 74 | 86 | 16% increase |
| Module Test (mean score) | | 82.2 | 88.6 | 8% increase |

A unique revision step in the Capacitance Module was the addition of another lesson, Lesson 10. It was introduced to serve as a review lesson and included drill and practice problems on major training objectives from each of the original nine lessons. The lesson did not contain a test, since no new objectives were introduced. The mean lesson time for Lesson 10 was 110 minutes, but this time increase was compensated for by time savings gained from revision of the other lessons. Total effect of revisions of the Capacitance Module was perhaps best shown by increases in the mean score on the Module Test between the first tryout and the operational test, 82.2% to 88.6%, respectively.

It is important to report that only two revisions of the Capacitance Module lessons were necessary between the first student tryout and the operational test for the module. This increase in efficiency was thought to be due to the fact that all lesson authors had received previous experience in writing and revising lessons during development of the Inductance Module. From the first student tryout, capacitance lesson test scores were very high and the main aims of revisions were to smooth instructional flow and to attempt to increase lesson time savings.

4. Revisions of Series Circuits and Resonance Module

Four tryouts and revisions, using a total of 44 students, were made on the Series Circuits and Resonance Module. The effects of these revisions are shown in Table 8. Total module training time was reduced by five hours (19%) despite the fact that an extra lesson was added to the module and the Supplemental Test Score mean was increased by 6%.

TABLE 8

Revision of Series Circuits and Resonance Module

| Tryout | N | Module Time | Supplemental Test Score (%) | Area Test Score |
|---|---|---|---|---|
| 1 | 10 | 26 hrs. | 80 | 78 |
| 4 | 12 | 21 hrs. | 85 | 80 |

C. Comparisons of CAI with Group Instruction

1. Experimental Design and CAI Modules Used

The five CAI Modules developed during this project were used in operational tests which compared CAI with standard classroom instruction. Each module was evaluated separately. The CAI modules were AC Theory, Inductance, Capacitance, Direct Current, and Series Circuits and Resonance. For details of the operational tests of AC Theory, Inductance and Capacitance see Ford and Slough (1970), Hurlock (1971), and Hurlock (1972).

Students who received CAI training were randomly selected from classes ready to receive instruction over the same training objectives included in the CAI material. In other words, all students used in CAI testing were taken from regular classrooms, and it was the responsibility of the project to see that these students received instruction over the same training objectives they would have received if they had remained in class. At the end of CAI training, CAI students had to be able to return to the BE/E School and resume normal classroom instruction with their regular class. This was the situation which existed from the very first CAI module tryouts through the operational test phase.

The basic experimental design employed to compare CAI with group instruction (classroom training) was a simple two-group, experimental/control experiment:

| Group | Training | Supplemental Test | School Exam |
|---|---|---|---|
| Experimental | CAI | Yes | Yes |
| Control | Classroom | Yes | Yes |

CAI students were treated exactly like control, classroom students except for the training mode, CAI. Both groups received both the CAI Supplemental Test and the School Area Examination at the end of training.

2. Results of Comparisons of CAI with Group Instruction

The results of comparisons of the five CAI modules with standard classroom instruction are summarized in Table 9. The summary includes data expressed as means for CAI and class on training time and test performance scores as well as attitude information obtained from CAI students at the end of CAI training. CAI Inductance and Capacitance Module data are partially combined because they comprised the School Area Five curriculum and were evaluated together during the operational test of the capacitance module.

TABLE 9

Comparisons of CAI and Class Performance

| Comparisons | | AC Theory | Inductance/Capacitance | | DC | Series Circuits |
|---|---|---|---|---|---|---|
| N | CAI<br>Class | 51<br>200 | 64<br>64 | | 50<br>20 | 50<br>64 |
| Training Time (hrs) | CAI<br>Class | 9.5*<br>15.6 | 8.1*<br>17.0 | 7.6<br>17.0 | 5.5*<br>10.3 | 17.7*<br>34.0 |
| Supplemental Test (%) | CAI<br>Class | 92*<br>82 | 85*<br>80 | 90*<br>78 | 76*<br>58 | 86*<br>79 |
| School Examination (%) | CAI<br>Class | 94*<br>87 | 85*<br>80 | | 88*<br>85 | 82<br>80 |
| % CAI Preferred<br>CAI Rating | | 70.4<br>4.6 | 70.4<br>4.4 | | 82.7<br>4.3 | 78.2<br>4.1 |

*Statistically significant compared to class instruction.

The CAI modules showed 39 to 54% savings in comparison to corresponding classroom training time. These differences were statistically significant for all five modules at the .001 level.

The CAI students scored significantly higher than classroom students on all module supplemental tests at the .001 level. Statistical differences at the .001 level were also found between groups on the AC Theory and on the Inductance/Capacitance School Examinations and at the .05 level on the DC School Examination. The CAI and Class students did not differ in their performance on the Series Circuits School Examination.

Attitude questionnaire answered by CAI students at the end of their CAI training indicated that if given a choice, they would prefer over 70% of their entire BE/E School training via CAI. On a five point scale, where 1 = very poor, 3 = average and 5 = outstanding, CAI students rated CAI training with an average of 4.4 points.

D. Effects of Long Term CAI

The purpose of this research was to determine if there is any decrement in student performance or motivation as a result of extended experience with CAI. A comparison was made between students who took a single CAI module without any prior CAI and students who had had prior experience on one to four CAI modules. Data on the performance of students taking only a single module of CAI had already been collected in the operational tests previously described. An additional 50 students were given all five modules consecutively. These students were randomly selected in the same manner as in the short term single module studies. Analysis of aptitude scores indicated that the short term and long term groups were equal in ability.

Long term CAI was found to be beneficial rather than detrimental to student performance. The top part of Table 10 shows the experimental design. For AC Theory, Inductance and the first half of Series Circuits (SC 1-10), the short term CAI students had zero hours of prior CAI. During training on these modules, lower half of Table 10, the long term CAI students obtained time savings over the short term CAI students ranging from 7 to 23%.

TABLE 10

Mean Time Savings Produced by Extended Experience with CAI

| Module: | ACT | IND | SC 1-10 | CAP | SC 11-20 |
|---|---|---|---|---|---|
| Prior CAI (hrs.) | | | | | |
| Short Term CAI: | 0 | 0 | 0 | 8.1 | 8.5 |
| Long Term CAI: | 7.4 | 14.7 | 29.6 | 22.2 | 37.3 |
| Training Time (hrs.) | | | | | |
| Short Term CAI: | 9.5 | 8.1 | 7.3 | 7.6 | 5.2 |
| Long Term CAI: | 7.3 | 7.5 | 6.4 | 7.4 | 5.1 |
| % Time Saved | 23 | 7 | 12 | 3 | 2 |

For short term CAI, students taking Capacitance or the last half of Series Circuits (SC 11-20) had already had about eight hours of CAI. These students did not differ from the long term students in training time, as the right side of Table 10 shows (2% and 3% difference). Apparently, students exhibit a small amount of "learning how to learn" in CAI and this process takes no more than about eight hours of experience.

Table 11 shows that both groups were practically the same in module test performance and student ratings of CAI. However, long term CAI resulted in a measurable increase in the preference of students for CAI rather than standard instruction. The superiority of CAI is not due to novelty.

TABLE 11

Mean Posttest Performance and Student Ratings in Short Term and Long Term CAI

| | Area Tests | Suppl. Tests | CAI Rating* | % CAI Preferred |
|---|---|---|---|---|
| Short Term | 86 | 88 | 4.5 | 71 |
| Long Term | 86 | 88 | 4.2 | 83 |

* 1 = very poor; 5 = outstanding

## E. Paired Students Trained by CAI

An experiment was conducted to determine if students working in pairs at a CAI terminal were as effective as students working individually (Hurlock & Hurlock, 1972). The problem has potential implications for cost feasibility of CAI as well as for research on learning and instruction. The CAI Inductance and Capacitance Modules were used for the experiment. Students were randomly assigned to the experimental (pairs) and control (individual) groups. During training the paired students exchanged positions from lesson to lesson in the role of using the keyboard to answer questions. All students in the experiment took the two module tests and the Area Examination individually.

No significant differences were found between students trained in pairs (N = 50) and students trained alone (N = 25) in performance on two major tests and a comprehensive examination or in training time. Mean percent correct scores on the CAI Inductance and Capacitance Module Tests and on the School Area Examination for pairs were 86.0, 90.4, and 83.9, respectively. Mean scores for individuals were 89.1, 92.6, and 84.8, respectively. Mean training time was 869 minutes for pairs and 820 minutes for individuals.

The data strongly supported the hypothesis that students can be trained in pairs at a CAI terminal without degradation in performance or in training time over that expected for students trained alone. In conclusion, it appears that paired student training is a potentially feasible method to reduce the cost per terminal hour of CAI, where CAI course materials are basically fixed sequenced and where students are paired on the basis of learning rate and aptitude.

## F. Evaluation of Branching Technology

In this section, brief summaries are given of experimental evaluations of six types of branching technology previously described in Section II. Most of these techniques were developed and incorporated into CAI materials for the operational tests, including the long term CAI test. Two of the techniques were tested in separate experiments at the conclusion of the operational tests.

1. Remedial Branching

This study evaluated the effectiveness of the CAI branched remedial pretraining previously described in Section II.B.4. The pretraining was given just before the CAI module on DC series-parallel circuits and provided remediation for students coming from class instruction on simpler circuits. The pretraining was needed by most students because analysis of student tryout data showed that the ability to analyze simple series and parallel circuits was a necessary prerequisite to training on more complex series-parallel circuits.

The remediation was designed to be maximally adaptive to individual differences in knowledge of prerequisites. There were three remediation lessons. In each lesson, the student could bypass training on any of the objectives. However, if the student missed an item on the lesson test and had skipped the pertinent training, he was immediately branched to that training before continuing with the test. (Refer to Figure 4.)

A control group of 15 students took the CAI DC Module without any remediation. The experimental group (N = 50) consisted of students used in the Long Term CAI study. They were given the CAI remedial pretraining before taking the CAI DC Module. Results are shown in Table 12.

TABLE 12

Remediation Time and Module Test Performance

| | Remediation Time (min.) | | | | Mean Module Scores | | |
|---|---|---|---|---|---|---|---|
| | Lessons Mean | Lessons Range | Tests Mean | Tests Range | Lesson Tests | Criterion Test | School Exam |
| No Remediation | — | — | — | — | 69 | 58 | 78 |
| Remediation | 57 | 2-198 | 58 | 19-134 | 78 | 76 | 88 |

The remediation appeared to be very adaptive to individual differences. Total remediation time ranged from 2 to 198 minutes on the lessons and 19 to 134 minutes on the lesson tests. The average student required less than two hours (57 + 58 minutes) for the entire pretraining. This pretraining provided remediation for about 22 hours of previous class instruction.

Test performance on the CAI DC Module is shown in the right half of Table 12. Students who had received remediation scored significantly higher on all three tests than students who had not received remediation. The difference was particularly large for the CAI criterion test for the series-parallel training. This was a very difficult test - both CAI students who did not receive remediation and students who took their entire training in class averaged 58%.

2. Pretest Branching Designs

The instructional strategies for these two designs, Pretest Design I, "Skip Ahead," and Pretest Design II, "Minimal Training," were discussed in Section II.B.5. Two lessons in the CAI Capacitance Module were constructed to serve as evaluation vehicles. Lesson 3 (CAP 6) incorporated the "skip ahead" strategy, and Lesson 6 (CAP 6) used the "minimal training" strategy. Time and manpower restrictions prevented an experimental comparison with fixed sequence training controls using the same lessons. It was therefore necessary to evaluate the pretest designs descriptively against two other lessons, CAP 5 and CAP 7, which were developed as fixed sequence training lessons.

During the operational test of the CAI Capacitance Module, frame-by-frame computer performance data were recorded for each of 64 experimental students as they proceeded through the lessons. Lesson training time, beginning with the first lesson frame and ending with the last lesson frame, and lesson test scores (% correct) were also recorded. Performance data on each lesson were sorted and listed for each student. Student trails, student-by-frame, were analyzed to obtain a count of total frames encountered. A frame was counted only once, i.e., retrys and light pen mismatches were not counted.

Lesson test scores were high on both the experimental and the control lessons. Median scores on the lessons ranged between 88 and 96%. All four lessons appeared to be instructionally effective, if not equal. These data were interpreted as being supportive justification for making further comparisons between the experimental and the control lessons.

Amount of training received was determined by comparing a count of the total number of frames encountered by each student in each lesson. The hypothesis that pretest branching designed lessons would permit large individual variations in the amount of training given to each student was positively supported. This was especially shown in the measures of variability such as range (46-101 and 13-56), range ratio (2.1 and 4.3) and coefficient of variation (15.4 and 42.2) for CAP 3 and CAP 6, respectively. By definition, there was no variability in the fixed sequence lessons for amount of training.

Training time to complete instruction in each lesson is presented in Table 13. Although the amount of training (mean number of frames) received in CAP 5 and CAP 7, fixed sequence lessons, (45 and 60 frames) fell between that of the two pretest lessons (73 and 23 frames), students took two to four times longer to complete the control lessons. Pretest lessons appeared to allow for large individual variations in training time, especially in the direction of completing training rapidly.

Range ratios (ratio between the longest time and the shortest time) and coefficients of variation for the pretest lessons were much larger than those for the control lessons. Figure 16 shows that pretest training lessons produced positively skewed completion times, while fixed-sequence lessons resulted in training time approximating a normal distribution.

TABLE 13

Training Time on Pretest and Fixed-Sequence Lessons

| | Pretest | | Fixed Sequence | |
|---|---|---|---|---|
| | CAP-3 | CAP-6 | CAP-5 | CAP-7 |
| Median (minutes) | 20.2 | 13.9 | 56.5 | 46.7 |
| SD | 7.6 | 9.9 | 9.5 | 9.9 |
| Range | 12-47 | 5-60 | 37-83 | 31-70 |
| Range Ratio | 4.0 | 12.0 | 2.2 | 2.3 |
| Coef. Var. | 34.2 | 59.5 | 16.8 | 20.7 |

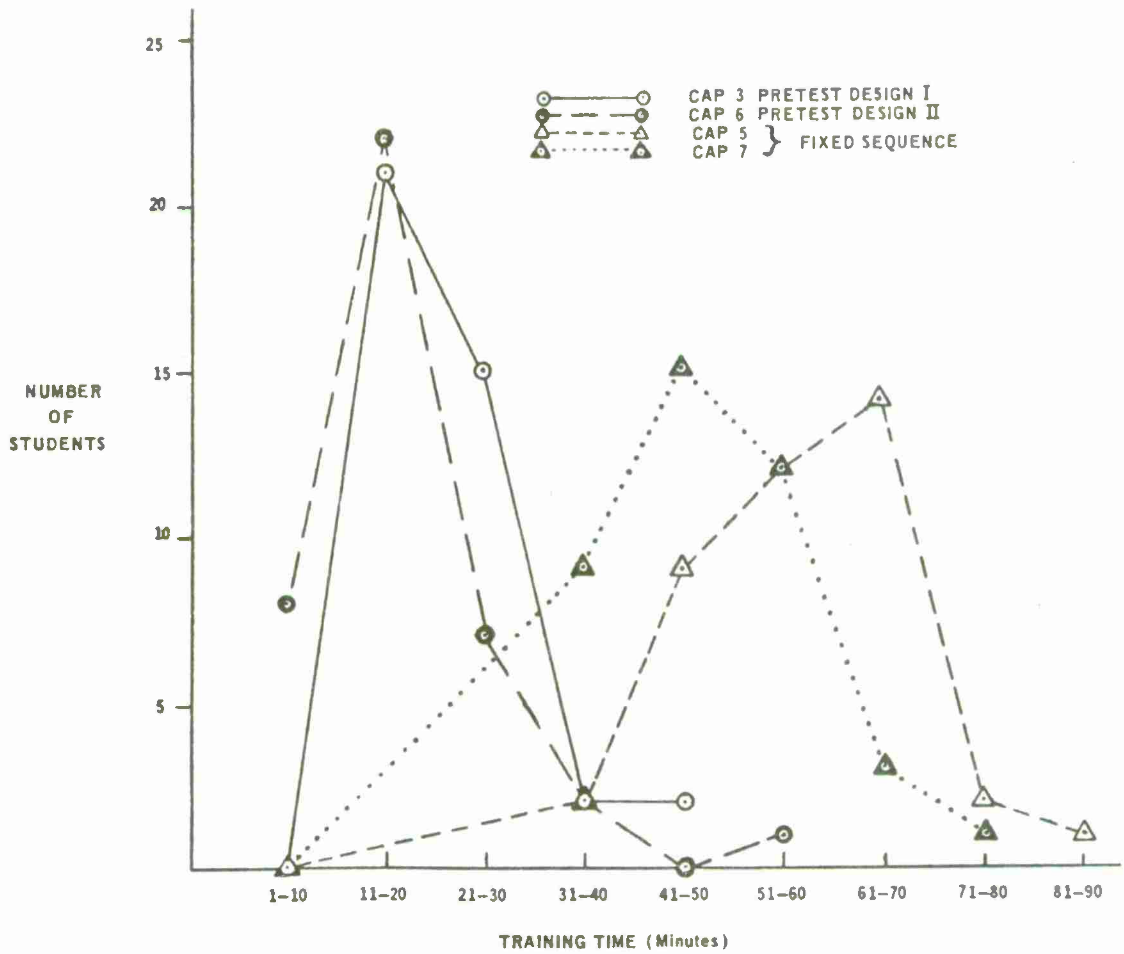



Figure 10. Training time distribution of Pretest and Fixed Sequence lessons

The evaluation of "skip ahead" and "minimal training" pretest designs appeared to demonstrate that adaptive training allowed each student to receive the amount of instruction that he needed on each training objective. As the number of training frames encountered by students tended to be positively skewed or normal, the importance of pretest or individually adaptive branching is supported. It indicates that the majority of students need only minimal or selective training. The pretest designed lessons allowed the fast learner to take 50 to 75% less instruction than the naive or slow learner. Training time differences between students going through the adaptive lessons were very pronounced. Pretest designed lessons allowed fast learners to proceed through the lessons 4 to 12 times more quickly than slow learners. On the other hand, in fixed sequence CAI lessons fast learners could complete lessons no more than twice as quickly as slower learners.

3. Multiple Branching

Much of CAI has followed a fixed sequence structure with extensive internal branching within frames (retries and hint frames) but with limited opportunities for external branching involving whole sequences of frames. The present study (Slough, et al. 1972) compared fixed sequence lessons with branching lessons which incorporated a variety of branching applications under the control of the program or the student or both.

Lessons C and E of the CAI Series Circuits and Resonance Module were used for this research. In their original form, the lessons were basically fixed sequence lessons with little opportunity for external branching. The revised version of lesson C provided multiple opportunities for branching in remediation, instruction, practice, and review. The branching version of lesson E provided preliminary instruction in the student's Study Guide and emphasized the use of dual control practice for the CAI portion of the training. Flow charts of the branching versions of lessons C and E have previously been shown in Figure 7 and Figure 8, Section II.B.

The first branching versions produced a very large time savings over fixed sequence instruction. However, there was also a loss in test performance so the lessons were revised. The final branch versions provided increased scope for branching and optional formal review at the end of the lessons.

Table 14 compares performance on the fixed sequence version with performance on the final branching version. Branching produced a significant ($p<.01$) and very substantial time savings in both lessons. Furthermore, branching was equally effective for students of high and low aptitude. Scatter plots and regression analysis indicated that average time savings were the same at all aptitude levels sampled.

Although test scores decreased slightly, performance on the branching versions was quite satisfactory (94 and 93%).

TABLE 14

Mean Training Times and Test Scores for
Fixed Sequence and Branched Instruction

| Measure: | Time (min.) | | Score (%) | |
|---|---|---|---|---|
| Lesson: | C | E | C | E |
| Fixed Sequence: | 77 | 81 | 98 | 94 |
| Branching: | 33 | 57 | 94 | 93 |

A comparison of this experiment with previous research suggests that the following factors are particularly critical in designing branched instruction: (1) The usefulness of optional bypassing of initial instruction depends on the extent to which the student is provided with exact knowledge of the course objectives; (2) branching programs are most useful when there is some prior student attainment of these objectives, or if there is provision for pretraining or concurrent training which produces a range of attainment; (3) "dual-control" practice provides a useful balance between complete program control and complete student option; (4) availability of formal review is very important in providing sufficient retention.

4. Branching in Drill and Practice

This study compared program control and dual control methods for determining the amount of practice to be given to each student. Lesson 15 of the Series Circuits and Resonance Module was used as the research vehicle. This lesson was a drill and practice lesson on analysis of LCR circuits. Training on each objective consisted of practice on the two components of the objective (e.g., find phase angle and impedance) followed by a criterion problem which combined both components.

Two versions of the lesson were prepared. In the program control version, practice was continued until the student had done two problems correctly on the first try. The student then did the criterion problem and went on to the next objective. In the dual control version, the practice was completely optional. However, if the student missed the criterion problem and had skipped the practice, he was required to go back and do the practice. Practice continued until he did one problem correctly.

Results are shown in Table 15. Dual control practice required much less time than program controlled practice, and as might be expected, the difference was statistically significant ($p<.001$). Although test performance was higher in the dual control version, it was not significantly different from the program control version.

These findings, combined with those from the previous section, clearly indicate that strict program control of drill and practice is less efficient than dual control procedures where the student is allowed to enter into the decision process.

TABLE 15

Comparison of Program Control and Dual Control Branching in Drill and Practice

| Measure: | Training Time (min.) | Test Score (%) |
|---|---|---|
| Program Control: | 69 | 87 |
| Dual Control: | 39 | 95 |

5. Student Control Versus Program Control in Training

The goals of this study were to compare two instructional strategies for individualizing CAI training materials, and to evaluate the effect of providing a lesson narrative before training.

Two types of adaptive instructional strategies were compared: (1) the student selected his own training, and (2) the course program controlled training for the student based on his pretest results. The influence of having the student read a narrative overview of training content before CAI instruction on each lesson was also examined. The course material was a modified version of the previously developed CAI AC Series Circuits and Resonance Module.

Ninety-six students from BE/E School were divided into four different instructional strategy groups for taking the 11-lesson CAI Module. One training strategy allowed the student to select his training from an index of descriptive lesson objectives. A second training strategy pretested the student immediately before each lesson objective and branched him to appropriate training sequences on the basis of his test results. Each of these two strategies were used with and without a narrative presentation before each lesson to make the third and fourth experimental training conditions.

At the end of training and after completing an attitude questionnaire about their CAI training experience, all four groups took the School Area Examination and a Supplementary Test comprised of school training objectives not represented on the examination.

No significant differences were found between the four experimental conditions in test performance or training time measures. Questionnaire data indicated that students who selected their own training maintained a significantly more favorable attitude toward CAI. In addition, students who had a pre-training narrative available to them felt that it was a valuable aid.

The best indicators of CAI training success were scores on previous school examinations and prior time spent in the BE/E School's individualized training curriculum. Performance on the CAI Module was not significantly related to General Classification Test scores or to two other aptitude measures.

6. Effects of Student Control in Remediation

This study questioned whether student choice might prove to be the better way to select remediation training since the student would at that point have a better understanding of the lesson objectives. Course material was a modified version of the previously developed CAI AC Series Circuits and Resonance Module.

Two modes of lesson presentation were used: student option and pretest program control. All students took Lessons 1 and 2 in the same manner. For the remaining nine lessons, half of the students took training in odd-numbered lessons in the pretest mode, and training in even-numbered lessons in the student option mode. The sequence was reversed for the other half of the students to counterbalance the design.

Students were also assigned to one of three remediation modes: student option, program control, and test/retest. Remediation followed the lesson test if the student failed to pass a criterion of roughly 80% correct. The student option groups could take as much or as little of the scheduled remediation training as they chose. The program control groups took all scheduled remediation. The test/retest group received and went directly to the lesson remediation test. The results indicated no difference in performance as a result of either lesson treatment or remediation treatment. This suggests (1) that student choice is at least as effective as program control as a training strategy, and (2) that remediation which occurs immediately after a posttest is ineffective. Since student choice was preferred by students, and since it eliminates many problems in the preparation of training materials, it promises to be a superior training strategy for CAI lessons.

## IV. Evaluation of IBM 1500 System

An evaluation was made of both the technical and economic feasibility of the IBM 1500 system. Technical feasibility included general training effectiveness, hardware and software limitations, and operational limitations. The evaluation was derived from empirical data and experience in developing CAI for the application in basic electronics which was described in earlier sections of this report. The evaluation of any CAI system must take into account many factors, and these must be specified and evaluated in terms of the specific application. It is not intended that this evaluation be generalized to other applications where some of the factors which were found to be critical in this application may have substantially different levels of criticality.

### A. Technical Feasibility

1. General Training Effectiveness

a. Achievement of students. One of the first questions which must be answered is whether the 1500 system can be used to provide effective training. Based upon the results of the five CAI module evaluations as well as the long term CAI study, the answer to that question is that the training is very effective. CAI students scored consistently higher than students given conventional instruction. (See Section III for details.)

b. Efficiency of training. Not only should training be effective but it should be efficient. Time comparisons of CAI with classroom training on comparable sets of training objectives showed that CAI training required about 45% less time. (See Section III.)

c. Student reactions. Student reactions to the CAI programs were predominantly favorable with but a few exceptions. They preferred to take the bulk of their training via CAI. This was true whether they had experience with one CAI module or with all five modules. (See Section III.)

d. Output of information on student progress. While the 1500 system could not perform detailed analysis of student performance records simultaneously with providing CAI at the terminals, several student performance summaries were developed for on-line use. These proctor messages were especially useful to instructors for spotting student weaknesses and for managing the progression of individual students through the course. These messages also provided the lesson designers with a "quick look" at the effectiveness of lessons. In addition, a variety of off-line programs were developed in this project to provide more detailed course analysis. These made the 1500 system a very effective instrument for course evaluation and revision. (See Sections II.C., II.D., and III.B.)

It may be concluded that the 1500 system provides very effective training.

2. Hardware and Software Limitations

There are a number of limitations of the 1500 system which make it unsatisfactory as a training system for this application. Some of these limitations may not be as serious in certain other education or training applications or in research and development applications.

a. Coding. The language in which the CAI lessons were written is an authoring language called COURSEWRITER II. Writing code for lessons in this language is a long and tedious task except for lessons with very simple logic. It is not likely that instructional personnel will be able to code in this language without substantial training and considerable time being made available. In this project most of the lesson material was developed by research and instructional personnel using special lesson planning guides. Then college students trained in the use of COURSEWRITER coded and debugged the lessons at CAI terminals.

b. Programming of advanced instructional logics. Most advanced CAI techniques, such as student interaction with graphic simulation models, require complex instructional logics. While COURSEWRITER II can be used to implement some of these, the programming is cumbersome and results in large amounts of coding. With the limited amount of on-line direct access storage capacity for lessons, this limitation must be given even greater weight.

c. Graphic displays. Because author developed graphics are stored in core memory and because of limitations of core memory (32K words), there are severe limitations on the use of graphics with the 1500 system. Many advanced CAI techniques have a heavy requirement for graphics.

d. Amount of lesson material stored on-line. In the 1500 system the maximum amount of storage on disk drives for lesson material is four million characters. The five CAI modules in basic electronics require slightly more than four million characters of storage. If all lesson materials are not accessible at one time, serious problems of scheduling and utilization will develop. Thus, when CAI lessons are designed as in this project, training programs in excess of about five weeks in length would require more than one 1500 system to meet the requirement of having all lessons on-line simultaneously.

e. System response time. There were a few special conditions under which the response time of the system degraded seriously. One set of conditions involved the updating of graphics in a number of lessons which were being used at the same time. Under these circumstances, system response time degraded to an average of from 6 to 10 seconds. On a few occasions response times as long as 30 seconds were observed. These were special conditions encountered in only a few lessons. For the most part system response times were under five seconds, usually less than one second, as required by the specifications.

f. Audio capability. The audio units had several deficiencies which made them unsuited for training purposes. First the search time in finding a message on the audio tape was frequently long enough to disturb the training sequence within a lesson. Maximum search time was six minutes, but search times of several minutes occurred under branching conditions. Second, if the program failed to find the required message, the station was signed off and the intervention of a proctor was needed with the consequent interruption of a training sequence. Third, the procedure for entering audio message addresses into COURSEWRITER programs was cumbersome and time consuming and required special training. These problems were so severe that course authors tended to use less audio in lessons near the end of the project.

3. Operational Limitations

The 1500 system has a serious operational limitation with respect to its employment in many Navy training applications. The system has a limit of 32 terminals. Thus, for the application to basic electronics many more terminals would be required, since the daily on board count is between 300 to 500 students. Such an expansion would require the acquisition of additional 1500 systems. This solution would be very costly and would increase the operational support requirements and the complexity of managing the system. The 32 terminal limitation not only imposes severe operational restrictions but also adds to the inherently high cost per terminal output of the system. Computer equipment such as central processing unit, disk and tape drives, line printer, card reader, and multiplexing equipment may be considered as computer overhead costs which must be prorated across the number of terminals served. Thus, a system with hundreds or thousands of terminals will generally have a much lower prorated cost of computer equipment than the 1500 system, even though the computer equipment in such a system may cost up to 10 or 20 times as much.

### B. Economic Feasibility

Economic feasibility refers to the cost of operating a CAI system as compared to the cost of an alternative program. When compared to the cost and effectiveness of the classroom training program, the IBM 1500 system can probably achieve sufficient cost savings through reductions in training time to pay for itself. However, the BE/E School has been converted to an individualized learning system, and it is reported that average training time has been reduced to about 21 training days in contrast to the former six week curriculum. Thus, the difference in training time between CAI and the individualized system is much smaller than between CAI and the classroom program.

It is not useful to introduce detailed cost figures on the IBM 1500 system since the configuration used in this project had only 16 terminals. The lease cost for this configuration was approximately $144,000 per year including maintenance. Costs of the 1500 system on a per terminal hour basis range from about $2.00 to $4.00 depending upon accounting procedures and whether a one or two shift operation is assumed. The lower figure, $2.00 per terminal hour, is several times larger than the target figure of between $0.40 to $0.80 per terminal hour estimated for some third generation CAI systems. Finally, although no announcement has been made, it is assumed that IBM Corporation is no longer devoting resources to develop or enhance the 1500 system.

## V. Related Applications

Since the results of evaluation indicate that CAI is a very effective method of instruction, the question arises as to the feasibility of shipboard CAI as well as other shipboard computer applications to training. It must be emphasized that the following discussion is based upon an extrapolation of experience with CAI at a shore based facility and not upon actual experience with CAI on shipboard. Work is being conducted on this problem at this Laboratory under ADO P43-03X.14, Application of Shipboard Computers to Training and Training Management.

### A. Computer Based Training Aboard Ship

#### 1. The Problem

The emphasis on more and better training aboard ship has been increasing steadily. The major reasons are the costs and inconveniences of sending shipboard personnel to shorebased training centers, and the basic fact that training ashore provides even the best student with terminal behaviors that are not synonymous with job entry behaviors upon his return or assignment to a ship. The increased emphasis on better shipboard training has naturally led to consideration of utilizing computers aboard ship for instructional and training management purposes.

The kinds of computer systems being considered fall into two main categories: first, those already installed for operational, non-training purposes, and secondly, those which could feasibly be added to shipboard inventory to satisfy training needs and requirements. The basic training applications that may be considered for both categories are fourfold: (1) simulation, (2) CAI, (3) CMI, and (4) training administration/management.

2. Shipboard Operational Computer Systems

A major breakthrough in utilization of shipboard operational computer systems for training purposes came with the advent of the Navy Tactical Data System (NTDS). The NTDS system incorporates a video simulator component which generates up to 32 synthetic targets for training purposes. Opinions vary as to whether or not this training capability has been effectively exploited for utilization on many NTDS ships. A library of well designed exercises is recommended for training individual NTDS operators and the entire Combat Information Center (CIC) team. Admittedly, the training capability of the video simulator is limited compared to large scale shore-based simulators like the Tactical Advanced Combat Direction and Electronic Warfare System (TACDEW). However, the usefulness of the simulator for shipboard use has been amply demonstrated.

More recently, a pioneer precedent for shipboard CAI with the NTDS system was PROF-E (Programmed Review of Operator Functions-Elementary) for the ASW function aboard a few ships. A later development was L-TRAN (Lesson Translator Program) which may be described as an AAW counterpart of PROF-E. Various constraints inherent in PROF-E show greater promise of resolution in L-TRAN. Work on L-TRAN has emphasized feasibility aspects with respect to computer programming and equipment, and much needs to be done in these two areas.

Prototype training packages are being delivered to NTDS ships but continued development work is needed in the areas of instructional design and preparation and validation of training materials.

Possibilities for CMI aboard ship utilizing presently installed computer systems are more promising than those for simulation and CAI. The basic reasons are fewer requirements for equipment, programming, and on-line time. The problems with respect to lessonware are of equal or greater magnitude since several instructional media are involved.

Shipboard computers which have at least a minimum potential for CMI as well as for training administration and management are the AN/UYK-5 and the CP789. Both would be used in the batch data processing mode. There may be serious problems of availability of the CP789 when underway. The AN/UYK-7 holds much greater potential for use in both applications as well as limited applications for CAI. Again the availability of the system is a serious question.

### 3. Minicomputers and Other Alternatives

An alternative to the use of shipboard computers installed for operational purposes is the installation of minicomputers configured for training and training management applications. A configuration consisting of the following would probably be required for CAI or CMI applications: CPU with 32K words core storage, disk units, magnetic tape units, card read/punch, line printer, multiplexer, typewriters and keyboard cathode ray tubes. An authoring language such as APL, BASIC, or a similar one would be required. Such a configuration would meet or exceed the requirements for training management provided that the data file requirements were not too large. The minicomputer would have many advantages for these applications, the most important being flexibility of scheduling. A major disadvantage is the cost of the system.

A second alternative is to use terminals aboard ship which are connected to a large, distributed terminal computer system ashore. Communication would probably be by satellite. There are many problems which must be solved before such a system configuration could become operational. Among these are communication problems, development of libraries of courses (both CAI and CMI), and utilization and training management aboard ship.

## B. Uses of Computer Based Instruction in a Training Program

Experience in this and other projects suggests three main alternatives in the use of computer based training methods: (1) mainline CAI, (2) CMI employing remote batch terminals or interactive terminals, and (3) mixed mode CAI/CMI.

In mainline CAI, a major portion of the instruction is provided at an interactive computer terminal and the instructional functions include presentation, practice, correction, testing and remediation. In CMI the instruction is provided by non-computer methods. Computer functions are employed to record and analyze student progress tests, provide test scores and diagnosis of training deficiencies and (optionally) prescribe training and materials for practice and remediation. In mixed mode CAI/CMI, non-computer training modules are under sequence and control of CMI functions. CAI is available for specialized practice and remediation, and for mainline instruction for selected parts of the training. All of these alternatives employ individualized instruction methods, that is, individually administered, modularized training materials. The designs may also be applicable to small tutorial groups.

While each of these alternatives might be most feasible for a given application, several advantages make the mixed mode CAI/CMI the most attractive. First, it allows for incremental development of computer based training systems; all development problems need not be solved before the computer based training operations can start. Second, computer based support is provided for individualized curriculum development and testing. Third, this design provides a highly controlled learning environment when it is needed. Fourth, cost effective off-line training can be used for large portions of training. Fifth, such a method provides a facility for development and testing of training modules. Sixth, the modularized, computer based features of the training system permit the entire training system to be moved and operated effectively at a site remote from a formal school without a complete replication of the school. For example, an entire curriculum can be installed in trailers or vans and transported dockside. For these reasons, and considering the state of the art, a mix of off-line training, CAI, and CMI, is viewed as the preferred system design.

## C. Third Generation Computer Based Instructional Systems

Two types of system configurations have been developed to meet the requirements for CAI and CMI. A major goal of each design is to reduce the operating cost of instructional terminals to within the cost range of $0.35 to 0.50 per terminal hour. Technological breakthroughs have made it possible to locate CRT type displays at great distances from the computer. Other innovations are directed toward simplyfing the authoring tasks such as course entry and editing. Each configuration will probably be optimal for certain training or instructional situations. Prototype examples of the systems are described below.

### 1. The TICCET System

Until recently no computer system hardware configurations were designed to meet the unique processing requirements of CAI or computer based instruction. If a system is designed specifically for computer based instruction, it is probable that very high performance can be achieved with a modest hardware configuration. Several such systems are being designed. A prototype example is the TICCET system (Time-Shared, Interactive, Computer-Controlled Educational Television), which is being developed under an NSF grant by MITRE Corporation in conjunction with the University of Texas and Brigham Young University (Stetten, Morton, and Mayer, 1970). MITRE is responsible for the hardware configuration and computer operating software. A technological breakthrough in this system is the use of a video player to refresh the TV display. There is also the possibility of using cable TV technology as the communication channel from computer to terminal. The system consists mainly of off-the-shelf components. The CPU is a mini-computer with fast cycle time, its disks are fast and high-capacity but low cost, and data channels are high speed. Terminal equipment consists of ordinary TV monitors with keyboards. For electronics training these terminals must be augmented by microfiche projectors. The system can drive approximately 125 terminals. The cost of the entire system including terminals is estimated to be under $350,000. The system will have virtually all the capability of the IBM 1500 system, but the cost per terminal hour would be reduced by a factor of four or five to one. The system could provide the required computer based training functions for many applications of a mixed mode CAI/CMI system.

### 2. The PLATO System

A large time sharing system can be made cost feasible if thousands of terminals can be connected to it. The problem with such a configuration is that a large number of users usually means that the terminals must be distributed over a large area, perhaps hundreds of miles. To reduce costs of communication lines, either clusters of terminals must have sufficient memory for the displays in the cluster, or each CRT type display must have its own display memory. PLATO IV is a large time sharing system which utilizes a plasma tube for display (Alpert and Bitzer, 1970). The image is very persistent, remaining on the display until written over by new information. The physical configuration of the display screen permits back projection of still images. Thus, a combination of random access still images and computer generated information can be produced. Responses can be made either by keyboard or by pointing to a position on the screen. This terminal is a very versatile and powerful device for instruction as well as for other purposes.

The PLATO system is being evaluated at this Laboratory as part of the 43-03X project.

## VI. Conclusions and Recommendations

Computer assisted instruction provides a very effective method of training. CAI students scored higher than class instructed students on both the School Examinations and the Supplemental Tests. CAI required 39% to 54% less training time than class instruction. Students gave high ratings to their CAI instruction and would prefer to have about 70% to 80% of their instruction via CAI.

Extended experience with CAI does not have a detrimental effect. On the contrary, long term CAI was found to produce a small improvement in training time and an increase in the students' preference for CAI. Posttest performance was not affected.

Computer based training methods are ideally suited to the development of good instruction because the computer performance recording and processing capabilities make it possible to improve instruction to any required level. Data analysis and summary programs were developed in this project which allowed lesson designers to identify specific course weaknesses. Course revisions based on these analyses resulted in marked improvements in instruction.

Although CAI showed about a 45% time savings over group instruction, there is reason to believe that the efficiency of CAI can be improved even further. To do this, increased use must be made of branching technology in order to provide instruction which is maximally adaptive to individual differences. A number of advances in branching technology were made in this project and incorporated into the later lessons. The result was an improvement in student performance over the previous less adaptable CAI. In addition, it was found that student option was just as effective as program control of training by means of pretests. The use of student option simplifies course preparation. Finally, it was found that dual control of drill and practice using a combination of program control and student option was superior to strict program control. Continued research and development is needed to further improve the adaptability of instruction to student differences in ability, knowledge and motivation.

The most costly and time consuming part of CAI course development is the initial preparation of basic instruction -- computer coding and programming of these materials takes far less effort. CAI shares this materials development problem with all forms of individualized instruction.

Earlier CAI systems such as the IBM 1500 system can compete costwise with classroom instruction in some applications. However they are generally not cost effective in comparison to individualized instruction. The newer CAI systems, such as TICCET and PLATO IV, will be cost effective compared to off-line individualized instruction, and will provide greatly improved computer based training capabilities.

There are several promising new areas for application of computer based training techniques. These include shipboard training, use of CAI in multimedia individualized courses, and the utilization of standard CAI terminals for part of the training in programs which normally require expensive equipment or a high instructor-student ratio.

REFERENCES


Alpert, D. & Bitzer, D. L. Advances in computer-based education. Science, 20 March 1970, 167, 1582-1590.

Curriculum for U. S. Naval Schools, basic electricity and electronics course. A-100-010, A-100-011, Bureau of Naval Personnel, NAVPERS 93517, December 1967.

Final Report on the Naval Academy's CAI Projects. Report PR-0571-43, October 1971, Educational Systems Center, United States Naval Academy.

Ford, John D., Jr., & Slough, Dewey A. Development and evaluation of computer assisted instruction for Navy electronics training: I. Alternating current fundamentals. San Diego: Naval Personnel and Training Research Laboratory, May 1970. (Research Report SRR 70-32)

Hurlock, Richard E. Development and evaluation of computer assisted instruction: 2. Inductance. San Diego: Naval Personnel and Training Research Laboratory, May 1971. (Research Report SRR 71-22)

Hurlock, Richard E. Applications of pretest branching designs to CAI basic electronics training. San Diego: Naval Personnel and Training Research Laboratory, September 1972. (Research Report SRR 73-8)

Hurlock, Richard E. & Hurlock, Judith A. Paired students trained by computer assisted instruction. Proceedings, 80th Annual Convention, American Psychological Association, 1972, 495-496.

Preliminary instructor's guide for U. S. Naval School, basic electricity/electronics, A-C phase. A mimeographed edition, August 1967.

Slough, Dewey A., Ellis, Burl, & Lahey, George. Fixed sequence and multiple branching strategies in computer assisted instruction. San Diego: Naval Personnel and Training Research Laboratory, September 1972. (Research Report SRR 73-6)

Stetten, K. J., Morton, R. P. & Mayer, R. P. The design and testing of a cost effective computer system for CAI/CMI applications. The MITRE Corporation, document M69-39, Rev. 1, April 1970.

# DISTRIBUTION LIST

Chief of Naval Personnel (Pers-10)
(Pers-11b)
(Pers-A)
(Pers-A3)
(Pers-A31)
(Pers-A32) (3)
Chief of Naval Operations (OP-987F)
(OP-964)
(OP-39)
(OP-099)
(OP-29)
(OP-59)
Chief of Naval Technical Training (Code 34)
Office of Naval Research (Code 458) (2)
Commanding Officer, Service School Command, Naval Training Center, SDiego
Commanding Officer, Naval Training Equipment Center, Orlando
Commanding Officer, Naval Personnel Research and Development Laboratory
Superintendent, Naval Academy, Annapolis
Technical Director, CAI Project, U. S. Army Signal Center and School, Fort Monmouth
Air Force Human Resources Laboratory, Brooks Air Force Base, Texas
Office of Assistant Secretary of Defense (Manpower and Reserve Affairs)
Defense Documentation Center (12)
Air Training Command, Randolph Air Force Base, Texas (3)
Human Resources Research Organization (HumRRO)
COMASWFORLANT (Code 711)
U. S. Army Behavior and Systems Research Laboratory
Chief of Naval Training (Code 017)
Chief of Naval Training (CNT-N5)
Navy Education and Training Support Center, SDiego
Department of the Navy, Navy Recruiting Command, Washington, D. C.
Center for Naval Analyses, Arlington, Virginia
Chief of Naval Training Support
Commanding Officer, Service School Command, Naval Training Center, GLakes
Commanding Officer, Service School Command, Naval Training Center, Orlando
Commanding Officer, Navy Schools Command, Treasure Island, SFrancisco
Superintendent, Naval Post Graduate School, Monterey
Commandant, Marine Corps Headquarters, Washington, D. C.
Commanding General, Marine Corps Development and Education Command, Quantico
President, Naval War College, Newport, R. I.