COST-EFFECTIVENESS OF COMPUTER-BASED INSTRUCTION FOR MILITARY TRAINING

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ABSTRACT

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, Individualized Instruction, Computer-Assisted Instruction (CAI) and Computer-Managed Instruction (CMI). Student achievement at school is about the same with all methods of instruction. CAI and CMI save about 30 percent (median) of the time required by students to complete the same course given by conventional instruction. Individualized instruction (without computer support) also saves student time; the addition of CAI or CMI to courses taught this way saves little additional student time. Student attrition appears to increase with CMI compared with conventional instruction, but changes in student quality may also account for this increase; no such data are available on CAI. Students prefer CAI or CMI to conventional instruction; attitudes of instructors, considered in only a few studies, are unfavorable to CAI and CMI. Direct comparisons of the cost and effectiveness of different methods of instruction are not now possible because of incomplete cost data. Most 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; data for other costs, such as for CAI or CMI equipment, courseware and instructors must also be considered.

INTRODUCTION

The training of military personnel is a large and continuing activity for the military Services. This paper evaluates the cost and effectiveness of modern training methods which use computers to instruct students and to manage students' progress through a course. (1)

In Fiscal Year 1981, about 428,000 enlisted personnel will receive initial skill training, 173,000 will receive skill progression training and 515,000 will receive functional training at a cost of over $2 billion. (2) About 70 percent of all recruits complete their initial enlistment; less than 40 percent reenlist for a second term; thus about 75 percent of the training loads and costs noted above are related to new accessions each year. (2)

After graduating from technical training schools, personnel are assigned to operational commands where they receive additional on-the-job training, crew, team and unit training and practice in field exercises. These types of training have large costs which must be added to the costs cited above.

Industry is well aware of the need to reduce the costs of military training and some type of computer-based instruction is often incorporated now in new proposed systems such as, for example, the new aircraft training system (Navy VTXTS) and maintenance simulators (F-16). This paper evaluates what is now known about the cost and effectiveness of various types of computer-based instructional systems.

METHODS OF INSTRUCTION

Carpenter-Huffman lists 20 different methods of instruction in "Method of Designing Instructional Alternatives" (MODIA) (3); these include lectures, discussions, tutoring, independent study, drill and practice. For convenience, we have organized these methods of instruction into four groups; more than one method of instruction may be used in a course.

Conventional Instruction. Conventional instruction refers to many possible combinations of lectures, discussions, laboratory exercises and tutorial sessions. 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 also referred to as lock-step instruction and group scheduling. It is used in 75 to 90 percent of all military courses, although a precise estimate is not available.

Individualized Instruction. In individualized instruction, a course is arranged in a series of lessons through which each student proceeds at his own pace. Mastery of each lesson is required as a condition of progress and there is a test for each lesson. Differences among students are reflected in the amount of time it takes them to complete a course, although grades may also be given.

Various versions of individualized instruction may differ in such ways as the amount of new material between lessons, the order in which lessons are 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; the term "individualized instruction", as used here, is meant to apply only to individualized instruction conducted *without* computer support. The terms individualized instruction, self-pacing, and programmed instruction are often used synonymously.

Computer-Assisted Instruction (CAI). The term computer-based instruction, as used here, includes both CAI and CMI. 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 ability and way of learning. Most CAI systems diagnose student performance, prescribe lessons, and maintain student records. Examples of some CAI systems follow:

- PLATO: Programmed Logic for Automatic Teaching Operation. The 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 lessons and playback.

Computer-Managed Instruction (CMI). In computer-managed instruction (CMI), instruction takes place away from the computer. After each lesson, the student takes a test, and places the answer sheet on an optical scanner; the computer scores the test and interprets the results. The student receives the results on a printout which tells him how well he performed, what lesson to take next, and where to find it. The computer also manages student records, instructional resources, and administrative data. 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. It contains 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 account for about 25 percent of the student body. The management terminals are used 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, handles about 6,000 students in 11 schools at 5 training centers. It is based on a Honeywell Series 60, level 66 computer.
- CTS: Computerized Training System. This system, installed at U.S. Army Signal Center and School, Fort Gordon, Georgia, can provide CAI and CMI services for 128 terminals. 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.

DISTINCTIONS BETWEEN MILITARY AND NON-MILITARY TRAINING

Military personnel receive pay and allowances while they are being trained. 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 help to reduce the cost of training; it can also help to increase 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.

This situation differs from that found in almost all types of public and private schools where students are not paid and must remain at school for required periods of time. These schools receive no direct benefit if students complete their 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 applications. 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 emphasized student achievement at school and has not been concerned with the amount of time needed by students to acquire course materials.

THE EFFECTIVENESS OF COMPUTER-BASED INSTRUCTION

The military Services have supported research and development on computer-based instruction since the early 1960's when this concept first appeared to be feasible. The use of CAI and CMI in military training has been evaluated in about 30 studies conducted since about 1968; these studies provide 48 sets of data. Most of these studies were of a research nature and only a few approximated an operational application. The nature of these studies must be understood in order to interpret properly the data they provide.

Military training is intended to prepare personnel to perform various jobs in operational commands. Thus, the effectiveness of any method of instruction should be evaluated by measuring how well a course graduate performs certain jobs in the field. No studies provide this type of information. Instead, all studies of different methods of instruction compare only student achievement at school, as measured by tests administered there. This limitation applies generally to most research on training and selection.

Most studies were, in fact, experiments. About half involved 50 or fewer students; about half the courses studied lasted one week or less. In a few studies, the courses lasted 2 to 10 months and involved 600 to 2000 students. This information is summarized in Fig. 1. A wide variety of subject matter was considered in these courses (see Fig. 2);

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".

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FIGURE 1. Distributions of Course Length and Number of Students in 48 Evaluations of Military CAI and CMI Instruction

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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FIGURE 2. Courses Used in Various Studies of CAI and CMI

many of them are directly related to technical training, e.g., basic electronics and electricity; some involved hands-on maintenance checkout and repair. Note, however, that no single course was given both by CAI and CMI; as a result, this means that we cannot directly compare the effectiveness of CAI and CMI for giving the same course.

Student Achievement at School. Student achievement at school with CAI was about the same as with conventional instruction in 24 cases, superior in 15, and inferior in one (Fig. 3). The differences in achievement, although statistically significant, were not judged to have practical significance. Student achievement at school with CMI was about the same as with conventional instruction (8 cases).

Amount of Student Time Saved. Data on the amount of student time saved by CAI and CMI, compared to conventional instruction, are shown in Fig. 4. The amounts saved range from -31 to 89 percent; most values are positive; the median value is about 30 percent. No particular significance can be attributed to differential time savings between CAI and CMI shown in these data because direct comparisons, using the same courses, were not made. A major uncontrolled variable in these studies is the unknown quality of the instructional materials used in the various comparisons. This argues against trying to make quantitative comparisons about the amount of student time saved by different types of CAI or CMI, or in different courses, and so on.

The fact that CAI and CMI save student training time is consistent with the well-known fact that there are wide differences in student ability (represented by the normal distribution curve); there are also differences between students in the amount of relevant knowledge held by them at the start of any course. In conventional instruction

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT ACHIEVEMENT AT SCHOOL (compared to conventional instruction)			TYPE OF TRAINING
				INFERIOR	SAME	SUPERIOR	
CAI	IBM 1500	A	SIGNAL C&S		• • • •	• •	ELECTRONICS
		N	SAN DIEGO			• • • • •	ELECTRICITY
	PLATO IV	A	ABERDEEN		• • •		MACHINIST
		N	SAN DIEGO		• •	• • • •	ELECTRONICS
		N	SAN DIEGO		• •		RECIPE CONVERSION
		N	NORTH ISLAND			•	A/C PANEL OPERATOR
		AF	SHEPPARD		• •	• •	MEDICAL ASSISTANT
		AF	CHANUTE		• • • •		VEHICLE REPAIR
	LTS-3	AF	KEESLER		• •	•	ELECTRONICS
		AF	KEESLER		•		WEATHER
	TICCIT	N	NORTH ISLAND		•		TACTICAL CO-ORD. (S-3A)
	IDIOM	N	DAM NECK	•	•		FIRE CONTROL TECHNICIAN
	PLATO IV	N	DAM NECK		• •		FIRE CONTROL TECHNICIAN
				TOTAL 1	24	15	
CMI	NAVY CMI	N	MEMPHIS		• •		AVIATION FAMILIARIZATION
		N	MEMPHIS		• •		AV. MECH. FUNDAMENTALS
	AIS	AF	LOWRY		•		INVENTORY MGMT.
		AF	LOWRY		•		MATERIEL FACILITIES
		AF	LOWRY		•		PREC. MEASURING EQPT.
		AF	LOWRY		•		WEAPONS MECHANIC
				TOTAL 0	8	0	

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FIGURE 3. Student Achievement at School for CAI and CMI, Compared to Conventional Instruction, in Military Training

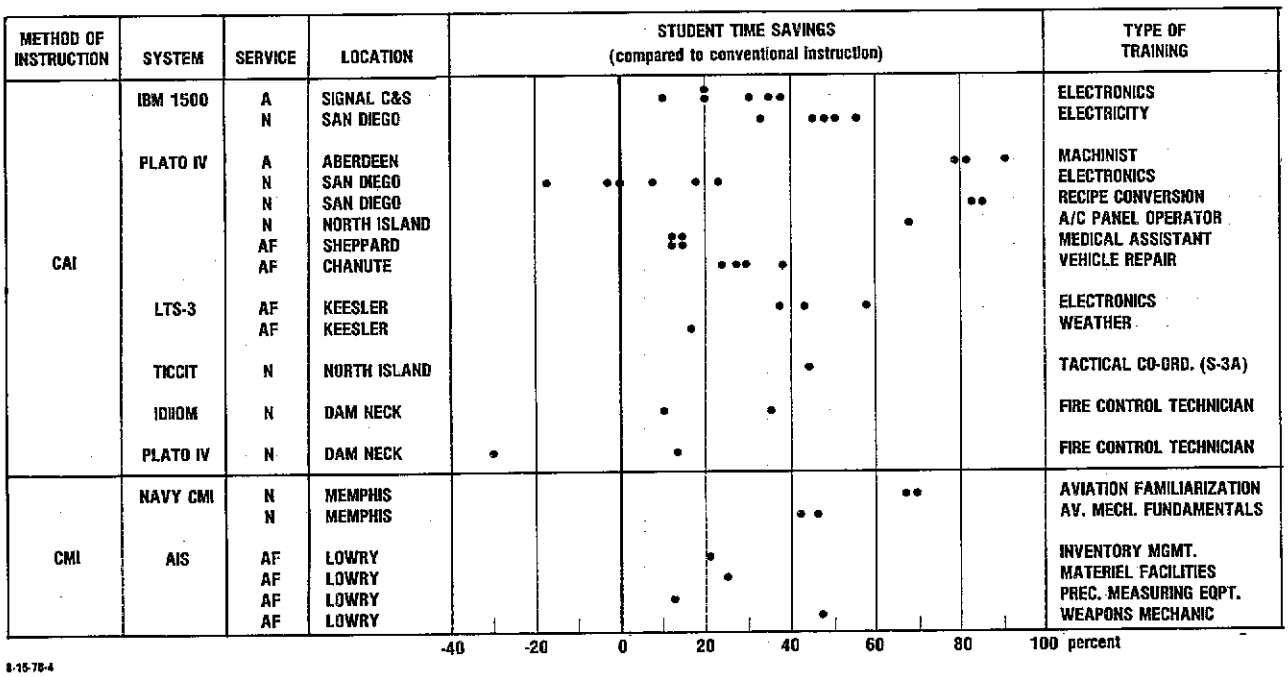

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FIGURE 4. Amount of Student Time Saved in Courses Given by CAI and CMI, Compared to Conventional Instruction, in Military Training

with a fixed amount of time, these differences lead to variations in the amount of knowledge held by students at 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 amount of time needed to acquire the course materials. Differences in the amount of information acquired is not a major variable. The bulk of the time savings in individualized instruction is 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. Figure 5 summarizes the amounts of student time saved shown above.

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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FIGURE 5. Amounts of Student Training Time Saved by CAI and CMI, Compared to Conventional Instruction

Course Completion Times at AIS over 24 Months. Almost all of the data shown previously represent time savings found in experiments or operational applications over short time periods and with limited numbers of students. Figure 6 shows time saved by about 11,000 students in four courses on the Air Force Advanced Instructional System (AIS), Lowry AFB for 24 months ending 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. These reductions are probably due to periodic revisions in the courses (indicated on the figure) and to improved control over the new method of instruction; fluctuations are probably due, at least in part, to variations in student aptitude and to other factors that are presently unknown.

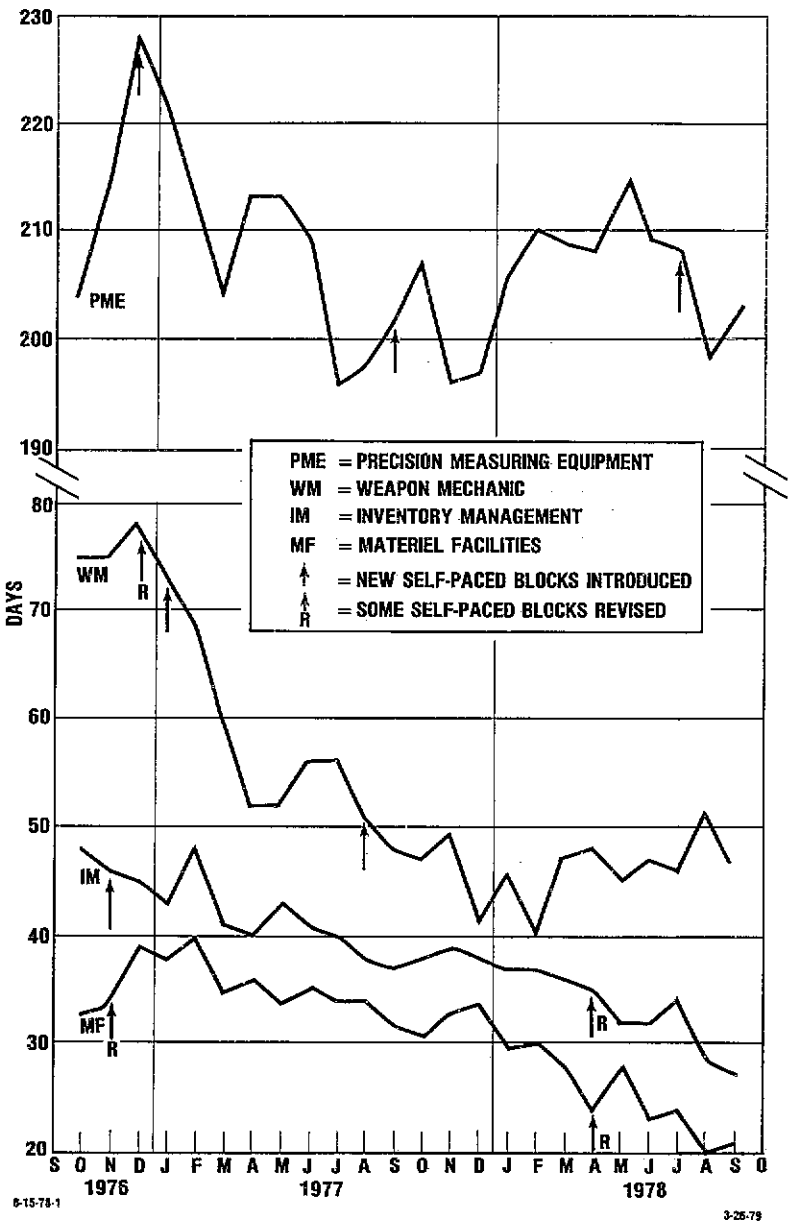

FIGURE 6. Days Required to Complete Four Courses on Air Force Advanced Instructional System, Lowry AFB, October 1976 - September 1978

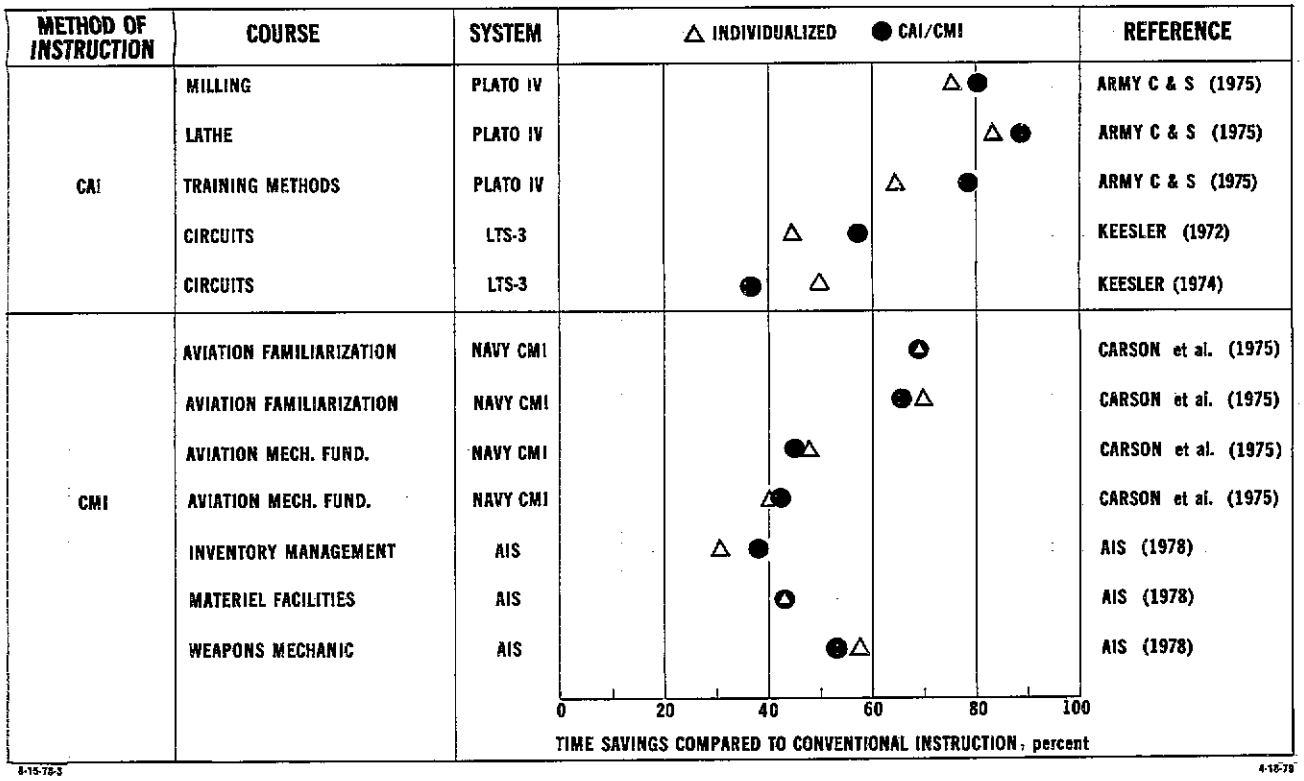

FIGURE 7. Amount of Student Time Saved, Compared to Conventional Instruction, by Individualized Instruction and by CAI or CMI on the Same Courses

Comparison of Time Savings Found with Individualized Instruction and Computer-Based Instruction. Student training time in courses can be reduced without the use of computer-based instruction, i.e., by individualized (or self-paced) instruction without computer support in place of conventional instruction. The question raised here is "what does computer support do that self-pacing does not do, at least with respect to the amount of student time saved?"

Figure 7 shows how much student time was required to complete twelve courses that were given, at various times, by conventional, individualized and CAI or CMI instruction. Only the percent time saved, compared to conventional instruction, is shown. There are only small differences between the amounts of student time saved by these three methods of instruction; the data are summarized in Fig. 8. Individualized instruction can save large amounts of the time required by students in conventional instruction (average savings of 50 percent or more in these samples). The addition of CAI to five individualized courses produced an additional average time saving of 5 percent; the addition of CMI to seven courses produced no additional average time saving. No significance can be placed on the differential effect of adding CAI rather than CMI to the base values because no course was given in both a CAI and CMI mode. The addition of computer support may or may not be economical, depending on its impact, in specific applications, on the numbers of instructors and support personnel, administrative costs and similar factors. The issue of cost is not addressed by these data.

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

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FIGURE 8. Average Amount of Student Time Saved by Individualized Instruction and CAI or CMI in the Same Courses Compared to Conventional Instruction

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 should be a matter of concern. Meaningful data on student attrition should come from a steady-state application of computer-based instruction and not from short-term experiments. This condition was met marginally by the Air Force Advanced Instructional System (AIS), where four courses were increasingly implemented in a CMI mode over the period of 1974-1978 and by the Navy Computer Managed Instruction System, where data are available on seven courses for 15 months after implementation in March 1977. It should be recognized that the rate of attrition observed in a

course may also 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.

Figure 9 shows that academic attrition may have increased in the four courses on AIS during the period under observation. Note, however, that academic attrition appeared to rise in all (non-AIS) courses at Lowry AFB over the same period; thus, it is not necessarily true that the increased attrition in the AIS courses can be attributed primarily to the introduction of CMI.

Figure 10 shows academic attrition for seven courses before and after implementation on the Navy Computer Managed Instruction System. The average rate of attrition in these courses was 3.2 percent before and 4.6 percent after implementation in a CMI mode; it increased in six courses and decreased in one. Data on comparable courses not on CMI during the same period were not provided.

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

Attitudes of Students and Instructors. Attitudes of students and instructors to CAI or CMI, in comparison with conventional instruction, are noted here only as qualitative aspects of these methods of instruction; they are not direct measures of effectiveness. Data on student attitudes are found in 39 of the 48 reports of military training summarized in this paper. As shown in Figure 11, students overwhelmingly prefer CAI or CMI to conventional instruction, or at least say so when asked; students are favorable to CAI in 29 of 40

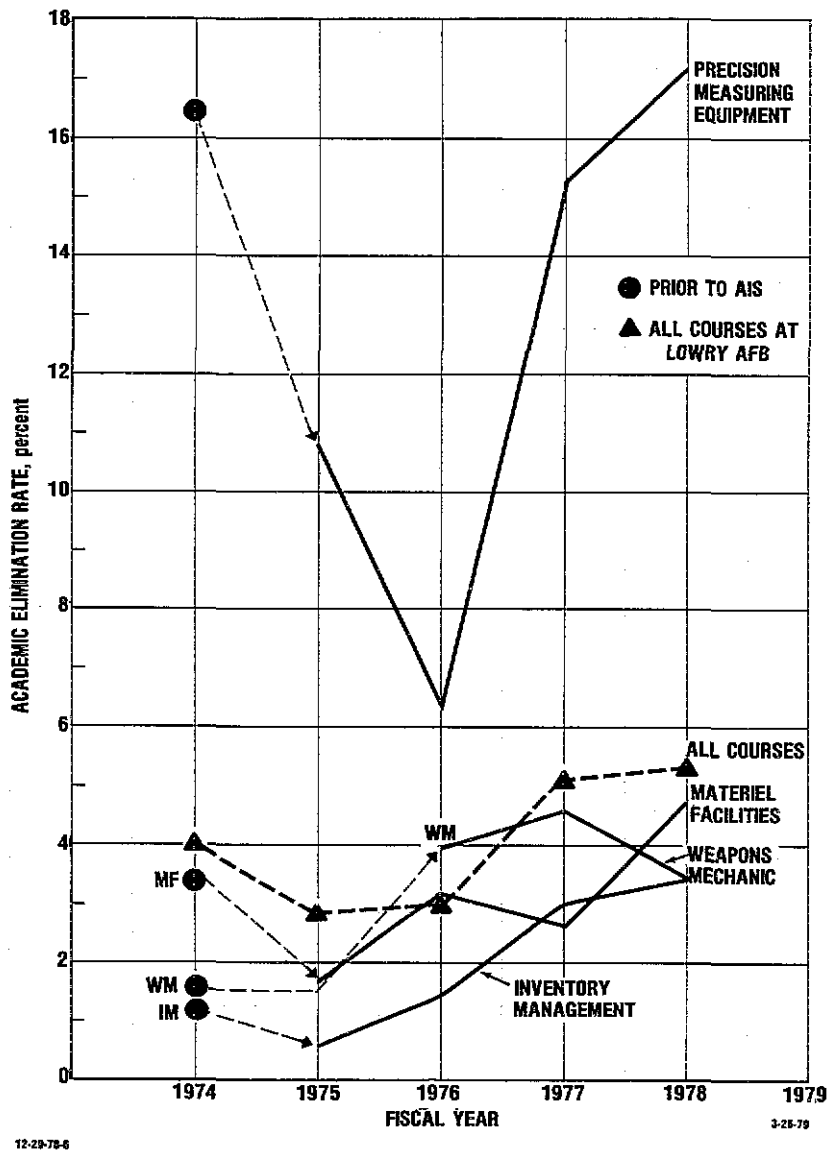

FIGURE 9. Academic Elimination Rate in Four Courses Before and After Implementation on AIS at Lowry AFB

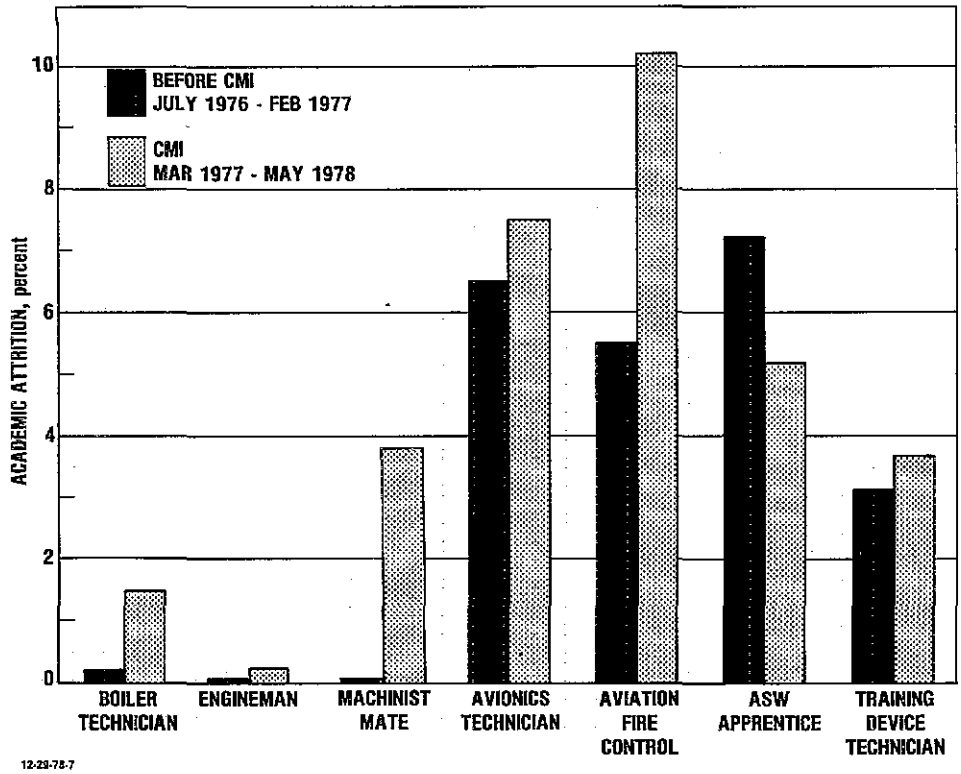

FIGURE 10. Academic Attrition in Seven Courses Before and After Implementation on Navy Computer Managed Instruction System

Attitude to CAI/CMI	Students		Instructors	
	CAI	CMI	CAI	CMI
Favorable	29	8	1	-
No difference	1	-	-	-
Unfavorable	1	-	4	4[b]
No report	9	-	39	4
Total	40	8	40	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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FIGURE 11. Attitudes of Students and Instructors Comparing CAI or CMI to Conventional Instruction in Military Training (a)

comparisons; they are unfavorable in one case and find no difference in another; no data are provided in 9 cases; they are favorable to CMI in all cases (N=8). Instructor attitudes are reported only in 9 of these 48 comparisons; instructors are unfavorable to CAI or CMI in 8 of these cases and favorable to CAI only in one.

Instructors of courses taught by CAI or CMI have not received much attention by researchers. The training of instructors is still oriented largely towards conventional instruction and instructors receive little guidance on how to properly conduct CAI or CMI courses.

THE COST OF COMPUTER-BASED INSTRUCTION

The cost of computer-based instruction is not a popular subject for examination; only eight of the 30 studies cited above provide any cost data;

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.

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FIGURE 12. Number of Sources of Data on Costs of Instruction

only five consider the cost-effectiveness of computer-based instruction.

Data on the Costs of Instruction. Figure 12 identifies the various resources needed to conduct instruction, broken down according to type or function. All methods of instruction require resources (for example, for program design, instructors, materials and facilities); CAI and CMI, in particular, require resources for computer systems and software. Relevant cost data could be found for some but not all of these types of resources. Figure 12 shows the number of sources of data we were able to find on the costs of each of these resources for various methods of instruction; blank spots indicate that relevant cost data could not be found. The data that were found were meager at best. These data are summarized in many tables in the original report. (1) The following points may be noted: (a) There are few data on the costs of conventional instruction and individualized instruction. (b) More cost data could be provided by converting student time savings into cost savings, on the basis of student pay and allowances. (c) There is no convenient way to summarize the available cost data in a single table.

The Cost of Computer Systems Hardware. There may be some interest in discussing the costs of central processors and terminal units, for selected instructional systems. The costs shown in Fig. 13 are limited to hardware and do not include the costs of preparing instructional materials, programming, instructors and the like; note that the cost data are for 1978 and some earlier dates.

System hardware costs can be expressed in three ways: (a) system procurement cost, (b) cost per terminal connected, and (c) cost per student-hour

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

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[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.

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FIGURE 13. Costs of Computer Systems Hardware

(over some chosen amortization period). In terms of computer system hardware, procurement costs can range from about $35,000 (the stand-alone GETS) to over $10 million (a 1,000-terminal PLATO IV system), a factor of close to 300 times. On a per-terminal basis, there appears to be an inverse relationship between system size and cost. As an example, for the TICCIT system, the per-terminal system cost is $27,000 in a 32-terminal configuration and $10,000 in a 128-terminal configuration. This indicates a substantial economy of scale for larger systems.

A more meaningful relationship for comparing computer-based instruction with other methods of instruction is the cost per student-hour. Assume that terminals are used 2000 hours per year and that the system hardware lasts 5 years; then, the cost of hardware per student hour for CAI systems ranges from about $1.00 (for the 128-terminal TICCIT system) to $3.50 (GETS); PLATO IV costs about $1.50. The lower cost per student-hour 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 for CMI 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.

THE 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. Figure 14 summarizes the results of these studies. All of these studies are based on the premise that the amount of student training time saved by a method of instruction indicates 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 student time savings in studies of 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 include some other costs, such as for preparing course materials, purchase or use of computers, and the number of instructors required by each method of instruction.

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 5,500 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 was 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

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
	PLATO IV	A	Aberdeen	65 - 89	3	535	–	PLATO IV not cost-effective [1]	U.S. Army Ordnance Ctr. and School (1975)
CAI	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 Gilman (1977)
Conventional (revised course)	–	N	Memphis	50 [4]	4	480	300 per class per week	$ 6M [5]	Carson, Graham, Harding, et al. (1975)
	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	–	–	–	–	$ 8.9M FY 75 [7]	Briefing material (1978)
							–	$ 9.8M FY 76 [7]	Briefing material (1978)
							52,672 graduates [8] (actual)	$10.0M FY 77 [7]	Briefing material (1978)
CMI	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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FIGURE 14. Summary of Studies Reporting Cost Savings and/or Cost-Effectiveness of Various Methods of Instruction

Center and School, Aberdeen Proving Ground, Maryland, 1975; 1261 students in four courses at Chanute AFB, Illinois, 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 results are based on incomplete cost data, the findings should not be generalized or taken as conclusive.

Other benefits, beyond those of saving student training time, are often said to occur with CAI or CMI, because of the many services that can be provided by a computer. The following list illustrates a variety of claims that have been made:

1. More precise data for improving and updating course materials
2. Improved control over equipment, facilities and materials for instruction
3. Improved allocation of resources among students
4. Improved ability to accommodate fluctuations in student loads
5. Reduced instructor:student ratios (including the ability to use less-qualified instructors)
6. Reduced need for support by non-instructional personnel
7. Reduced time of students on base waiting for courses to start
8. Reduced time of students on base waiting for travel orders after completing courses
9. Improved integration of personnel records of students at school
10. Improved utilization of instructors.

Few of these potential benefits have been included in any cost-effectiveness evaluation known to us. The AIS Service Test (1978) estimated the numbers and costs of instructors required for individualized and computer-managed instruction by observing what instructors were doing in each case. Records kept on the AIS show that the amounts of time spent by students at Lowry AFB waiting to enter a course and waiting for an assignment after completing a course have been reduced for those instructed by AIS. Records kept by the Navy CMI system show that, because of course time reductions,

the average on board count of students in school has been reduced for those instructed by that system. However, the cost savings, if any, implied by these reductions were not included in any of the cost-effectiveness analyses.

CONCLUSIONS

1. 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.

2. 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.

3. 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 student time saved by computer-based instruction 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.

4. 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.

5. Student Attrition. Computer-managed instruction may increase the rate of student attrition for academic reasons, compared to that with conventional instruction. However, the observed increases in attrition may also be due to decreases in student quality; the influence of this factor has not been carefully examined. No data have been reported on student attrition with computer-assisted instruction.

6. 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 method of instruction.

7. 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.

8. 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 all of the 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.

REFERENCES

1. This paper is based on a study performed for the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology). See Jesse Orlansky, and Joseph String, "Cost-effectiveness of Computer-Based Instruction for Military Training", IDA Paper P-1375, Institute for Defense Analyses, Arlington, Virginia 22202, April 1979 (DDC AD 073 400).

2. Military Manpower Training Report for FY 1981, Department of Defense, March 1980, p. III-3, V-4 to V-11, 6, 4.

3. Carpenter-Huffman, P., MODIA, R-1701-AF, The Rand Corporation, Santa Monica, California, 1977.

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