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IDA PAPER P-1375

COST-EFFECTIVENESS OF COMPUTER-BASED INSTRUCTION IN MILITARY TRAINING

Jesse Orlansky
Joseph String

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April 1979

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

IDA

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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IDA Log No. HQ 78-20721

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Cost-Effectiveness of Computer-Based Instruction in Military Training	5. TYPE OF REPORT & PERIOD COVERED Final Report October 1977-March 1979
	6. PERFORMING ORG. REPORT NUMBER IDA Paper P-1375
7. AUTHOR(s) Jesse Orlansky, Joseph String	8. CONTRACT OR GRANT NUMBER(s) DAHC 15 73 C 0200
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, VA 22202	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task T-134
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology), The Pentagon, Washington, D.C. 20301	12. REPORT DATE April 1979
	13. NUMBER OF PAGES 220
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, VA 22209	15. SECURITY CLASS (of this report) Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

N/A

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer-assisted instruction, computer-managed instruction, technical training, cost-effectiveness of training, cost of training, effectiveness of training, military training, PLATO, TICCIT, IBM 1500, IDIIOM, LTS-3, GETS, CBTS, AIS, Navy CMI, Navy Computer-Managed Instruction System (continued)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The cost and effectiveness of computer-based instruction for military training are evaluated on the basis of about 30 studies conducted since 1968. Four methods of instruction are distinguished and compared:

- Conventional Instruction: group-paced lectures, and discussions.
- Individualized Instruction: self-paced (without computer support).
- Computer-Assisted Instruction (CAI): computer stores and provides instructional materials to students individually via interactive

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) terminals; computer tests and guides students; self-paced.

Computer-Managed Instruction (CMI): instructional materials and tests provided away from computer; computer scores the tests and guides students; self-paced.

Much of the data come from experiments of limited duration and with relatively few students; by contrast, some CMI systems have been used for 4 years. All findings are confounded by effects that may be due either to CAI or CMI, in comparison to conventional instruction, or to the revisions in course materials needed to modify a course from conventional to CAI or CMI instruction.

CAI and CMI save about 30 percent (median) of the time required by students to complete the same courses given by conventional instruction; CAI and CMI cannot be compared directly because different courses were used in each study. Student attrition appears to increase with CAI and CMI compared with conventional instruction, but changes in student quality may also account for this increase. Students prefer CAI or CMI to conventional instruction; attitudes of instructors, considered in only a few studies, are unfavorable to CAI and CMI. Individualized instruction (without computer support) also saves student time; little additional student time is saved when the same courses are given by CAI or CMI.

Direct comparisons of the cost and effectiveness of different methods of instruction are not now possible because only incomplete cost data were found. So-called cost savings attributed to CAI and CMI are based on estimates of pay and allowances of students for the time saved by these methods of instruction; allowances are seldom made for the costs of the CAI or CMI equipment and courseware, instructors, and other costs incremental to computer-based instruction.

19. KEY WORDS (continued)

General Electric Training System, Computer-Based Training System, Advanced Instructional System, Lincoln Training System.

ACCESSION for		
NTIS	White Section	☑
DDC	Buff Section	☐
UNANNOUNCED		☐
JUSTIFICATION		
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Contract DAHC15 73 C 0200
Task T-134

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- Individualized Instruction: self-paced (without computer support).
- Computer-Assisted Instruction (CAI): computer stores and provides instructional materials to students individually via interactive terminals; computer tests and guides students; self-paced.
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ACKNOWLEDGEMENTS

We gratefully acknowledge the receipt of information and advice offered by many colleagues, perhaps not all of whom are identified below. We hope they recognize improvements due to their help and overlook any failures to follow their advice. Comments made by reviewers of an initial draft were particularly helpful.

Macy L. Abrams	Navy Personnel Research and Development Center
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Earl A. Alluisi	Old Dominion University (now at Air Force Human Resources Laboratory)
Lt. Col. George Beall, USAF	Academic Instructor and Foreign Officer School of Air University
Richard Braby	Training Analysis and Evaluation Group, Navy
Dan Brown	Academic Instructor and Foreign Officer School of Air University
Margaret Carpenter-Huffman	The RAND Corporation
L. Dwayne Chambers	Office of the Chief of Naval Technical Training
Commander Paul Chatelier, USN	Office of the Deputy Under Secretary of Defense, Research and Engineering (Research & Advanced Technology)
Alice M. Crawford	Navy Personnel Research and Development Center
Lt.Col. Graham F. Crow, USAF	Air Training Command
Brian Dallman	Air Force Human Resources Laboratory
Dexter Fletcher	Defense Advanced Research Projects Agency

John Ford, Jr.	Navy Personnel Research and Development Center
Charles A. Gainer	Army Research Institute
Linda Graham	Office of the Chief of Naval Technical Training
Lt.Col. Roger Grossel, USAF	Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics)
Capt. Glenn E. Head, USAF	Air Force Human Resources Laboratory
Ronald W. Hess	The RAND Corporation
Richard E. Hurlock	Navy Personnel Research and Development Center
Charles Jorgenson	Army Research Institute
Norman Kerr	Office of the Chief of Naval Technical Training
Donald A. Kimberlin	Army Training Support Center
Dewey Kribs	Instructional Science and Development
Harvey S. Long	IBM Corporation
Merl K. Malehorn	Office of the Deputy Chief of Naval Operations (Manpower)
Linda Mark	Instructional Science and Development
Arthur S. Melmed	National Institute of Education
Donald E. Meyer (deceased)	Air Training Command
William E. Montague	Navy Personnel Research and Development Center
Robert L. Nadeau	Hazeltine Corporation
Lt.Col. Fred Nordhauser, USAF	Air Force Human Resources Laboratory
Harold F. O'Neil, Jr.	Army Research Institute
Wanda Rappaport	The MITRE Corporation
James J. Regan	Navy Personnel Research and Development Center
Marty R. Rockway	Air Force Human Resources Laboratory
Maj. Kenneth P. Rousseau, USAF	Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics)

Worth Scanland	Office of the Chief of Naval Education and Training
Capt. Philip J. Scott, USN	Office of the Chief of Naval Technical Training
Vincent J. Sharkey	Naval Training Equipment Center
Maj. J. Simmons, USAF	Air Training Command
Dewey Slough	Navy Personnel Research and Development Center
Joseph N. Small	Control Data Corporation
Robert G. Smith, Jr.	Office of Research, Development Test and Evaluation, Navy
Alfred F. Smode	Training Analysis and Evaluation Group, Navy
Harvey W. Stern	Navy Personnel Research and Development Center
William H. Stobie	McDonnell Douglas Astronautics Company
Michael H. Strub	Army Research Institute
Capt. William Strickland, USAF	Air Training Command
William M. Swope	Training Analysis and Evaluation Group, Navy
Col. Henry L. Taylor, USAF	Academic Instructor and Foreign Officer School of Air University
Martin A. Tolcott	Office of Naval Research
Nicholas Van Matre	Navy Personnel Research and Development Center
Keith T. Wescourt	Office of Naval Research
Lt.Col. Robert E. Wilkinson, USAF	Air Force Systems Command
Wallace H. Wulfeck, II	Navy Personnel Research and Development Center
Joseph Zeidner	Army Research Institute

CONTENTS

FIGURES

TABLES

ABBREVIATIONS

ADP	Automated Data Processing
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory (Brooks AFB)
AFOSR	Air Force Office of Scientific Research
AFPTRC	Air Force Personnel and Training Research Center (now AFHRL)
AIMS	Automated Instructional Management System (Army)
AIS	Advanced Instructional System (Lowry AFB)
ARI	Army Research Institute (Alexandria, VA)
ARPA	Advanced Research Projects Agency
ASIMS	Automated Shipboard Information Management System
ATSS	Aviation Training Support System (Navy)
B	Billion
CAI	Computer-Assisted Instruction
CAISMS	Computer-Assisted Instruction Student Management System
CBI	Computer-Based Instruction
CDC	Control Data Corporation
CERL	Computer-Based Education Research Laboratory (University of Illinois)
CII	Computer Integrated Instruction
CMI	Computer-Managed Instruction
CMS	Command Management System
CPU	Central Processor Unit
CRT	Cathode Ray Tube
CTS	Computerized Training System (Army; also Project ABACUS)
DARPA	Defense Advanced Research Projects Agency

DEC	Digital Equipment Corporation
DoD	Department of Defense
DoDI	Department of Defense Instruction
ESM	Extended Swap Memory
FY	Fiscal Year
GETS	General Electric Training System
GSA	General Services Administration
ICAI	Intelligence Computer-Assisted Instruction
IDIIOM	Information Displays, Inc. Input-Output Machine
IIA	Individualized Instruction Assignment
IM	Inventory Management
ISD	Instructional System Development
ITRO	Interservice Training Review Organization
LTS	Lincoln Terminal System (Lincoln Laboratories)
M	Million
MF	Materiel Facilities
MODIA	Method of Designing Instructional Alternatives (RAND Corporation)
MOS	Metal Oxide Semiconductor
MSP	Manually Self-Paced
MTBF	Mean Time Between Failures
Navy CMI	Navy Computer Managed Instruction System (Millington, Tennessee)
NPRDC	Navy Personnel Research and Development Center (San Diego, California)
NTDC	Naval Training Device Center (now NTEC)
NTEC	Naval Training Equipment Center (Orlando, Florida)
OJT	On-the-Job Training
ONR	Office of Naval Research
PCS	Permanent Change of Station
PLATO	Programmed Logic for Automated Teaching Operations (University of Illinois; CDC)

PME	Precision Measuring Equipment
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
SPM	Student Progress Management
TAEG	Training Analysis and Effectiveness Group (Navy)
TDY	Temporary Duty
TEC	Training Extension Course (Army)
TECEP	Training Effectiveness, Cost Effectiveness Prediction (Training Analysis and Evaluation Group)
TICCIT	Time-shared, Interactive Computer-Controlled Information Television (The MITRE Corporation; Hazeltine Corporation)
VTS	Versatile Training System (Navy; renamed ATSS)
WM	Weapons Mechanic

SUMMARY

This paper evaluates the cost and effectiveness of computer-assisted and computer-managed instruction for use in military training. The military Services have supported research and development on these methods of instruction since about 1960.

A. METHODS OF INSTRUCTION

Methods of instruction can be placed conveniently in four groups, as described below:

- Conventional instruction, where an instructor may use lectures, discussions, laboratory demonstrations, and tutorial sessions. Groups of students proceed through the curriculum at the same pace; differences in achievement among students are reflected in grades at the end of the course.
- Individualized instruction, where each student proceeds at his own pace through the curriculum that is arranged in a series of lessons and tests. Mastery of each lesson is set as a condition of progress. Differences among students are reflected in the amounts of time needed to complete the course, although grades may also be given. In general, an effort is made to assure about the same level of achievement for all students.
- Computer-assisted instruction (CAI), where all instructional materials, *i.e.*, lessons and tests, are stored in the computer; the student interacts with this material in real time via a terminal and display system. The

computer can perform many functions, such as diagnose student performance, prescribe lessons, maintain records on student progress, and predict individual course completion dates. Current CAI systems differ in the number of terminals linked to a central computer (1 to 1000) and location of the central computer (which may require long-distance communications). In "stand-alone" systems, a terminal and its computer comprise the entire system. The PLATO IV system is used in courses for medical technicians at Sheppard AFB and for vehicle repair at Chanute AFB. TICCIT is used in courses for tactical coordinators for S-3A aircraft at Naval Air Station, North Island. GETS, a stand-alone system, will be used to handle training overloads in the TRIDENT program.

- <u>Computer-managed instruction (CMI)</u>, where instruction using self-paced lessons takes place away from the computer. The computer scores the tests and interprets results to each student; advises him to take following or alternative lessons; recommends remediation; and manages student records, instructional resources, and administrative data. The Air Force Advanced Instructional System (AIS) is a prototype CMI system used for technical training at Lowry AFB. It can support up to 3000 students a day in four courses; the present version consists of 50 student terminals (for scoring tests), 11 management terminals (for use by instructors), and a CDC CYBER 73-16 computer. The Navy Computer Managed Instruction System (Navy CMI) at Naval Air Technical Training Center, Millington, Tennessee, now handles about 6000 students a day in 11 schools at five training centers in the United States; by 1980, it is expected to handle 16,000 students in 24 schools at 6 centers.

B. APPLICATIONS OF CAI AND CMI IN MILITARY TRAINING

CAI and CMI seem well-suited to providing specialized skill training both at military schools and at operational units in the field. Skill training at military schools is estimated to cost $3 billion a year and produce 1.1-million course graduates a year (FY 1979 data). The amount of technical training that occurs in operational units, *i.e.*, away from formal schools, is thought to be large, but its magnitude is unknown; this includes on-the-job training, crew and unit training, refresher and upgrade training.

The Department of Defense is estimated to spend about $12 million a year for research and development on the use of computers in military education and training (FY 1977 data).

C. NATURE OF THE DATA ON COST AND EFFECTIVENESS OF CAI AND CMI

The use of computer-assisted and computer-managed instruction in military training has been evaluated in about 30 studies (producing 48 sets of data) since 1968. Most (70 percent) of the data on CAI come from experiments with few students (up to 50) and limited course materials (1 day to 1 week). There are fewer studies of CMI but these involve more students (600 to 2500) and longer courses (2 to 10 months). There is a wide range of subject matter in these studies, *e.g.*, knowledge, theory, and hands-on performance skills; electronics machinist, recipe conversion, vehicle repair, fire-control technician.

Each of the 30 studies report effectiveness. However, only eight of the studies which report effectiveness also provide some cost data. The latter data are limited to expenses incurred during the experiment and are incomplete with respect to costs of program management, maintenance and repair, instructional support, and other factors important in determining life-cycle costs. It is probably inappropriate to extrapolate from cost data in experiments to the costs of large-scale, long-term operational training programs.

The effectiveness of training should be measured by how well course graduates perform specific jobs in operational units. Instead, all studies use student achievement at school as a measure of effectiveness. The relation between achievement at school and performance on the job is essentially unknown, even for conventional instruction. Data on length of time required for students to complete a course (generally less for CAI and CMI than for conventional instruction) should be treated as a measure of the cost of instruction rather than a measure of its effectiveness. The same argument applies to academic attrition rate. The attitudes of students and instructors to CAI and CMI may be interesting; however, they are qualitative in nature and it is difficult to relate such data either to the cost or the effectiveness of instruction.

The comparisons of alternative methods of instruction are limited. Generally, CAI or CMI is compared to conventional instruction; we found only a few comparisons of CAI and CMI with individualized instruction (without computer support), a comparison which relates to the benefits of computer support. In addition, time savings found when CAI or CMI are compared to conventional instruction may be due to a combination of self-pacing, computer support, revised and possibly reduced amounts of course materials.

D. EFFECTIVENESS OF CAI AND CMI

Based on evidence provided by military research studies and qualified as noted above, the effectiveness of CAI and CMI is evaluated as follows:

- Student achievement. Student achievement at school with CAI is about the same as that with conventional instruction in most comparisons and superior in about one-third of the comparisons. The differences in achievement are not thought to have practical significance. Student achievement with CMI is about the same as that with conventional instruction. These findings are important but also inevitable because students are held in CAI and CMI courses until they achieve at least the standards established previously for conventional instruction.

- Student time savings. Students instructed by CAI or CMI save about 30 percent (median value) of the time required to complete the same courses given by conventional instruction. There is a wide range in amounts of time reported as saved in these studies. The amounts of time saved by CAI and CMI cannot be compared directly because different courses were used for tests of these methods of instruction. Where courses have been given for relatively long times, the initial student time savings are maintained and, despite monthly fluctuations, tend to increase. This finding is based on four courses given by the Air Force Advanced Instructional System for about 4 years and on three courses given by the Navy Computer Managed Instruction System for about 15 months; both systems are CMI systems.

- Student attrition. The academic elimination rates in four courses on the Air Force Advanced Instructional System (AIS) appear to have increased slightly over 4 years compared to the previous base rates; however, the average academic elimination rate for all courses at Lowry AFB, *i.e.*, those not on AIS, increased at the same time. Thus, the increase in attrition may be attributed to AIS (*i.e.*, CMI) instruction or to a decrease in student quality or to some combination of these two factors. Similar increases in attrition seem to have occurred in six courses on the Navy CMI system over a 15-month period; attrition dropped in one course; data on non-CMI courses for the same time period were not provided.

- <u>Attitudes of students and instructors</u>. Students in experiments almost always prefer CAI or CMI to conventional instruction. The attitudes of instructors are reported only in a few studies but these are almost always unfavorable to CAI and CMI in comparison to conventional instruction.

- <u>Time savings found with individualized instruction and computer-based instruction</u>. Some data were found where the same course was given by conventional instruction, individualized instruction (*i.e.*, self-paced instruction without computer support) and either CAI or CMI. Individualized instruction saves student time. However, the addition of computer support (either CAI or CMI) to individualized instruction does not increase the amount of student time saved very much beyond that achieved by individualized instruction alone (*i.e.*, without computer support). Again, differences between time savings attributed to CAI and CMI cannot be evaluated because different courses were used in each group of studies. These data do not necessarily imply that the addition of CAI or CMI to individualized instruction (*i.e.*, transforming the method of instruction) is not cost-effective. That would depend on whether the incremental costs of computer support are offset by benefits in other areas such as, *e.g.*, a need for fewer instructors and support personnel and for less administrative support.

E. COSTS OF INSTRUCTION IN MILITARY TRAINING

The benefits of computer-based instruction have to be compared with the cost of providing this type of instruction, but only incomplete cost data were found.

- <u>Collection of cost data</u>. The military Services maintain systems that report the costs of individual courses.

These are useful for such purposes as setting reimbursement rates for training students from other Services or other governments. They are not useful for analyses of the costs of different methods of instruction for the following reasons: (1) they do not distinguish the costs of parts of a course, which would permit determining the costs of different methods of instruction used within a course; (2) costs of training support and management, that may vary considerably between methods of instruction, are allocated to individual courses on essentially arbitrary bases, such as the student load of all courses.

- Type of data needed on cost of instruction. Each method of instruction in military training requires the expenditure of funds for most, but not necessarily all, of the following functions:

PROGRAM DEVELOPMENT
- Program Design
- Instructional Materials
  - Conventional Instruction
  - Individualized Instruction
    - Programming
    - First-Unit Production
  - Computer-Based Instruction
    - Programming
    - Coding

PROGRAM DELIVERY
- Instruction
  - Instructors
  - Instructional Support Personnel
- Equipment and Services
  - Laboratory (including simulators)
  - Media Devices
  - Computer Systems
  - Communications

Materials (including Consumables)

Facilities

PROGRAM MANAGEMENT AND ADMINISTRATION

STUDENT PERSONNEL

Pay and Allowances

Other (Permanent Change of Station, Temporary Duty)

Limited cost data were found for some of these resources and these are presented in the report. Cost data were *not* found or were extremely limited for the following resources for *all* methods of instruction:

- Program Design
- Instructional Material: conventional instruction
- Instructional Support Personnel
- Laboratory Equipment
- Materials (including consumables)
- Program Management and Administration
- Student Personnel: Permanent Change of Station, Temporary Duty, *etc.*

• Collection of More Complete Data. Detailed cost data, required for analytical purposes, may be collected in three possible ways:

- Universal, more complete reporting for all courses and support functions
- Sampling selected courses and support functions
- *Ad hoc*

The costs and benefits of these ways of collecting the cost data needed to evaluate alternative methods of instruction should be examined.

F. COST-EFFECTIVENESS OF COMPUTER-BASED INSTRUCTION

There have been few attempts to assess the cost-effectiveness of computer-assisted or computer-managed instruction and all of these are limited, as indicated above, particularly with respect to the cost data that have been used. The following results have been reported:

- CAI. The PLATO IV system was judged to be not cost-effective in two evaluations. Although substantial amounts of student time were saved (19 to 89 percent in eight courses), PLATO IV was judged to be not as cost-effective as self-paced instruction (because of high communications and maintenance costs) in one case and not as cost-effective as programmed instruction (because of greater development and operating costs) in the second case.
- CMI. It was estimated that the Navy CMI system avoided costs of $10 million in FY 1977 and that the Air Force AIS avoided costs of $3 million in FY 1978. Both of these estimates are derived by translating amounts of student time saved into dollars avoided for student pay and allowances because of the reduced training times. The costs of providing CMI instruction are not considered in these reports. In a recent test, the AIS was judged to be cost-effective, compared to instructor-supported self-pacing in one course but not in three others because of costs attributed to the AIS computer; however, the computer costs were small in comparison to other school costs.

CONCLUSIONS

A. MEASURES OF EFFECTIVENESS

The effectiveness of computer-assisted and computer-managed instruction for military training has been measured only by student achievement at school and not by performance on the job. Correlations between performance at school and on the job have not been established for any method of instruction.

B. STUDENT ACHIEVEMENT AT SCHOOL

Student achievement in courses at military training schools with computer-assisted instruction is the same as or greater than that with conventional instruction; the amount of additional achievement is small and has little practical importance. Student achievement in courses with computer-managed instruction is about the same as that with conventional instruction. Both of these results are due to keeping students in CAI and CMI courses until they achieve standards set previously for conventional instruction.

C. STUDENT TIME SAVINGS

Computer-assisted and computer-managed instruction in military training save about 30 percent of the time (median value) needed by students to complete the same courses given by conventional instruction. The amounts of time reported as saved vary widely, but little attention has been given to the factors that could account for the wide variation. Most of the results on computer-assisted instruction come from experiments of limited duration, with limited amounts of course materials, and with relatively few students. Where computer-managed instruction has been used for extended periods (up to 4 years), the initial time savings have been maintained or increased.

D. INDIVIDUALIZED AND COMPUTER-BASED INSTRUCTION

Individualized instruction (self-paced instruction without computer-support) saves student time; little or no additional student time is saved when the same courses are given by computer-assisted or computer-managed instruction.

E. STUDENT ATTRITION

Computer-managed instruction may increase the rate of student attrition for academic reasons, compared to that with conventional instruction. The observed increases in attrition may also be due, at least in part, to decreases in student quality, but this relationship has not been carefully examined. Student attrition appears not to increase with computer-assisted instruction, but this finding is based on tests of limited duration.

F. STUDENT AND INSTRUCTOR ATTITUDES

Attitudes of students toward computer-assisted and computer-managed instruction appear to be favorable. Attitudes of instructors are reported as unfavorable, but this finding is based on very limited data. Little attention has been given to the role of instructors in computer-based instruction and to how they should be prepared for this type of instruction.

G. COST DATA

Only limited and incomplete data are available on the costs of computer-assisted and computer-managed instruction in military training. Data that are collected routinely on the costs of operational training programs are too highly aggregated, particularly with respect to training support functions, for use in analytical comparisons of computer-based instruction with conventional instruction.

H. COST-EFFECTIVENESS

Estimates based on the amounts of student time saved suggest that the Navy Computer Managed Instruction System avoided costs of about $10 million in FY 1977 and that the Air Force Advanced Instructional System avoided costs of about $3 million in FY 1978. These estimates are incomplete because they do not consider the other costs of providing computer-managed instruction at these installations or compare these costs with the costs of alternative methods of instruction for the same courses.

RECOMMENDATIONS

A. JOB-PERFORMANCE DATA

Improve methods currently available for measuring performance on the job in areas related to technical training. Compare achievement at school with performance on the job for students in courses given by computer-assisted and computer-managed instruction; to whatever extent opportunities exist, do the same thing for the same courses given by conventional and individualized instruction. The job-performance data should be collected for several time intervals after students leave school to determine whether benefits in favor of any method of instruction are sustained as job experience increases.

B. COST AND EFFECTIVENESS DATA

Evaluate alternative methods of collecting reliable data on the costs and effectiveness of instruction in military training. Based on these findings, develop and initiate data-collection programs on the costs and effectiveness of alternative methods of instruction.

C. RESEARCH AND DEVELOPMENT PLAN

Bring up to date the "Integrated Department of Defense Plan for Research and Development on Computers in Education and Training" (Department of Defense, September 1975). Support is needed for Exploratory and Advanced Development (6.2 and 6.3 RDT&E funds) on many subjects identified in this paper, such as the development of objective measures of performance on the job, comparisons of student achievement at school with performance on the job, the development of methods to measure the quality of course materials and delivery of instruction, and studies to account for the relative contributions of self-pacing, course revision, computer support, and other factors to the amounts of student time saved by computer-assisted and computer-managed instruction. Support for other studies to improve various aspects of computer-assisted and computer-managed instruction may well be questioned until more reliable cost data are available to determine areas of high pay-off.

D. CURRENT AND PROPOSED SYSTEMS

Collect data on the costs of instruction for courses and course segments given now by computer-assisted or computer-managed instruction for military training, *e.g.*, PLATO IV at Sheppard Air Force Base, Texas, and at Chanute Air Force Base, Illinois; TICCIT at North Island Naval Air Station, San Diego, California; Advanced Instructional System at Lowry Air Force Base, Denver, Colorado; and Navy Computer Managed Instruction System at Naval Air Technical Training Center, Millington, Tennessee. Comparable baseline cost data should also be collected, as far as possible, for alternative methods of instruction for the same courses. Projections of cost should be made for computer-managed instruction systems that are now being planned; *i.e.*, the Navy Aviation Training Support System, the Army Automated Instructional Management System, and the Marine Corps Communication-Electronics School CAI/CMI System.

E. RANGE OF TIME SAVINGS

Determine the factors which account for the large variations in the amounts of student time saved by computer-assisted and computer-managed instruction in various studies. Consideration should be given to such factors as quality of courseware (including that in conventional courses), instructional strategy, types of subject matter presented in courses, and the amount and type of guidance provided by instructors. An effort should also be made to resolve the extent to which such factors as self-pacing, course revision, shortening courses, and various types of computer-support contribute to the total amounts of student time saved.

F. STUDENT ATTRITION

Determine the extent to which observed increases of student attrition with computer-managed instruction are due to this method of instruction and to other factors that may also be present, such as changes in the quality of students.

G. INSTRUCTORS' ATTITUDES

Determine the attitudes of instructors to computer-based and other methods of instruction in a systematic manner so that remedial actions can be taken as required.

I. INTRODUCTION

A. PURPOSE

The purpose of this study is to evaluate research and development on the cost-effectiveness of computer-based instruction for military training.

The use of computers to provide and support instruction is the result of significant developments that have occurred since about 1960: (1) growth in the capabilities of computer hardware and software and (2) improved procedures for designing lessons in a self-paced or individualized format needed for computer-based instruction. The Department of Defense and the military Services have supported the development of computer-based instruction because of its potential value to improve the effectiveness and reduce the cost of training, particularly where large numbers of students are involved.

This study was performed for the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology), Office of the Under Secretary of Defense for Research and Engineering. It responds to a recommendation made by the Defense Science Board:*

> To improve the effectiveness of training and training technology R&D, the DoD should:
>
> 1. Develop a capability to perform cost-effectiveness analyses of training technology.

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*Summary Report of the Task Force on Training Technology, Defense Science Board, 27 February 1976, (p. x).

B. METHODS OF INSTRUCTION

The Rand Corporation's "Method of Designing Instructional Alternatives (MODIA)" identifies 20 different methods of teaching (Carpenter-Huffman, 1977). For convenience, methods of instruction are organized here in four groups; more than one method of instruction may be used in a course. (See Appendix A for a more complete discussion.)

1. Conventional Instruction

Conventional instruction refers to many possible combinations of lectures, discussions, laboratory, and tutorial sessions as a method of instruction. A key feature of conventional instruction is that groups of students proceed through a course at the same pace. Differences in the amount of information retained by students are reflected in their grades at the end of the course. Conventional instruction is used in 75 to 90 percent of all military courses, although a precise estimate is not available. It is also referred to as lock-step instruction, platform instruction, and group scheduling.

2. Individualized Instruction

In individualized instruction, a course is arranged in a series of lessons and tests and each student proceeds at his own pace. Mastery of each lesson is prescribed as a condition of progress. Differences among students are reflected in how long it takes them to complete a course, although grades may also be given.

There are various forms of individualized instruction that differ primarily in such ways as the structure of lessons provided to the student (main line, branching) and the extent to which the student is completely free to proceed at his own pace. All methods of computer-based instruction rely on some form of individualized instruction; by definition, the term "individualized instruction" will be used here to apply only to this method of instruction conducted without computer support. The terms individualized instruction, self-pacing, and programmed instruction will be used synonomously unless otherwise specified.

3. Computer-Assisted Instruction (CAI)

In this paper the term *computer-based instruction* refers generally to both CAI and CMI methods of instruction. In computer-assisted instruction (CAI), the student interacts in real time, via an interactive terminal, with instructional material that is stored in the computer. This offers great flexibility for presenting alternative versions of the same lessons according to each student's particular way of learning. Most CAI systems diagnose student performance, prescribe lessons, and maintain student records. Examples of some CAI systems follow (see Appendix B for a more complete discussion):

- PLATO: Programmed Logic for Automatic Teaching Operation. A current version of this system, PLATO IV, can support about 950 terminals linked through microwave and land-line communications to a large central computer (CDC CYBER 74) located at the University of Illinois.
- TICCIT: Time-Shared Interactive Computer-Controlled Information-Television. The basic TICCIT system uses one or two mini-computers to support up to 128 terminals at one location.
- LTS: Lincoln Terminal System. The latest version, LTS-5, uses microfiche to store both visual images and an audio track. This is a self-contained or "stand-alone" system.
- GETS: General Electric Training System. This is a stand-alone system which uses a random access 35-mm slide projector for visual displays and floppy discs for lesson preparation and playback.

4. Computer-Managed Instruction (CMI)

In computer-managed instruction (CMI), instruction takes place away from the computer. The computer scores tests and interprets results to the student; advises on following or alternative lessons; recommends remediation; and manages student records, resources, and administrative data. (See Appendix B for a more complete discussion.)

This process is initiated typically when the student places a test answer sheet on an optical reader connected to the central computer. He receives the results on a printout which tells him how well he performed, what lesson to take next, and where to find it. Examples of some CMI systems follow:

- AIS: Advanced Instructional System. This prototype system is installed at the Air Force Technical Training Center, Lowry Air Force Base, Denver, Colorado. The present version consists of 50 student terminals, 11 management terminals, and a CDC CYBER 73-16 computer which can support up to 3,000 students a day in four courses. These courses were selected to represent a cross section of the technical training courses at Lowry AFB and serve about 25 percent of the student body there. The management terminals provide CAI services for use by instructors (for developing or revising lessons and for retrieving data collected by the system). The system could be expanded to provide CAI services to students.
- Navy CMI: Computer Managed Instruction System. This system, installed at Naval Air Technical Training Center, Millington, Tennessee (also referred to as Memphis, Tennessee), handles about 6,000 students in 11 schools at 5 centers. It is based on a Honeywell Series 60, level 66 computer.
- CTS: Computerized Training System. This system can provide CAI and CMI services for 128 terminals at the U.S. Army Signal Center and School, Fort Gordon, Georgia. It is based on six mini-computers (PDP-11/35s). Each terminal contains a visual display unit and a keyboard

which can provide both interactive instruction and course management services. (Note: A report evaluating the CTS in a CMI mode arrived too late for use in this paper. See Seidel, Rosenblatt, Wagner, Schulz, and Hunter, 1978.)

C. DISTINCTIONS BETWEEN MILITARY AND NON-MILITARY INSTRUCTION

Military personnel receive pay and allowances while they are in training. Thus, any procedure which can reduce the length of time required for training, without significantly affecting the amount and/or quality of information acquired, can assist in reducing the cost of training at military schools; it can also result in increasing the amount of time spent by military personnel in operational assignments during their military careers. Military training courses are designed to qualify students for well-defined jobs to which they can be assigned upon successful completion of these courses.

The situation differs in almost all types of public and private education where students remain at school for required periods of time and are not paid while being instructed. These schools receive no direct benefits for completing instruction in less than the required time. Courses are generally not designed to qualify students for particular jobs and, obviously, schools cannot assign students to jobs when they graduate.

A major consequence of these distinctions is that methods of instruction that are cost-effective for military training may not be cost-effective in other areas. Another is that research on computer-based instruction supported by the military Services has emphasized the possibility of saving student time while maintaining student achievement constant. Research on instruction in non-military settings has been concerned more with the amount of student achievement at the completion of a course than with the amount of time needed by students to acquire the material.

D. APPLICATION OF CAI AND CMI

The potential application of CAI and CMI would appear to be primarily for specialized skill training at technical schools which prepare military personnel for specific jobs in the military Services. About 300,000 people complete recruit training each year and become candidates for specialized skill training. Skill training is estimated to cost $3 billion and to produce 1.1 million course graduates each year (124,000 man-years of training in FY 1979); about 79,000 people (75 percent military) are needed to conduct and support this training (Department of Defense, Military Manpower Training Report for FY 1979, March 1978). About 75 percent of all training loads are for new accessions to the military Services.

CAI and CMI also appear appropriate for certain types of training that occurs away from formal schools, such as on-the-job training, crew and unit training, refresher and upgrade training in operational units. The magnitude of these efforts is thought to be large but no estimate of its cost has been made. The "Integrated DoD Plan for R&D on Computers in Education and Training", prepared by a tri-service group in September 1975, proposed that $12.1 million be allocated in FY 1977 for research and development on computer-based instruction. An estimate of the funds allocated by the DoD to R&D on computer-based instruction in recent years has not been made.

II. PROBLEMS ENCOUNTERED IN EVALUATING THE COST EFFECTIVENESS OF COMPUTER-ASSISTED AND COMPUTER-MANAGED INSTRUCTION

The military Services have provided strong support to research and development on computer-based instruction since the early 1960s because of its obvious application to military training. This same time period saw the development of new tools for analysis and management of military (and other government) resources. The analytic procedures are best described as the adaptation of traditional economic analysis to government operations.

Traditional economic analysis is identified with production processes in which organized markets exist for determining the values of both resource inputs and outputs in a common unit of measure, such as dollars. In military activities, resource inputs are typically obtained from organized markets and valued in dollars, but no such market exists for determining the dollar value of resource outputs (*e.g.*, the cost of military training may be determined, but what dollar value should be placed on its results?). The lack of comparability between inputs and outputs in economic analyses of military systems has led to the development of special analytic techniques. Cost-effectiveness analysis is one of these, and it has become a general requirement for the management of military resources.

A. REQUIREMENT FOR COST-EFFECTIVENESS ASSESSMENT

Department of Defense Instruction (DODI) 7041.3, Economic Analysis and Program Evaluation for Resource Management (1972) establishes the general policy for cost-effectiveness analyses and outlines the requirements to which such analyses must adhere. Cost-effectiveness analyses are required for first-time funding of projects and periodically for on-going activities. This policy has been promulgated in each of the Services by implementing instructions and has been interpreted in numerous writings.

There are two ways of evaluating the cost-effectiveness of alternative military systems. Given two systems of the same cost, one would prefer the system that provides greater effectiveness. Given two systems of the same level of effectiveness, one would prefer the system that costs less. All studies of computer-assisted and computer-managed instruction have used the second approach. Computer-based instructional systems have been designed to provide the same degree of effectiveness (student achievement) as the method of instruction they might replace (conventional instruction). Therefore, these alternative methods of instruction must be evaluated in terms of differences in their costs.

To date, evaluations of computer-assisted and computer-managed instruction have addressed questions concerning the technical and operational feasibility of these methods of instruction, including the design of courses for these methods of instruction. Most studies have addressed the effectiveness of instruction; some treated costs and some treated cost-effectiveness. However, cost and cost-effectiveness appear to have been secondary considerations in these studies. Table 1 lists 30 studies that generated 48 data sets on the effectiveness of CAI or CMI in military training; only eight of these provided any data on the costs of these programs, most of which were experimental rather than operational in nature; only five evaluated cost-effectiveness.

At some point, the cost-effectiveness of computer-based instruction will have to be established in a definitive fashion. Taken as a group, these 30 studies do not provide a sufficient basis on which to evaluate the cost-effectiveness of either computer-assisted or computer-managed instruction.

TABLE 1. DATA ON EFFECTIVENESS AND COSTS IN EVALUATIONS OF COMPUTER-ASSISTED AND COMPUTER-MANAGED INSTRUCTION

Method of Instruction	System	Service	Location	References	Number of Evaluations (Data Sets)		
					Effectiveness	Cost	Cost-Effectiveness
	IBM 1500	A	Army Signal Center & School, Ft. Monmouth	IBM (1968)	1		
				Longo (1969)	1		
				[illegible] & Longo (1971a)	1		
				[illegible] & Longo (1971b)	1		
				Longo (1972)	2		
	IBM 1500	N	NPRDC San Diego	Ford & Slough (1970)	1		
				Hurlock & Lahey (1971)	1		
				Hurlock (1972)	1		
				Ford, Slough, & Hurlock (1972)	2	1	
	PLATO IV	A	Army Ordnance Center & School, Aberdeen PG	U.S. Army Ordnance Center & School (1975)	3	1	1
	PLATO IV	N	NPRDC San Diego	Stern (1975)	1		
				Slough & Coady (unpublished)	4		
				Lahey, Crawford, & Hurlock (1976)	1		
CAI				Crawford, Hurlock, *et al.* (1976)	1	1	1
				Fredericks & Hoover-Rice (1977)	2		
				Hurlock & Slough (1976)*		1	
	PLATO IV	AF	Sheppard AFB	Steinkerchner, Deignan, *et al.* (1977)	1	1	
				Deignan (no date)	1		
				Deignan & Duncan (1977)	2		
	PLATO IV	AF	Chanute AFB	Dallman, De Leo, *et al.* (1977)	4	1	1
	PLATO IV/ IDBOM	N	Guided Missile School, Dam Neck, VA	General Electric Ordnance System (1975)	4		
				Radkson & Grosson (1975)			
	LTS-3	AF	Keesler AFB	Harris, Greenberg, *et al.* (1972)	1		
				Downs, Johnson, *et al.* (1972)	1		
				Keesler AFB (1972)	1		
				Keesler AFB (1973)	1		
				Keesler AFB (1974)	**	1	
	TICCIT	N	NPRDC, San Diego	Walker (1978)	1		
CMI	Navy CMI	N	NATTC Memphis	Carson, Graham, *et al.* (1975)	4	1	1
	AIS	AF	AFHRL-TT Lowry AFB	AIS Briefing (1978)	4		1

*Addresses costs of programs discussed in the above five references.

**Effectiveness addresses programmed text.

6-8-79-2

There is an extensive literature that describes procedures for conducting cost, cost-effectiveness, and cost-benefit analyses, *e.g.*, Sassone and Schaffer (1978), Quade and Boucher (1968), and Fisher (1971). Applications of these procedures to a variety of fields may be found in Alfandary-Alexander (1968) and Goldman (1967). The application of these procedures to military training is described by Doughty, Stern, and Thompson (1976) and Swope (1976). Resource estimation procedures associated with the conduct of military training are identified, among others, by Hess and Kantar (1977) and Braby, Henry, Parrish, and Swope (1975).

B. CRITIQUE OF THE LITERATURE

Computer-assisted and computer-managed instruction in military training have been evaluated in about 30 studies conducted since 1968. Most of these were experiments conducted with R&D funds, while a few approximated operational conditions. Most of these studies were concerned primarily with the effectiveness of computer-based instruction, a few with its costs; some implied that their results related to cost-effectiveness but did not actually perform any analyses. The critique that follows discusses the following issues:

- The scope of the studies
- The measures of effectiveness used
- The incompleteness of cost information
- Treatment of expenditures as costs
- The incomplete range of alternatives considered.

1. Scope of the Studies

Most of the data were collected under programs funded through the RDT&E appropriation, *i.e.*, Exploratory Development (6.2) and Advanced Development (6.3). Such programs are generally small in scale with regard to numbers of students, hours of instruction, and duration. The 48 data sets developed in these programs are based on totals of about 800 hours of computer-based instructional materials, 9,000 students, and 400,000 student hours. The four data sets for the Advanced Instructional System (AIS), a demonstration rather than an experimental program, account for approximately 40 percent of all instructional hours, over 70 percent of the students, and over 85 percent of the student hours in these 30 studies. Of the remaining 44 programs, only 21 involve more than 10 hours of instruction and only 18 include more than 50 students as subjects (see Table 2).

TABLE 2. DISTRIBUTIONS OF COURSE LENGTH AND NUMBER OF STUDENTS IN 48 EVALUATIONS OF MILITARY CAI AND CMI INSTRUCTION

No. of Students (CAI/CMI only)	Average length of conventional course: up to								Total	
	Not Stated	1 Day	1 Week	1 Month	2 Months	3 Months	4 Months	>4 Months	CAI	CMI
Not stated			1						1	
1 - 9		1	1						2	
10 - 49	2	9	5		5				21	
50 - 99		3	5	2/2					10	2
100 - 199			1	2/2	1				4	2
200 - 299			1						1	
300 - 399		1							1	
600 - 699						0/1		0/1		2
2000 - 2999						0/1		0/1		2
Total CAI	2	14	14	4	6				40	
CMI				4		2		2		8

NOTE: All entries in table refer to CAI except where two values are shown. Then, read "CAI/CMI".

11-29-78-9

The results obtained with respect to student achievement and time required to complete courses in short-term experiments may differ from those found in large-scale, long-term operational training programs. Some data in Chapter III suggest that similar results are found in both cases. However, the extrapolation of cost data from experiments to operational programs is particularly inappropriate. Management and accounting of resources differ between operational programs and those funded through Research, Development, Test and Evaluation. In addition, differences in cost may be anticipated between training in operational and in research settings because of different scales of operation, different organization of the training program, and differences in the utilization of equipment and personnel.

2. Measures of Effectiveness Used

The purpose of military training is to provide personnel with the skills and knowledge required to perform specific tasks in the operational forces under both peacetime and combat situations. Thus, the effectiveness of alternative methods of instruction must be evaluated by comparing how well personnel, trained by either method, perform in operational units. Measurement of performance of graduates on jobs in the field implies a system for postgraduate monitoring of students for some period of time after their assignment to duty stations. This measure was not used in any of the studies. At present, data on the effectiveness of training in schools are not collected systematically; the data that are collected consist of supervisors' opinions about the job performance of graduates. Such data are subjective in nature and may be influenced by factors not related to training, *e.g.* relevance of the training course to the actual job, nature of the work environment, personality, and so on.

Instead, we found that the following measures of effectiveness were used in these studies: (1) student achievement on tests administered during and/or at the end of course, (2) the length of time required for students to complete a course, (3) academic attrition rates, and (4) student and instructor attitudes. None are appropriate measures of effectiveness. The use of multiple measures may lead to contradictory conclusions, unless they can be combined in a meaningful way.

Training course curricula are based on assessment of skills required of personnel in operational billets as determined, for example, by a task analysis. To the extent that such assessments are valid, student achievement in school as shown by test results may serve as a proxy (or predictor) of future field performance and, hence, training effectiveness. However, correlations between performance at school and on the job have not been established for any method of instruction, and the use of results collected only at schools cannot be taken to be conclusive. On the whole, the data suggest that student achievement at school is about the same with all methods of instruction considered in this paper. The differences that were found are not thought to have practical importance. This will be discussed later in this paper.

To the extent that student time is relevant to the analysis of cost-effectiveness, it is a measure of the cost and not of the effectiveness of training. The studies would have gone a long way toward fixed-effectiveness or net cost evaluations if the observed decreases in the time needed by students to complete courses given by computer-based instruction had been converted to decreased (or avoided) cost of instruction, through standard factors for pay and allowances and other personnel-related resources; these decreases would have to be offset against the costs of other resources that are incremental to the use of computer-based instruction, *e.g.*, computers and courseware. Cost is similarly associated with student attrition. With lower attrition rates, fewer students are required to enter training to produce a specified number of graduates and, thus, a smaller total number of student days are spent in training.

Student and instructor attitudes are qualitative and not yet quantifiable factors. To the extent that student attitudes might impact on school achievement, it might be manifest in test performance, course time, and attrition; these possibilities are not known and have not been explored. While it may be granted that attitudes might affect either cost or effectiveness through such considerations as later field performance and reenlistment rates (including those of instructors), the relationships, if any, are oblique and remain unknown.

3. Incompleteness of Cost Information

In the eight studies that addressed cost, the cost data described only some of the direct expenditures that were incurred during the course of the studies. Some of this information appears to have been reconstructed after the fact rather than recorded during the period of experimentation and it may not be accurate.

Training is an intricate process that requires different types of resources to perform a variety of functions. Some resources may be uniquely associated with a single method of instruction while others will be common to several methods. For example, computer hardware (a type of resource) is a unique requirement of computer-based instruction. Development of courseware (a function provided by resources) is associated with all methods of instruction, but its cost per unit (*e.g.*, man-hours per hour of instruction developed) appears to vary widely between different methods of instruction. Similarly, instructional personnel are employed by all methods of instruction; while its nominal cost (per hour of instruction) may be constant between instructional methods, its effective cost (per student hour) depends on the student:instructor ratio characteristic of each method of instruction. In comparing the costs of alternative methods of instruction, it is necessary to account for all resources whose costs may differ between alternatives. That is, all such costs must be considered relevant to the analysis.

It is a relatively straightforward exercise to identify the resources for which data are needed to compare the costs of computer-based instruction and of other methods of instruction. Table 3 displays a list of these resources, at a major category level, developed from our reading of the literature. None of

TABLE 3. RESOURCES REQUIRED TO SUPPORT VARIOUS METHODS OF INSTRUCTION (MAJOR CATEGORIES ONLY)

RESOURCE (TYPE OR FUNCTION)
PROGRAM DEVELOPMENT
PROGRAM DESIGN
INSTRUCTIONAL MATERIALS
CONVENTIONAL
INDIVIDUALIZED INSTRUCTION
PROGRAMMING
FIRST-UNIT PRODUCTION
COMPUTER-BASED
PROGRAMMING
CODING
PROGRAM DELIVERY
INSTRUCTION
INSTRUCTORS
INSTRUCTIONAL SUPPORT PERSONNEL
EQUIPMENT AND SERVICES
LABORATORY (INCLUDING SIMULATORS)
MEDIA DEVICES
COMPUTER SYSTEMS
COMMUNICATIONS
MATERIALS (INCLUDING CONSUMABLES)
FACILITIES
PROGRAM MANAGEMENT AND ADMINISTRATION
STUDENT PERSONNEL
PAY AND ALLOWANCES
OTHER (TEMPORARY DUTY, PERMANENT CHANGE OF STATION, ETC.)

3-19-79-7 3-26-79

the eight studies which reported costs of computer-based instruction provided data for all items on this list.

The extent of incompleteness may be judged by the following comments. Computer hardware (either leased or procured) and courseware development are two categories of major impact associated with the cost of computer-based instruction; three studies[1] provided no information regarding courseware costs and two[2] provided no information regarding computer hardware costs. Only four of the studies provided cost information for anything other than computer hardware or courseware development[3]; in two of these cases, the only other costs reported were for compressed air and carrels for PLATO IV terminals, relatively minor items.[4]

More notable than the incompleteness of data on the costs of computer-based instruction is the lack of information regarding the costs of alternative methods of instruction. All studies compared the effectiveness of computer-based and an alternative method of instruction (generally conventional instruction), using the measures described above. Only one of the eight studies addressing costs (Crawford, Hurlock, *et al.*, 1976) compared the cost of the experimental program to that of the method by which the same material was normally taught. Two studies provided incomplete information on courseware development for individualized instruction (U.S. Army Ordnance Center and School, 1975; Dallman, DeLeo *et al.*, 1977); the data were taken from other studies. In essence, even when some data were provided on the costs of

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[1]Ford, Slough, and Hurlock (1972); Crawford, Hurlock, *et al.* (1976); Steinkerchner, Deignan, *et al.* (1977).

[2]Carson, Graham, *et al.* (1975); Keesler AFB (1974).

[3]Crawford, Hurlock, *et al.* (1976); Carson, Graham, *et al.* (1975); Steinkerchner, Deignan, *et al.* (1977); Dallman, DeLeo, *et al.* (1977).

[4]Steinkerchner, Deignan, *et al.* (1977); Dallman, DeLeo, *et al.* (1977).

computer-based instruction, comparable cost data were not provided for alternative methods of instruction.

4. Expenditures as Cost

Most studies that considered the cost of training treated expenditures of funds during the course of the experimental programs as equivalent to the cost of training. For example, in experiments using PLATO IV, no distinction was made between funds expended for the purchase of terminals and for access to the central processor. The expenditure for terminals is an investment in long-lived assets that can provide training both during and after the period of the experiment; thus, only a fraction of the procurement cost is a cost of training, *i.e.*, during the limited time of the experiment. On the other hand, expenditure for purchase of central processor time is strictly a cost of the experimental program; access to the central processor during the experiment provided no residual capability to support training after the experiment was completed. The simple sum of expenditures for terminals (investment) and access to the computer (operations) is meaningless for any period less than an assumed total life-cycle of the system. Two studies (Hurlock and Slough, 1976 and Crawford, Hurlock, *et al.*, 1976) were exceptions to this type of treatment. In these cases, a portion of the recorded expenditures was translated into estimated costs of an operational PLATO IV training program.

Translations from current expenditures to costs that can be summed into meaningful totals require resort to some form of analytic framework or model, and a *formal* model is called for in cost-effectiveness analysis. It imposes the discipline of explicitly identifying all inputs, assumptions, and relationships so that alternatives can be compared in a consistent manner. For example, alternative methods of instruction may be affected differently by such conditions as limits on utilization of equipments (*e.g.*, attainable terminal hours), availability of required resources, (*e.g.*, media devices) and differences in lifespans of various resources (*e.g.*, computer hardware versus laboratory equipment); yet, such conditions are difficult to treat completely and consistently. Models which would call attention to the full range of inputs and assumptions and the ways they are incorporated into evaluations of cost were missing from the studies reviewed.

5. Incomplete Range of Alternatives Considered

All studies compared student achievement and the times needed by students to complete the same course given by conventional instruction and by computer-based instruction. A course given by conventional instruction must be rearranged into a series of lessons and tests in order to be given by computer-assisted or computer-managed instruction, or by individualized instruction without computer support. During the process of revision, course materials are reviewed and modified; if a task analysis is performed, material that is no longer relevant will be dropped and new material may be added. The result is that the course materials used with a new method of instruction are rarely identical to those used in the old course; note that the revised course materials could be taught by any method of instruction, including conventional instruction. Figure 1 describes the steps involved in changing a course from conventional to computer-based or any other form of instruction: the course materials are revised and restructured into an appropriate format. Each step in this process implies an expenditure of resources; each method of instruction implies a different final cost, and may yield different levels of instructional effectiveness.

Thus, all comparisons of computer-based instruction with conventional instruction produce results (generally student time savings) that may be due to the new method of instruction and/or to the process of course revision (which may also shorten or lengthen the course). There is one study where a computer-based course was compared indirectly to its revised, conventional version; all other comparisons are with the original conventional course. There are some data where a computer-based course was compared to its revised, individualized version.

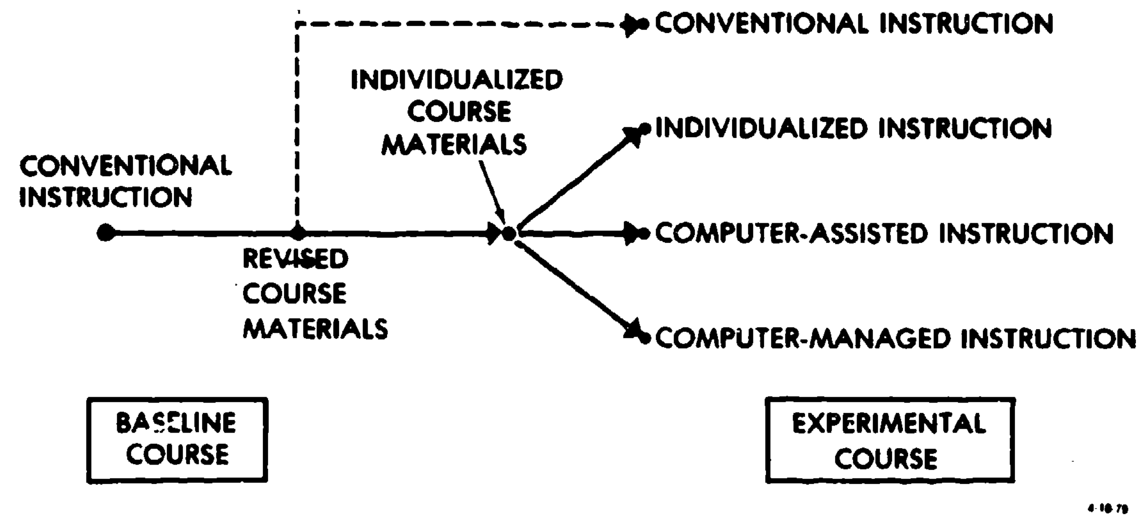

FIGURE 1. Steps involved in modifying a course from conventional to individualized or computer-based instruction.

C. SUMMARY

The data base used to evaluate the cost-effectiveness of computer-assisted and computer-managed instruction in military training has the following limitations:

- Thirty studies, conducted since 1968, provide 48 data sets on the effectiveness and 8 data sets on the costs of computer-based instruction. About half of the studies are based on 10 or less hours of instruction; about half of the studies are based on 50 or less students; a few studies (on computer-managed instruction) involve longer courses (2 to 10 months) and larger numbers of students (600 to 2500).

- The most relevant measure of effectiveness of instruction is the performance of graduates of courses on the job in an operational unit. Such data are not now available. All studies use student achievement at school as a measure of effectiveness. The relation between student achievement at school and performance on the job has not been demonstrated. Some measures of effectiveness that have been used (*e.g.*, student time saved and student attrition in courses) should be treated as measures of cost.
- The cost data derived from these studies are generally incomplete; the cost data reported in experiments do not extrapolate readily to operational settings because of major differences in training organizations and accounting procedures. No data are provided that permit comparisons between the costs of computer-based and conventional instruction.
- None of the studies provide an explicit distribution of costs over some specified life cycle for comparable methods of instruction; none provide a model for use in estimating costs.
- Most comparisons of student achievement with computer-based and conventional instruction provide confounded results that may be attributed either to the method of instruction and/or to revision of course materials.

III. EFFECTIVENESS OF COMPUTER-BASED INSTRUCTION

Military training is intended to provide the skills and knowledge required to perform various tasks in operational units. Thus, the effectiveness of computer-based instruction for teaching a particular course should be compared to that of conventional instruction by measuring how well graduates taught either way perform the same tasks in the field. Such data were not found in the research literature dealing with the effectiveness of computer-based and conventional instruction in military training.

Instead, we found that the following measures of effectiveness have been used:

- The amount and/or quality of information and skills acquired by students at school (end-of-course achievement)
- The amount of time required by students to complete a course (student time savings)
- The number of students who do not complete a course for academic reasons (academic attrition)
- Attitudes of students (acceptability of computer-based instruction to students)
- Attitudes of instructors (acceptability of computer-based instruction to instructors).

These measures can be collected conveniently at schools or experimental sites before students scatter to other assignments but they are not necessarily appropriate for evaluating the effectiveness of computer-based instruction. Various limitations of these measures were discussed in Chapter II.

Here the effectiveness of CAI and CMI is considered on the basis of the evidence provided by military research studies and with explicit recognition of some major limitations to this evidence, as follows: (1) measures of student achievement at school must be validated by data on performance on the job and (2) measures of time saved by students at school and measures of academic attrition at school should be treated as measures of cost rather than of effectiveness.

In general, the military interest in CAI and CMI is based on the premise that these methods of instruction may save student training time with little, if any, loss in student achievement. The interest of schools and colleges is based on the premise that CAI may provide the same or greater student achievement than that provided by conventional instruction; there is much less concern here for the amounts of time spent by students under various methods of instruction. Schools and colleges have shown little interest in CMI. A brief summary of the findings on the effectiveness of CAI for instruction in schools and colleges, based primarily on evaluations of PLATO IV and TICCIT in community colleges, appears in Appendix C.

A. SOURCES OF INFORMATION

CAI and CMI instruction have been evaluated in about 30 studies conducted by the military Services over the period of 1968 to 1978. These studies are summarized in a series of tables in Appendix D. These studies sample a wide variety of courses in technical training, *e.g.*, basic electronics, electricity, vehicle repair, inventory management, fire control, and precision equipment, among others (see Table 4). The courses include cognitive skills (knowledge, theory, and rules) and performance-oriented skills (hands-on maintenance, checkout, and repair) at a wide range of skill levels. There is no overlap between the courses used in evaluations of CAI and CMI.

TABLE 4. COURSES USED IN VARIOUS STUDIES OF CAI AND CMI

Courses	No. of Evaluations	
	CAI	CMI
Basic electronics	15	
Electricity	5	
Machinist	2	
Training materials development	1	
Recipe conversion	2	
Aircraft panel operation	1	
Medical assistant	4	
Vehicle repair	4	
Weather	1	
Tactical coordinator (S-3A)	1	
Fire control technician	4	
Aviation familiarization		2
Aviation mechanical fundamentals		2
Inventory management		1
Materiel facilities		1
Precision measuring equipment		1
Weapons mechanic		1
Total	40	8

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8. STUDENT ACHIEVEMENT

The effectiveness of CAI and CMI as methods of instruction, compared to conventional or individualized instruction, has been measured only by performance of students on tests administered at schools, rather than by performance on the job after graduation. Student achievement at school might predict quality of performance on the job but correlations between these two measures have not been established for conventional or for computer-based instruction. The Services evaluate some courses by means of supervisors' ratings of the performance of graduates on the job; however, these results are qualitative in nature and have not been collected systematically. Data on student achievement at school, found in various studies, are summarized in Table 5.

In 40 comparisons, student achievement with CAI was about the same as with conventional instruction in 24 cases, superior in 15, and inferior in one. The differences in performance, although statistically significant, were judged not to have practical significance. In eight comparisons of CMI with conventional instruction, no significant differences were found in student achievement at school.

In addition to these results, there were five cases where student achievement on CAI was compared to that on individualized instruction. Achievement was the same in four cases, and superior with CAI in one.

The fact that student achievement with CAI and CMI is about the same as that with conventional instruction or individualized instruction is also a direct consequence of the fact that students instructed by CAI and CMI are held in these courses until they master all lessons. The critical variable thus becomes the amount of time needed to complete courses given by computer-based instruction.

TABLE 5. STUDENT ACHIEVEMENT AT SCHOOL FOR CAI AND CMI, COMPARED TO CONVENTIONAL INSTRUCTION, IN MILITARY TRAINING

TYPE OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT ACHIEVEMENT AT SCHOOL (compared to conventional instruction) INFERIOR	SAME	SUPERIOR	TYPE OF TRAINING	REFERENCES
CAI	IBM 1500	A	SIGNAL C&S		• • • •	• •	ELECTRONICS	IBM (1968), Longo (1969, 1972) Giunti and Longo (1971)
		N	SAN DIEGO			• • • • •	ELECTRICITY	Ford & Slough (1970), Hurlock & Lahey (1971, 1972), Ford, Slough *et al.* (1972)
	PLATO IV	A	ABERDEEN		• • •		MACHINIST	U.S. Army Ordnance Center and School (1975)
		N	SAN DIEGO		• •	• • • •	ELECTRONICS	Stern (1975), Lahey, Crawford *et al.* (1976), Slough and Coady (unpubl.)
		N	SAN DIEGO		• •		RECIPE CONVERSION	Fredericks and Hoover-Rice (1977)
		N	NORTH ISLAND			•	A/C PANEL OPERATOR	Crawford, Hurlock *et al.* (1976)
		AF	SHEPPARD		• •	• •	MEDICAL ASSISTANT	Steinkerchner, Deignan *et al.* (1977), Deignan and Duncan (1977)
		AF	CHANUTE		• • • •		VEHICLE REPAIR	Dallman, De Leo *et al.* (1977)
	LTS-3	AF	KEESLER		• •	•	ELECTRONICS	Harris, Grossberg *et al.* (1972), Keesler AFB (1972, 1973)
		AF	KEESLER		•		WEATHER	Downs, Johnson *et al.* (1972)
	TICCIT	N	NORTH ISLAND		•		TACTICAL CO-ORD. (S-3A)	Walker (1978)
	EDCOM	N	DAM NECK	•	•		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grossen (1975)
	PLATO IV	N	DAM NECK		• •		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grossen (1975)
				TOTAL 1	24	15		
CMI	NAVY CMI	N	MEMPHIS		• •		AVIATION FAMILIARIZATION	Carson, Graham *et al.* (1975)
		N	MEMPHIS		• •		AV. MECH. FUNDAMENTALS	Carson, Graham *et al.* (1975)
	AIS	AF	LOWRY		•		INVENTORY MGMT.	Briefing (1978)
		AF	LOWRY		•		MATERIEL FACILITIES	Briefing (1978)
		AF	LOWRY		•		PREC. MEASURING EQPT.	Briefing (1978)
		AF	LOWRY		•		WEAPONS MECHANIC	Briefing (1978)
				TOTAL 0	8	0		

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C. STUDENT TIME SAVINGS

Most studies take the amount of student time saved to complete courses given by CAI or CMI, in comparison to conventional instruction, as a measure of effectiveness. As pointed out above, the amount of student time saved is a measure of cost. Student time savings reported in 30 studies are shown in Table 6 and summarized in Table 7.

When the findings for CAI and CMI are combined, computer-based instruction appears to save about one-third of the time required by students to complete the same courses when given by conventional instruction. However, there is a wide variation in the amounts of savings that have been reported. The amounts of student time saved by CAI and CMI cannot be compared because in no case was the same course given by both methods of instruction. Two major uncontrolled variables in these studies are the unknown quality of the instructional materials used in the various comparisons and uncertainty that the same amounts of course materials were used in both methods of instruction. This argues against trying to interpret apparent differences in the amounts of student time saved by CAI or CMI, or by different courses, and so on.

There are three instances where the use of CAI increased rather than decreased student training time and one where its effect was zero. These may be attributed to inadequate preparation of course materials or other factors not explained in these experiments. These atypical results occur only in some initial studies and not in more recent ones; in any case, such findings would not be recommended for operational use.

The fact that CAI and CMI save student training time is consistent with well-known information about wide differences in student ability (as represented in the normal distribution curve) and in the amounts of relevant knowledge held by students at the start of any course. In conventional instruction with a

TABLE 6. AMOUNT OF STUDENT TIME SAVED IN COURSES GIVEN BY CAI AND CMI, COMPARED TO CONVENTIONAL INSTRUCTION, IN MILITARY TRAINING

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT TIME SAVINGS (compared to conventional instruction)	TYPE OF TRAINING	REFERENCES
CAI	IBM 1500	A	SIGNAL C&S		ELECTRONICS	IBM (1968), Longo (1969, 1972) Giunti and Longo (1971 a&b)
		N	SAN DIEGO		ELECTRICITY	Ford & Slough (1970), Hurlock & Lahey (1971, 1972), Ford, Slough *et al.* (1972)
	PLATO IV	A	ABERDEEN		MACHINIST	U.S. Army Ordnance Center and School (1975)
		N	SAN DIEGO		ELECTRONICS	Stern (1975), Lahey, Crawford *et al.* (1976), Slough and Coady (unpubl.)
		N	SAN DIEGO		RECIPE CONVERSION	Fredericks and Hoover-Rice (1977)
		N	NORTH ISLAND		A/C PANEL OPERATOR	Crawford, Hurlock *et al.* (1976)
		AF	SHEPPARD		MEDICAL ASSISTANT	Steinkerchner, Deignan *et al.* (1977), Deignan and Duncan (1977)
		AF	CHANUTE		VEHICLE REPAIR	Dallman, DeLeo *et al.* (1977)
	LTS-3	AF	KEESLER		ELECTRONICS	Harris, Grossberg *et al.* (1972), Keesler AFB (1972, 1973)
		AF	KEESLER		WEATHER	Downs, Johnson *et al.* (1972)
	TICCIT	N	NORTH ISLAND		TACTICAL CO-ORD. (S-3A)	Walker (1978)
	IDIOM	N	DAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grossen (1975)
	PLATO IV	N	DAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grossen (1975)
CMI	NAVY CMI	N	MEMPHIS		AVIATION FAMILIARIZATION	Carson, Graham *et al.* (1975)
		N	MEMPHIS		AV. MECH. FUNDAMENTALS	Carson, Graham *et al.* (1975)
	AIS	AF	LOWRY		INVENTORY MGMT.	Briefing (1978)
		AF	LOWRY		MATERIEL FACILITIES	Briefing (1978)
		AF	LOWRY		PREC. MEASURING EQPT.	Briefing (1978)
		AF	LOWRY		WEAPONS MECHANIC	Briefing (1978)

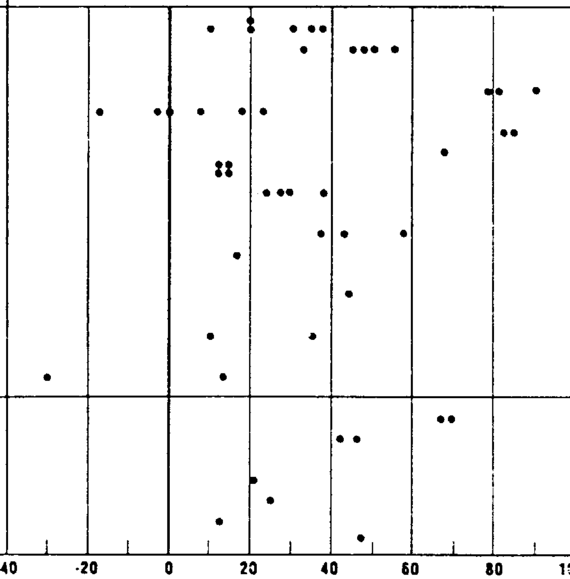

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TABLE 7. AMOUNTS OF STUDENT TRAINING TIME SAVED BY CAI AND CMI, COMPARED TO CONVENTIONAL INSTRUCTION

Method of Instruction	Number of Comparisons	Student time savings, compared to conventional instruction, percent	
		Median	Range
CAI	40	29	-31 to 89
CMI	8	44	12 to 69
Combined	48	32	-31 to 89

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fixed amount of time, these differences lead to variations in the amounts of knowledge acquired by the end of the course, *i.e.*, as shown by a distribution of final grades. In individualized instruction, whether computer-based or not, each student proceeds at his own pace and differences between students influence the amounts of time they need to complete the course more than it does the amounts of information acquired. Most of the time savings in individualized instruction are produced by those students for whom the rate of progress set in conventional instruction would be too slow; typically that rate might be one that permits about 90 percent of the students to complete the course during the fixed period of time.

Almost all of the data shown in Table 6 represent time savings found in experiments or operational tests over short time periods and with limited numbers of students. Figure 2 shows the amounts of time required by about 11,000 students to complete four courses on the Air Force Advanced Instructional System (AIS), Lowry AFB over 24 months ending September 1978.

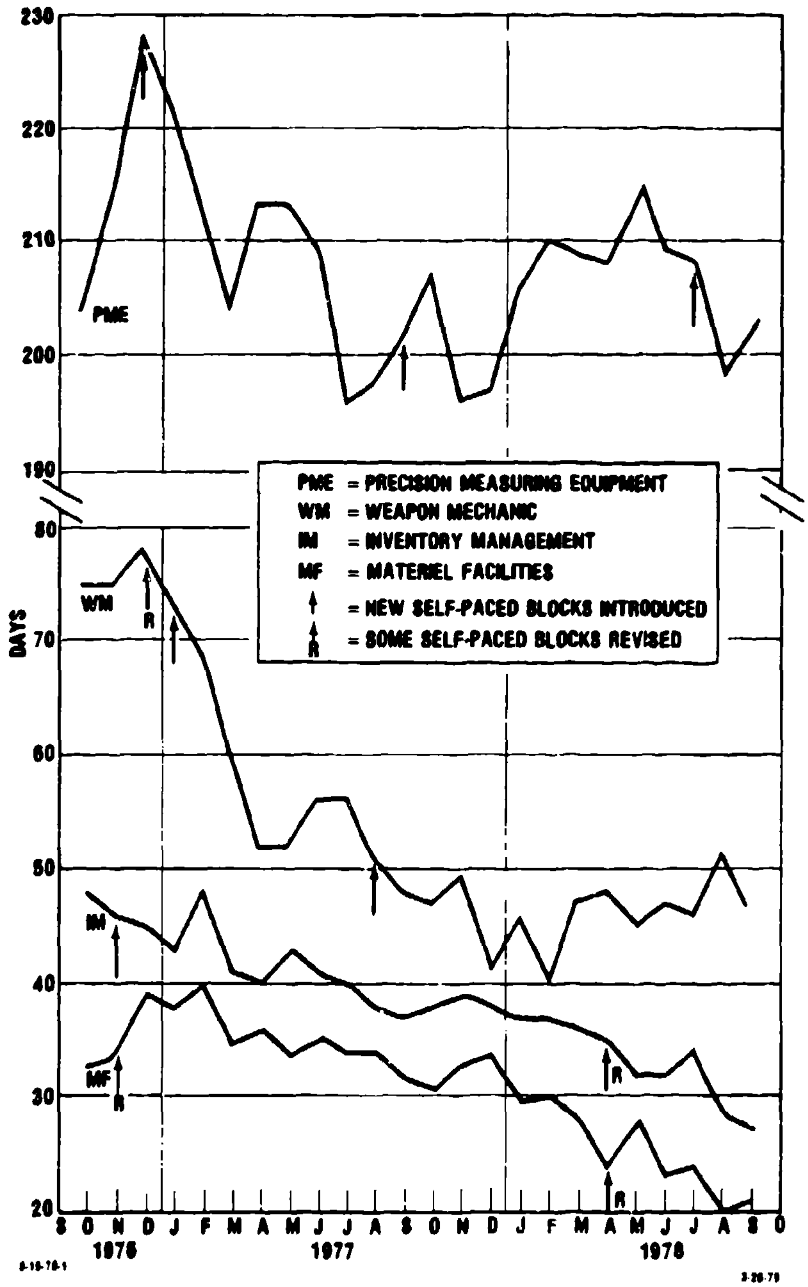

FIGURE 2. Days Required to Complete Four Courses on Air Force Advanced Instructional System, Lowry AFB, October 1976-September 1978

It is clear that the initial savings, such as might be reported in an experiment, are maintained over time and, despite monthly fluctuations, tend to increase. The reasons for these reductions and fluctuations have not been explored; they could be due, at least in part, to periodic revisions in the courses (indicated on the figure), to improved control over the new method of instruction, to variations in student aptitude and to turnover among instructors. Similar reductions in student time are shown in Fig. 3 for about 12,000 graduates in three courses on the Navy Computer Managed Instruction System at Naval Air Technical Training Center, Millington, Tennessee, over a 15-month period ending May 1978. No significant changes were made in these courses during this period.

D. STUDENT ATTRITION

Since the method of instruction may influence the number of students who can successfully complete a course, the rate of academic attrition associated with alternative methods of instruction is a matter of concern. As noted previously, the rate of attrition is a measure of the cost of instruction since it influences the number of students needed to enter a course in order to produce a specified number of graduates. Attrition for nonacademic reasons, such as for medical or disciplinary reasons, is not considered here. It should also be recognized that the rate of attrition observed in a course may be influenced from time to time by policy decisions on standards for recruitment and the number of graduates to be produced by various courses. Such influences, if present, are not addressed here.

Meaningful data on student attrition related to computer-based instruction should come from steady-state applications and not from short-term experiments. This condition is met marginally by the Air Force Advanced Instructional System (AIS), where four courses were increasingly implemented on a computer-managed instructional system over the period of 1974 to 1978 and

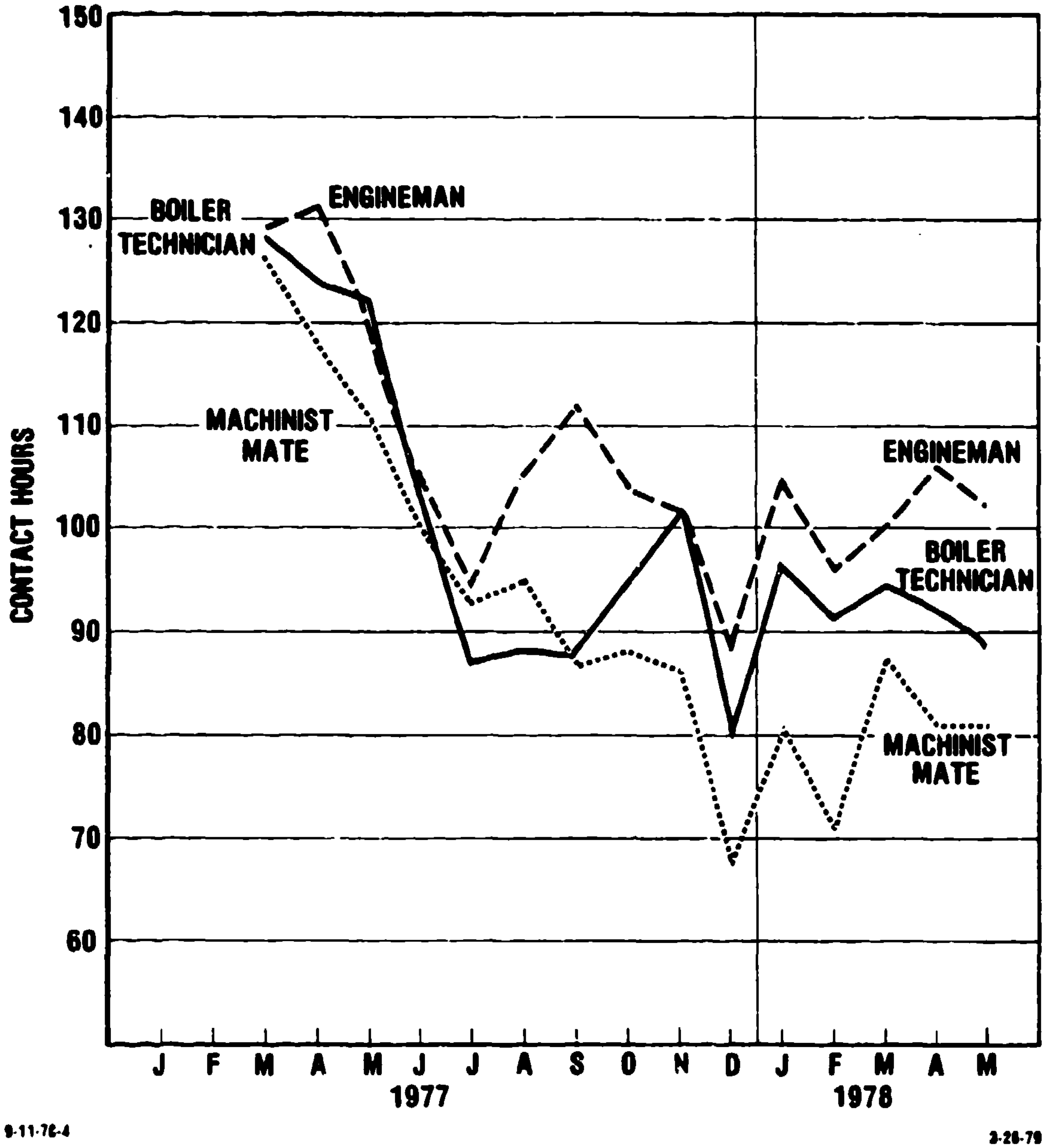

FIGURE 3. Time (Student Contact Hours) Required to Complete Three Courses in Propulsion Engineering Basics on the Navy Computer Managed Instruction System, Millington, Tennessee, March 1977 to May 1978 (Students at Navy Training Center, Great Lakes, Illinois)

by the Navy Computer Managed Instruction System, where data are available on seven courses before and after implementation in March 1977.

Figure 4 shows that, compared to previous rates, academic attrition may have increased in the four courses implemented on AIS. Note, however, that academic attrition appeared to rise in all (non-AIS) courses at Lowry AFB over the same period; thus, it is not obvious that the increased attrition in the AIS courses should be attributed primarily to the introduction of CMI instruction.

Figure 5 shows academic attrition for seven courses before and after implementation on the Navy Computer Managed Instruction System. The average rate of academic attrition in these courses was 3.2 percent before and 4.6 percent after implementation on the Navy CMI system (it increased in six courses and decreased in one). Data on comparable courses not on CMI during the same period were not provided.

Little data are available on academic attrition during experiments. Longo (1972) says that academic attrition was about the same for two courses in basic electronics taught by CAI or by conventional instruction; Giunti and Longo (1971b) say that attrition was 22 percent lower for the CAI group in another study; there were few students (66 - 186) in any of the studies summarized here. The use of CAI on four Special Purpose Vehicle Repairman courses at Chanute AFB produced no significant effect on academic attrition over a 9-month period (Dallman, DeLeo, Main, and Gillman, 1977); about 300 students were involved. Initial results for four courses on the Navy CMI system in 1975 suggested that there were no effects on student attrition at that time (Carson, Graham, Harding, *et al.*, 1975).

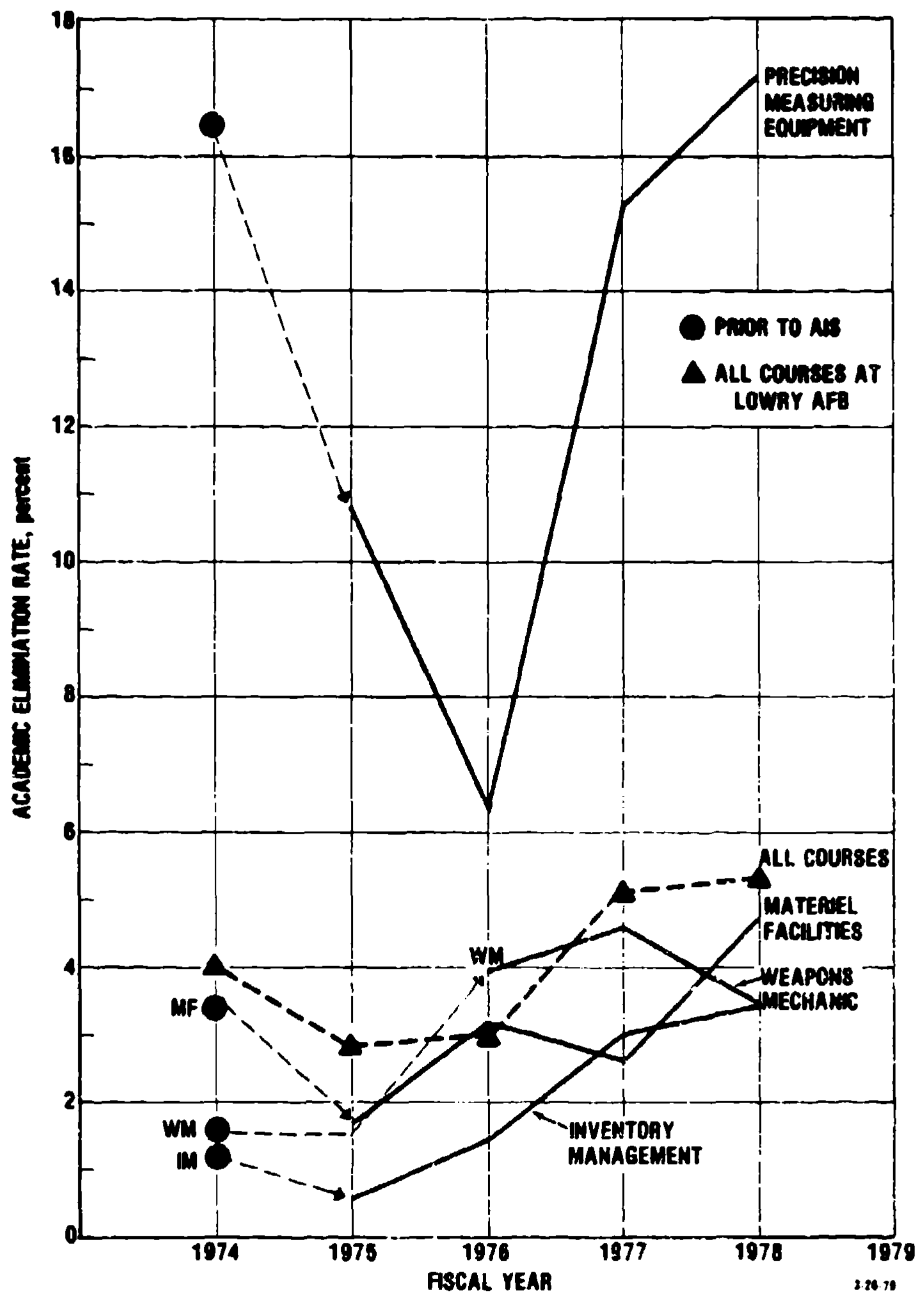

FIGURE 4. Academic Elimination Rate in Four Courses Before and After Implementation on AIS at Lowry AFB

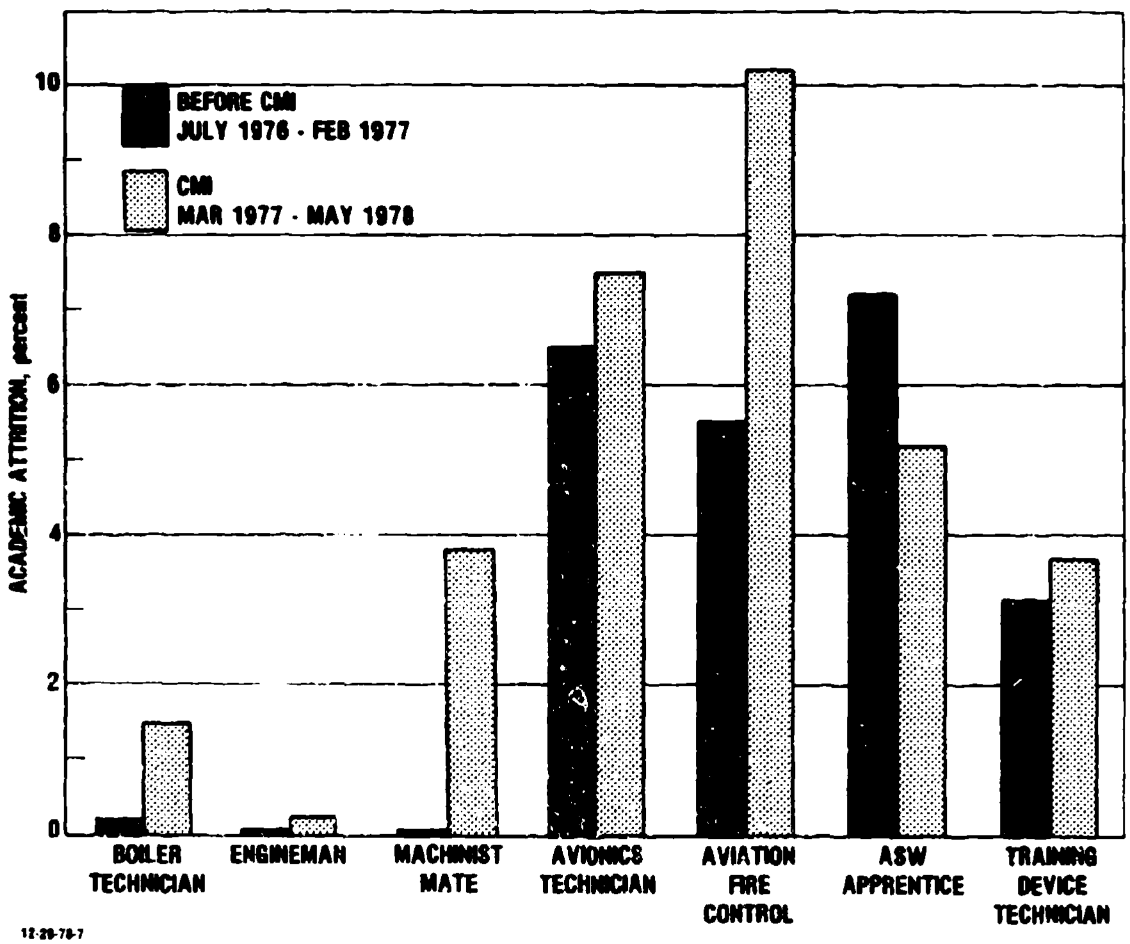

FIGURE 5. Academic Attrition in Seven Courses Before and After Implementation on Navy Computer Managed Instruction System

In summary, only two CMI systems, the Air Force AIS and Navy CMI, have received extended, though still limited, use in military training. Academic attrition may have increased in courses taught this way, compared to attrition with conventional instruction during prior periods. Since these comparisons do not take into account possible changes in the qualifications of students over the same time periods, the available data suggest but do not prove that CMI may increase academic attrition over that found with conventional instruction.

E. ATTITUDES OF STUDENTS AND INSTRUCTORS

Attitudes of students and instructors to CAI or CMI in military training, compared to conventional instruction, are noted here only as ıalitative aspects of these methods of instruction. Most of the data came from experiments of short duration. Data on student attitudes towards CAI or CMI are found in 39 of the 40 reports summarized in Appendix D. As shown in Table 8, students almost always favor CAI or CMI over conventional instruction, or at least say so when asked; they are unfavorable to CAI in one case and find no difference in another.

TABLE 8. ATTITUDES OF STUDENTS AND INSTRUCTORS COMPARING CAI OR CMI TO CONVENTIONAL INSTRUCTION IN MILITARY TRAINING[a]

Attitude to CAI/CMI	Students		Instructors	
	CAI	CMI	CAI	CMI
Favorable	29	8	1	-
No difference	1	-	-	-
Unfavorable	1	-	4	4[b]
No report	1	-	27	4
Total	32	8	32	8

[a] All data are number of reports summarized in Appendix D.

[b] Favorable to CMI at first, changing to unfavorable by end of study.

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Instructors' attitudes are reported only in 9 of these 40 comparisons; instructors are unfavorable to CAI or CMI in 8 of these 9 cases and favorable to CAI only in 1.

Instructors of courses taught by CAI or CMI have not received much attention by researchers. According to two studies still in draft (February 1979), only half of 54 instructors sampled in 1977 at the Naval Air Technical Training Center, Millington, Tennessee, believe that individualized instruction is as effective as conventional instruction.* The training of instructors is still oriented largely towards conventional instruction, and instructors assigned to CMI receive little guidance on how to conduct such courses.

F. COMPARISON OF TIME SAVINGS FOUND WITH INDIVIDUALIZED INSTRUCTION AND COMPUTER-BASED INSTRUCTION

Student training time in courses can be reduced without resort to computer-based instruction, *e.g.*, by reducing the amount of material to be mastered in courses, increased reliance upon on-the-job training, improved conventional instruction, and by individualized instruction (which, by definition, excludes computer support). It is far beyond the scope of this paper to consider all of these possibilities. However, we found some data on the amount of student time saved when the same courses are given by individualized instruction and by computer-assisted or computer-managed instruction, compared in all cases

*Practical problems in the implementation of individualized instruction, Navy Personnel Research and Development Center, San Diego, California (draft).

Instructors' attitudes towards computer-managed instruction, Navy Personnel Research and Development Center, San Diego, California (draft).

to conventional instruction. The essential issue concerns the benefit, in terms of additional student time saved, when computer support is given to individualized instruction (without computer support). Data on 12 courses are summarized in Table 9 and shown in Fig. 6.

TABLE 9. AVERAGE AMOUNT OF STUDENT TIME SAVED BY INDIVIDUALIZED INSTRUCTION AND CAI OR CMI IN THE SAME COURSES, COMPARED TO CONVENTIONAL INSTRUCTION

No. of Courses	Average Amount of Student Time Saved		
	Individualized Instruction	CAI	CMI
5	64%	69%	•
7	51%	•	51%

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Individualized instruction saves large amounts of student time otherwise required by conventional instruction (average savings of 50 percent or more in these samples). The addition of CAI to five individualized courses produced additional average time savings of 5 percent; the addition of CMI to seven courses produced no additional time savings. Again, no significance can be given to the differential time savings observed by adding CAI or CMI to individualized instruction because different courses were used in each comparison.

These data do not necessarily imply that the addition of computer support to individualized instruction is not cost-effective. That would depend, in each case, on whether the incremental costs of computer support are offset by cost reductions in other areas, such as for the number of instructors and support personnel, administrative services, and other factors.

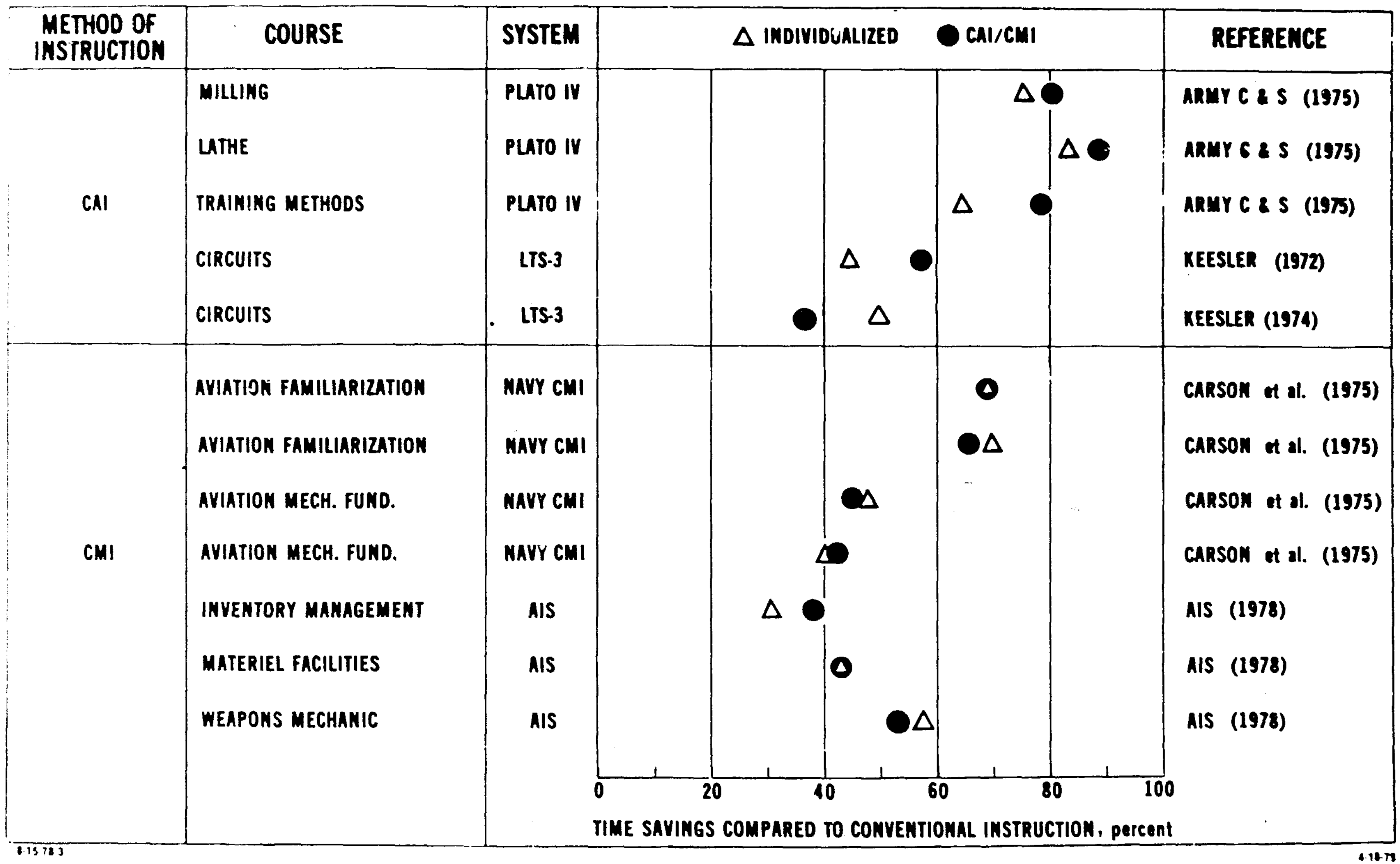

FIGURE 6. Amount of Student Time Saved, Compared to Conventional Instruction, by Individualized Instruction and by CAI or CMI on the Same Courses

Little attention has been given to the benefits associated with different types of computer-based support of individualized instruction. For example, from early AIS data, Student Progress Management saved an average of 9 percent of student time in four courses and Individualized Instructional Assignment saved an additional 3 percent in one course and none in three others (McDonnell Douglas Astronautics 1977a). Only student time savings were considered in these reports and no attention seems to have been given to other possible benefits of computer-support to instruction.

G. SUMMARY

1. Effectiveness of CAI and CMI

The effectiveness of CAI and CMI has been evaluated in many different types of courses in military training, *e.g.*, electronics, vehicle repair, and inventory management. These courses include both knowledge and performance-oriented skills. The effectiveness of CAI and CMI cannot be compared directly because in no case was the same course given by both of these methods of instruction.

2. Student Achievement

Student achievement at school is about the same for CAI, CMI, and conventional instruction. Some evaluations show that student achievement with CAI is superior to that with conventional instruction but these differences are judged not to have practical significance.

3. Time Savings: Computer-based Instruction vs. Conventional Instruction

Computer-based instruction appears to save about one-third of the time required by students to complete courses given by conventional instruction. There is a wide variation in the amounts of time reported as saved in experiments but research has not addressed this issue. Based on experience gained in the AIS and Navy CMI systems, the amounts of student time saved appears to increase over time; the amounts of student time saved also fluctuates from month to month.

4. <u>Time Savings: Computer-based Instruction vs. Individualized Instruction</u>

About the same amounts of student time are saved when the same courses are given by individualized instruction without computer support or by CAI or by CMI.

5. <u>Student Attrition</u>

Student attrition for academic reasons appears to increase slightly when CMI replaces conventional instruction, based on experience with the AIS and Navy CMI systems. The possibility that these increases may be due, in part, to changes in student quality and to other factors has not been examined.

6. <u>Student and Instructor Attitudes</u>

Student attitudes to CAI and CMI tend to be favorable. The attitudes of instructors appear unfavorable to CAI and CMI in comparison to conventional instruction, but this finding is based on limited data. The role of instructors in CAI and CMI has received little attention, both as to collecting more reliable information about their attitudes and to preparing them for handling these new methods of instruction.

IV. COSTS OF MILITARY INSTRUCTION

Surprisingly little appears to be known about either the determinants or composition of the costs of instruction. Each Service has a system for reporting the costs of training courses for such purposes as development of estimating relationships and evaluation of proposed training program alternatives; their actual use appears to be limited to providing the average total (bottom-line) costs of individual courses for such purposes as setting reimbursement rates for training foreign students and those from other Services. This information sheds no light on questions of why training costs are what they are or how they would change in response to changes in training courses, such as the method of instruction or the content of course materials. In general, it may be said that neither the detailed data on training costs nor the methodology for analysis (as opposed to accounting) of training costs have been developed. The development and maintenance of a data base on the costs of military instruction are far from cost-free, and the question of what data "should" be collected can only be assessed by further questioning their cost and worth of such data in supporting cost-effectiveness analyses of military training.

This chapter addresses two problems associated with the collection of data on the costs of training. The first is to examine how the organizational structure of formal military training affects the collection of relevant cost data. The second is to assess data on costs of training that have been developed in various experimental programs and studies of computer-based instruction.

A. COLLECTION OF COST DATA

The resources required for instruction are structured similarly in both military training and civilian education. For example, consider a school which offers a few courses in a limited number of subjects and grades. Resources can be grouped according to *type* or *function*. They can also be grouped according to where, within the organizational structure, these resources are directly applied and identified. This two-way grouping describes a matrix, as shown in Fig. 7. Some resources, such as for instructors and certain equipment, are dedicated to a particular course and their costs can be associated directly with that course. Other resources, such as for facilities and other equipments, serve a number of courses in common. Requirements for the use of common resources may vary widely between the courses offered, with the result that the costs of different courses may vary significantly in ways that are concealed.

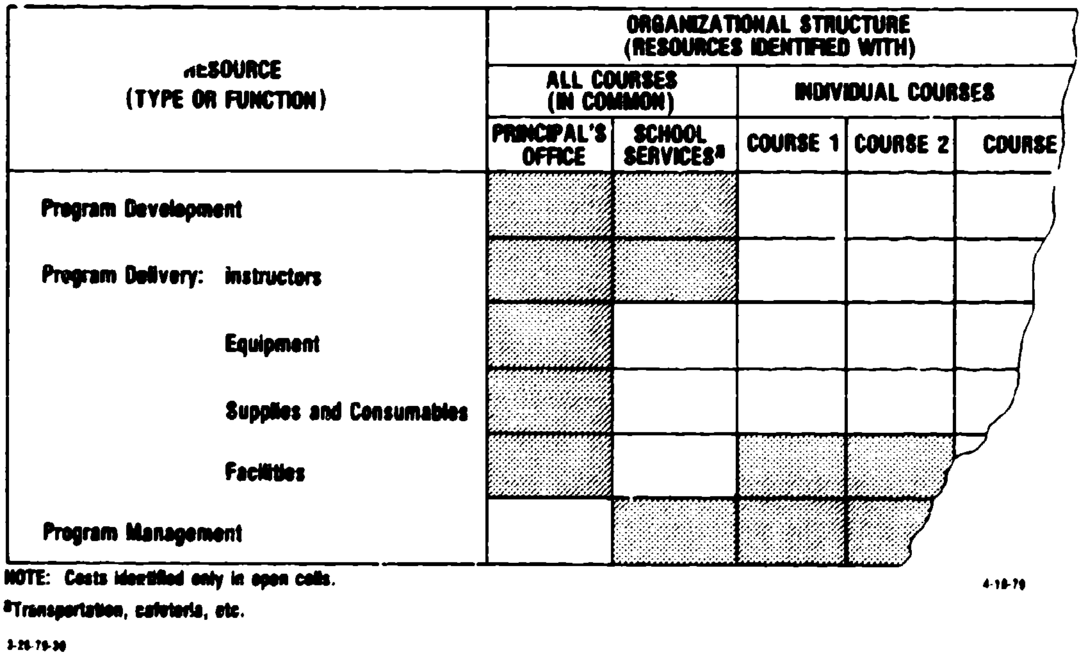

FIGURE 7. Resource matrix

1. Organization of Military Training

At a small school, the use of common resources by particular courses are readily visible and thus their costs may be easily associated with different courses. For example, the cost of using media devices may be allocated systematically to individual courses by keeping simple records of purchase and maintenance costs and the hours of use in different courses. In current military training, the relationships between courses, resource use, and costs of training are complex and obscured by the large size of training establishments and the manner in which they are organized. Some types of resources are expensive to use compared with others, and some courses are expensive to offer compared with others; the records required to trace the use of resources by particular courses are, themselves, complex and expensive. This is the heart of the problem faced in the collection and evaluation of data on the costs of training.

A representative organizational structure for military training is shown in Fig. 8. It is adapted from a "typical" U.S. Air Force organization as shown in Hess and Kantar (1977). The critical feature is the deep hierarchy of organizations that support and manage individual courses and lessons. An explanation for this degree of complexity is that it is needed to attain an efficient scale of operation. For example, instructional material is typically associated with an individual lesson and instructors may be best utilized as specialists in a single course. However, some training resources, especially in technical training, come in large and indivisible units that may be employed efficiently only where student loadings exceed those of individual courses, training branches, departments, schools, and possibly the total student population of a training facility. A conspicuous example of a large and indivisible training input is the central processor of the PLATO IV system.

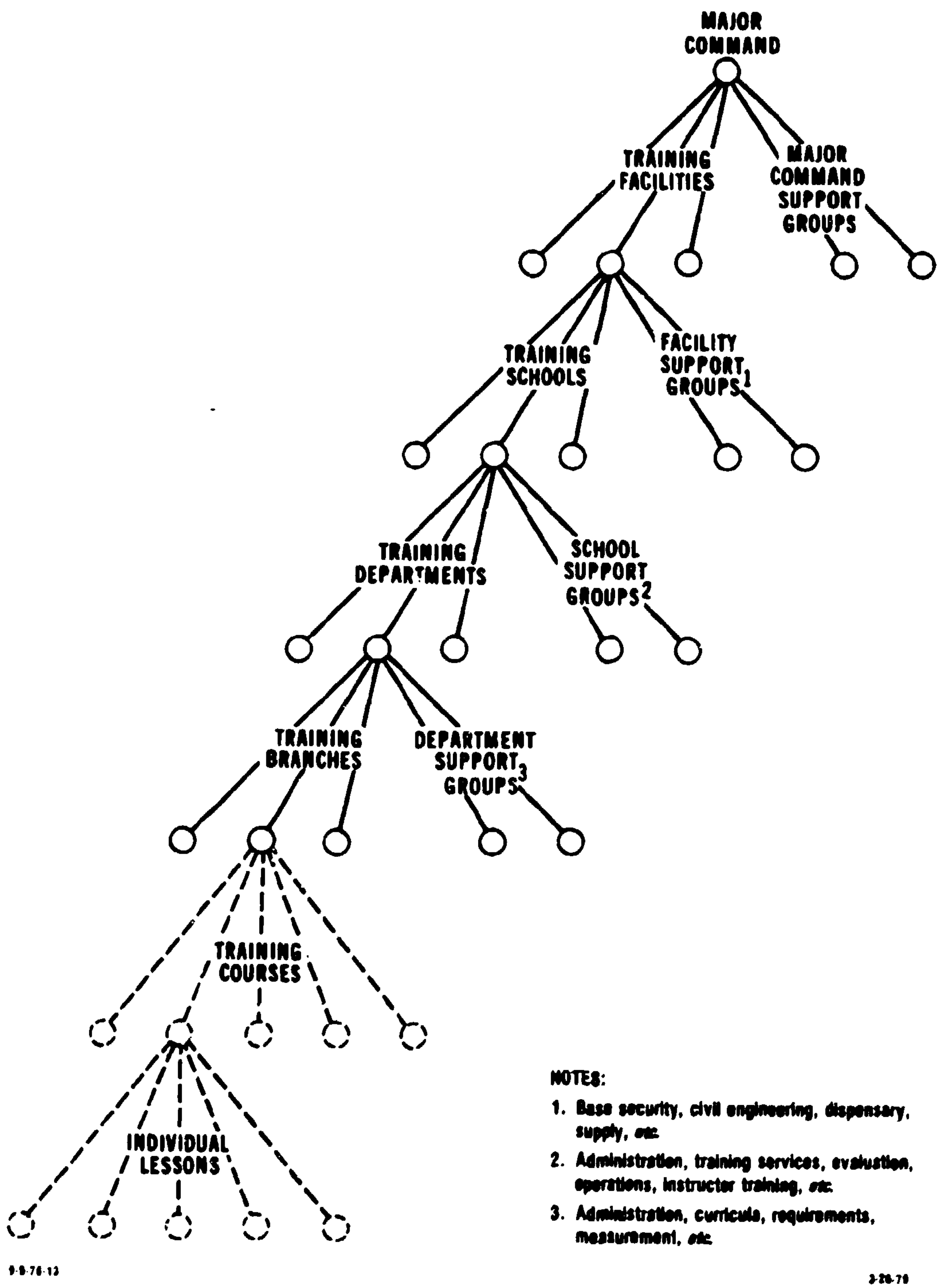

FIGURE 8. Management of instruction according to organizational structure

The formal organizational structure extends through the training branches that are responsible for a number of closely related courses. The course (and ultimately the individual lesson) is the elemental unit of training and the generator of all training costs; resource expenditures necessary for its conduct occur at each of the higher levels of the structure (including the training branches), and the expenditures incurred at any higher level node may support the whole range of instruction and support activities beneath it. In essence, the whole structure above the course level is equivalent to the columns labelled "all courses" in a small school (Fig. 7). In a large training organization, the visibility of who provides what for whom and who receives what from where is quickly lost. The relationships among units at various levels in military training organizations are too complex to be traced by simple bookkeeping procedures.

In the absence of extensive data, the relationships between instruction and the expenditure of resources for instructional support in military training cannot be determined. The costs of supporting particular courses can be estimated only by highly arbitrary allocation rules that may bear little resemblance to the true sources of cost. Discovering these relationships is an essential ingredient of the capability to evaluate training costs.

2. Alternative Ways of Collecting Cost Data

More precise and detailed cost data are needed to support cost-effectiveness analyses of alternative methods of instruction in military training. Training cost data can be collected in three ways that differ widely in scope of effort and cost. The first is to collect cost data, through a formal reporting system, for all training courses offered by a Service, including all costs for conducting and supporting training programs. The extent, detail, and identification of cost data would have to be greater than that provided by current systems, especially with regard to training support functions. Since a course may employ several methods of instruction (conventional, individualized, and computer-based), data would have to be identified with small units of instruction, possibly individual lessons, if the system were to provide information on the relative costs of different methods of instruction.

The second method is to collect information, also through a formal reporting system, for a sample of organizations that conduct and support training. It is recognized that the military Services have rarely applied sampling techniques to collect cost data. Basic questions regarding the extent and duration of sampling would have to be resolved before a program for collecting data could be designed or procedural problems addressed. The collection system could not disturb existing management and data-collection systems, and it would have to be implemented in a manner that would not distort either the level or structure of training costs in the activities to be observed.

The third alternative is to perform *ad hoc* studies of organizations that conduct and support training programs. Costs of *ad hoc* study should be lower than those of formal reporting systems, and it offers the advantage of flexibility. Studies can address specific topics of high interest and focus attention on cost and non-cost responses to systematic changes in study parameters, *e.g.*, student:instructor ratios or length of training day; data collection may be tailored to the questions addressed and organizations examined. *Ad hoc* study programs also have problems. A principal one is to maintain financial support that is adequate for pursuing a coherent and on-going program and for providing data in a timely fashion and depth that recognizes the full extent and sources of all training costs.

B. AVAILABLE DATA ON COSTS OF INSTRUCTION

This section summarizes the data we were able to find on the costs of computer-based and other methods of instruction;

the detailed data are presented in Appendix E. Here, we discuss the adequacy of these data for assessing the costs of different methods of instruction. We have excluded data that were not described well enough to be interpreted with confidence. All data are shown as they were found in the literature. No investigations of their validity have been performed, and no adjustments have been made for changes in price levels.

Table 10 shows the number of sources of data on costs of instruction, arranged according to method of instruction and type of resource. The cost data come either from eight experiments (identified in Table 1, p. 27) or from other sources (identified in Appendix E); shaded cells indicate that cost data are not applicable; blank cells indicate that relevant cost data are not available.

Table 10 shows that there are few sources of data on the costs of instruction in military training; especially notable is the absence of information on the costs of conventional instruction. The troublesome nature of this is obvious when one considers that the cost-effectiveness of CAI or CMI must be compared to that of some other method of instruction, generally conventional instruction. Two other important omissions concern Program Design and Program Management. The design of instructional programs (Program Design) may be a significant cost item because of current emphasis on Instructional System Development in all military Services, but its costs appear to be either ignored or combined with those of instructional materials. Since Program Design is independent of the method of instruction and may have its own impact on instructional costs, its cost should be separated from the cost of instructional materials. Program Management may be a major cost item because of the large and highly structured organizations in which military instruction takes place, and this cost may differ between instructional methods.

TABLE 10. NUMBER OF SOURCES OF DATA ON COST OF INSTRUCTION, ACCORDING TO METHOD OF INSTRUCTION AND RESOURCE TYPE OR FUNCTION (See Note)

RESOURCE (TYPE OR FUNCTION)	METHOD OF INSTRUCTION				
	CONVENTIONAL INSTRUCTION	INDIVIDUALIZED INSTRUCTION	COMPUTER-BASED INSTRUCTION		
			PLATO IV	NAVY CMI	OTHER[a]
Program Development					
Program Design					
Instructional Materials:[b] Conventional Instruction					
Individualized Instruction		4			
Programming		1			
First Unit Production[c]		2			
Computer-Based Instruction			4	1	3
Programming			2	2	2
Coding			2	2	2
Program Delivery					
Instruction: Instructors			1	2	
Instructional Support Personnel[d]				1	
Equipment and Services:[e] Laboratory (incl. simulators)	h	h		h	
Media Devices	h	3		h	
Computer Systems			7	2	8
Communications			5		2
Materials (incl. Consumables)[f]					
Facilities[g]		1	2		
Program Management and Administration					
Student Personnel: Pay and Allowances			1	2	
Others (PCS, TDY, etc.)[i]				1	

NOTE: Shaded cells are not applicable. Blank cells indicate that relevant cost data are not available.

[a]Includes TICCIT, IBM 1500, LTS-3, GETS, and an experimental shipboard system.

[b]Includes revision.

[c]Master copy.

[d]All direct personnel not included in other categories.

[e]Includes all hardware related costs: Initial (including installation and checkout), modification, and replacement; operation and maintenance; lease and user fees; computer system software; etc.

[f]Includes copies of instructional materials (books, courseware copies, etc.).

[g]Structures, fixtures, and furnishings.

[h]Laboratory equipment and media devices are applicable to all methods of instruction (except where simulated in CAI systems), and there is no reason why costs of their use would differ with method of instruction.

[i]Permanent change of station, temporary duty.

3-26-79-29

The sample of data on costs of training presented here is meager by any standards. We cannot begin to explain the range of costs that has been observed, and we feel uncertain as to the feasibility of a generalized parametric approach to estimating the costs of training. Extensive further efforts to collect and interpret data on the costs of training would be required before the value of parametric analysis of training costs could be judged or a general model could be formulated.

The following sections discuss the cost data that we were able to find and use.

1. Program Development: Program Design

No data were found on these costs of instruction.

2. Program Development: Instructional Materials for Conventional Instruction

No data were found on these costs of instruction.

3. Program Development: Instructional Materials for Individualized Instruction

Development of instructional material for individualized instruction encompasses two distinct and separable functions: the programming (authorship) and the production of first units (master copy) of media material (including printed text). The cost data we found are shown in Table 11. The most notable feature of resource requirements is the great variation associated with both functions.

With regard to programming (authorship), the available information shows two widely separated values; *i.e.*, 40 and 280 man-hours per instructional hour; the source provides no discussion for the large difference in values for the two media.

With respect to first unit production (*i.e.*, master copy), costs of different media range from $12,000 for an hour of sound motion picture or TV tape to a few hundred dollars for printed text and silent slide or film-strip (assuming 30 pages or frames per hour). For the same media, costs range from near $500 to $2,000 per instructional hour for sound-slide and $10 to $400 for printed illustration, and the literature provides no explanation for these differences.

TABLE 11. INDIVIDUALIZED INSTRUCTION: INSTRUCTIONAL MATERIALS DEVELOPMENT, REQUIREMENTS, AND COSTS

RESOURCE	UNIT OF MEASURE	NUMBER OF SOURCES OF DATA	ESTIMATES	REFERENCES
Programming				
Sound Motion Picture or TV	Man-hours/Instructional Hour	1	280	U.S. Army Ordnance Center and School (1975)
Sound-Slide	Man-hours/Instructional Hour	1	40	U.S. Army Ordnance Center and School (1975)
First Unit Production				
Sound Motion Picture or TV	Dollars/Instructional Hour	2	$6,000-12,000	Hess and Kantar (1977); U.S. Army Ordnance Center and School (1975)
Sound-Slide	Dollars/Instructional Hour	2	$ 500- 1,925	Hess and Kantar (1977); U.S. Army Ordnance Center and School (1975)
Silent Motion Picture	Dollars/Instructional Hour	1	$ 10,200	Hess and Kantar (1977)
Silent Slide (or Film Strip)				
Realia	Dollars/Slide	1	$ 1	Hess and Kantar (1977)
Illustration	Dollars/Slide	1	$ 3 - 115	Hess and Kantar (1977)
Printed				
Text	Dollars/Page	1	$ 7	Hess and Kantar (1977)
Illustration	Dollars/Page	1	$ 11 - 430	Hess and Kantar (1977)
Audio	Dollars/Instructional Hour	1	$ 180	Hess and Kantar (1977)
Combined or Not Specified	Man-hours/Instructional Hour	2	40 - 200	Dallman, DeLeo *et al.* (1977); Middleton, Papetti, and Michell (1974)
	Dollars/Instructional Hour	2	$1,130-15,800	Pelcyn, Baudhuin, Brekka *et al.* (1977); Temkin, Connolly *et al.* (1975)

3-28-79-31 4-18-79

With such wide ranges, the usefulness of cost-effectiveness analysis may be questioned. One of its principal applications lies in identifying and separating promising from unattractive alternatives early in course design, *i.e.*, before significant resources have been committed. Much of its value in this role is lost if a significant course design effort, to identify media mixes, is required to provide initial assessments of alternatives. This situation argues for the application of course design procedures such as MODIA (Carpenter-Huffman, 1977) and TECEP (Braby, Henry, *et al.*, 1975) at command levels where relevant policy is formulated and decisions are made (see Lackland AFB, 1978).

4. Program Development: Instructional Materials for Computer-Based Instruction

In computer-based instruction, development of instructional materials also encompasses two distinct functions. The first is programming or authorship, similar to individualized instruction. The second, coding, organizes the material into a form suitable for machine processing. Resource requirements for close to 1,000 hours of instruction were cited, and large variability is again present (see Table 12).

TABLE 12. COMPUTER-BASED INSTRUCTION: REQUIREMENTS FOR INSTRUCTIONAL MATERIALS DEVELOPMENT

METHOD OF INSTRUCTION	SYSTEM	INSTRUCTIONAL HOURS DEVELOPED	MAN-HOURS PER INSTRUCTIONAL HOUR			REFERENCES
			PROGRAMMING	CODING	TOTAL	
CAI	PLATO IV	39.0	27 to 248	50 to 467	77 to 714	Hurlock & Slough (1976)
		6.0			156	Kribs (1976)
		2.0			400	Kribs (1976)
		30.0			284	U.S. Army Ordnance Center & School (1975)
		20.0			100 & 200	Dallman, DeLeo *et al.* (1977c)
		32.0	141	81	222	Himwich (1977)
		315.0			80	Grimes (1975)
	TICCIT	10.0			200	Kribs (1976)
		3.0			400	Kribs (1976)
		32.0	150	96	246	Himwich (1977c)
	LTS-3	30.0			175	Keesler AFB (1973)
	IBM-1500	3.5	356	119	475	Rogers & Weinstein (1974)
	Unspecified CAI	Unknown			150 & 200	Middleton, Papetti & Michell (1974)
CMI	Navy CMI	50.0	100	10	110	Carson, Graham *et al.* (1975)
		300.0			30 & 60	Hansen, Ross *et al.* (1975)
		Unknown	(293)[a]	(25)[a]	(318)[a]	Polcyn, Baudhuin *et al.* (1977)

[a]Requirements were given in terms of dollars per instructional hour and have been converted on the assumption of $10 per hour for military labor.

3-26-79-32

4-18-79

For CAI, authoring is cited as ranging between about 30 and 360 man-hours per instruction hour, and coding between 50 and 470 man-hours. These ranges cannot be attributed to extraneous factors, such as differences in the way expenditures are accounted for, since close to the total range of variation was noted in one study (Hurlock and Slough, 1976) summarizing eight experimental programs performed by the same organization and utilizing the same CAI system in roughly the same time period. These data are also insufficient for attributing different programming and coding requirements to different CAI systems and/or alternative instructional strategies. For CMI, the variation is similar; from less than 30 to 290 man-hours for authoring and 10 to 25 man-hours for coding.

5. Program Delivery: Instruction, Including Instructors and Instructional Support Personnel

Only three sources provide data on costs of instructors and instructional support personnel. A few citations to student personnel cost are also included here. The data are limited to pay and allowance rates, student:instructor ratios, and, in one source, instructional and indirect support personnel ratios (see Table 13).

Personnel expenditures are considered to account for the bulk of training costs, and those associated with students, instructors, and with instructional support personnel must be assumed to be significant. In the absence of other changes, decreases in course lengths (*e.g.*, associated with an introduction of computer-based instruction) would result in lower student loads and proportional decreases in instructor personnel.

6. Program Delivery: Laboratory Equipment

No data were found on these costs of instruction.

7. Program Delivery: Media Devices

Estimating costs of use of media devices entails extensive training course specification similar to that associated with production of master copies of media materials. A large variety of devices is available at widely differing costs. Equipment is long-lived and can be shared by different courses. Representative cost ranges are shown in Table 14.

One comprehensive catalogue (The Audio-Visual Equipment Directory, 1978, published by the National Audio-Visual Association)

TABLE 13. INSTRUCTOR AND SUPPORT COSTS FOR PROGRAM DELIVERY, COMPUTER-BASED INSTRUCTION

DATA ITEM	SOURCE		
	Carson, Graham, Harding *et al.* (1975)	Hansen, Ross, Bowman, & Thurmond (1975)	Crawford, Hurlock, Padillo, & Sassano (1976)
System	Navy CMI	Navy CMI	PLATO IV
Change in Ratios			
Students : Instructors	10:1 to 16:1	7.5:1 to 9.0:1	a
Students to Instructional (Direct) Support	--	Unchanged at 24:1	--
Students to Indirect (Base) Support[b]	--	Unchanged at 12.5:1	--
Pay and Allowance Rates			
Students	$5,899	$ 5,300	$61,000[c]
Instructors	9,697	10,800	61,000[c]
Instructional Support	--	--	--
Indirect Support	--	12,400	--

[a]Cannot be expressed in these terms. The net result was to eliminate the single instructor-hour contained in a 9-hour training segment.

[b]Applies to students, instructors, and instructional support personnel.

[c]The $61,000 figure is described as billet cost and includes a variety of personnel support items over and above pay and allowances, *e.g.*, command and administration, dependent school costs, recruiting costs, reenlistment bonuses, and retirement; students and instructors were pilots.

3-28-79-33 4-18-79

lists nearly 1,000 presentation and presentation control devices classified into over 50 types of commercially available equipment. The size of some types of equipment (*e.g.*, motion picture projectors) varies between that suitable for a large auditorium to that used by an individual. The purchase cost of some types of equipments will vary by more than an order of magnitude, depending upon size and features. Selections of equipments, then, require specifications of both the type of device and the environment in which course materials will be presented.

TABLE 14. MEDIA DEVICES: UNIT COSTS AND OTHER INFORMATION[a]

MEDIA DEVICE	RANGE OF INITIAL COST (DOLLARS) HESS AND KANTAR (1977)	LIFE SPAN (YEAR) HESS AND KANTAR (1977)	MEAN TIME BETWEEN FAILURES (HOURS)	
			HESS & KANTAR (1977)	McDONNELL DOUGLAS (1977a)
Sound Movie Projectors	175-1,000	6	90-110	197
Videotape Recorders/Players	600-8,000	5		463
Sound Slide/Strip Projectors	100-1,000			820
Silent Movie Projectors	150-250			
Silent Slide/Strip Projectors[b]	25-900	6-10	90-150	377-3,711
Random Access Slide Projectors	500-2,000			
Microfilm/Fiche Readers	80-800			2,785
Audiotape/Disc Players	30-325			2,783
Teaching Machines (Individual)				
Audio Visual				
Rate Control	230-1,000			
Constant Control	1950			
Visual				
Rate Control	140-380			
Constant Control	220-1,200			
Audio				
Rate Control	190-470			
TV Monitor				2,315
Headset				27,240

[a]Excludes equipments too large for use in individual classrooms. Costs are for commercial quality equipments.

[b]Includes overhead projectors.

3-28-79-34 4-18-79

Complicating the problem of determining the cost of use is the fact that media devices are typically long-lived and repairable assets, are generally portable, and can be employed in a number of classes at a number of locations. The cost of use, then, depends upon anticipated lifespan, failure rates, and repair costs, in addition to purchase cost and rate of usage. The cost attributed to an individual course also depends upon whether required equipments are currently on hand and available for use (*i.e.*, currently unemployed). The latter point implies that one must also consider current inventories and usage rates of other courses in determining the cost of using media devices.

8. Program Delivery: Computer Systems

Substantive cost information is available on five computer hardware systems--IBM 1500, PLATO IV, TICCIT, GETS, and Navy CMI. These five represent a wide range of capabilities in terms of the number of terminals supported by a single central processor. They also differ widely in terms of contractual arrangements under which they have been obtained (purchase, lease, or a combination). This makes interpretation of the information imprecise and subject to considerable qualification.

The detailed information that we were able to compile appears in Appendix E. Table 15 summarizes the costs of these systems expressed in the following ways:

- Central processing unit
- Terminal
- Total system hardware
- System cost per terminal
- System cost per student-hour

These data should be accepted primarily for illustrative purposes; any contemplated application would need current data on systems configured to particular specifications of interest.

Three principal resource categories can be associated with computer system use: (1) the hardware, (2) its operation, and (3) its maintenance. Little information is available on either maintenance or operations. Maintenance estimates, based on the IBM 1500 and PLATO IV, range from 15 to 35 percent of hardware purchase cost over a 5-year period; the lower limit is associated with the IBM 1500. However, all IBM 1500 systems in the sample were leased, and the 15 percent figure is based on amortizing lease charges over a 5-year period. Operating cost may vary greatly as a function of the user's organization, and sketchy information on IBM 1500 use indicates such a variation, ranging between 5 and 50 percent of annual lease costs.

TABLE 15. COSTS OF COMPUTER SYSTEMS HARDWARE

Method of Instruction	Computer System	Central Processor Cost (Thousands)	Terminal, Unit Cost (Thousands)	System Hardware Cost (Thousands)	System Hardware Cost Per Terminal (Thousands)	System Hardware Cost Per Student-Hour[a]
CAI	IBM 1500 32 Terminals[b]	—	—	$ 800	$ 25	$ 2.49
	PLATO IV 1,000 Terminals[c]	$ 5,000	$ 5.7	10,700	11	1.48[d]
	TICCIT 32 Terminals[e]	760	2.1	850	27	2.66
	64 Terminals	870	2.8	1,050	16	1.64
	128 Terminals	970	2.8	1,330	10	1.04
	GETS One Terminal	—	—	34	34	3.40
CMI	Navy CMI 6,000 Students[f]	2,300	14.3	4,020	34	0.07
	16,000 Students[g]	2,300	14.3	6,880	22	0.04

4-18-79

[a]2,000 hours per terminal per year for 5 years.

[b]Includes maintenance. Based on lease rates and amortizing equipment over a 5-year period, 1967, 1972, 1977.

[c]Control Data Corporation quotation, from private communication dated 14 August 1978.

[d]Based on 725 active terminal constraint.

[e]Hazeltine quotation, from private communication, 1978.

[f]120 terminals at 50 students per terminal, 1977.

[g]320 terminals at 50 students per terminal, 1977.

3-26-79-35

System hardware costs can be expressed in three ways: (1) system procurement cost, (2) cost per terminal connected, and (3) cost per student-hour (over some chosen amortization period). In terms of system procurement cost, a range between near $35,000 (the stand-alone GETS) and over $10 million (a 1,000-terminal PLATO IV system) can be noted, a factor of close to 300 times. On a per-terminal basis, though, available information indicates an inverse relationship between system size and cost. As an example, for the TICCIT system, the per-terminal system cost of the 32-terminal configuration is close to two-and-one-half times that of the 128-terminal configuration. This information indicates a substantial economy of scale for larger systems.

A more meaningful relationship in comparing computer-based instruction with other methods is the cost per student-hour. This cost is inversely proportional to terminal utilization rates, to system life span and, for computer-managed instruction, to the number of students a terminal can accommodate. Realized costs per student-hour will be highly sensitive to each of these. An average of 2,000 hours per year per terminal is a widely cited target value, but one which appears difficult to attain. Should it prove attainable, and assuming a system life span of 5 years, indicated student-hour costs for CAI systems range between roughly $1.00 (the 128-terminal TICCIT system) and $3.50 (GETS). The lower per student-hour cost associated with large systems implies a large initial commitment of funds (if central hardware is purchased) and a large commitment to CAI with the other costs and risks it entails. Assuming that each CMI terminal would accommodate 50 students, student-hour costs would appear to be less than $0.10.

Note that the $3.50 associated with the GETS is based on information that is several years old. Systems of comparable capability, incorporating recent technological advances in microprocessors and data storage devices, can be anticipated to cost considerably less.

9. Program Delivery: Communications

Communications are relevant only for large systems where terminals may be geographically separated from central processors. In current military applications, these are limited to PLATO IV and the Navy CMI system. Communications have been accomplished through two modes--microwave transmission and landlines, but microwave transmission has received too little discussion to allow characterization of its costs here. The rate schedule for communications over commercial long lines, as reported in two studies, is shown in Table 16.

TABLE 16. RATE SCHEDULE FOR COMMUNICATIONS OVER COMMERCIAL LONG LINES

DISTANCE INTERVAL (MILES)	COST PER INCREMENTAL MILE PER MONTH	AVERAGE COST PER MILE PER MONTH (AT LIMIT OF DISTANCE INTERVAL
1-25	$3.30	$3.30
26-100	2.31	2.56
101-250	1.65	2.01
251-500	1.15	1.58
> 500	0.83	1.20[a]

[a]At 1000 miles.

Source: Ball and Jamison (1973), and Middleton, Papetti, and Michell (1974).

3-26-79-37 4-18-79

For land-lines, a commonly used rule of thumb is $1.00 per mile per month for long lines (interstate), but line distances of greater than 1,000 miles are required before costs decrease to this level. Rates charged government agencies for lines leased through the General Services Administration are typically stated at half the commercial rate, and $0.50 per mile per month is the value commonly used in military studies. The significance of communications costs for a large system with a central computer can be appreciated by the following. At the $0.50 per mile per month rate, estimated communications costs in the PLATO IV experimental programs averaged over 50 percent of computer rental and terminal maintenance costs.

10. <u>Program Delivery: Materials</u>

No data were found on these costs of instruction.

11. Program Delivery: Facilities

During time periods in which the military services are not expanding, the need for additional facilities and furnishings should be a minor consideration in instructional costs. Cases where such costs would be incurred would be limited to the introduction of new training courses (as might accompany the introduction of new operational equipments) and major changes in the way instructional material is presented. In both cases, requirements might be levied for modifying and outfitting instructional areas (classrooms and laboratories) with fixtures to accommodate new training equipments.

This appears to be the case in transitions from conventional to either individualized or computer-based instruction, but such costs appear to be modest (see Table 17). The introduction of individualized or computer-based instruction would normally require replacement of traditional classroom desks with carrels and might require the extension of electric service to individual student positions and the conversion of classrooms to larger learning centers. Introduction of computer-based instruction

TABLE 17. COSTS OF FACILITIES: LEARNING CARRELS, ELECTRIC AND PNEUMATIC LINES

ITEM	COST PER UNIT	REFERENCE
Individual Learning Carrel		
30 Carrels	$90	Dallman, DeLeo, *et al.* (1977)
20 Carrels	260	Steinkerchner, Deignan, *et al.* (1977)
Electric and Pneumatic Lines (PLATO IV)		
30 Carrels	$61	Dallman, DeLeo, *et al.* (1977)
20 Carrels	141	Steinkerchner, Deignan, *et al.* (1977)

3-26-79-38 4-18-79

might require other utility service; for example, PLATO IV terminals require compressed air and communication lines.

12. Program Management and Administration

No data were found on these costs of instruction.

13. Student Personnel: Pay and Allowances and Other Costs

Data on pay and allowances are widely available. Nevertheless, such data appeared only in three studies (see Table 13).

An alternative to training at schools is to conduct the same training at operational sites. It has been proposed that computer-based instruction would increase the amount of operational site training that is feasible and avoid costs of relocating personnel to the schools. Relocation costs were treated by only one study. Polcyn, Baudhuin, *et al.*, (1977) present data that permit estimation of transfer costs (including per diem) per course: $425 for advanced training based on permanent change of station, $400 for advanced training based on temporary duty transfer, and $140 for initial training based on permanant change of station. A significantly higher cost ($825) for permanent change of station for advanced training is cited by the Air Force in "USAF Cost and Planning Factors" (Air Force Regulation 173-10)

C. DISCUSSION AND SUMMARY

There is no evidence that one method of instruction is most cost-effective for all types of military training. The most cost-effective method for a particular situation will depend upon such factors as type of course material, location of instruction, numbers of students, and life-span of the training. It is apparent that the cost data currently available make it impossible to examine satisfactorily the conditions which would make a particular method of instruction the most cost-effective alternative.

Unless there are key studies that have been overlooked, both the quantity and quality of current data on training costs are meager.

The training-management and data-reporting systems currently employed by the Services do not provide information needed for evaluating the cost-effectiveness of alternative methods of instruction for two reasons. First, they provide information only to the level of complete training courses, while analyses of the cost of methods of instruction need data that can be associated either exclusively or predominantly with a single method of instruction within a course. Second, training courses use many resources provided by school management and organizations at higher echelons (*i.e.*, "training support"). The use of such resources may differ significantly between different methods of instruction. However, current reporting systems veil the cost differences by allocating support on arbitrary bases, such as averaging across all students located at a training facility.

Data reporting systems that would provide information suitable for cost-effectiveness analyses of instructional methods would be more complex and expensive than current systems for two reasons. The first is the straightforward multiplication of the number of training activities whose costs may be separately identified and compiled; that is, each course has many segments. The second reason lies in the structure of military training. If the costs of training support functions are to be attributed in other than an arbitrary manner, they must be initially recorded in a way that empirically associates the support provided with the individual course segments receiving the support. Considering the size and complexity of military training organizations, this is a task of great magnitude.

Two steps are necessary to lay a foundation for building a data base on the costs of training. The first is to formulate hypotheses regarding causal relationships between training program characteristics and resource requirements in order to identify the types of data that should be collected. The second step is to formulate and evaluate alternative schemes for collecting the data.

Table 18 identifies, for hypothetical purposes only, some determinants of costs for various methods of instruction, based on our review of the literature, analogies to weapon system costs, and intuition. The determinants shown are respresentative, rather than exhaustive, and probably encompass only the more obvious factors. At that, the table shows the extensive range of cost and non-cost data required to assess training costs in a manner suitable for analyses of the cost-effectiveness of methods of instruction.

We note that training cost data could be collected in three fundamentally different ways: universally (continually on all training activities), by a sampling procedure, or on an *ad hoc* basis. We have discussed the nature of each of these methods but have not evaluated them or the costs and benefits associated with each alternative. The question of how best to collect data on the costs of alternative methods of instruction is a central issue requiring further and thorough study.

TABLE 18. HYPOTHESIZED DETERMINANTS OF COSTS

RESOURCE — TYPE OR FUNCTION	APPLICABLE METHOD OF INSTRUCTION	HYPOTHESIZED DETERMINANTS OF COSTS: NONRECURRING	HYPOTHESIZED DETERMINANTS OF COSTS: RECURRING
Program Development Program Design	All	Unknown	Unknown
Instructional Materials: Conventional Instruction	Conventional Instruction (Incl. Laboratory)	Course Hours of Instruction* Teaching Format and Strategy Type and Mix of Equipment Used (media, laboratory, etc.)	Rate of Revision (e.g. Annual)
Individualized Instruction: Programming	Individualized Instruction		
Individualized Instruction: First Unit Production	Individualized Instruction		
Computer-Based Instruction: Programming	CAI; CMI		
Computer-Based Instruction: Coding	CAI; CMI		
Program Delivery Instruction: Instructors	All	(Not Applicable)	Student: Instructor ratio Average Course Completion Times* Average Daily Attendance* Instructor Training Costs
Instructional Support Personnel	All		
Equipment and Services: Laboratory (including simulators)	Conventional Instruction Individualized Instruction CMI	Type and Mix of Equipment Availability of Equipment Number of Shifts Operated Life Span of Equipment Attainable Equipment Utilization Rates Average Daily Attendance* Unit Costs of Equipment	Equipment Failure Rates and Repair Costs Operating Personnel Requirements Course Hours of Instruction* Average Daily Attendance*
Media Devices	Conventional Instruction Individualized Instruction CMI		
Computer Systems	CAI; CMI		
Communications (leased land-lines)	CAI; CMI	(Not Applicable)	Average Distance Multiplex Capability
Materials (including consumables)	All	Reproduction Costs of Instructional Materials Days of Supply Requirement	Failure/Replacement Rates of Instructional Materials
Facilities	All	Availability of Facilities Area Requirement (per student, etc.)	Maintenance Costs per Unit (e.g. Area) Average Daily Attendance*
Program Management and Administration	All	(Not Applicable)	Unknown
Student Personnel Pay and Allowances	All	(Not Applicable)	Average Course Completion Times Average Daily Attendance Student Pay Grades
Other (PCS, TDY, etc.)	All		

*By Method of Instruction, Type of Equipment, etc.

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V. DISCUSSION

Computer-assisted and computer-managed instruction for military training have been evaluated in about 30 studies conducted since 1968. Most of these were experiments of limited duration. In a few cases, CAI still remains in use, *e.g.*, PLATO IV for training medical technicians at Sheppard AFB, Texas, and vehicle repair mechanics at Chanute AFB, Illinois, and TICCIT for training S-3A tactical coordinators at Naval Air Station, North Island, San Diego, California. There have been fewer evaluations of CMI systems but most of these systems are still operating after 4 or more years, *e.g.*, the Navy CMI, Air Force AIS, and Army CTS. A wide variety of courses, involving both the acquisition of knowledge and performance skills, were included in these evaluations.

A. MAJOR FINDINGS

The principal findings are summarized in Table 19. Computer-assisted and computer-managed instruction are as effective as conventional instruction when measured by student achievement at school, but a more direct and relevant measure of effectiveness is the performance of graduates on jobs in operational units. Correlations between performance in school and on the job, though thought to be high, have not been demonstrated either for computer-based or conventional instruction.

Computer-based instruction typically saves 30 percent or more of the time students need to complete the same courses given by conventional instruction. The amounts of time saved range widely, but research has not addressed the factors that could

TABLE 19. SUMMARY OF FINDINGS ON CAI AND CMI, COMPARED TO CONVENTIONAL INSTRUCTION

Measure	Finding (Compared to Conventional Instruction)			Comments
	CAI		CMI	
Student Achievement	Same or more		Same	Performance measured only at school. Relation between performance at school and on the job not demonstrated. Observed differences not of practical importance.
Course Completion Time	No. of Comparisons	40	8	CMI: Most time savings maintained or increased with extended use.
	Time saved (Median)	29%	44%	
	Range	-31 to 89%	12 to 69%	
	No. of Comparisons	5	7	Computer-support saves little time beyond that of individualized instruction.
	Time saved Individualized Instruction	64%	51%	
	CAI	69%	CMI 51%	
Student Attrition	About the same		Slight increase may occur	CAI: very limited data CMI: possible decline in student quality
Student Attitudes	Favorable		Favorable	
Instructor Attitudes	Unfavorable		Unfavorable	Very limited data. Little attention given to instructors.
Cost	Less, due to student time savings		Less, due to student time savings	Data limited and incomplete.
Cost-effectiveness				Not known because cost data are limited and incomplete.

2-7-79-2 4-10-79

account for these variations. Thus, no explanation can be given at present for the different amounts of time savings found between CAI and CMI, between various types of CAI, between various types of CMI, between different courses, between different types of instructional strategies (*e.g.*, drill and practice, tutorial, simulation, student pacing algorithms, types of remediation) and the like.

It is widely believed that transforming a course from conventional to individualized (or self-paced) instruction saves student time. Three explanations are generally offered for this effect:

- Faster students are not held back by rates of presenting material in conventional instruction set to permit 85 to 90 percent of the students to complete the course.
- Course materials are reviewed and irrelevant materials tend to be eliminated when courses are modified in format from conventional to individualized instruction.
- Special remedial materials can be provided to students on the basis of information gained by frequent diagnostic testing of their progress through a structure of relatively brief lessons.

Computer-assisted and computer-managed instruction are, of course, forms of individualized instruction. Little attention has been given to the incremental benefits, if any, that computer support may bring to individualized instruction (without computer support). Some data were found where student performance could be compared on the same courses given by conventional, individualized, and CAI or CMI instruction. Student achievement at school was about the same with each method of instruction. Individualized versions of five courses saved 64 percent of the time required by conventional instruction; the CAI version saved an additional 5 percent or a total of 69 percent. For seven other courses, the individualized and CMI versions each saved 51 percent of the time required by conventional instruction.

Transforming a course from conventional to individualized instruction is expected to save student time, as occurred here. But, it is also clear that the addition of computer support to the individualized versions of these courses does not further increase to any appreciable degree the amount of student time saved. The extent to which shortening the course may have contributed to saving student time cannot be determined from these studies. Since the same instructional material, both in content and in structure, was provided in the individualized and computer-based versions of these courses, there is no special reason to expect that the addition of computer support should produce any incremental time savings. However, there is a substantive question as to whether the incremental cost of computer support in these cases produced incremental benefits. The particular studies from which these data were taken did not address this issue. It is not implied here that computer support *per se* does not produce benefits equal to or greater than its cost. Computer support to an instructional program may bring certain unique benefits such as reducing the number of instructors and support personnel needed for instruction, reducing the costs of maintaining student records, and reducing the costs of modifying and updating courses because of an ability to keep detailed records on student performance. Whether the costs of adding computer support (CAI or CMI) to individualized instruction (without computer support) produces benefits equal to or greater than these costs is an issue that clearly needs careful exploration.

B. COST-EFFECTIVENESS OF CAI AND CMI

There have been only a few attempts to estimate the cost-effectiveness of CAI and CMI and these are based on incomplete analyses of the costs of instruction. Table 20 summarizes the results of these studies. All of them are based on the premise that the amount of student training time saved by a method of

TABLE 20. SUMMARY OF STUDIES REPORTING COST SAVINGS AND/OR COST-EFFECTIVENESS OF VARIOUS METHODS OF INSTRUCTION

Method of Instruction	System	Service	Location	Time Savings (%)	Number of Courses	Number of Students in Experiments	Number of Students Assumed for Estimate	Estimated Savings Per Year	Reference
CAI	PLATO IV	A	Aberdeen	65 - 89	3	535	–	PLATO IV not cost-effective[1]	U.S. Army Ordnance Ctr. and School (1975)
	PLATO IV	N	No. Island	67	1	22	200 pilots per year	$0.57M[2]	Crawford, Hurlock, Padilla and Sassano (1976)
	PLATO IV	AF	Chanute	19 - 27	4	1261	375 per week	PLATO IV not as cost-effective as programmed instruction[3]	Dallman, DeLeo, Main and Gillman (1977)
Conventional (revised course)	–	N	Memphis	50	4	480	390 per class per week	$ 6M[4]	Carson, Graham, Harding, et al. (1975)
CMI	Navy CMI	N	Memphis	41 - 70	4	480	300 per class per week	$ 3M[6]	Carson, Graham, Harding, et al. (1975)
	Navy CMI	N	Memphis	–	–	–	– – 52,672 graduates[8] (actual)	$ 8.9M FY 75[7] $ 9.8M FY 76[7] $10.0M FY 77[7]	Briefing material (1978) Briefing material (1978) Briefing material (1978)
	AIS	AF	Lowry	24 - 35	4	–	21,128 (actual)	1417 m/yrs $ 6M (4 yrs)	Jul.1, 1974-Sept.31, 1978 Briefing material (1978)
	AIS	AF	Lowry	10 - 52	4	–	5561 (actual)	710 m/yrs $ 3M[10]	Oct.1, 1977-Sept.31, 1978 Briefing material (1978)
	AIS	AF	Lowry	-3.6 - 12.5[9]	4	–	–	AIS cost-effective compared to instructor-supported self-pacing on one course, not in others; computer costs small in comparison to other school costs	Feb. 1978-July 1978 AIS Service Test Briefing material (1978)

[1] Due to high communication and maintenance costs; PLATO IV cost-effective on basis of costs of developing and revising course materials; all comparisons with regard to self-paced instruction by sound-on-slide or television cassette.

[2] Pro-rated from cost avoidance of $5.7M over 10 years *provided* other training applications found to provide full-time utilization of PLATO IV terminals; the S-3A co-pilot training required only 8 percent of this capacity. Baseline was workbook and use of high-fidelity simulator of the Integrated Control System panel.

[3] Because of greater developmental and operating costs for PLATO IV.

[4] Compared to conventional instruction before revision.

[5] Savings due solely to course revision.

[6] Incremental to $6M above.

[7] Cost avoidance savings.

[8] Average on board, 6053

[9] Comparison of manually self-paced instruction vs. CMI in special test.

[10] Derived by pro-rating estimate shown above.

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instruction provides major cost savings; the amounts of cost savings are estimated by computing the pay and allowances of students for the amounts of student time saved in training; the resultant amounts should more properly be called "cost avoidance savings". This procedure was applied to time savings due to PLATO IV, Navy CMI, and AIS and, in one case, to revised course materials in a course given by conventional instruction. Four of these studies consider other costs in addition to those avoided by student time savings, such as for preparing course materials, purchase or use of computers, and the number of instructors required by each method of instruction (Crawford, Hurlock *et al.*, 1976; U.S. Army Ordnance Center and School, 1975; Dallman, DeLeo *et al.*, 1977; and the AIS Service Test, described in an Air Force briefing, 1978).

The dollar amounts of such "savings" could be large, depending, of course, on the number of students assumed for these estimates, *e.g.*, about $10 million a year for about 50,000 students instructed in FY 1977 by the Navy CMI system and about $3 million a year for about 5500 students instructed in FY 1978 by the Air Force AIS system. According to two cost-effectiveness evaluations that have been reported, the PLATO IV system is judged to be not as cost-effective as individualized instruction. These conclusions are based on incomplete cost data in two small-scale tests (535 students in four courses at U.S. Army Ordnance Center and School, Aberdeen Proving Ground, Maryland, 1975; 1261 students in four courses at Chanute AFB, Illinois; Dallman, DeLeo *et al.*, 1977). The Air Force AIS was found to be cost-effective, compared to instructor supported, self-paced instruction in one course (Inventory Management) but not in three others; the computer costs which made the latter courses not cost-effective were judged to be small in comparison to other school costs (AIS Service Test, 1978). Since all of these findings are based on incomplete cost data, the findings cannot be generalized or even taken seriously.

Other benefits, beyond those of saving student training time, are often said to occur with CAI and CMI, largely because the computer can compile records and direct the attention of instructors, on the basis of various algorithms. The following list is illustrative rather than complete:

- More precise data for improving and updating course materials
- Improved control over equipment, facilities, and materials for instruction
- Improved allocation of resources among students
- Improved ability to accommodate fluctuations in student loads
- Increased student:instructor ratios, as well as the ability to use some instructors with less advanced qualifications
- Reduced need for support by noninstructional personnel
- Reduced time of students on base waiting for courses to start
- Reduced time of students on base waiting for orders after completing courses
- Improved integration of records of students at school with those in central, computer-based personnel files
- Improved utilization of instructors.

Many of these benefits may occur with the use of CAI and CMI. None of them have been included in any cost-effectiveness evaluation known to us. Records kept at Lowry AFB for students instructed by the AIS show that, compared to prior periods, they spend less time waiting to enter a course and waiting for an assignment after completing a course. Records kept by the Navy CMI system show that the average on-board count of students in school has been reduced for those instructed by that system: the extent to which this may be attributed to various benefits has not been examined.

C. WHAT SHOULD BE DONE NEXT?

The potential value of computer-assisted and computer-managed instruction for military training rests primarily on findings that (1) computer-assisted and computer-managed instruction save 30 percent or more of the time (median value) required by students under conventional instruction and that (2) student achievement at school is about the same with computer-assisted and computer-managed instruction as with conventional instruction. However, these results do not necessarily imply that computer-assisted and computer-managed instruction are cost-effective because of fundamental problems with the measures of effectiveness and of cost used in the studies from which these results are taken. Effectiveness, as measured by student achievement at school, is not necessarily a measure of performance by course graduates in relevant jobs after they leave school. Data on the costs of alternative methods of instruction reported in various studies are essentially incomplete, particularly with respect to courseware, student:instructor ratios, support and management services; this applies both to computer-based and conventional instruction. The results that have been reported are limited to obvious costs observed during experiments (*e.g.*, preparation of courseware, rental of computers) and do not consider long-term costs associated with operational applications (*e.g.*, numbers of instructors and support personnel, revisions to course materials, maintenance of software and facilities, management). Next, we discuss steps that should be taken to remedy these deficiencies.

1. Measures of Effectiveness

There is a need to compare performance on the job of students instructed in the same courses by alternative methods of instruction. In practice, comparisons will be required between conventional, individualized, and computer-assisted or computer-managed instruction. The general absence of objective data on the performance of students on jobs after graduation from military training courses is a major deficiency of research on many aspects of military training and is not limited solely to determining the cost-effectiveness of computer-based instruction. (See McCluskey, Trepagnier, Cleary *et al.*, 1975; Pickering and Anderson, 1976; and Foley, 1974, 1975, for recent efforts on measurement of job performance in the Army, Navy, and Air Force, respectively. Note: ". . . major assessment programs, either within or outside the military, that rely on performance tests as their primary data source are almost non-existent." Pickering and Anderson, 1976, p. 3.) It is also important to collect on-the-job performance data for several time intervals after students leave school (*e.g.*, 3, 6, and 12 months) in order to observe the short as well as longer-time effects of different methods of instruction. It may turn out that time saved at school must be compensated by spending more time in training on the job and that deficiencies in performance on the job attributed to one method of instruction disappear relatively quickly. Thus, there may well be a variety of trade-offs between the costs and benefits of various methods of instruction and amounts of training in schools and on the job.

It would be a major undertaking to develop objective methods of measuring performance on the job and to collect on-the-job performance data. If the school-job correlations are found to be high, we would have a basis for accepting student achievement at school as a proxy for the measurement of performance on the job. At present, we do not know the extent to which such correlations may exist and, if they do, that they have about the same magnitude for various methods of instruction, for various types of courses, and for varying periods of time on the job after leaving school. There should also be a feasibility study to examine the advantages, disadvantages, and costs of various methods of collecting and reporting on-the-job performance data. Although these data are proposed here to evaluate the effectiveness of various methods of training, they would also be useful for other purposes such as (1) setting standards for recruitment and advancement and (2) estimating the technical and maintenance readiness of the operational forces.

2. Measures of Cost

Available cost data are unsatisfactory for conducting cost-effectiveness evaluations of computer-based and other methods of instruction used in military training. Data on the costs of instruction provided by recent analytical studies of military training are incomplete. Further, since such cost data come from experiments that were limited with respect to amounts of courseware, numbers of students, and duration of the experiments, it is questionable whether the results should be used to estimate the costs of instruction under operational conditions. Data collected through the Services' current cost-reporting systems are not satisfactory because costs are identified only with complete training courses and the costs of training support are allocated to courses on arbitrary bases not related to actual utilization or requirements by specific courses. Cost element structures for collecting such data are identified in this paper and elsewhere. (See Petruschell and Carpenter, 1972; Braby, Henry, Parrish, and Swope, 1975; Seidel and Wagner, 1977; and McDonnell Douglas Astronautics Company East, 1977c).

A comprehensive effort to collect data on all the relevant costs on all methods of instruction used in military training would be a very large effort. In effect, however, identification of the major cost drivers for various methods of instruction is a necessary condition for assessing the cost-effectiveness of feasible alternatives. Decisions about using or not using new methods of instruction must be made now without benefit of reliable cost data. However desirable, a large-scale effort to collect such data cannot be recommended now without further examination of its scope, benefits, and costs. Instead, initial efforts should be directed towards evaluating alternative ways of developing a data base. In addition, cost data should be collected on major instructional systems that have recently come into use and on new ones being considered for procurement. These systems are identified below:

a. Air Force Advanced Instructional System (AIS). The current AIS incorporates capabilities for research that would not be needed in an operational version. Thus, cost data are needed on an operational AIS and on alternative methods of instruction for technical training. The recent AIS Service Test (unpublished as of February 1979) suggested that AIS was cost-effective compared to instructor-managed instruction only in one of four courses used in that evaluation.

b. Navy Computer Managed Instruction System (Navy CMI). Published information suggests that the Navy CMI system saves student time and thereby avoids costs. However, complete cost data on this system have not been published. For cost-effectiveness evaluation, cost data are also needed for comparable courses using individualized and conventional instruction.

c. Navy Aviation Training Support System (ATSS). This planned system will support computer-managed instruction for enlisted men and officers at 20 Naval and Marine Corps Air Stations; additional units, not yet planned, could support Naval surface warfare facilities. Cost data will be needed to support cost-effectiveness evaluations of this system and the methods of instruction that it would replace.

d. Army Automated Instructional Management System (AIMS). The Army AIMS is based on the Navy ATSS and the above remarks about cost data also apply here. About 20 units will be acquired if the initial installation at the Field Artillery School, Fort Sill, Oklahoma, is found to be effective.

e. Marine Corps Communication-Electronics School CAI/CMI System. The Marine Corps plans to procure a CAI/CMI system for the Marine Corps Communication-Electronics School, Twenty-nine Palms, California. The initial configuration of this system calls for installing 260 terminals in 3 years with a potential growth to manage 2000 students and a maximum of 1000 terminals. A preliminary cost analysis is being conducted by the Navy Personnel Research and Development Center.

3. Research and Development

An "Integrated DoD Plan for R&D on Computers in Education and Training" was prepared in draft form by a tri-Service group in September 1975. This plan should be revised and brought up to date on the basis of more recent information now available on computer-based instruction. Next, consider steps that should be taken to improve our ability to provide more relevant and accurate information on the effectiveness and cost of various aspects of computer-based instruction.

a. Factors Which Influence the Amount of Student Time Saved. The data show that computer-assisted and computer-managed instruction save appreciable amounts of student training time compared to conventional instruction. However, there is great variation in the amounts of student time savings found in many studies; extreme values of -31 to 89 percent have been reported. Other things being equal, the military Services should obviously favor those applications of computer-based instruction which promise greater student time savings. Thus, research is clearly needed to explore the conditions which influence the amount of student time saved. Factors which could influence the amount of student time saved by CAI and CMI probably include the quality of the course materials (for which metrics should be developed and standards set), types of courses (*i.e.*, some may save more time than others), and instructional strategy (*e.g.*, effects of combinations of drill and practice, simulation as a method of instruction, frequency of testing, length and difficulty of lessons, and methods of managing students' rates of progress through a course). On a longer-term basis, it is important to know whether student time savings accomplished at school bring any penalties, such as in quality of performance on the job and a need for additional on-the-job training.

b. Student Attrition with CMI. Currently available data suggest that student attrition with CMI may be somewhat larger than that with conventional instruction. However, it is not clear that the observed increases in attrition are due primarily to computer-managed instruction because the qualifications of students in these courses appeared to drop at the same time. Other factors may also be involved, *e.g.*, changes in the number, quality, and support provided by instructors. Put simply, there is a need to determine the extent to which CMI and other factors may increase attrition of students, compared to the rates that occur with other methods of instruction.

c. Role of Instructors in Computer-Based Instruction. The role of instructors probably differs significantly in conventional, individualized, computer-assisted, and computer-managed instruction. Yet the benefits to be derived from each method of instruction surely requires that instructors perform adequately the particular functions required of them in each case. Only a few studies consider the attitudes of instructors to CAI or CMI: all of these are unfavorable in comparison to conventional instruction. The limited amount of data cannot be regarded as conclusive. Thus, there is a need to develop more reliable information on the attitudes of instructors to all methods of instruction used at present by the military Services. The survey instruments should be diagnostic in nature so that steps could be taken later to remedy problems that may be identified, *e.g.*, experience and training of instructors, relevance of this training to their jobs as instructors, and areas where instructors believe that problems exist. Emphasis should be given to (1) computer-managed instruction, since that is in greater use by the military Services than is computer-assisted instruction and to (2) individualized instruction, because this method of instruction is a reasonable alternative to conventional as well as to computer-managed instruction. On a longer-term basis, steps should be taken to identify what instructors should do to make computer-assisted and computer-managed instruction most effective at least cost.

d. Comparison of Individualized and Computer-Based Instruction. A significant finding of this paper is that, compared to conventional instruction, computer-based instruction saves no more time than does individualized instruction. Student achievement in school was about the same in all cases. The obvious question is whether computer-assisted and computer-managed instruction provide benefits, greater than those of individualized instruction, that are worth their incremental costs. On the surface, it does not appear that the additional savings in student time obtained with computer support would be sufficient to pay for the incremental costs. However, this observation does not consider significant cost savings that computer-based instruction might bring in a reduced need for instructors, improved record keeping and management of students, instructional materials, and the like. An analysis of the costs of individualized, computer-assisted and computer-managed instruction for the same courses is very desirable.

e. Methods of Collecting Cost Data on Methods of Instruction. There will be a continuing need to collect various types of cost data on alternative methods of instruction. It is clear that current management and reporting systems do not provide data that are satisfactory for use in analyses of methods of instruction. Three methods of collecting cost data appear to be available:

- Universal collection
- Sample collection
- *Ad hoc* collection.

A feasibility study is needed to examine the advantages, disadvantages, and costs of various ways of collecting cost data that will be needed to support cost-effectiveness evaluations of methods of instruction in the near future.

f. Other Types of Research and Development. Certain types of research and development might improve the effectiveness and/or reduce the costs of computer-assisted and computer-managed instruction in military training but there is an insufficient basis, at present, to recommend funds for their support. Major items of this type would probably include the following:

- Further development of "intelligent computer-assisted instruction". This refers to the use of the computer to model each student's style of learning and to use this information to construct lessons best suited to his unique needs from detailed materials stored in the computer. In effect, this eliminates the need to prepare complete lessons for storage in the computer, as in present CAI systems; it may also improve the effectiveness of CAI in instructing individual students.
- Improved methods of preparing courseware to reduce high costs currently encountered in this area.
- Improved video discs and solid-state memories to significantly reduce the costs of major components in computer-assisted and computer-managed instruction, particularly for stand-alone instructional systems used away from schools.
- Improved communications for computer-assisted and computer-managed instructional systems which use a large central computer to support many terminals at different locations.
- Investigate the feasibility of developing a general model for use in cost-effectiveness studies of military training.
- Determine the maximum acceptable costs of stand-alone terminals or other system-design concepts for them to

be cost-effective in selected applications of CAI and CMI, *i.e.*, to establish cost goals for the improvement of technologies useful for computer-based instruction, such as video discs and solid-state memories.

- Define ways of measuring various benefits claimed for CAI and CMI. It has been suggested that CAI and CMI provide various benefits not now available with conventional instruction. These include, for example, improved control of materials and facilities required for instruction, improved utilization and assignment of instructors, more accurate information derived from computer records to improve lessons and tests, more accurate and complete student records, and the like. No data have been offered to support such claims and their impacts are not clear on the costs or the effectiveness of computer-based instruction. An exploratory study would be useful to define ways of measuring various potential benefits of computer-based instruction and of identifying the cost and other data that would be needed to estimate the magnitude of such benefits.

Given the absence of precise information on the major cost-drivers in computer-assisted and computer-managed instruction, for either large-scale or small-scale installations, it is difficult to establish any amounts or priority for funding research and development on most of the items noted above. Nor is it clear how much improvement is needed or is feasible in any of these areas in order to make a significant impact on the cost and/or effectiveness of computer-based instructional systems that would incorporate such improvements. It may also be noted that some of these studies, no matter how desirable, cannot be undertaken until more detailed cost data become available.

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APPENDIX A

METHODS OF INSTRUCTION

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METHODS OF INSTRUCTION

There are many methods of instruction, such as lecture, discussion, tutoring, independent study, and the like; 20 different methods of teaching listed in the Rand Corporation's "Method of Designing Instructional Alternatives (MODIA)" (Carpenter-Huffman 1977). More than one method of instruction may be used in any course. For purposes of this study, we group methods of instruction into four general categories, as follows:

Category	Examples
Conventional instruction	Lecture, discussion, demonstration
Individualized instruction	Programmed instruction, self-paced instruction, precision teaching
Computer-managed instruction (CMI)	Advanced Instructional System (AIS) Navy Computer Managed Instruction System (Navy CMI)
Computer-assisted instruction (CAI)	PLATO IV, TICCIT, GETS, LTS

These categories embody several key distinctions: conventional and individualized instruction do not require computer support; CAI and CMI do, and are generically referred t as computer-based instruction (CBI). Conventional instruction is aimed (by definition) at instructing groups of students at the same pace (counselling and tutoring of individual students are, of course, attempts to individualize instruction within the structure of conventional instruction); the other three methods are designed to permit each student to learn at his own pace.

Each of these methods of instruction is described below.

A.1 CONVENTIONAL INSTRUCTION

Conventional instruction typically consists of lectures and discussion in which all students are supposed to learn the same material at the same rate; it is sometimes referred to as "lock-step" instruction, platform instruction, group scheduling, or block scheduling. A shortcoming of this method is its relative inflexibility, particularly with large groups of students. Students differ in their rate of learning and they enter a course with varying degrees of knowledge about the material to be taught. However, information is presented at a constant rate for all. Even if the rate is one at which most members of the class can learn, it will necessarily penalize those for whom that rate is either too fast or too slow. Thus, slow learners may progressively fall further behind and perhaps fail and fast learners may simply lose interest in coming to class. All students spend about the same amount of time in the class and at the completion of the course differences between them are reflected in how much has been learned, *i.e.*, in final grades from norm-referenced tests.

A.2 INDIVIDUALIZED INSTRUCTION

Individualized instruction is a way of arranging a curriculum into small lessons and tests so that each student can proceed at his own rate. Although the term "individualized instruction" could also apply to computer-based instruction, its use here will be limited strictly to various forms of individualized instruction conducted <u>without</u> a computer. There are many types of individualized instruction that do not rely on computers such as self-paced instruction, programmed instruction, personalized system of instruction, and precision teaching; these differ primarily in the instructional strategies and in the role assigned to the instructor in order to provide each student with the type of materials best suited to his style of learning.

The term "self-paced" needs to be qualified. Obviously, no student is permitted an unlimited amount of time to finish a course; students are encouraged to request assistance from the instructor when some difficulty is encountered or the instructor may intervene when he observes that a student is proceeding slowly. Various incentive schemes may be employed, such as assigning a completion date to each student, the posting of average class progress, or assistance to slower students by faster ones. Other differences among methods of individualized instruction concern whether all students must progress through the same set of lessons ("straight-line") or whether alternative lesson materials are provided ("branching").

Lessons can be presented in booklets, by audio-visual devices, in a laboratory set-up, or in work situations such as a maintenance shop; the lesson material can consist of knowledge or skill or both, as in the maintenance, calibration, and repair of equipment. Instruction is oriented to the complete mastery of lessons; lessons and tests are tied to each other. If a student passes a test, he goes on to the next lesson; if not, he repeats the lesson in the same or modified form. The student can take tests without taking lessons since successful completion of a test is presumed to show that he knows the required material; he need take only the lessons prescribed for the tests that he failed. It is not a trivial matter to determine the proper amount of information to be included in a single lesson, to decide whether a slide or a written text is the more effective way of presenting certain information, and to arrange a sequence of lessons that is efficient for instructional purposes. The essence of individualized instruction is to provide a structure of lessons and tests that a student can take at his own rate to master an entire course. It does not require the use of a computer.

To graduate, all students must pass the required lesson and end-of-course tests. The instructional material is prepared so that there is a high probability that all students can complete the course. Students either know what they are supposed to know or they do not graduate, as determined by criterion-referenced rather than norm-referenced tests. Differences among students are reflected primarily in the amount of time they need to complete the course, although grades and test scores may also be recorded.

A.3 COMPUTER-MANAGED INSTRUCTION (CMI)

Individualized instruction permits each student to proceed at his own pace, but it generally increases the instructor's clerical and advisory loads. The instructor needs to give and score more tests than he would in a conventional classroom. He must keep track of each student's rate of progress on almost a daily basis and work closely with students when they have problems with any part of the course. He must find the right lesson, audio-visual cassette, or test bench whenever a student needs it and keep track of all available resources. All of these functions, and certainly all of the clerical and bookkeeping tasks, can be accomplished readily by a modern computer (see Baker 1978 for a recent review).

In computer-managed instruction (CMI), all instruction takes place off-line, *i.e.*, away from the computer. The point of contact between the student and the computer is the test which accompanies each lesson. The test may be given either on-line or off-line with a machine-scorable answer sheet. In either case, the computer scores the test, immediately reports the results to the student, tells him which lesson to take next and where it may be found in the learning center. The next lesson, of course, may represent progress or remediation; if there is too much of the latter, the computer advises the student to consult the instructor.

A CMI facility can provide many of the services associated with training such as the following:

- Testing
  - -Scoring
  - -Diagnosis
  - -Prescription, such as drill and practice, or remediation (repetition of all or part of a lesson, or assignment of the student to parallel tracks that differ in the level of difficulty between steps or in the method of presenting information).
- Management
  - -Monitoring
  - -Pacing students according to predetermined rules
- Scheduling
  - -Assignment of students
  - -Optimum allocation of instructional materials and facilities
  - -Assignment of instructors
- Administrative record keeping
  - -Student personnel records
  - -Student test data, graduation
  - -Instructor records
  - -Inventory and control of learning resource materials (films, tapes, workbooks, projectors, *etc.*)
  - -Frequency and time of use of materials and facilities
- Course development
  - -Since test results show how students answered each test item, information is available to identify

the difficulty of the different parts of each lesson. This provides a basis for modifying the course and testing the effectiveness of various improvements.

Examples of CMI systems are:

<u>Army</u>: Automated Instructional Management System (AIMS)
Field Artillery School, Fort Sill, Oklahoma

<u>Navy</u>: Computer Managed Instructional System
Naval Air Technical Training Center,
Millington, Tennessee.

Aviation Training Support System (ATSS)
[planned for about 20 Naval and Marine Corps
Air Stations; previously called Versatile
Training System (VTS)].

<u>Air Force</u>: Advanced Instructional System (AIS)
Air Force Technical Training Center
Lowry Air Force Base, Denver, Colorado

A.4 COMPUTER-ASSISTED INSTRUCTION (CAI)

In Computer-Assisted Instruction (CAI), the instructional materials are stored in and presented by the computer. Each student interacts individually with segments of the material and takes tests through some type of terminal. The typical terminal contains one or more output and input devices; for output, a television or plasma panel display, screen for slides or fiche, paper printer, loudspeaker; for input, a keyboard, teletypewriter, pointing-type capability, graphic tablet, microphone.

CAI systems generally include many terminals. In the TICCIT (Time-shared, Interactive, Computer-Controlled, Information Television) system, up to 128 terminals and one control computer are located at the same site; in the PLATO IV system (Programmed Logic for Automatic Teaching Operation), about 1000 terminals in different locations are linked to a central computer by long-distance communication lines. In principle, each CAI terminal could have its own mini- or micro-computer, but such an arrangement is expensive at present. Systems of this type (called "stand-alone") have been developed for the military Services, *e.g.*, the Lincoln Terminal System (LTS) and the General Electric Training System (GETS).

A narrow definition of CAI would consider it to be a way ("medium") of presenting instruction, comparable to TV, slide, or filmstrip and regard its flexibility as a form of CMI. However, this distinction has little practical meaning. The interactive nature and flexibility of a CAI system distinguish it from CMI or programmed instruction of any variety. With appropriate programming, CAI permits a dialogue to occur between student and computer on every frame of an instructional sequence. The computer can tutor, prompt, drill, and test the student on a frame-by-frame basis; by means of simulation, it can guide and test the student on complex dynamic processes. By diagnosing the student's progress, it can identify and select the material best needed to meet specific deficiencies; it could compose (in fact create) appropriate lessons and tests from a large store of elemental materials.

Although CAI is defined narrowly as a medium of presentation, most CAI systems also provide the administrative and record-keeping capabilities inherent in CMI systems.

A developing application of computers to instruction is "Intelligent Computer-Assisted Instruction" (ICAI). In ICAI, subject matter knowledge is stored in the computer, but not in the form of previously defined lessons. Instead, the computer models each student and selects stored subject matter material to construct instructional interactions for individual students. These interactions can be very flexible, and hold some promise for "human-like" tutoring of students.

ICAI is a very new area with work currently underway, sponsored by DARPA, ONR, and others. However, no data are available yet on costs or effectiveness, and therefore, ICAI will not be treated further in this paper. There can be little question about the superior instructional capabilities provided by a CAI system. The real issue is whether these capabilities are worth their cost.

Examples of some CAI systems evaluated in military training are listed below. These are described in Appendix B.

CTS	Computerized Training System U.S. Army Signal School Fort Gordon, Georgia
PLATO IV	Programmed Logic for Automatic Teaching Operation Computer-based Education Research Laboratory University of Illinois
TICCIT	Time-shared, Interactive, Computer-Controlled, Information Television The MITRE Corporation
LTS	Lincoln Terminal System Lincoln Laboratory Massachusetts Institute of Technology Lexington, Massachusetts
GETS	General Electric Training System General Electric Ordnance Systems Electronics Systems Division Pittsfield, Massachusetts

The idea of individualized instruction, which underlies all forms of computer-based instruction, long precedes the development of modern computers. It was promoted by John Dewey about 1900 at the University of Chicago (and by Socrates centuries ago). Sidney L. Pressey (1926, 1927) designed several mechanical "teaching machines" which provided preprogrammed drill and practice frames as well as automatic self-scoring of tests. His concept was to provide immediate feedback and self-pacing in education. Testing one of these machines, Little (1934) found that

> Students immediately apprised of their test results, and given opportunity to correct deficiencies by make-up tests, profit markedly in terms of final examination results over students who do not have such advantage.
>
> Students. . .given opportunity to correct deficiencies by drill and by make-up tests, likewise so profit.
>
> The greatest benefit accrues to students who usually score in the lower half of the distribution, although the entire group moved upward.
>
> (Reprinted in Lumsdaine and Glaser, 1960, p. 65)

Pressey expected his machines to produce a "coming industrial revolution in education" but this did not occur. In 1932, he wrote, "The writer has found from bitter experience that one person alone can accomplish relatively little and he is regretfully dropping further work on these problems." (Quoted in Skinner, 1958). Skinner's teaching machines required the student to compose his response rather than, as did Pressey's, select it from a set of alternatives. Skinner presented material in a progression of small steps, each of which the student could probably understand and, in so doing, become ready for the next; the student got feedback by being reinforced for every correct response. (Skinner, 1954, 1958). Skinner's work was done at the right time and had impact. By 1962, over 80 different teaching machines and 630 instructional programs were commercially available; six machines were computer controlled (Aeronutronics, DEC, Marquardt, Rheem, TRW, and USI Robodyne; Finn and Perrin, 1962). IBM simulated a Skinner teaching machine on an IBM 650, starting in 1958, and work on PLATO started at the University of Illinois in 1960. (Rath, Anderson and Brainerd, 1959; Alpert and Bitzer, 1970). Some noted engineers contributed to this progress. In a well-known article, Vannevar Bush (1945) predicted a computerized desk which would contain a large volume of library materials and monitor a reader's progress. In 1957, Simon Ramo described how "teaching engineers" with pushbutton classes and memorizing machines could help meet the increasing need for more education in a growing technical society. The Department of Defense (AFOSR, AFPTRC, NTDC, ONR) supported much of the original R&D on teaching machines during the 1950s.

A.5 ADVANTAGES AND DISADVANTAGES OF VARIOUS METHODS OF INSTRUCTION

The Services conduct individual training at 126 different facilities (76 for specialized skill training alone); each Service offers 3000 to 4000 courses. The average number of students on board in these courses can vary at any time from about 10 to 2,500 (the largest is for a course in propulsion engineering at the Navy Training Center, Great Lakes, Illinois). Course length can vary from days to months. It is not likely that any method of instruction is best suited for all courses in this wide spectrum of requirements. With this obvious qualification in mind, it is useful to compare the advantages and disadvantages generally attributed to the four methods of instruction that have been described. The main points are summarized in Table A-1.

A.5.1 Conventional Instruction

Conventional instruction permits flexibility in presentation of material to suit the needs of individual students, provided the instructor is free to do so. Human contact can serve to motivate students. The standard rate of progress is established to produce some goal established by policy, *e.g.*, that at least 90 percent of the students master the course; the slow learners may fall too far behind to catch up; the fast learners waste time and may lose interest. Individualized attention becomes increasingly difficult as class size increases.

TABLE A-1. ADVANTAGES AND DISADVANTAGES OF FOUR METHODS OF INSTRUCTION

METHOD OF INSTRUCTION	ADVANTAGES	DISADVANTAGES
Conventional Instruction	Low delivery cost for large class sizes. Flexible in mode of instruction, use of media, course content, emphasis. Direct human contact. Simplifies planning because all students must progress at the same rate and complete the course at the same time. Instructors prepare instructional material. Grades at end of course define how much each student has learned in relation to a normative sample.	Not all students are able to progress at same rate with equal mastery. Low student:instructor ratios increases costs. Individual attention to students difficult as class size increases. Differences between instructors may lead to non-uniform achievement. Fast learners may lose interest in course. Slow learners become increasingly penalized. Load on instructor for scoring tests and managing students' progress increases markedly with class size. Difficult to insure student mastery of training objectives since norm-referenced rather than objective-referenced testing procedures are used. Difficult to insure that instructors present the relevant instructional information.
Individualized Instruction	Explicit course and lesson objectives. Standardized instruction. All students progress at their own rate (*i.e.*, slow learners do not hold up faster learners). Students can skip course material they already know, as shown by preassessment tests. Testing and evaluation closely tied to small lesson-steps. Lessons generally one track. All graduates are warranted to know the required information (*i.e.*, students pass the required tests or they do not graduate). Instructors can concentrate their time on those students who need assistance at both ends of the distribution. Permits use of instructor's aides, thereby reducing average level of qualification required of instructors. Permits wide use of different instructional media. Instructors relieved from rote repetition of basic materials. Instructors can have time to address concepts as well as student evaluation, motivation, and enrichment.	High initial costs for development of course materials, carrels, audio-visual equipment, etc. Increases demand for qualified personnel to prepare instructional materials. Requires changes in the instructor's role in conventional instruction. Load on instructor for scoring tests and managing students' progress increases markedly with class size.
CMI	All of those for individualized instruction, plus: Reduces demand for number of instructors. Presentation of lessons and taking of tests not dependent on computer. Automated test scoring, evaluation, prescription. Student progress monitoring. Multi-track lessons readily handled. Automated student management, record-keeping and scheduling. Resource management. Detailed information routinely available for evaluating and modifying lessons and tests. Manual scoring possible if computer and/or communication fails. Predict graduation date, based on rate of student progress in course and personal data in student's file. Provides data base for research, course development, and management decisions.	All of those for individualized instruction, plus: High initial costs for courseware, CPU, terminals. High operating costs for communications, where required. Instructional material poorly matched to students' abilities and expectations may discourage students and reduce effectiveness. Instructor's attitudes often unfavorable. Scoring and student management inoperative if computer and/or communications fail.

(continued)

TABLE A-1. (Continued)

	ADVANTAGES	DISADVANTAGES
CMI	A wide array of courses can be offered with few instructors (or, at remote facilities, without instructors, limited primarily by cost factors and availability of communications).	
CAI	All of those for CMI -- except that ability to operate when computer is inoperative is extremely limited -- plus: Very flexible means for presenting material and taking tests via computer. Interactive tutorial modes feasible. Simulation of processes and equipment feasible. Computational aids readily available. Can provide detailed information needed to improve specific lessons and tests, *e.g.*, student success with various subjects, method of presentation (graphic, text), instructional strategy, delay times. Can provide instructors with data bases, formats, guidelines for developing improved course materials Facilitates maintaining security of tests. Probably the greatest degree of individualized instruction currently available, except where very low student:instructor ratios are acceptable.	All of those for CMI, plus: Instruction becomes difficult when computer responses are delayed. No instruction possible when computer and/or communications fail.

Instructors favor this perhaps because the role offers high visibility and a position of authority. Low investment costs are required for current courses because, generally speaking, they were paid long ago when courses were originally developed.

A teacher can reach a large audience in a lecture hall and multiply this reach almost without limit by means of a movie or TV recording. However, as McKeachie (1970, p.13) said in a frequently quoted comment:

> The technological bottleneck in education is that we have no device that allows a teacher to listen or respond to more than one student at a time.

A.5.2 Individualized Instruction

Individualized instruction, whether delivered by programmed texts, a multi-media approach, or by computer, has the advantage of dealing more efficiently with different rates of learning and different amounts of prior knowledge among students. Its major limitations lie in the efforts required to

- Identify the specific lesson objectives which, in some progression, satisfy the overall course objectives
- Develop instructional material that delivers the required information
- Develop tests that measure the student's progress on each lesson and diagnose the types of remediation that may be required, and
- Prepare the remedial treatments.

Course materials must be pretested with students to ensure that lessons are neither too easy nor too difficult for students; it is often necessary to modify lessons in order to "validate" them. Developing courses for individualized instruction requires qualified subject matter experts and curriculum development experts who are not always available when needed.

Individualized instruction inherently makes more efficient use of the student's time than does conventional classroom instruction since each student can start a course when he arrives at a school without having to wait for a class of some optimum size to be formed. Each student can graduate when he has mastered the specified material. Because each lesson has a test, the instructor can identify students who are falling behind early in the course, give them personal guidance, and provide them with material selected to deal with their particular problems. This contrasts with conventional instruction where tests tend to measure student competence but do not provide a basis for remediation; tests are also given less frequently.

In this environment, an instructor must grade tests more often than in a conventional classroom; this in itself can become a large load. Since the instructor has more detailed knowledge about each student's progress, he can provide more individualized guidance than is possible in a conventional setting.

A.5.3 Computer-Managed Instruction

CMI provides a means to handle many of the administrative loads encountered in individualized instruction, such as scoring and prescribing lessons, identifying students who need remediation, managing and scheduling instructional resources, and predicting course completion times so that students can be sent promptly to their next assignment. CMI systems readily complement and can be tied into automated manpower and personnel management systems that are used by all military Services.

A.5.4 Computer-Assisted Instruction

All of this can also be provided by CAI. The preparation of course material for presentation by CAI is similar in concept but often more sophisticated than that for programmed instruction or for CMI. It is obvious that it is probably inefficient to use computers to present programmed materials (*i.e.*, to "turn pages") unless, of course, it costs less to do so by computer than by printing the same material on paper (which may soon be the case if frequent reprinting is required to update instructional material and if the costs of word-processing types of computer systems continue to be reduced). The major advantage of CAI is that it permits extraordinary flexibility in querying and prompting each student, a process which permits the computer to select material of a complexity or level of difficulty most likely to meet each student's rate of learning and best suited to deal with his misunderstandings and errors. Such a dialogue is highly motivating and serves to engage the attention of the student. It is indeed possible that a student may get more individual attention from a computer than he may get from many human instructors, particularly where large classes are involved.

APPENDIX B

TYPES OF COMPUTER-ASSISTED AND COMPUTER-MANAGED INSTRUCTION SYSTEMS

APPENDIX B

TYPES OF COMPUTER-ASSISTED AND COMPUTER-MANAGED INSTRUCTION SYSTEMS

Almost every existing computer-based instructional system, whether CAI or CMI, is tailored to some particular requirement such as the number and types of courses, location of school(s), student flow, and the availability of instructors, resources, and funds. Hardly less important is the influence of such factors as whether the method of instruction should be primarily CMI or CAI, and whether the required computer, wherever it may be located, will be used solely for instructional purposes or also for some noninstructional purposes, such as maintaining medical and personnel records, base accounting, preparing payrolls, and the like. For such reasons, there are no "standard" computer-based instructional systems and few are likely to be identical.

An inventory of computer-based instructional systems in current use by the military services does not exist. In a 1974 survey, it was found that computer-based instruction was used by the Army in 217 courses, the Navy and Marine Corps in 102, and the Air Force in 210. Compared to all other military instruction, this accounted for 2, 3.6, and 2 percent, respectively, of all courses (Sherron, 1976). In another survey of 116 Army courses at 16 schools, also in 1974, use of the computer in these courses varied over the widest possible range, *i.e.*, from 0.01 to 100 percent (Rich and VanPelt, 1974).

The military Services have conducted experiments on most of the CAI and CMI systems that have been available since about 1965. Even the most recent acquisitions, such as the Air Force Advanced Instructional System or the Navy Computer Managed Instruction system, represent computer technology of the early 1970s. Only the major features of the systems used in military studies are described here (see Sherron 1975 for additional information).

B.1 ARMY COMPUTERIZED TRAINING SYSTEM

The Army installed a prototype Computerized Training System (CTS) at the U.S. Army Signal School, Fort Gordon, Georgia, over the period 1974-1976. The program to evaluate CTS for Army use was called Project Abacus, a name used interchangeably with CTS. The Army refers to CTS as a CAI/CMI instructional system. There are 128 terminals in CTS, each with a Visual Display Unit and a keyboard. CTS also contains six mini-computers (PDP-11/35); four of these computers, called Display Controllers, support 32 CAI terminals each; the two other computers serve as System Controller and Data Base Controller, respectively.

The CTS features a fast response time: each of the 32 terminals in a cluster can be updated in less than 250 milliseconds. Three courses were developed for CTS:

- Field Repair Radio Course (31E20)
- Teletypewriter Equipment Repair Course (31J20)
- Avionics Communications Equipment Repair Course (35L20).

CTS was applied to these courses at Fort Gordon after feasibility and follow-up studies (conducted at the U.S. Army Signal Center and School, Fort Monmouth, New Jersey, during 1968-1971) showed that CAI is as effective or better than conventional instruction for training in basic electronics (Longo, 1972). Those initial tests were conducted with the IBM 1500 Instructional System, using the IBM Coursewriter II language.

Results of the Fort Monmouth tests are described elsewhere in this report; results of the Fort Gordon tests were published after this report was completed (see Seidel, Rosenblatt, Wagner, Schulz and Hunter, 1978).

B.2 PLATO IV

Development of the PLATO system (Programmed Logic for Automatic Teaching Operations) began in 1960 under the leadership of Donald Bitzer at the Computer-based Education Research Laboratory, University of Illinois (called Coordinated Science Laboratory until 1967). (See Computer-based Education Research Laboratory, 1977; Smith and Sherwood, 1976; Lyman, 1977). PLATO IV, the current version, uses a large central computer (CDC CYBER 74) at CERL which supports 950 terminals at about 150 locations throughout the United States and one in Sweden. Other PLATO systems are located at Control Data Corporation, Arden Hills, Minnesota, and at Florida State University, Tallahassee, Florida. The basic architecture of the PLATO IV system can support up to 1008 terminals; a Computer Interface Unit controls data communication between the central computer and up to 32 site controllers, each of which can support up to 32 terminals via direct connection or telephone line. The PLATO terminal contains a touch-sensitive display panel, keyboard, and microfiche projector; it can also control various multi-media devices that are attached to it. PLATO was developed with the support of the National Science Foundation, the Office of Naval Research, the Defense Advanced Research Projects Agency, the National Institute of Education, and Control Data Corporation. Control Data Corporation now offers CDC PLATO and PLATO Author Language on a commercial basis; these are production versions of the PLATO system and TUTOR language developed at CERL.

The PLATO IV system is the most highly sophisticated, interactive, individualized instructional system currently available (excluding various experimental devices still under development). It provides tutorial inquiry, drill and practice, dialogue modes of instruction, dynamic simulation, and many types of computational services and games. The TUTOR programming language contains over 250 commands which fall into five large groups: display, calculation, branching, answer judging, and data collecting. A wide variety of data on student performance with various segments of curricula and tests are available to instructor and management personnel for analytical and management purposes; the system supports the development of instructional material. The current CDC catalogue lists over 800 courses and games that are available on a commercial basis.

The military Services have evaluated PLATO IV in studies conducted at the U.S. Army Ordnance Center and School, Aberdeen Proving Ground; Navy Recruit Training Command, Chanute Air Force Base; and other locations. These are summarized elsewhere in this report. The National Science Foundation supported a demonstration program with PLATO IV at five community colleges in the area of Chicago; a total of 11 courses in selected areas of business, biology, chemistry, English, and mathematics were developed for this program (Murphy and Appel, 1977). In 1976, about 80 organizations (12 military) had dedicated communications lines to PLATO (CERL); PLATO (CDC) serves many universities and commercial organizations as well as its own learning centers. (See Computer-based Education Research Laboratory, 1977, p. 37.)

In addition to instruction, the PLATO IV system presently provides a broad set of services, such as:

- Electronic mail.
- On-line communications, including text, graphics, and animation.

- Entertainment, including games, musical presentations, and simulation.
- Personal services, including medical, financial, psychological, educational and career planning.
- Research computation.
- On-line research. Physical experiments are controlled by the PLATO terminal, and analyzed results are displayed graphically in real time. In addition, educational and social research can be conducted on-line and in real time.
- Data processing.
- Information retrieval.

B.3 TICCIT

The TICCIT system (Time-shared, Interactive, Computer-Controlled, Information Television) was developed, starting in 1971, by the MITRE Corporation, with support from the National Science Foundation. C. Victor Bunderson at the Institute for Computer Uses in Education, Brigham Young University (previously at the University of Texas), and M. David Merrill, at Western Montana College (previously at Brigham Young University) were closely associated with this development, primarily using courses in freshman-level mathematics and English. Hazeltine Corporation has offered TICCIT on a commercial basis since 1976.

TICCIT was designed to provide complete courses of individualized instruction via computer on a lower cost basis than appeared possible with existing PLATO and IBM systems. Wherever possible, TICCIT used commercially available rather than specially designed components. The basic system uses two mini-computers to support up to 128 terminals and maintain records for up to 3000 students. One computer serves as a main processor, the other as a terminal processor (both are Data General Nova 800). The terminals consist of a color TV receiver, teletypewriter keyboard, function keys, and a light pen; graphic and audio-visual material can also be presented. As in all CAI and CMI systems, the student controls the pace of instruction. TICCIT courseware is structured on a modular basis; within each segment of instruction, the student can select material to be presented at different levels of complexity and in formats that provide either the basic rule, examples, or practice. The TICCIT system provides authors with one instructional strategy (that of learner control) in order to simplify the task of programming; this differs from PLATO where TUTOR offers several types of instructional procedures, *e.g.*, inquiry, dialogue, and simulation.

The National Science Foundation supported a demonstration program with TICCIT at two community colleges; Northern Virginia Community College (Alexandria Campus), and Phoenix College of the Maricopa County Community College District, Arizona; the courses selected for evaluation were mathematics and English (Alderman, 1978). Other TICCIT installations are at the Model Secondary School for the Deaf at Gallaudet College in Washington, D.C., and at Brigham Young University. In the Department of Defense, TICCIT has been used on an experimental basis to train tactical coordinators for anti-submarine warfare in the S-3A aircraft at the Naval Air Station, North Island, San Diego; a mobile system was installed for evaluative purposes at the Air University, Maxwell Air Force Base, Montgomery, Alabama.

B.4 AIR FORCE ADVANCED INSTRUCTIONAL SYSTEM

Planning for the Advanced Instructional System (AIS) at Lowry Technical Training Center, Lowry Air Force Base, Denver, Colorado, started in February 1969, when the Air Force Human Resources Laboratory (Technical Training Division) published a plan for the development of a computer-managed, computer-assisted instructional system. The system was developed as a computer-managed instructional system and tested under a contract with the McDonnell Douglas Astronautics Company, May 1973 to December 1977. The AIS was designed to be a prototype system;

it incorporates capabilities for research, development, test, and evaluation that might not be needed in an operational system. (McDonnell Douglas Corporation, 1977a, 1977b).

Current (April 1978) capabilities of the AIS are as follows:

Training load	
No. of courses	4
No. of students per day	3000 (4500 with additional terminals)
Hardware	
Computer	CDC CYBER 73-16
Interactive terminals	50
Management terminals	11
Student carrels	847
Media devices	500
Media allocation	
Printed materials	60%
Audio/Visual Presentation/ Illustrated Text	38%
CAI (used for management, research and course development)	2%

AIS provides the following functions common to most CMI systems:

- Printed feedback to students of total score on tests and of objectives failed on tests
- Printed assignment to next lesson, including resources required
- Learning center rosters and individual student progress reports

- Resource management, including material in learning centers, use of carrels, audio-visual devices and remote terminals
- Advising instructors about students whose results on preassessment tests indicate potential problems
- Displaying or printing student course and preassessment records for counseling
- Providing course evaluation and test item evaluation summaries
- Student Progress Management (SPM): SPM predicts a target completion time for each student for each block and for the entire course. The predictions are based on the student's aptitude, ability, and performance; students and instructors receive a daily feedback on each student's progress toward the target completion times. The purpose of SPM is to pace each student to work at a rate judged to be within his capability.
- Individualized Instruction Assignment (IIA): IIA assigns individual students to alternative modules of instruction for a lesson in order to achieve maximum progress by each student. An adaptive decision process considers the individual characteristics and past performance of each student (preassessment and within-course data), his current placement in the course hierarchy and the availability of instructional resources. Each student is assigned to those modules, among the available alternatives, which the algorithm predicts he will complete in the shortest time. Three methods of making this assignment were tested: a regression model, "learner's choice" and an heuristic method, (*i.e.*, assignment based on logical rules). IIA is a capability unique to AIS at present.

Most of the effort required to develop AIS was needed to convert four courses from conventional instruction to self-paced form suitable for support by CMI. These four courses were selected to represent a cross section of all technical training and a wide range of student aptitudes and abilities in the Air Force. These courses account for about 25 percent of the total training load at Lowry Technical Training Center.

Average course length and number of graduates in these courses for FY 1978 were:

Courses on AIS	Average Length (weeks)	Number of Graduates FY 1978 (Projected)	(Actual)
Inventory Management (IM)	7	3000	2492
Materiel Facilities (MF)	6	900	743
Precision measuring equipment (PME)	32	600	659
Weapons Mechanic (WM)	13	3000	1514
Totals		7500	5408

B.5 NAVY COMPUTER MANAGED INSTRUCTION

The development of the Navy's Computer Managed Instruction (CMI) system can be traced directly to work started in 1967 by G. Douglas Mayo, then on the staff of the Chief of Naval Air Technical Training, Millington, Tennessee (Kerr, 1978; Middleton, Papetti and Micheli, 1974). At that time, it appeared that computer-assisted instruction, such as provided by PLATO or the IBM 1500 Instructional System, would be effective in the sense of saving student time. However, it appeared that implementation of CAI systems in the Navy would be too costly. Mayo's premise was that instruction in the Navy's technical training courses should be revised from conventional to individualized formats and that computers should be used to manage but not to deliver instruction.

The Navy began to implement its CMI system in 1973 and expects to complete its installation by 1980. The system will handle 16,000 students in 24 separate schools at six Navy training centers; there were 6,000 students in 11 schools at five training centers in 1978.* Each "learning center" (an area for about 100 students in a training center) has an optical test scanner (OPSCAN 17) and a General Electric Terminet 1200 keyboard/printer. Each school has access to a remote batch terminal, with high-speed printer and card reader, which serves various management functions, such as daily progress reports, class rosters, and the like. The schools are linked to a central processor (Honeywell Series 60, level 66 computer) located at the Management Information and Instructional Systems Activity, Millington, Tenn.

Based on actual student loads, cost-avoidance savings were estimated to be $9 million to $10 million per year from FY 1975 to FY 1977; they are expected to continue at the latter rate when the system is fully implemented. The initial savings result largely from reductions in student loads because of improved management of student time by CMI; reductions in support billets are expected to occur in the future. Acquisition of the system will cost $23.5 million in automatic data processing equipment alone; the development of courseware represents an additional cost. Expansion of the system is contingent on the rate at which courses can be individualized. Instructional Program Development Centers have been established to develop and maintain these courses.

In addition to the CMI system centered at Millington, the Navy has CMI systems at the Naval Air Station, Lemoore, California (VA-122) and the Naval Air Station, Miramar, California (VF-124); these are part of the Aviation Training Support System.

*Based on data provided by Chief of Naval Technical Training (Code 0153), April 1978.

The Automated Shipboard Information Management System is a test installation of a shipboard computer which also provides CMI services on the USS GRIDLEY (transferred from the USS DAHLGREN, NPRDC 1977). The Marine Corps had an installation at Twenty-Nine Palms, California that is inactive at present (1978) pending receipt of a new computer. Use of a communications satellite has been considered to link the central CMI computer at Millington with ships at sea to provide CMI for training personnel away from schools (Polcyn, 1977).

The Navy has also supported development of Computer-Aided Instruction Study Management System (CAISMS) which uses PLATO IV to give reading assignments, to give tests on-line, and to maintain student records. These functions could also, of course, be performed less expensively by using mini-computers rather than PLATO. (Alessi, Anderson, Anderson *et al.*, 1974, Nievergelt, Alessi, and Montague, 1978).

More recently, CAISMS was evaluated in a Navy technical training course. A conventionally taught section in an interior communications course was augmented with CAISMS; this was intended to provide adjunct instructional activities, so that students could more appropriately manage their study. There is potential for considerable cost savings if courses are configured to take advantage of the flexibility offered by computer management (NPRDC Technical Report "A Computer-Based Study Management System: Implementation and Evaluation in a Navy Technical Training School," in preparation).

Also, CAISMS has been reprogrammed to run on a mini-computer, and in that configuration has managed the study of over 4000 students in a week of a Navy technical course. Reports describing this implementation, and its cost, are being prepared at the time of this writing (December 1978).

B.6 STAND-ALONE SYSTEMS

Every computer-based instructional system needs terminals to deliver instruction (as in CAI) or to score tests (as in CMI). From the student's point of view, it hardly matters whether the terminal is supported by a computer that is located in the terminal or elsewhere. By definition, a "stand-alone" instructional system contains a terminal and computer in one unit which needs only external power to operate. Two stand-alone CAI systems that have been evaluated by the military Services are described here. They now are estimated to cost between $30,000 and $50,000 per unit, without courseware. Interest in stand-alone CAI systems will probably increase when, as is often predicted, the home entertainment market will make micro-computers, video storage discs, and solid-state memories available at lower cost.

Stand-alone systems seem promising for training in locations away from schools where there are relatively small student loads, few or no instructors available on site, and a demand exists for a large variety of courses. Stand-alone systems could provide and guide instruction and also provide administrative information, such as student progress and courses completed, in computer-compatible form, for communication to central personnel data files.

B.6.1 Lincoln Terminal System

The Lincoln Terminal System is a self-contained, interactive, computer-based training system developed by Lincoln Laboratory, MIT, Lexington, Massachusetts. The latest version, LTS-5 (Butman, 1977) uses microfiche to store and project visual images in a conventional manner; the fiche can also store audio messages to accompany each visual frame (up to 750 microfiche, each with 12 audio/visual pairs of frames per fiche). The user interacts numbers and function keys. A teletypewriter and touch panel could be added to the system but they are not in the present version. The LTS processor supports several standard author programs, which may be either branching or nonbranching in form. The system is designed particularly to teach facts, principles, and computational skills.

Only a limited number of LTS terminals have been built (about 40). The system has been tested at Keesler Air Force Base, Biloxi, Mississippi (air traffic control operator course and an electronics principles course) and at Lincoln Laboratory (digital systems engineering; see Butman and Frick, 1972; Butman, 1975; Butman and Kunze, 1976).

B.6.2 General Electric Training System

The General Electric Training System (GETS) is another self-contained, automated, interactive, instructional system (Rupp, 1976; General Electric Ordnance Systems, 1976). The terminal contains a plasma display panel, teletypewriter keyboard, function keys, sonic pen, and a random-access, 35-mm slide projector (80 slides/tray). Floppy discs are used for lesson preparation and playback. The plasma screen and slides can be used for interactive training, *e.g.*, using text, simulated control panels, or circuit diagrams. To date, GETS has been used for training on operating and maintenance procedures for the TRIDENT weapon control system at the Guided Missile School, Dam Neck, Virginia and the Fleet Ballistic Missile Training Center, Charleston, South Carolina; it is scheduled for use at the Fleet Ballistic Missile Training Center, Bangor, Washington. There will be about 25 GETS units in the TRIDENT program. The TRIDENT program relies heavily on the use of tactical equipment and equipment simulation for training purposes. GETS will be used primarily to handle peak training loads that exceed the capacity of the available training equipment (called "laboratory" training in this program). GETS is viewed as cost-effective for procedural training in the TRIDENT program compared to the cost of acquiring additional tactical equipment. Current training loads on GETS are small, but larger loads are expected to occur in April 1981.

APPENDIX C

EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION IN NONMILITARY TRAINING

APPENDIX C

EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION IN NONMILITARY TRAINING

C.1. INTRODUCTION

This appendix considers briefly the effectiveness of CAI and CMI instruction in nonmilitary settings, primarily in schools and colleges. Education in schools and colleges differs from military training in one major characteristic of interest here: students in military training receive pay and allowances while they are being trained, while those in schools and colleges do not. This means that reducing the time spent at school could reduce the cost of military training while no such incentive exists in schools and colleges (at least at present). Other distinctions between schools and colleges and military training might also be drawn with respect to such factors as subject matter, tenure of instructors, and the relationship of training to jobs and careers; however, these are not critical to the present discussion.

The effectiveness of CAI and CMI in schools and colleges has been the subject of many excellent books and reviews such as the following:

> Kearsley (1975); Seidel and Rubin (1977); Salomon and Clark (1977); Davisson and Bonello (1976); Froomkin, Jamison, and Radver (1976); Levien (1972); Goldstein (1974); Edwards, Norton, *et al.* (1974); Jamison, Suppes and Wells (1974); and Baker (1978).

Most of these are concerned with CAI which has received more attention in schools and colleges than has CMI. The issue of effectiveness here is almost entirely on student achievement, that is, the amount of course materials acquired as measured by tests; some attention has been given to the effect of CAI on academic attrition.

The literature cited above suggests that CAI is an effective supplement to regular instruction at the elementary school level; used as a replacement, it is about as effective as conventional instruction at the secondary school and college levels. The drill and practice and simulation modes of CAI are at least as effective as conventional instruction; some studies suggest that they are more effective than conventional instruction; the results are equivocal for the tutorial and problem-solving modes. The apparent differences in the effectiveness of various CAI modes may be the result of improper comparisons because, for example, CAI drill and practice is generally used to <u>supplement</u>, while the other modes are used to <u>replace</u> conventional instruction. Limited data suggest that CAI can reduce the time required for learning. According to Baker (1978), about 30 CAI systems are being used in academic environments at all levels of education.

The National Science Foundation supported two large-scale studies that evaluated the effectiveness of the PLATO IV and TICCIT systems in teaching basic courses at community colleges. Both of these CAI systems have been used experimentally by the military Services. These studies are summarized briefly here because of their importance and their potential relevance to the effectiveness of PLATO IV and TICCIT in military training. The studies do not consider the amount of time, if any, saved by students, the effectiveness of the particular coursewares in distinction to the delivery systems, or the cost-effectiveness of these two systems. A survey of student activities in the TICCIT [illegible] provides an indirect assessment of how much time students spend in conventional and CAI instruction.

C.2. EFFECTIVENESS OF PLATO IV AT COMMUNITY COLLEGES

The effectiveness of the PLATO IV CAI system was evaluated at five community colleges in the Chicago area, 1972 to 1976. (Murphy and Appel 1977; Computer-based Education Research Laboratory, 1977). Most of the time during this period was required to develop course materials and tests and to conduct preliminary evaluations. The final evaluation was conducted during two semesters (1975-1976) in 162 classes in five subject-matter areas (accounting, biology, chemistry, English, and mathematics) at four of the colleges. Most comparable PLATO and non-PLATO courses were taught by the same instructors, thereby holding constant the possible influence of instructors on student achievement, attrition, and attitudes. Instructors who participated in the test were not required to use PLATO IV for any specified amount of time or for any specified material; rather, they used PLATO IV in various ways to replace, supplement, or reinforce classroom instruction. Average student use of PLATO IV varied from a few minutes to more than 20 hours for individual students; in terms of courses, use of PLATO IV varied from 1 to 12 hours per course for 126 courses. The permissive approach made PLATO IV very acceptable to the faculty but it complicates and makes it more difficult to extrapolate the findings of this evaluation to the more highly controlled environments of most military studies where students and instructors had no option to shift back and forth between CAI and conventional instruction.

Bearing in mind the way in which the evaluation was performed, the following findings are significant:

- Student achievement on PLATO IV was about the same as that for regular classroom instruction
- PLATO IV produced no noticeable effect on student attrition
- Student and faculty attitudes to the use of PLATO IV were generally favorable

- The development of curriculum materials was a difficult undertaking. The test was postponed for one year while additional staff were added to the project to develop more PLATO IV lessons.

C.3. EFFECTIVENESS OF TICCIT AT COMMUNITY COLLEGES

The effectiveness of TICCIT was evaluated by comparing the performance of students in six mathematics and three English courses instructed by TICCIT or conventional lecture, textbook and discussion (Alderman, 1978). The study was conducted in 1975-1976 at Phoenix College, Arizona, and the Alexandria campus of the Northern Virginia Community College. Two years were required to develop the course materials and achievement tests and to train the staff involved in the evaluation. Over 2600 students were enrolled in the TICCIT courses and 3000 in the lecture courses; in addition, about 300 students at Alexandria took programmed courses in mathematics without computer support. A measure of effectiveness which turned out to be important was the percentage of students who completed the course under each mode of instruction.

Instruction by TICCIT was at least as effective as by lecture or by programmed material. Students instructed by TICCIT had higher test scores (by about 10 percent) than those instructed by lecture in nine of twelve mathematics courses and in four of seven English courses; where TICCIT test scores were lower, the differences were quite small.

Some of the differences that favor TICCIT may be attributed to the related finding that students who completed the TICCIT classes were more highly qualified than those in the conventional classes. The much lower course completion rates on TICCIT, compared to the lecture course, are certainly related to the finding that only the more qualified students completed the TICCIT course.

A surprise finding is the low completion rates for students taking courses on TICCIT, particularly mathematics. The overall completion rates for mathematics were 16 percent for TICCIT, 50 percent for lecture, and 20 percent for programmed instruction. When the data are adjusted to include students who did not complete the course or who withdrew and reenrolled, *i.e.*, completed the course in other semesters), the adjusted completion rates for mathematics on TICCIT are comparable to those for other methods of instruction. Completion rates were higher for English than for mathematics, but instruction by TICCIT resulted again in lower completion rates than by lecture.

This study shows that instruction in college algebra and English composition by TICCIT produces end-of-course results *i.e.*, test scores) that are equal to or higher than those associated with conventional instruction. TICCIT appears more effective for algebra than English. These findings may be an artifact due to the dropout of the poorer students before the end of the course. TICCIT instruction appears more favorable for higher-aptitude than for average or lower-aptitude students; very few of the latter completed the courses on TICCIT in this study. The TICCIT study is one of the few that have examined CAI instruction in entire courses, under stabilized conditions, and on a large scale; its use in more than one location is also unusual. However, there is little reason to believe that the permissive atmosphere of a community college with respect to failure to complete courses provides a basis for comparison with military training.

The amount of time required to complete courses by TICCIT or by conventional instruction, an important issue in military and industrial training, was not addressed directly in this study. However, the report contains survey data on how many hours students said they spent on course activities out of class. An analysis of these data suggests that students on

TICCIT completed these courses in less total time than did those in conventional courses. This analysis appears in the following section.

C.4. ANALYSIS OF TIME SPENT BY STUDENTS ON TICCIT AND IN CONVENTIONAL INSTRUCTION AT COMMUNITY COLLEGES

Two types of data reported by Alderman (1978) can be combined to estimate the total amounts of time spent by students to complete five courses instructed by TICCIT or conventional lecture and discussion. The data consist of (1) student contact hours (time spent on TICCIT or in c. ss) and (2) a Student Activity Survey (in which students report how much time they spent on course-related activities in addition to the time in class). A description of these data and how they were used to estimate total time spent by students on TICCIT and in conventional instruction follows. The results are shown in Table C-1.

C.4.1 Student Contact Hours

Data on student contact hours with TICCIT were compiled from records kept by the TICCIT system; data on hours spent in lectures are simply the result of scheduled hours for each class. Thus, for eight courses, a direct comparison can be made of the amount of time spent by students who used TICCIT and by students in class with conventional instruction. In five of the eight comparisons, students on TICCIT spent less time during the course than did those in class. These data are probably highly reliable but they do not include time spent on course work out of class.

C.4.2 Student Activity Survey

Data on student activities were collected only in five courses. A survey of student activities included the following questions about time spent by students in each course:

TABLE C-1. AMOUNT OF TIME NEEDED TO COMPLETE COURSES ON TICCIT AND CONVENTIONAL INSTRUCTION, 1976
Source: Alderman (1978)

Course					Student contact hours			Student survey report, hours[6]				Calculated total times, hours	
					TICCIT[1]		Lecture[2]	TICCIT		Lecture			
					N	Hours, Mean	Hours	N	Hours	N	Hours	TICCIT[8]	Lecture[9]
					(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Math	007	Beg. Algebra	Phoenix	Spring Semester	39	38.6	37.5[3]	20	97	120	116	46	107
	31	Algebra I	Alexandria	Winter Quarter	54	35.9	41.7[4]	64	87	23	123	43	114
	31	Algebra I	Alexandria	Spring Semester	27	34.2	41.7[4]	23	91	12	101	52	96
English	19	Basic Engl.	Phoenix	Spring Semester	29	30.6	37.5[3]						
	29	Rev. Engl. Fundamentals	Phoenix	Spring Semester	28	35.1	37.5[3]						
	19	Basic Engl.	Phoenix	Fall Semester	82	38.9	37.5[3]	109[7]	141	170[7]	102	83[10]	96
	29	Rev. Engl.	Phoenix	Fall Semester	40	33.7	37.5[3]						
	111	Engl. Comp.	Alexandria	Fall Quarter	66	37.1	25.0[5]	115	137	74	144	110[11]	105

[1]Time spent on TICCIT system, students with post test, Table 7.7, p.34.

[2]Classroom time, lecture and discussion.

[3]Three meetings/wk x 15 wks x 5/6 hr/meeting.

[4]Five meetings/wk x 10 wks x 5/6 hr/meeting.

[5]Three meetings/wk x 10 wks x 5/6 hr/meeting

[6]Based on data in Appendix S, Student Activity Data. Total hours as reported by students for time spent on TICCIT or in class plus time for discussion, and work away from TICCIT or class. ETS data, for hours per week, multiplied by 15 weeks for semester (Math 007, English 19,29) or by 10 weeks for quarter (Math 31, English 111). All N's are approximate.

[7]English 19 and 29 combined.

[8]Mean TICCIT hours (Table 7.7) plus student report for all non-TICCIT hours per week (Tables 7.1-7.4), multiplied by 15 weeks for semesters or 10 weeks for quarters.

[9]Total classroom time, as shown in this table, plus student report for all non-classroom hours per week (Tables 7.1-7.4), multiplied as above.

[10]Includes 18 hours attending regular class meetings without TICCIT.

[11]Includes 31 hours attending regular class meetings without TICCIT.

"Approximately how many hours per week did you spend:

(1) working on the TICCIT system/attending classes for this course?

(2) in small group discussions about this course (outside of class)?

(3) doing work for this course on your own away from TICCIT/working on homework assignments?

(4) in total for this course?"

The students' responses, in hours per week, were multiplied by the number of weeks in the semester (15 weeks) or quarter (10 weeks) to get the total times shown in the table. In four of the five comparisons, students on TICCIT say they spent less total time to complete the course than did those in conventional lecture and discussion. Naturally, these comparisons are based on the students' impressions and attitudes and cannot be verified.

C.4.3 Calculated Total Times

An estimate of the total time spent by students in each course was made by combining the documented time spent on TICCIT or in lecture (Columns 2 and 3) with students' reports of time spent out of class on course work (part of the total data shown in Columns 5 and 7, based on detailed data in the Appendix to Alderman's report). In four of the five comparisons, students on TICCIT appear to have spent less total time in the course than did those in the conventional classes; the reverse effect occurs in one comparison. In three of the five cases, students on TICCIT appear to have spent about half the total time needed to complete the course that those in conventional classes did.

Although there is no way to assess the reliability of these data on the times required to complete courses on TICCIT or in conventional classes, they are the only data we have. The apparent time savings on TICCIT would apply only to students who completed the course (16 percent on TICCIT, 50 percent on lecture, as reported by Alderman). Those who completed courses on TICCIT had higher pre-test scores than their lecture counterparts. Thus, the time and achievement advantages of TICCIT for the students described here do not apply to the majority of students who were unable to complete a course on the TICCIT program.

APPENDIX D

SUMMARY OF STUDIES EVALUATING COMPUTER-ASSISTED AND COMPUTER-MANAGED INSTRUCTION IN MILITARY TRAINING

LIST OF TABLES

11. Studies of computer-managed instruction (Advanced Instructional System) at Air Force Lowry Technical Training Center, Lowry AFB, Colorado, 1978.

TABLE D-1. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (IBM 1500) AT U.S. ARMY SIGNAL CENTER AND SCHOOL, FT. MONMOUTH, NEW JERSEY, 1968-72

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Basic electronics	Conventional[1]		11			Same			
	CAI		10	1	11			Tutorial CAI, with practical exercises on-line and off-line	IBM (1968)
Basic electronics	Conventional	278	11			Same on written; no diff. on written & perf. tests after additional week on CI	Favorable to CAI	20 terminals	Longo (1969)
	CAI	278	9	2	20				
Basic electronics	Conventional	155	72			CAI superior on performance test	Favorable to CAI		Giunti & Longo (1971a)
	CAI	155	50	22	30				
Basic electronics	Conventional	56	102			CAI superior on performance test	Favorable to CAI	22% less attrition in CAI group	Giunti & Longo (1971b)
	CAI	56	66	36	35				
Basic electronics	Conventional	142	119			Same on written & performance tests	Favorable to CAI	Attrition about the same[3]	Longo (1972)
	CAI	142	76	43	36				
Basic electronics	Conventional	142	186			Same on written & performance tests	Favorable to CAI	Attrition about the same[3]	Longo (1972)
	CAI	142	139	47	25[2]				

[1]Two control groups: instructor, TV.

[2]Overall savings after 4 weeks CAI (line above) followed by 2 weeks conventional instruction for CAI and CI groups

[3]High-aptitude students on CAI save more time (14%) than low-aptitude students on CAI and also achieve better test scores (written and performance)

TABLE D-2. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (IBM 1500) AT NAVY BASIC ELECTRICITY AND ELECTRONICS SCHOOL, SAN DIEGO, CALIFORNIA, 1970-1972

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Alternating current theory	Classroom	200	13.5-21.0[1]			CAI superior (7% on test)	Prefer CAI	CAI resulted in higher achievement at all ability levels	Ford & Slough (1970)
	CAI	51	6.4-11.7[1]	5-9[2]	33-44				
Inductance	Classroom	180	17.0			CAI superior (10% on test)	Prefer CAI		Hurlock & Lahey (1971)
	CAI	50	8.75	8.3	49				
Capacitance	Classroom	64	17.0			CAI superior (10% on test)	Prefer CAI		Hurlock (1972)
	CAI	64	7.6	9.4	55				
Direct current	Classroom	20	10.3			CAI superior (3% on test)	Prefer CAI		Ford, Slough & Hurlock (1972)
	CAI	50	5.5	4.8	47				
Series circuits	Classroom	64	34.0			CAI superior (2% on test)	Prefer CAI		Ford, Slough & Hurlock (1972,
	CAI	50	17.7	16.3	48				

[1]Completion times for different ability groups.

[2]Time savings for different ability groups.

TABLE D-3. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (PLATO IV) AT U.S. ARMY ORDNANCE CENTER AND SCHOOL, ABERDEEN PROVING GROUND, MARYLAND, 1975

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Machinist course 44E20									
Milling (4 lessons)	Conventional		7.0						
	CAI	354	1.3	5.7[1]	81	No significant difference	Students and instructors favorable to CAI	Basic comparison in study is between CAI and programmed instruction. See footnotes for those time savings. Improvement of course material alone FY74-75 saved 0.49 hrs. (30%) for CAI and PI not included in data shown.	U.S. Army Ordnance Ctr & School (1975)
	Programmed text	372	1.6	5.4	76				
Lathe (7 lessons)	Conventional		11.0						
	CAI	115	1.2	9.8[2]	89	No significant difference			
	Programmed text	183	1.8	9.2	84				
Evaluation and Training materials development (2 lessons)	Conventional		8.0						
	CAI	66	1.6	6.4[3]	79	No significant difference		PLATO not cost-effective 14 terminals	
	Programmed text	76	2.8	5.2	65				

[1]Savings due to PLATO CAI vs. programmed instruction is 0.35/1.65 hrs (22%).

[2]Savings due to PLATO CAI vs. programmed instruction is 0.60/1.77 hrs (34%).

[3]Savings due to PLATO CAI vs. programmed instruction is 1.12/2.77 hrs (40%).

TABLE D-4. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (PLATO IV) AT NAVY BASIC ELECTRICITY AND ELECTRONICS SCHOOL, FLEET AVIATION SPECIALIZED OPERATIONAL TRAINING GROUP, PACIFIC FLEET AND MESS MANAGEMENT SCHOOL, SAN DIEGO, CALIFORNIA, 1975-1978

Course	Comparison	No. of Subjects	Average Course Length,[1] hrs.	Time Savings Compared to Conventional Instruction Hrs.		Performance Scores	Attitudes	Comments	References
Navy BE/E School[2] Oscilloscope operation (Navy Sonar A trainees)	Actual oscillos.	29	5.2					CAI simulation more effective than actual oscilloscope for voltage & freq. msmt; less effective for manipulation of controls	Stern (1975)
	CAI simulation	20	5.2	No difference		No difference[3]			
Multimeter (ohm & volt)	Actual gear	42	10				Favor CAI	Additional time on CAI due to the novelty of the situation; students permitted to overtrain themselves.	Lahey, Crawford & Hurlock (1976)
	CAI/interactive simulation	42	12		-17	No difference			
Oscilloscope operation[4]	Conventional	18	4.0					Experimental study; only more effective procedures would be recommended, i.e., all except CAI practice which does not save time	Slough & Coady (unpubl.)[5]
	CAI practice	12	4.1	-0.1	-3	CAI superior			
	CAI control functions	12	3.7	0.3	8	CAI superior			
	CAI prompted practice	12	3.1	0.9	23	CAI superior			
	CAI measurement practice	12	3.3	0.7	18	CAI superior			
North Island Naval Air Station[6]									
S-3 co-pilot INCOS[3] panel operation	Specially developed work book	22	9.0[7]					"CAI more cost effective" (excluding cost of developing course materials)	Crawford, Hurlock, Padilla, & Sassano (1976)
	CAI interactive graphics	22	3.0	6	67[10]	CAI superior[6]		Study demonstrates use of CAI graphics for simulation of operational equipment at low cost	Crawford & Crawford (1978)
								CAI group also completed 2 tests in about 40% less time (each test less than 5 min.)	

Footnotes at end of table

(continued)

TABLE D-4. (Continued)

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Navy Mess Mgmt. Specialist A School									
Recipe conversion	Conventional	20	26.[illegible]				Favor CAI	CAI effective for average & below average personnel	Fredericks & Hoover-Rice (1977)
	CAI	20	4.3	22.2	84	No difference			
	CAI/job aids	20	4.4	22.1	83	No difference			

[1] Student contact hours.

[2] Basic electricity and electronics.

[3] PLATO group took 4 more minutes to complete test.

[4] See Hurlock and Slough (1976), p. 21-22.

[5] Integrated Control System.

[6] Mean number of problems completed in high fidelity position trainer.

[7] Eight hours workbook plus 1 hour on position trainer.

[8] Navy Sonar A School (controls), Navy BE/E School (experimental).

[9] Fleet Aviation Specialized Operational Training Group, Pacific Fleet.

[10] Compared to work book.

TABLE D-5. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (PLATO IV) AT AIR FORCE SCHOOL OF HEALTH CARE SERVICES, SHEPPARD AFB, TEXAS, 1977

Course	Comparison	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.		Performance Scores	Attitudes	Comments	References
Physician Assistant Course									
Respiratory systems and illness; clinical problem-solving skills	Lecture	6	16.5[1]			No significant difference	Students negative, worried about falling behind those in traditional lecture (this judgment was incorrect)	Preliminary findings only; most results inconclusive. Limited CAI material; 16 hrs spread over 13 weeks.[2]	Steinkerchner, Deignan, Waters, & DeLeo (1977)
	CAI	8	16.0[1]	2.5	14				
Medical laboratory	Lecture	154	9.0[1]			CAI 20% superior	Prefer CAI	16 terminals. CAI saves more time and yields greater achievement at high and low aptitudes; programmed instruction favors high & medium aptitudes.	Deignan & Duncan (1977)
	CAI	93	7.8[1]	1.2	14				
Radiology	Prog. text	59	4.5			CAI 3% superior	Prefer CAI		Deignan & Duncan (1977)
	CAI	97	4.0	0.5	11[4]				
Dental assistant	Lecture	--	8.0[3]			No difference	Prefer CAI	Preliminary findings	Deignan (no date)
	CAI	28	7.0	1	13				

[1]Includes 4.5 hrs. review for CAI and lecture groups.

[2]Experimental POMC (problem-oriented medical curriculum).

[3]Calculated from data in report.

[4]Compared to programmed text.

TABLE D-6. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (PLATO IV) AT AIR FORCE CHANUTE TECHNICAL TRAINING CENTER, CHANUTE AFB, ILLINOIS, 1977

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	Time Savings Compared to Conventional Instruction %	Performance Scores	Attitudes	Comments	References
Special purpose vehicle repairman						No significant difference between PLATO and conventional groups in field performance ratings 6-12 mos. after graduation, (PLATO N=119; conventional N=101.) All other data based on performance scores at school.	Students prefer PLATO to programmed instruction	PLATO not cost effective.	Dallman, DeLeo, Main & Gillman (1977)[3]
Crash/fire vehicles	Conventional[1]	38	236			No significant difference	Instructors favorable to PLATO at first but became dissatisfied later.	No advantage to unvalidated CAI materials.	Dallman, DeLeo, Main & Gillman (1977)
	PLATO[2]	13	145	91	39			Programmed instruction saves time;(amount not stated) FLATO saved 10% more. 30 terminals	Dallman DeLeo, Main & Gillman (1977)
Refuelling vehicles	Conventional[1]	35	233			No significant difference		No advantage to unvalidated CAI materials.	Dallman, DeLeo, Main & Gillman (1977)
	PLATO[2]	37	166	67	29			Programmed instruction saves time; (amount not stated) PLATO saved 10% more. 30 terminals	Dallman, DeLeo, Main & Gillman (1977)
Material handling vehicles	Conventional[1]	57	236			No significant difference			
	Unvalidated PLATO	30	233						
	PLATO[2]	21	173	63	27		Instructors favorable to PLATO at first but became dissatisfied later.	No advantage to unvalidated CAI materials. Programmed instruction saves time; (amount not stated) PLATO saved 10% more. 30 terminals	Dallman, DeLeo, Main & Gillman (1977)

Footnotes at end of table.

(continued)

TABLE D-6. (Continued)

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Towing and Servicing vehicles	Conventional[1]	50	227			No significant difference		Above comments apply.	Dallman, DeLeo, Main, & Gillman (1977)
	Unvalidated PLATO	14	234						
	PLATO[4]	41	174	53	23			No significant effect on attrition over a 9-month period	

Only Blocks 1 - 4 (common course segment shared by all four courses) were instructed by PLATO IV.

[1]Data collected prior to PLATO study, Apr. 1974 - 15 Jan. 1975; includes programmed text.

[2]Data collected during PLATO study, group paced, 15 Jan. 1975 - 30 Sept. 1975.

[3]See Himwich (1977) for a critique of the Chanute study.

[4]Validated so that failure rate not larger than 10 percent on Master Validation Exam with sample of 20-30 students.

TABLE D-7. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (LST-3[6]) AT AIR FORCE KEESLER TECHNICAL TRAINING CENTER, KEESLER AFB, MISSISSIPPI, 1972-73

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	Time Savings Compared to Conventional Instruction %	Performance Scores	Attitudes	Comments	References
Resistive, capacative and inductive circuits (week 5 in air traffic control standardized electronics principles course)	Conventional[1]	55	30			No significant differences at end of course or 6 weeks later.	Favorable to CAI	Students in CAI relied on instructor only 2% of time; lesson material tested but not validated prior to test.[3]	Harris, Grossberg, Downs *et al.* (1972).
	Conventional[2]	55	30						
	CAI	55	19	11	37				
Weather (part of air traffic control operator course)	Conventional[1]	22	16.0			CAI lower than conventional but not statistically significant	Favorable to CAI	Students in CAI relied on instructor only 2% of time; lesson material tested but not validated prior to test.[3] Lesson materials judged not entirely adequate.	Downs, Johnson, Barnes *et al.* (1972)
	Conventional[2]	22	16.0						
	CAI	20	13.4	2.6	16				
Resistive, capacitive and inductive circuits (week 5 in air traffic control standardized electronics principles course)	Conventional[7]	55	30.0			CAI superior	Favorable to CAI	Students in CAI relied on instructor only 2% of time; lesson material tested but not validated prior to test.[3] High aptitude subjects (upper 20%) only in both groups (excluded in previous tests)	Keesler AFB (1972)
	Self-paced	30	16.4[4]	13.6	45				
	CAI	30	12.3[4]	17.7	59				
Resistive, capacitive and inductive circuits (week 5 in air traffic control standardized electronics principles course)	Conventional:		30.0			Higher ability groups achieved higher scores but no significant differences between method of training; ability level of student in a pair does not effect other's score.	Favorable to CAI, especially when paired.	Paired students on CAI save more time than those working alone, except for the low-ability group.	Keesler AFB (1973)
	Low ability	12							
	Medium "	12							
	Higher "	14							
	Highest "	17							
	CAI-individual:								
	Low ability	10	22.4	7.6	25				
	Medium "	17	18.6	11.2	37				
	Higher "	19	18.0	12.0	40				
	Highest "	9	17.6	12.4	41				
	CAI-paired[5]:								
	Low ability	12	25.9	4.1	14				
	Medium "	12	18.2	11.8	39				
	Higher "	12	13.4	16.6	55				
	Highest "	12	12.7	17.3	58				

Footnotes at end of table

(continued)

TABLE D-7. (Continued)

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Resistive, capacitive and inductive circuits (week 5 in air traffic control standardized electronics principles course)	Conventional[1]	55	30.0			Programmed text and CAI better than conventional but no practical significance	Favorable to programmed text and CAI	Quality of training material (programmed text) more important for achievement and time savings than presentation mode (CAI)	
	Programmed text	66	12.8	17.2	57			Differences in time savings between programmed text and LTS not significant	Keesler AFB (1974)
	Programmed text	106	16.5	13.5	45				
	CAI[7]	55	19.0	11	37				

[1]Students aware of role as control group.

[2]Students not aware of role as control group.

[3]Lower aptitude students spend more time in training; correlation general AQE score and time spent in training is -.30 ($p < .05$) Butman and Frick (1972).

[4]Computed from statement in paper that self-paced group was 45.4 percent faster than conventionally taught students and LTS saved 25.3 percent over self-paced group.

[5]Two students at one terminal working jointly.

[6]Lincoln Terminal System-3.

[7]Data from Harris, Grosberg, Downs *et al.* (1972) above.

TABLE D-8. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (TICCIT) AT NAVY SQUADRON VS-41, NORTH ISLAND NAVAL AIR STATION, SAN DIEGO, CALIFORNIA, 1978

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Tactical coordinator S-3A ASW aircraft	Workbooks	6	0.67			No difference	No difference in attitude and confidence ratings.	Experiment limited to 1 lesson (under 1 hr.); 5 months needed to collect data; in addition to training time. CAI group also saved 42% time in taking test.	Walker (1978)
	CAI	5	0.38	0.29	43[1]				

[1]Compared to work book.

TABLE D-9. STUDIES OF COMPUTER-ASSISTED INSTRUCTION (IDIIOM AND PLATO IV) AT NAVY GUIDED MISSILE SCHOOL, DAM NECK, VIRGINIA, 1975

Course	Comparisons	No. of Subjects	Average Course Length, Hrs.	Time Savings Compared to Conventional Instruction Hrs.	Time Savings Compared to Conventional Instruction %	Performance Scores	Attitudes	Comments	References
Fire Control Technician Replacement Training								TICCIT included in study plan but insufficient data precludes evaluation.	General Electric Ordnance Systems, (1975)
Integrated Test Operating Panel	Conventional	35	2.2			Written: no diff. performance: CI-PLATO:no diff. CI superior to IDIIOM	Favorable to CAI except 5% unfavorable.		Radsken and Grosson (1975)
	IDIIOM[1]	13	1.9	0.3	14				
	PLATO IV	18	2.9	-0.7	-32				
Keyboard Subsystem	Conventional	38	3.0			No difference			
	IDIIOM[1]	19	1.9	1.1	37				
	PLATO IV	17	2.6	0.4	13				

[1] Information Displays, Inc. Input-Output Machine, a stand-alone CAI system.

TABLE D-10. STUDIES OF COMPUTER-MANAGED INSTRUCTION (NAVY COMPUTER MANAGED INSTRUCTION SYSTEM) AT NAVAL AIR TECHNICAL TRAINING CENTER, MILLINGTON, TENNESSEE, 1975

Course	Comparisons	No. of Subjects	Average Course Length, hrs.	Time Savings Compared to Conventional Instruction Hrs.	%	Performance Scores	Attitudes	Comments	References
Aviation Familiarization	Conventional	142[1]	33.6				No difference between methods	Conventional course revised for this study saved 50% time of previous course.	Carson, Graham, Harding, et al. (1975)
	Instr. managed[3]	142	10.3	23.3	69	Slightly better than conventional[4]			
	Comp. managed	142	10.5	23.1	69				
Aviation Familiarization	Conventional	99[2]	34.4						Carson, Graham, Harding, et al. (1975)
	Instr. managed[3]	99	10.3	24.1	70	Better than conventional[4]	No difference between methods		
	Comp. managed	99	11.7	22.7	66				
Aviation Mechanical Fundamentals	Conventional	142[1]	73.2				No difference between methods		Carson, Graham, Harding et al. (1975)
	Instr. managed[3]	142	38.3	34.9	48	Better than conventional[4]			
	Comp. managed	142	39.7	33.5	46				
Aviation Mechanical Fundamentals	Conventional	99[2]	70.3				No difference between methods		Carson, Graham, Harding et al. (1975)
	Instr. managed[3]	99	41.3	29.0	41	Better than conventional[4]			
	Comp. managed	99	41.0	29.3	42				

[1] Navy students ("minimum number").

[2] Marine students ("minimum number").

[3] Same course as computer-managed, except that instructors graded examinations and assigned lessons.

[4] Statistically significant on end of course test and shop grade; no difference at end of school or 6 weeks later; no difference in attrition.

TABLE D-11. STUDIES OF COMPUTER-MANAGED INSTRUCTION (ADVANCED INSTRUCTIONAL SYSTEM) AT AIR FORCE LOWRY TECHNICAL TRAINING CENTER, LOWRY AFB, COLORADO, 1978

Course	Comparisons	No. of Subjects	Average Course Length, Days	Time Savings Compared to Conventional Instruction[3] Days	%	Performance Scores	Attitudes	Comments	References
Inventory Management	Conventional[1]		49.5			No difference	Students favorable, instructors neutral or unfavorable	Data for 12 mos. ending 28 Feb 1978	Briefing material AFHRL-TT, Lowry AFB April 1978
	AIS[2]	2365	39.0	10.5	21				
Material Facilities	Conventional[1]		43.5			No difference	Students favorable, instructors neutral or unfavorable	Data for 12 mos. ending 28 Feb 1978	Briefing material AFHRL-TT, Lowry AFB April 1978
	AIS	634	33.1	10.4	24				
Precision Measuring Equipment[3]	Conventional[1]		229.0			No difference	Students favorable, instructors neutral or unfavorable	Data for 12 mos. ending 28 Feb 1978	Briefing material AFHRL-TT, Lowry AFB April 1978
	AIS	602	204.0	25	11				
Weapons Mechanic	Conventional[1]		94.0			No difference	Students favorable, unstructors neutral or unfavorable	Data for 12 mos. ending 28 Feb 1978	Briefing material AFHRL-TT, Lowry AFB April 1978
	AIS	2745	49.8	44.2	47				
Inventory Management	MSP[4]	--	34.8			No difference		Data for AIS Service Test, Feb-July 1978	Briefing material AFHRL-TT, Lowry AFB Sept 1978
	AIS		30.4	4.4	13[5]				
Materiel Facilities	MSP	--	24.7			No difference		Average course lengths not directly comparable to data above because reported differently.	Briefing material AFHRL-TT, Lowry AFB Sept 1978
	AIS		24.7	0	0[5]				
Precision Measuring Equipment[3]	MSP	--	89.9			No difference		Only limited segments of PME course used in test.	Briefing material AFHRL-TT, Lowry AFB Sept 1978
	AIS	--	92.8	-2.9	-3[5]				
Weapons Mechanic	MSP	--	40.6			No difference			Briefing material AFHRL-TT, Lowry AFB Sept 1978
	AIS	--	42.1	-1.5	-4[5]				

[1] 1974, prior to AIS.

[2] Advanced Instructional System.

[3] Time savings not corrected for changes in plan of instruction, i.e., PME course was a vacuum-tube oriented, AIS course is transistor/digital electronics oriented.

[4] Manually Self-paced (MSP). Students in both groups used some AIS course materials. In MSP group, instructors scored tests manually and guided students without using AIS terminals.

[5] Compared to Manually Self-paced, not conventional instruction.

APPENDIX E

SUMMARY OF DATA ON COSTS OF INSTRUCTION

E.1 PROGRAM DEVELOPMENT: PROGRAM DESIGN

E.2 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR CONVENTIONAL INSTRUCTION

E.3 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR INDIVIDUALIZED INSTRUCTION

E.4 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR COMPUTER-BASED INSTRUCTION

E.5 PROGRAM DELIVERY: INSTRUCTION, INCLUDING INSTRUCTORS AND INSTRUCTIONAL SUPPORT PERSONNEL AND STUDENT PERSONNEL

E.6 PROGRAM DELIVERY: LABORATORY EQUIPMENT

E.7 PROGRAM DELIVERY: MEDIA DEVICES

E.8 INSTRUCTIONAL PROGRAM DELIVERY: COMPUTER SYSTEMS

- E.8.1 PLATO IV
- E.8.2 TICCIT
- E.8.3 Navy CMI System
- E.8.4 IBM 1500
- E.8.5 General Electric Training System (GETS)
- E.8.6 Shipboard Computer-Based Instruction
- E.8.7 System Cost Comparison

E.9 PROGRAM DELIVERY: COMMUNICATIONS

E.10 PROGRAM DELIVERY: MATERIALS

E.11 PROGRAM DELIVERY: FACILITIES

E.12 PROGRAM MANAGEMENT AND ADMINISTRATION

E.13 STUDENT PERSONNEL

APPENDIX E

SUMMARY OF DATA ON COSTS OF INSTRUCTION

This appendix presents the data on costs of instruction that we were able to find and which are summarized in Chapter IV. The presentation is organized according to type or function of resources required to conduct military training. These categories are identified in Table E-1.

The data are shown as reported in the literature. No adjustments have been made to bring cost levels to a common base period. The time periods in which costs were incurred are generally not shown in the source documents and may differ, by varying periods, from dates of publication. The use of standard indices, such as wholesale prices, does not appear appropriate to adjust all costs to a common base; specialized indices, that are not available, would be required for some types of resources, such as various components of computer systems.

The validity of individual data has not been evaluated. Some data values were extracted from secondary sources that did not reference original sources. Data in some secondary sources duplicated information already available in primary sources and were not used; however, undetected duplications may remain. Data that were not well enough described to be interpreted with confidence have been excluded. Wherever a value was shown, it was assumed to be based on historical experience unless it was specifically described as a programmed or planned value.

No references to costs of conventional instruction were found. This may be due to our approach to the literature.

TABLE E-1. RESOURCES REQUIRED FOR VARIOUS METHODS OF INSTRUCTION IN MILITARY TRAINING

Resource (Type or Function)				See Section, This Appendix
Program Development				
Program Design				1*
Instructional Materials:[a]	Conventional Instruction			2*
	Individualized Instruction	Programming		3
		First Unit Production[b]		
	Computer-Based Instruction	Programming		4
		Coding		
Program Delivery				
Instruction:	Instructors			5
	Instructional Support Personnel[c]			
Equipment and Services:[d]	Laboratory (including simulators)			6*
	Media Devices			7
	Computer Systems			8
	Communications			9
Materials (including consumables)[e]				10*
Facilities[f]				11
Program Management and Administration				12*
Student Personnel:	Pay Allowances			13**
	Other (PCS, TDY, etc.)			

NOTE: * No data available.
** Included in discussion of Instruction: Instructors and Instructional Support Personnel (Section 5).

[a] Includes revision.

[b] Master copy.

[c] All direct personnel not included in other categories.

[d] Includes all hardware-related costs: initial (including installation and checkout), modification, and replacement; operation and maintenance, lease and user fees; computer system software; etc.

[e] Includes copies of instructional materials (books, courseware copies, etc.).

[f] Structures, fixtures, and furnishings.

Emphasis was placed on computer-based instruction, and we expected that it would be evaluated in terms of its alternatives (conventional or individualized instruction). This was not the case. Student hours required by computer-based and conventional instruction were frequently compared; however, these data were not converted to equivalent dollar costs. Other resources needed in computer-based instruction were simply presented in dollar or real terms, but no other data were reported on the costs of conventional instruction. This raises an obvious question. What good does it do to know the cost of some particular version of computer-based instruction if little is known about the cost of conventional instruction or of any other method of instruction to which it might be compared?

Several studies noted that significant man-hours are associated with Program Design, but provided no further information. Several studies noted that savings, due to decreases in student hours, represented the combined impact of course revision and a change in the method of instruction. One study noted an expenditure of 14 man-years for a course revision that decreased the length by 50 percent but provided no information regarding what was involved in the revision. The magnitudes of these values amount to a strong argument for considering the benefits of course revision alone, without changes in instructional method. The cost-effectiveness of course revisions alone should be evaluated as a competitor of CAI, CMI, and individualized instruction.

No data nor any discussion was found regarding Instructional Program Management requirements, and only one was cited that discussed other Instructional Support Personnel resources. This can be understood with regard to CAI where all applications, save one, have been experimental programs of limited duration. However, with respect to other instructional methods, including CMI, it should have been possible to develop such information. With the highly organized structure of military training, one must allow that both Program Management and Other Instructional Support may account for a significant share of total program cost, that they are subject to analysis, and that they may vary sufficiently between different methods to have a noticeable impact on cost-effectiveness.

E.1 PROGRAM DEVELOPMENT: PROGRAM DESIGN

No data were found on these costs of instruction.

E.2 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR COVENTIONAL INSTRUCTION

No data were found on these costs of instruction.

E.3 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR INDIVIDUALIZED INSTRUCTION

Development of instructional materials for individualized instruction involves two distinct functions that should be kept separate. The first is the Instructional Programming (or authorship). The second is the First Unit Production (or master copies) of the courseware material. Only two of six studies reporting costs maintained this distinction. The most notable feature of these data is their wide range, Table E-2. For master copy production the variability holds both between different types of media material and within one type. Depending upon the number of silent slides or printed pages that might comprise an hour of instruction, the data indicate a possible range between a few hundred dollars to over $10,000 per hour of instruction. The U.S. Army Ordnance Center and School (1975), the single source of information on authoring requirements, noted values of 40 man-hours per instructional hour for sound-slides and 280 man-hours per instructional hour for sound motion picture or TV. These limited data and the limited discussions presented in the citations make it impossible to understand the reasons for the difference. Table E-3 displays the only information found on courseware material reliability, and no information was provided as to the repairability or repair costs of failed courseware.

TABLE E-2. INDIVIDUALIZED INSTRUCTION: INSTRUCTIONAL MATERIALS DEVELOPMENT, REQUIREMENTS AND COSTS

Resource	Unit	Source: Hess and Kantar, 1977	Polcyn Baudhuin, Brekka, *et al.*, 1977	Temkin Connolly, *et al.*, 1975	U.S. Army Ordnance Center and School, 1975	Dallman, DeLeo, *et al.*, 1977	Middleton, Papetti, and Michell, 1974
		See Note 1	See Note 2	See Note 3	See Note 4	See Note 5	See Note 6
Programming							
Sound Motion Picture or TV	Man-hours/Instr. Hour				280		
Sound-Slide	Man-hours/Instr. Hour				40		
First Unit Production							
Sound Motion Picture or TV	$/Instructional Hour	$6,000-12,000			$ 12,000		
Sound-Slide	$/Instructional Hour	$ 1,800			$500-1,925		
Silent Motion Picture	$/Instructional Hour	$ 10,200					
Silent Slide (or Film Strip)							
Realia	$/Slide	$ 1					
Illustration	$/Slide	$ 3-115					
Printed							
Text	$/Page	$ 7					
Illustration	$/Page	$11-430					
Audio	$/Instructional Hour	$ 180					
Combined or Not Specified	Man-hours/Instr. Hour					40	200
	$/Instructional Hour		$1,130	$15,800			

Notes:

1) The wide range in first unit production costs observed for several categories is the result of condensing a rather detailed table contained in the original text. Cost of courseware copies is estimated to vary from less than 0.1 percent (printed material) to close to 5 percent (sound motion pictures) of first-unit production costs.

2) This value was attributed to the revision of current training courses. However, it was not stated whether the revisions would be in the form of traditional or programmed instruction.

3) Considering the nature of the TEC system, each lesson should be designed to be independent of other TEC lessons and instructional support. As a result, each lesson involves distinct job analysis, curriculum design, and lesson review processes, in addition to development of lesson material *per se*. Development of lesson material and production of the lesson master copy are contracted and account for roughly 70 percent of total development costs. The remaining functions are performed within the appropriate combat arms school.

4) The study reports conflicting values for the cost of master art work for illustrations. I[illegible] place $25 per slide is estimated while in another the estimate is $100 per slide (corresponding to approximately [illegible]ree and twelve man-hours, respectively). At the lower value the art work is estimated to comprise close to 60 percent of courseware (excluding instructional programming) and 85 percent at the higher value.

5) The 40 hours is described as that necessary "to develop one draft programmed text contact hour."

6) Two hundred man-hours per instructional hour is based on revision of the training course 'Basic Electricity and Electronics' (Navy) to individualized format. The revision consumed approximately 14 man-years of effort and resulted in a 4-week course. Although it is not made explicit, the context of the discussion makes it appear that the total effort was devoted to instructional programming.

TABLE E-3. MEDIA COURSEWARE RELIABILITY

Material	Uses	Failures
Super 8 Film	1,548	7
Video Tape	982	18
Filmstrip	24,445	221
Audio Tape	25,154	36

Source: AIS Integrated System Test, October 1977.

A variety of media are available for presentation of individualized instruction, and different media are substitutes for each other in presenting the subject matter of small units of instruction, *e.g.*, the individual lesson. As a result, a course (or segment of a course) may utilize a mixture of media. With the variations in courseware costs noted, different mixes of media can imply sizeable differences in course costs. However, determination of the most effective media mix requires a rather extensive course design effort, and systematic investigation of alternative course designs to determine cost differences associated with these mixes is an expensive process.

E.4 PROGRAM DEVELOPMENT: INSTRUCTIONAL MATERIALS FOR COMPUTER-BASED INSTRUCTION

Table E-4 displays information on development of computer-based instructional materials. Close to 1,000 hours of material are represented, but in only three cases were more than 40 hours produced by one authoring group. The striking feature of the table is the variability of the data--approaching an order of magnitude.

Several studies provided data on man-hours needed separately for authoring and coding. For CMI, authorship was the dominant requirement and accounted for 90 percent of the man-hours. For CAI, weighted averages indicate that the requirements for each function are roughly equal, with 52 percent of the total attributed to authoring. However, wide differences may be noted with authoring accounting for as little as 11 percent and as much as 75 percent.

Instructional materials may be developed in-house by military or civilian personnel or by contract. Military personnel would come from the more senior pay grades, *e.g.*, E-5 or E-6) with pay and allowance rates near $6 per hour. Costs of contract personnel should be roughly $30 per hour (Middleton, Papetti, and Micheli, 1974, adjusted to 1978 wage levels). On the basis of these hourly labor rates and the man-hours requirements shown in Table E-4, the costs of courseware development might currently be estimated as high as $21,000 or as low as $500 per instructional hour for CAI and as high as $3,300 or as low as $200 for CMI.

Grimes (1975) presented the only analysis of programming requirements. He cites 80 man-hours per instructional hour as the weighted average of 16 programmers, all of whom were either students or project personnel at the University of Illinois. On an individual programmer basis, man-hour expenditures per instructional hour averaged 182. The difference in averages indicates there are great differences in individual productivity. The eight most "productive" programmers developed 239 hours of instruction, expending a weighted average of 56 hours; the eight least productive programmers developed 76 hours of instruction with a weighted average expenditure of 157 man-hours; at the extremes, one programmer spent 1,389 man-hours to produce one hour of instruction while another programmer produced 34 instructional hours with an average expenditure of 31 man-hours per instructional hour.

TABLE E-4. TIME REQUIRED TO DEVELOP INSTRUCTIONAL MATERIALS FOR CAI AND CMI

Method of Instruction	Hardware System	Instructional Hours Developed	Man-hours Per Instructional Hour			Reference	See Note
			Programming	Coding	Total		
CAI	PLATO IV	39.0	27 to 248	50 to 467	77 to 714	Hurlock & Slough, 1976	1
		6.0			156	Kribs 1976	2,8
		2.0			400	Kribs, 1976	
		30.0			284	U.S. Army Ordnance Center & School, 1975	
		20.0			100 & 200	Dallman, DeLeo, *et al.*, 1977	3
		32.0	141	81	222	Himwich, 1977	
		315.0			80	Grimes, 1975	4
	TICCIT	10.0			200	Kribs, 1976	2,8
		3.0			400	Kribs, 1976	
		32.0	150	96	246	Himwich, 1977	
	LTS 3	30.0			175	Keesler, 1973	
	IBM 1500	3.5	356	119	475	Rogers & Weinstein, 1974	5
	Unspecified CAI	Unknown			150 & 200	Middleton, Papetti, & Micheli, 1974	6,8
CMI	Navy CMI	50.0	100	10	110	Carson, Graham, *et al.*, 1975	
		300.0			30 & 60	Hansen, Ross, *et al.*, 1975	
		Unknown	(293)	(25)	(318)	Polcyn, Baudhuin, *et al.*, 1977	7,8

3-26-79-32A

Notes:

1. The ranges for Programming (27 to 298), Coding (50 to 467) and Total (77 to 714) man-hours are the extreme values experienced in eight experimental applications.

Instructional Hours Developed	Man-hours Per Instructional Hour		
	Authoring (%)	Coding (%)	Total
8.8	27 (35)	50 (65)	77
5.2	115 (44)	148 (56)	262
1.2	173 (64)	97 (36)	270
12.0	158 (51)	150 (49)	308
3.0	167 (43)	217 (57)	383
3.0	54 (11)	427 (89)	480
4.0	107 (19)	453 (81)	560
2.0	248 (35)	467 (65)	714
Total 39.2			
Average	131 (39)	251 (66)	382

2. The man-hour rates of 400 reported for both PLATO IV and TICCIT appear to be the initial segments of courseware also reported in Himwich, 1977.

3. The difference is attributed to difficulty of the material programmed. In the case of the 100 man-hours per hour value, the courseware is described only as "simple".

4. The value of 80 man-hours per hour is a weighted average. Sixteen programmers were involved to differing extents in developing 315 instructional hours with a total expenditure of 25,000 man-hours. On an individual programmer basis their average man-hour expenditures ranged from 31 to 1,380 man-hours per instructional hour and averaged 182. In the case of two authors working in the experiment over a four year period the time required to program an hour of instruction in the third and fourth years averaged 45 percent and 15 percent less than that required in the initial two years.

5. This report concerns a civilian higher education application and is written in a very laconic fashion. The values for both instructional hours and man-hours expended were derived from other information contained in the report and may be subject to wide error of interpretation. The value of 475 man-hours per hour includes only the hours attributed to "Authors & Instructional Designers" and "Computer Programmers". However, other functions (such as curriculum analysis) appear to be included.

6. The difference in values is attributed to the *level of experience of authors*. The study asserts that annual revision requirements stand at 10 percent to 12 percent of initial requirements, but no source or back-up material is presented. In addition, an hourly rate of $21 is given for commercial courseware development based on a direct labor rate of $8.25 with overhead of 100 percent, general and administrative expenses of 15 percent, and profit of 10 percent. Again no source or back-up is presented.

7. Requirements were given in terms of dollars per hour (authoring at $2,390 and coding at $250) and have been converted on the basis of $10 per man-hour for military labor.

8. Secondary source.

3-8-79-2

In these data, there is no evidence of differences between students and project staff, and there is nothing in the information presented to tie man-hours expended with difficulty of either the material programmed or the instructional approach. In one case, two student programmers were employed for about 4 years and produced a total of 97 hours of course materials. Comparison of the productivities for the first and second 2-year periods presents evidence of appreciable learning.

The values of man-hours per instructional hour given by Hansen, Ross, Bowman, and Thurmond (1975) are so much lower than other reports that they are immediately suspect. They are based on the three courses converted to CMI at the Memphis Naval Air Training Station and represent roughly 300 hours of CMI materials. The value of 60 man-hours per instructional hour was derived from a survey of personnel participating in the programs. However, the sample was extremely limited; of 13 individuals polled, only five provided quantitative answers, and these ranged from 10 to 150 man-hours per instructional hour. The value of 30 man-hours per instructional hour is presented as a "currently estimated" requirement including "textual media conversion as well as computer activity" but does not reference the author survey or another source.

E.5 PROGRAM DELIVERY: INSTRUCTION, INCLUDING INSTRUCTORS AND INSTRUCTIONAL SUPPORT PERSONNEL AND STUDENT PERSONNEL

Studies of computer-based training typically define decreases in course durations as an element of training effectiveness. However, time spent by military personnel in any function is a cost, since personnel received resource support in the form of salaries, housing, *etc*. Of the several studies that addressed both training time and training cost, only four attributed costs to student and instructor time.

Many of the studies reported savings due to reduced times required by students to complete courses with computer-based instruction. Since computer-based instruction also requires some additional resources, such as for the computer, it is obvious that it is not clear that there are overall savings unless both values are expressed in comparable terms, *i.e.*, dollars.

The omission in translating student and instructor time to cost is inconsistent with the treatment generally afforded to the cost of developing instructional materials. In most cases, the courseware was developed by military personnel, and their costs were attributed to the cost of the courseware. There are no grounds for distinguishing these personnel costs from other personnel costs that were not included, *e.g.*, instructors and students.

The cost information developed in three of the four studies is shown in Table E-5. The $61,000 pay and allowance rate shown for Crawford, Hurlock, *et al.*, (1976) is described as the "billet cost for the lowest ranked student or instructor" (an aviation lieutenant). It is over two times the standard pay and allowance factor associated with junior flying officers and includes a variety of personnel support items over and above those included in pay and allowances, *e.g.*, command and administration, medical costs, dependents' schools, travel, and retirement.

The full effect of computer-based instruction on personnel costs includes its impact on requirements for instructors and other types of direct support personnel, and computer-based instruction is generally attributed with allowing increases in student:instructor ratios. From the information shown in Table E-5, this increase does not appear to have a relatively significant effect on cost. Development of instructional materials is a significant cost associated with the introduction of computer-based instruction, and the extent to which changes in student: instructor ratios offset its cost depends upon the number of students receiving a given hour of instruction. Based on the sketchy information provided by Table E-5 (assuming an expenditure

TABLE E-5. INSTRUCTOR AND SUPPORT COSTS FOR PROGRAM DELIVERY, COMPUTER-BASED INSTRUCTION

DATA ITEM	SOURCE		
	Carson, Graham, Harding *et al.* (1975)	Hansen, Ross, Bowman, & Thurmond (1975)	Crawford, Hurlock, Padillo, & Sassano (1976)
System	Navy CMI	Navy CMI	PLATO IV
Change in Ratios			
Students : Instructors	10:1 to 16:1	7.5:1 to 9.0:1	a
Students to Instructional (Direct) Support	--	Unchanged at 24:1	--
Students to Indirect (Base) Support[b]	--	Unchanged at 12.5:1	--
Pay and Allowance Rates			
Students	\$5,899	\$ 5,300	\$61,000[c]
Instructors	9,697	10,800	61,000[c]
Instructional Support	--	--	--
Indirect Support	--	12,400	--

[a]Cannot be expressed in these terms. The net result was to eliminate the single instructor-hour contained in a 9-hour training segment.

[b]Applies to students, instructors, and instructional support personnel.

[c]The \$61,000 figure is described as billet cost and includes a variety of personnel support items over and above pay and allowances, *e.g.*, command and administration, dependent school costs, recruiting costs, reenlistment bonuses, and retirement; students and instructors were pilots.

3 26 79 33 4 18 79

of 250 man-hours to develop a course-hour and a decrease in course duration of 30 percent) the course development man-hours are offset by a corresponding reduction in instructor man-hours when the course has been taught to approximately 3,100 students. By contrast, when the cost avoidance is based on the combined decrease in instructor and student costs (assuming the pay and allowance rate of instructors is twice that of students), the breakeven point is approximately 850 students. Direct support personnel are also identified with program management, the operation and maintenance of laboratory equipments and media devices, and other instructional support functions, but no information is available concerning how these personnel requirements are affected by the introduction of computer-based instruction.

The fourth study that treated student time as a cost of training (Polcyn, Baudhuin, *et al.*, 1977) investigated the use of CMI for training at duty stations instead of at training centers. Schools provide training at both initial and advanced skill levels. Both require transfer of students to schools that result in expenditures that are a cost of the training. Initial and advanced training, occurring between duty station assignments, involve an additional permanent change of station (PCS) transfer resulting in costs for one-way travel and movement of household goods. Advanced training that occurs during a duty station assignment involves a temporary duty (TDY) transfer and incurs costs for round-trip travel and per diem payments for the duration of training.

Data were presented that permit estimation of transfer costs (including per diem) per course: $425 for advanced training based on PCS transfer, $400 for advanced training based on TDY transfer, and $140 for initial training based on PCS transfer. A significantly higher cost ($825) for PCS transfer for advanced training is cited by the Air Force in "USAF Cost and Planning Factors" (Air Force Regulation 173-10). To the extent that CMI and CAI permit training to be provided at duty stations, the resulting decrease in relocation costs is a true cost avoidance.

E.6 PROGRAM DELIVERY: LABORATORY EQUIPMENT

No data were found on these costs of instruction.

E.7 PROGRAM DELIVERY: MEDIA DEVICES

The cost of using media devices presents methodological problems that were not addressed in the literature reviewed. Media devices are long-lived, independent of subject matter, and generally portable; these attributes introduce some problems in determining the costs of their use in a course or course segment.

Unit procurement cost data are easy to compile from such sources as published catalogues. Table E-6 contains unit cost and other data for broad groupings of equipments. The wide range of costs is a function of device size and other features. Note that the range of costs shown encompasses an order of magnitude yet does not include devices sized for presentation to large groups, such as in auditoriums. Determining their costs of use, in general, requires further data regarding operating costs, failure rates, and repair costs. A second citation to failure rates is shown in Table E-7, but we could find no information on repair costs. Their full cost of use would also require data regarding lifespans in order to amortize initial costs, and only Hess and Kantar (1977) contained any information.

The methodological problems arise in determining cost of use in a particular training situation. The first problem involves selection of devices. A variety of media are available for presentation of instruction, and different media can be selected for presenting the same subject matter in small units of instruction, *e.g.*, individual lessons. As a result, a course (or segment of a course) may utilize an extensive mixture of media. With the variation in the cost of media devices noted,

TABLE E-6. MEDIA DEVICES: UNIT COST RANGES AND OTHER INFORMATION[a]

Media Device	Range of Initial Cost (Dollars)	Life Span (Years)	MTBF[c] (Hours)
Sound Movie Projectors	$175 - 1000	6	90 - 110
Videotape Recorders/Players	$600 - 8000	5	
Sound Slide/Strip Projectors	$100 - 1000		
Silent Movie Projectors	$150 - 250		
Silent Slide/Strip Projectors[b]	$ 25 - 900	6 - 10	90 - 150
Random Access Slide Projectors	$500 - 2000		
Microfilm/Fiche Readers	$ 80 - 800		
Audiotape/Disc Players	$ 30 - 325		
Teaching Machines (Individual)			
Audio Visual			
Rate Control	$230 - 1000		
Constant Control	$1950		
Visual			
Rate Control	$140 - 380		
Constant Control	$220 - 1200		
Audio			
Rate Control	$190 - 470		

[a]Excludes equipments too large for use in individual classrooms. Costs are for commercial quality equipments.

[b]Includes overhead projectors.

[c]Mean time between failures.

Source: Hess and Kantar, 1977.

TABLE E-7. MEDIA DEVICE RELIABILITY

Media Device	Hours of Use	Number of Failures	MTBF[a] (Hours)
Motion Picture Projector	2,364	12	197
Videotape Player	2,315	5	463
TV Monitor	2,315	--	2,315
Sound/Filmstrip Projector	102,509	125	820
Slide Projector	3,711	--	3,711
Silent Filmstrip Projector	12,427	33	377
Microfiche Reader	30,636	11	2,785
Audio Tape Player	33,394	12	2,783
Headset	136,199	5	27,240

[a]Mean time between failures.

Source: AIS Integrated System Test (Draft). McDonnell Douglas, 1977a.

different mixes of media can imply sizeable differences in course costs. Determination of the device mix implies an extensive course design effort, including specification of equipment-to-student ratios and the environments in which different equipments will be used (*e.g.*, individual or auditorium presentation). The systematic investigation of alternative course designs to determine cost differences associated with these mixes could be an expensive process.

A second problem arises from the physical nature of media devices. Even if a mix of media devices were formulated for a training course or course segment, the cost of using those devices in that course must still be defined. Media devices are long-lived and independent of subject matter; once procured, they serve as an inventory to satisfy requirements levied by all courses offered at an installation. Operations and maintenance costs may be based on individual course usage in a straightforward manner. However, the full cost of the use of media devices will depend upon whether or not existing stocks are sufficient to meet the demands of all users. If stock levels are adequate, equipments will be available for proposed courses (the incremental user) with no additional outlays; if not, procurement of additional equipments would be indicated and these purchase costs must be accounted for in some manner. Information regarding the adequacy of existing inventories and user requirements is rarely available, and there are a number of ways in which purchase costs can be apportioned. Analyses must resort to assumptions and allocation schemes that are essentially arbitrary and the results would be dependent upon just what assumptions and schemes were employed.

E.8 INSTRUCTIONAL PROGRAM DELIVERY: COMPUTER SYSTEMS

Information on instructional computer hardware costs is unexpectedly hard to find in the literature, despite the central role it plays in system capability and costs. Computer hardware appears to account for no more than a modest share of computer-based instruction system life-cycle costs. However, a purchase of hardware represents the bulk of early system cost and amounts to a commitment to CBI and the other costs and risks that commitment entails.

Substantive information was found on five hardware systems--PLATO IV, TICCIT, GETS, IBM 1500, and Navy CMI; some information is available on a one-of-a-kind configuration assembled to evaluate shipboard use of CMI. One additional source contained a single aggregate figure for development of the Air Force Advanced Instructional System (AIS). However, this figure represented a contract value for a mixture of hardware, software, and courseware development that could not be separated by function.

Taken system by system, the detail and completeness of the data are diverse. In no case was the material sufficient for an adequate understanding of the drivers of system cost. Individual studies are typically limited in scope, and the cost information presented is generally limited to only that necessary to the principal issue addressed. For example, in experimental programs, the costs that were reported were normally limited to those directly (and incrementally) incurred as a result of the program, *i.e.*, those that could be identified as budget expenditures of the demonstration.

The discussion that follows is organized according to computer system rather than type or location of hardware. Note that all costs are displayed as then-year dollars rather than being adjusted to a common base period. In the light of changing CAI/CMI hardware configuratios and technology, no satisfactory price index could be found. In several studies, it appeared that costs given were not current with the publication date, and no information was provided as to the applicable dates of the costs.

E.8.1 PLATO IV.

More studies have addressed PLATO IV than any other system. Although purchase of a PLATO IV system is very expensive, access to its services can be purchased in small and divisible units, *e.g.*, the individual terminal, with a small initial outlay, and its software system is highly developed. These features are particularly attractive for small-scale programs, typical of experimental applications.

Most military use of PLATO IV was supported by a contract between DARPA and the military Services with the Computer-Based Education Research Laboratory (CERL) at the University of Illinois. This arrangement, however, casts some question on the value of cost data reported. In addition to being non-profit, CERL is the originator of PLATO IV and has a vested interest in its use. The CERL contract charges are considerably less than those of Control Data Corporation (CDC), currently providing PLATO IV services on a commercial basis; the CERL charges may well be less than the military could provide the same services for on an in-house basis. The values shown in Table E-8 are reported actuals from experimental programs funded through the CERL contract for Hurlock and Slough, 1976; U.S. Army Ordnance Center and School, 1975, Dallman, DeLeo *et al.*, 1977; and Steinkerchner, Deignan, *et al.*, 1977. The values shown for Kribs, 1976, for terminals and PLATO IV system support and the system support shown for Crawford, Hurlock, *et al.*, 1976, are quotations from CDC.

The costs displayed in Table E-8 are based on the use of a small fraction of the central hardware capability of a PLATO IV system. The computer access is charged to cover central system operating costs, amortization of the hardware, and other services provided by CERL on the basis of the number of terminals connected. Large-scale use of PLATO IV by the Services would probably involve purchase of both terminal and central processor hardware with a sizeable initial outlay.

Control Data Corporation has provided an estimate of hardware procurement costs for a 1000-terminal system capable of supporting 725 terminals simultaneously in a student mode, or 425 in an author mode. The configuration and component costs are shown in Table E-9. The simultaneous terminal constraint is a function of central processor cycle time rather than the "swap" time between the random access and swap memories. Saturation of a swap memory capacity is reached at approximately 800 students; this level restricts student blocks to 4000 words when all students are accessing different programs.

As shown in Table E-9, the configuration contains components not currently available on a commercial basis. The extended swap memory (ESM), currently in development, is of metal oxide semiconductor (MOS) technology and will employ a controller with

TABLE E-8. COSTS ASSOCIATED WITH THE USE OF PLATO IV

Item	Hurlock and Slough, 1976		Crawford, Hurlock, et al, 1976		U.S. Army Ordnance Center and School, 1975		Dallman, DeLeo, et al 1977		Steinkerchner, Deignan, 1977		Kribs, 1976	
Number of Terminals On Line	12		16		14		30		20		12	
See Note	1,2		2		1		1,3		1		2,4	
	$	Code	$	Code	$	Code	$	Code	$	Code	$	Code
PLATO IV Terminal												
Basic	10,500	P,T	10,500	P,T			5,205	P,T	5,000	P,T	11,650	X,P,T
Touch Panel		I		I			544	P,T	410	P,T		I
Slide Option		I							600	P,T		I
Audio Unit							2,000	P,T	2,000	P,T		
PLATO IV System Support			35,820	0,4T								
Computer Access Fee	2,500	T,C,Y			2,500	T,C,Y	1,500	T,C,Y	1,500	T,C,Y	7,200	C,X,T,Y
Maintenance and Other	1,300	T,C,Y			1,000	T,C,Y	1,000	T,C,Y	1,000	T,C,Y	1,980	C,X,T,Y
Communications												
Commercial Lease Line							204	T			95	M,4T
GSA Lease Line	50	M,4T			50	M,4T			61	M,4T		
Microwave System							9,630	P				
Multiplexor	10,500	P,4T							4,680	P,4T	6,300	C,X,4T,Y
Data Port									300	P,4T		
Varian Printer							7,588	P				

Code C Contract service or lease
P Purchase
X Quotation
I Included in "basic" cost
M Per mile month
T Per terminal
4T Per four terminals
Y Per year

Notes

1 These studies report the results of small scale evaluations of the PLATO IV system that were partially funded by DARPA. Since the programs were complete at the time of documentation all costs shown are assumed to be actuals except those noted as estimates. DARPA support included all items shown in the table and one would expect to find the costs of like items to be the same. The higher maintenance cost noted in Hurlock and Slough, 1976, is explained by the longer distance between San Diego and the University of Illinois, but the documentation provided no explanation for the other differences.

2 The experimental program addressed in Crawford, Hurlock, et al, 1976, is one of a number of programs addressed in Hurlock and Slough, 1976. The lower PLATO IV system support costs shown by Hurlock and Slough, 1976, is based on the CERL contract while the higher value shown in Crawford, Hurlock, *et al*, 1976 is a quotation solicited from CDC. The estimates shown in Kribs, 1976, for both the terminal and system support were obtained from CDC.

3 Communications for this program were achieved by microwave for transmission from CERL to Chanute AFB (a distance of 15 miles) and local telephone lines for transmission from Chanute to CERL.

4 The basic terminal is noted as including a local MODEM.

3 8 79 1

TABLE E-9. PLATO IV HARDWARE PROCUREMENT AND MAINTENANCE COSTS

	Model Number	Year of Availability	Quantity	Purchase Price (000)	Monthly Maintenance Cost (000)	See Note
Central Site Equipment						
Central Processor	--	1978	1	$1529	$ 4.6	1
Extended Swap Memory	--	1981	1	1351	2.0	2
Computer Interface Unit	4001	1978	1	14	0.1	3
Computer Interface Unit Expansion	4001-2	1978	2	12	0.0	4
Tape Controller	721-21	1978	2	61	0.3	
Tape Drive	667-2	1978	2	41	0.3	
Disk Controller	7054-41	1978	4	297	1.0	
Disk Drive	844-41	1979	20	515	2.1	
Line Printer	580-12	1978	1	71	0.3	
Site Controller	40002-1	1978	22	213	2.8	5
Remote Interface Module	40002-13	1978	176	211	0.9	6
Multiplexor/MODEM	--	1979	125	688	3.1	7
Total				$5003	$17.5	
Remote Site Equipment						
Terminal	IST2	1980	1000	$5000	$25.0	8
Multiplexor/MODEM	--	1979	125	688	3.1	7
Total				$5688	$28.1	

Source: Unpublished materials received from and conversations with R. A. Moe of Control Data Corporation.

Notes:

1. CIBER 174-6 with 131K words of random access memory.
2. MOS technology with 4-million word capacity.
3. Capable of controlling 256 active terminals.
4. Each expansion unit is capable of controlling 256 active terminals after the first 256 terminals controlled by the master computer interface unit.
5. Capable of controlling 32 active terminals.
6. Capable of controlling 4 active terminals (i.e., eight per site controller).
7. Eight-port multiplexor and 9600 bps MODEM.
8. Production version of the current terminal. Principal changes to permit production of larger lot sizes. The number of circuit boards will be reduced, the keyboard made integral to the case, and tube will be smaller.

eight times the addressing capability of those used with the current magnetic core units. The higher capability controller will permit ESM growth to 16 million words, compared with the 2-million word limit of the current controller. The terminal is a smaller integrated unit with emphasis placed on producibility of larger lot sizes. The eight-port multiplexor is currently in pilot use. Its impact on system costs lies in the potential of reducing the number of multiplexors and MODEMs and the costs of communications services by up to one-half. With one exception, the prices shown are current values rather than projected values. The one exception is the extended swap memory where the recent trend decline in MOS chip costs has been projected to reflect anticipated 1981 costs.

E.8.2 TICCIT.

Very little information was found concerning TICCIT hardware costs in the literature. Much of what was found is out of date as the result of a recent major configuration change instituted by Hazeltine Corporation, which currently markets TICCIT on a commercial basis. Among other changes, the new configuration substitutes the Nova 3/D central processor for the Nova 800 processor.

One description of TICCIT hardware and costs is shown in Table E-10, (Kearsley, 1977). This information was obtained from the MITRE Corporation in 1974 and pertains to the Nova 800 configuration. Kribs (1976) provides an estimate of $270,000 for hardware and $130,000 for system installation and checkout for a 13-terminal configuration. This figure is in close agreement with the MITRE information and is based on the NOVA 800 configuration installed at North Island Naval Air Station.

Unpublished information received from Hazeltine regarding the new configuration indicates that the central system has a degree of modularity and may consist of one or two central processors, depending upon the number of terminals to be supported,

TABLE E-10. ESTIMATED COST OF TICCIT HARDWARE
(The Mitre Corporation, 1974)

Central Processor Unit		
Main Processor		$34,000
Terminal Processor		15,000
Disc Drive & Controller (3 at $23,300 each)		70,000
Tape Unit		9,000
Card Reader		4,000
Line Printer		11,000
CRT Terminal		3,000
Computer-Computer Line		3,000
Character Generator		7,000
Keyboard Interface		6,000
Audio System		56,000
Refresher Control		6,000
Crossbar Switch (Audio/Video Switching)		17,000
Video Tape Players (20 at 850 each)		17,000
Cabinets		7,500
Total		$265,500
Terminals		
TV Monitor (including modification)	128 at $320	
Keyboards	128 at $170	
Refreshers	128 at $735	
Signal Processors	128 at $125	
Total	$1350	$172,800
Total		$438,300

Source: Kearsley, 1977

and varying numbers of disc units, depending upon the extent of courseware and number of students to be supported. Hazeltine has provided what is described as "budgetary pricing information" as of June 1977, as shown in Table E-11. Hazeltine indicates that as of June 1978 these prices had increased approximately 20 percent, bringing the hardware cost of a 128-terminal system to well over $1 million.

E.8.3 IBM 1500

Three references to IBM 1500 system costs were found in the literature, and one included the IBM 1460 system, as summarized in Table E-12. Two sources provided tabular breakouts (Kopstein and Seidel, 1969 and Kearsley, 1977) while the third (Ford, Slough, and Hurlock, 1972) provided a single "bottom line" cost. Only Kearsley (1977) explicitly stated that the costs came from accounting records of operating experience.

Two points are to be noted regarding this material. The first is that the hardware costs are monthly lease values in all cases, with maintenance provided by the contractor. The second is that the lease costs are roughly the same, although the publication dates span a 10-year period of rising general cost levels and falling costs of computer service. The discussions in the references were insufficient to explain the similarity, but some rationale may be gleaned from the different environments on which the estimates are based. The values provided by Kearsley (1977) are based on an extended period of operation that began in the late 1960s; it was not noted to which part of the time period the values pertain. Further, the system was installed at a Canadian university where relative costs may differ from those in the United States. Data provided by Kopstein and Seidel (1969) are based on civilian installations, while those of Ford, Slough, and Hurlock (1972) are based on military use. With the different ways data categories are combined, it is possible that central

TABLE E-11. ESTIMATED COST OF TICCIT SYSTEM
(Hazeltine Corporation, 1977)

Basic Systems		
System I (32 Terminals) Capacity		$520,000
System II (64 Terminals) Capacity		585,000
System III (128 Terminals) Capacity		630,000
Options		
Graphic Digitizer		25,000
Disc Drive		21,000
Software Support Package (Not available for System I)		24,000
Optical Spares Package		21,000
Video Tape Option - System I		45,000*
System II		60,000*
System III		90,000*
Audio Option - System I		100,000
System II		100,000
System III		70,000
Terminal: Average Cost for Quantity:	32	2,375**
	64	2,325**
	128	2,275**

*Deduct $20,000 when audio option is also included.

**Add $250 for light pen.

Source: Hazeltine Corporation, 1978.

TABLE E-12. IBM 1500 SYSTEM COSTS

Item	Source			
	Kopstein and Seidel, 1969		Ford, Slough, and Hurlock, 1972	Kearsley, 1977
Date of Installation	--	--	--	1968
System Designation	1460	1500	1500	1500
Number of Terminals	32	32	32	32
Monthly Hardware Lease Cost				
Central Processor	$ 5,900	$14,800	$12,000	$ 6,700
Data Storage	2,800			
Terminals	4,600			4,548
Maintenance				1,884
Total	$13,300	$14,800[a]	$12,000[a]	$13,242
Monthly Operating Cost				
Number of Personnel	1	1	--	6
Operators' Salaries	700	700	--	$ 3,198
Programmers'/Managers' Salaries			--	3,968
Total	700	700	--	$ 7,166

[a] Includes Maintenance.

processor lease rates might have declined and maintenance costs increased over time and without this being noticeable.

E.8.4 Navy CMI System.

The Navy CMI system has used two different central hardware systems. Initial development and application of the system was accomplished using a Xerox Sigma 9 system, located at Memphis State University and dedicated to Navy use during regular training hours. Later, the Navy procured a Honeywell Series 60 Level 66 system. The configuration, shown in Table E-13, is described in Hansen, Ross, *et al.*, 1975. At the time of publication the hardware was under contract for procurement, and we have not verified whether configuration changes occurred between then and its final installation. Costs of its components were obtained from issues of computer price survey publications, as noted.

Student terminal configuration and cost information is taken from Polcyn, Baudhuin, *et al.*, (1977) and is shown in Table E-14. The date of this publication would allow these values to be based on historical records that antedate installation of the Honeywell central processor. With regard to maintenance costs, neither the philosophy (in-house or contract) nor a breakdown between labor and material was given.

E.8.5 General Electric Training System (GETS).

GETS (also known as Computer-Based Training System or CBTS) is a stand-alone (single terminal) unit. The only military application at present is for crew training for the TRIDENT system when there are more students than the regular laboratory equipment can handle. A life-cycle cost evaluation (Kribs, 1976) estimated unit hardware production cost to be $34,000 and other nonrecurring costs associated with procurement of 13 units (spares, manuals, installation, *etc.*) at approximately $125,000. These values are based on a contractor quote that is several years old, and its timeliness is open to serious question.

TABLE E-13. NAVY CMI SYSTEM: INITIAL CENTRAL SITE HARDWARE COST

Component	Model Number	Quantity	Unit Cost (000)	Source	Total Cost (000)
Central Processor (131K 36-bit 4-byte words)	CPS 6202	2	$743.0	2	$1486.0
Removable Disc Units	MSU 0400	8	21.9	1	175.2
Unit Record Processor (disc)	MSP 0600	2	61.9	1	123.8
Magnetic Tape Processor	MTP 0600	1	25.7	1	25.7
9-Track Tape Drive (800/1600 cpi)	MTU 500/ MTF 0012	4	20.6	1	82.2
7-Track Tape Drive (556/800 cpi)	MTU 410/ MTF 0116	1	15.5	1	15.5
Unit Record Processor (peripherals)	URP 0601	1	19.6	2	19.6
Line Printer (1200 lpm)	PRU 1200	1	44.4	1	44.4
Card Reader (1050 cpm)	CRU 1050	1	19.2	1	19.2
Card Punch (300 cpm)	CPZ 0201	1	34.0	1	34.0
Console	CSU 6001	2	36.2	3	36.2
Datanet-Front End Processor	DCP 6632	2	124.9	2	249.4
System Total					2311.2

Unit Cost Sources:

1. Computer Review 1978, Vol. 18, No. 2. GML Corp., Lexington, Mass. 1978.
2. Datapro 70. Datapro Research Corp. (Subsidiary of McGraw Hill). Delron, N.J., 1977.
3. Authorized ADP Schedule Price List. Federal System Operations, Honeywell Information Systems. McLean, VA., Undated. (GSA price list, FY 1978).

Configuration Source: Hansen, Ross, et al., 1975.

TABLE E-14. NAVY CMI STUDENT TERMINAL COST

Item	Unit Initial Cost	Unit Annual Maintenance
Opscan 17, Optical Scanner	$ 8,998	$ 828
Opscan Auto-Feed	652	60
GDC-202-9D Modem	400	60
Terminet 1200, Keyboard/Printer	4,200	816
Total	$14,250	$1,764

Source: Polcyn, Baudhuin, *et al.*, 1977.

Technological advance in the intervening period has had its greatest impact on the types of components used in stand-alone systems; in particular the costs of microprocessors and both integral and peripheral data storage devices have experienced relative declines.

E.8.6 Shipboard Computer-Based Instruction.

Shipboard use of automated data processing for non-tactical applications has been investigated by the Navy for about 10 years. Two areas of application have been investigated under the designation "Automated Shipboard Information Management System (ASIMS)". The first is a general data management capability "Command Management System (CMS)", and the second is computer-based instruction, "Computer Integrated Instruction (CII)". The first shipboard test, a Data General NOVA 1200 system installed aboard the USS Dahlgren in 1973, emphasized Command Management System applications. In 1975, the system was transferred to the USS Gridley where emphasis shifted to Computer Integrated Instruction applications. The NOVA 1200 has now been replaced with a Digital Equipment Corporation (DEC)

PDP 11/60, and the application has been extended to include both CMS and CII.

Both the NOVA 1200 and PDP 11/60 are considered mini-computers. Little information was found concerning the configuration or cost of this installation. The configuration displayed in Table E-15 is contained in unpublished information received from the Navy Personnel Research and Development Center (undated) and pertains to the USS Gridley. Component costs were contained in a discussion of the USS Dahlgren installation in Middleton, Papetti, and Micheli (1974). There is an ambiguity between these two sources concerning whether the costs shown for the disc drives and CRTs represent unit costs or the costs of two and four units, respectively. In Table E-15, they are treated as costs of the quantities shown; if they should have been treated as unit costs the total installation cost would rise to over $100,000. Note that the cost values are based on 1973 information, and it is questionable whether they represent the current costs of mini-computers of like capability.

TABLE E-15. HYPOTHETICAL SHIPBOARD SYSTEM: ESTIMATED HARDWARE PROCUREMENT COST

Component	Cost
Central Processor (NOVA 1200, 32K Memory)	$20,500
Line Printer and Controller (365 lpm)	13,100
Card Reader and Controller (100 cpm)	6,050
Disc Drive and Controller (2 units, 12 million 16-bit words each)	24,000
Alphanumeric CRT (4 units, Hazeltine 2000)	3,000
Other (Cassette Tape Drives, Teletype)	2,000
Total	$68,650

Source: Unpublished information received from the Naval Personnel Research and Development Center (undated); also Middleton, Papetti, and Micheli, 1974.

E.8.7 System Cost Comparison.

The hardware systems discussed in this Appendix include the extremes of current system capabilities in terms of the number of terminals supported. The cost of these systems can be expressed in three ways: (1) system procurement cost, (2) system procurement cost per terminal, and (3) system procurement cost per student-hour based on assumed life spans and utilization rates. Table E-16 displays the comparisons between each system for each of the three measures. The inverse relationship between system size (or initial procurement cost) and cost per connected terminal or per student hour is rather consistent within the data sample, but we have strong reservations regarding the reliability and timeliness of the data and of drawing strong conclusions based on them. Although it appears safe to say that computer hardware for the Navy CMI instructional system costs less per student hour than the computer hardware for any of the CAI instructional systems, it should also be obvious that other computer system costs, such as for installation and maintenance, are not included in these values.

E.9 PROGRAM DELIVERY: COMMUNICATIONS

Communications costs arise only in large computer-based systems where terminals may be located at appreciable distances from central processors. Currently, this applies only to PLATO IV and the Navy CMI systems. Four methods of communication have been suggested--land lines, microwave systems, satellites, and closed-circuit television. All applications of these systems, with the exception of one PLATO IV experimental program, have employed land lines. The program pursued at Chanute AFB, reported in Dallman, DeLeo, *et al.*, 1977, utilized a microwave system as a primary communication link.

The PLATO IV programs that utilized land lines employed GSA leased lines with costs of roughly $.50 per mile per month. This rate was also cited in several other studies where it was also reported to be approximately one-half of the commercial interstate

TABLE E-16. COSTS OF COMPUTER SYSTEMS HARDWARE

Method of Instruction	Computer System	Central Processor Cost (Thousands)	Terminal, Unit Cost (Thousands)	System Hardware Cost (Thousands)	System Hardware Cost Per Terminal (Thousands)	System Hardware Cost Per Student Hour[a]
CAI	IBM 1500 32 Terminals[b]	–	–	$ 800	$ 25	$ 2.49
	PLATO IV 1,000 Terminals[c]	$ 5,000	$ 5.7	10,700	11	1.48[d]
	TICCIT 32 Terminals[e]	760	2.9	850	27	2.66
	64 Terminals	870	2.8	1,050	16	1.64
	128 Terminals	970	2.8	1,330	10	1.04
	GETS One Terminal	–	–	34	34	3.40
CMI	Navy CMI 6,000 Students[f]	2,300	14.3	4,020	34	0.07
	16,000 Students[g]	2,300	14.3	6,880	22	0.04

4 18 79

[a]2,000 hours per terminal per year for 5 years

[b]Includes maintenance Based on lease rates and amortizing equipment over a 5 year period, 1967, 1972, 1977

[c]Control Data Corporation quotation, from private communication dated 14 August 1978

[d]Based on 725 active terminal constraint

[e]Hazeltine quotation, from private communication, 1978

[f]120 terminals at 50 students per terminal, 1977

[g]320 terminals at 50 students per terminal, 1977

3 26 79 35

rates. In fact, the commercial tariffs are based on complex rate structures set by the Federal Communications Commission for interstate (or long) lines and individual states for wholly intrastate (or short) lines.

The rate schedule (Table E-17) for commercial long lines was found in Ball and Jamison, (1973) and Middleton, Papetti, and Micheli (1974):

TABLE E-17. RATE SCHEDULE FOR COMMUNICATIONS OVER COMMERCIAL LONG LINES

DISTANCE INTERVAL (MILES)	COST PER INCREMENTAL MILE PER MONTH	AVERAGE COST PER MILE PER MONTH (AT LIMIT OF DISTANCE INTERVAL
1-25	$3.30	$3.30
26-100	2.31	2.56
101-250	1.65	2.01
251-500	1.15	1.58
> 500	0.83	1.20[a]

[a]At 1000 miles.

Source: Ball and Jamison (1973), and Middleton, Papetti, and Micheli (1974).

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In addition to the line rates, "conditioning" and "termination" charges of approximately $90 per line per month are levied. On the basis of this schedule, it can be seen that close to transcontinental distances of greater than 2,000 miles are required before the average rate approaches one dollar per mile. Only one paper (Ball and Jamison, 1973) addressed the cost of short-line communications. These rates were characterized as a constant function of mileage that approximates $4 per mile per month plus line conditioning and termination charges of approximately $125 per month.

Ball and Jamison, (1973) was also the only paper that addressed the costs of equipment associated with land-line communications. Since the document was not concerned with particular hardware systems, it provided only typical costs for generic types of equipments with no references to sources or particular equipments on which the estimates were based. The limits of these estimates are shown in Table E-18.

TABLE E-18. COSTS OF LAND-LINE COMMUNICATIONS EQUIPMENT

Equipment	Unit Cost (Dollars)
Multiplexors	
8 Channel	$ 1,600
Central	7,000
System	10,000
Modems	
1200 Baud	500
2400 Baud	1,750
4800 Baud	5,400
Multiplex Computer	9,000

E.10 PROGRAM DELIVERY: MATERIALS

No data were found for these costs of instruction.

E.11 PROGRAM DELIVERY: FACILITIES

Furnished instructional facilities are a requirement of any formal training program and, given a static-sized force, it may be considered that existing facilities would generally be available without further expenditure for commonly used assets. However, the introduction of self-pacing imposes a requirement for assets not associated with traditional instruction, and the introduction of PLATO IV (or any other computer-based system) imposes other requirements. These are properly costs of the newly employed training technology, *i.e.*, CAI or CMI. Two USAF PLATO IV demonstration programs--Dallman, DeLeo, *et al.*, 1977, and Steinkerchner, Deignan, Waters, and DeLeo, 1977, reported costs of facility modifications and furnishings required for instruction.

In the case of these two USAF demonstrations, only two facility items fell into this class. The first is individual learning carrels and the second is the provision of electric and pneumatic outlets at the carrels to service the PLATO IV terminals. Other requirements such as communication links would appear to be required also, but these were not listed. The cost of carrels was reported at $90 per unit in one study and at $260 per unit in the other. No descriptions were provided to explain such a wide difference, but it is of note that Hess and Kantar, (1977) reported an average or typical cost of carrels for programmed instruction at $160.

The cost of installing electric and pneumatic service can be expected to vary widely as a function of the characteristics of the building in which they are installed. In the case of these two programs, service for 30 carrels was installed at an average cost of $61 per carrel and service for 20 carrels was installed at an average of $141 per carrel. In neither case was a breakdown between electric and pneumatic provided, and in neither case was it noted whether pneumatic service was already available in the building or whether the program involved procurement and installation of a compressor as well as the running of the compressed air lines.

E.12 PROGRAM MANAGEMENT AND ADMINISTRATION

No data were found on these costs of instruction.

E.13 STUDENT PERSONNEL

Data on costs of Student Personnel are included in Section E.5, Program Delivery: Instruction, Including Instructors and Instruction Support Personnel and Student Personnel.