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ABSTRACT

The Computer Assisted Instruction (CAI) Division of the U.S. Army Signal Center and School (USASCS) at Fort Monmouth, New Jersey evaluated CAI's success in teaching basic electronics. An initial feasibility study, interim assessments, and a summative evaluation assessed the value of the developmental, user-oriented, individualized CAI programs created by the USASCS. The CAI material was presented in the tutorial mode on the IBM 1500 System, utilizing the IBM Coursewriter language, an IBM 1510 Display Console, and an IBM 1512 Image Projector. CAI and conventional instruction were compared with respect to student achievement in the first four weeks of the electronics course and their achievement in the fifth and sixth weeks; attitudes toward CAI were also assessed. A matched group statistical design was employed, and fixed effects analysis of variance and t-tests for equivalent groups used to analyze data. The results indicated that CAI is as effective as, or better than, conventional instruction in teaching basic electronics, demonstrated CAI's capability to reduce training time by 35%, and revealed student satisfaction with the CAI methods. These favorable findings have contributed to the recommendation that the Army continue to expand its CAI capabilities. (PB)

COMPUTER ASSISTED INSTRUCTION DIVISION
US ARMY SIGNAL CENTER AND SCHOOL
FORT MONMOUTH, NEW JERSEY

A SEQUENTIAL EVALUATION OF COMPUTER ASSISTED INSTRUCTION IN US ARMY BASIC ELECTRONICS TRAINING

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ANNUAL CONVENTION OF
THE ASSOCIATION FOR THE DEVELOPMENT OF
INSTRUCTIONAL SYSTEMS

AT

ECOLE NORMALE NOTRE-DAME DE FOY
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A Sequential Evaluation of Computer Assisted Instruction in US Army Basic Electronics Training

Introduction

The Computer Assisted Instruction (CAI) Division of the US Army Signal Center and School (USASCS) at Fort Monmouth, N. J., recently completed a series of evaluations of CAI in teaching basic electronics in the US Army. This series of studies included an initial feasibility study, several interim investigations and a final summative evaluation. Each successive study, which dealt with an increased amount of electronics instructional material, offered supportive evidence in favor of CAI. The aim of this paper is to synthesize the basic results of these studies and indicate the direction toward which CAI at USASCS is headed.

Before launching into the various study findings, some brief notes are appropriate at this point regarding the general "modus operandi" and the specific instructional mode and computer hardware utilized thus far at the Signal School. First, the CAI effort at the Signal School is not oriented toward research per se but development, operational use and evaluation. As with any new technology, CAI is being subjected to many hard questions regarding the feasibility, efficiency and cost, and early answers are expected. In order to meet this challenge squarely, the Signal School opted for a user-development approach in CAI. On the one hand, the CAI instructional programmers are challenged to make optimum use of the CAI capability for individualized instruction; on the other hand, the systems analysts are challenged to make optimum use of the CAI hardware/software capabilities. Subsequent to the CAI course development, testing and debugging, the integrated CAI course package is taken out of vacuum existence and immersed in a real-time Army training milieu to determine if it will "sink or swim" in terms of Army training criteria.

Secondly, it should be noted that the CAI material developed at the Signal School is designed in accordance with the tutorial mode of instruction. In this mode, primary emphasis is placed on the presentation of instructional material to the student according to an instructional logic formalized in detail. The material and its sequence of presentation vary to fit the individual characteristics of the student. Thus, in a sense, each CAI student interacting with the computer has his own private "tutor". Therefore, strictly speaking, in accordance with customary evaluation procedures, the results of this study are generalizable only to the tutorial mode of CAI. Therefore, no implication is suggested from the results to be discussed that CAI under any mode (drill and practice/dialogue/problem solving/inquiry) is applicable for teaching Army basic electronics. These must receive independent verification.

Thirdly, it should be noted that the specific hardware medium of instruction by which this tutorially prepared material was presented was the IBM 1500 System which utilizes the IBM Coursewriter language, an IBM 1510 Display Console (CRT/light pen/keyboard) and an IBM 1512 Image Projector. With respect to the CAI terminal configuration employed, the assumption is made that given other such hardware, having the same basic configuration, similar findings may be expected. Therefore the results are not hardware specific. However, an intriguing experimental-statistical question poses itself: given more or less sophisticated CAI terminal hardware will there be a corresponding improvement/decrement in student achievement, completion time, and attitude. This can only be speculated upon at the present. An experimental answer to this question can only be given when computer hardware itself can be introduced as an independent variable for study (i.e., different types and degrees of hardware configurations). This will be a continuing challenge as new hardware and software innovations are introduced into the market.

Methodology

Before I commence the presentation of the various study findings, a brief overview of the evaluation objectives and procedures also would be pertinent at this point. From an evaluation perspective, specific emphasis is put on the following topic areas: design, performance, measurement, analyses and ultimately, given success, application. Paradigmatically, in the logical flow of things, the development of the evaluation design was subsequent and contingent upon the development of CAI material. Inherent in the evaluation design were requirements for the identification of study goals and variables and the determination of the necessary measurement instruments and data collection/analyses procedures. These were all prerequisites to an adequate field testing of the CAI material.

While some variations necessarily existed between studies, the specific objectives, variables and instruments of the several sequential investigations of CAI were fundamentally the same. This enabled direct comparisons among the study results and particularly insured the possibility for empirical replication of all basic findings observed in the initial feasibility study. Briefly stated, the ultimate objectives were threefold:

A. Compare achievement on the first four weeks of basic electronics as taught by 2 different methods of instruction (CAI/CI) at 3 different aptitude levels (Hi/Med/Lo).

B. Follow-up student achievement in Phase III (Wks 5-6).

C. Survey student attitudes toward CAI/solicit comments. Achievement, here, is broadly defined to include three standard criteria of student performance: test achievement (written/performance), class attrition, (setbacks/failures) and time to complete training. In experimental terms, the variables under study were threefold: independent, dependent and matching. The indpendent variables were: (a) training method (CAI/CI) and (b) aptitude level (Hi/Med/Lo): the dependent variables were (a) achievement measures (continuous/categorical). (b) completion time and (c) attitudes; and, the matching variable was a statistically weighted composite of 4 subtests of the Army Classification Battery. These subtests and the resulting multiple linear regression equation in raw score form are contained in Figure 1.

$$Y = .34\,ELI + .31\,AR + .18\,PA + .05\,ARC - 1.23$$

where:

Y = Predicted Ph I Score
ELI = Electronics Information Score
AR = Arithmetic Reasoning Score
PA = Pattern Analysis Score
ARC = Army Radio Code Score

Figure 1

Predicted Score Equation

The data collection and analysis procedures for each of the studies conducted were based upon requirements for a matched group statistical design. In regards to the data collection, the final training paradigm for the experimental and control groups is shown in Figure 2. In actuality, two pools of students were

Study Group	Phase I (Wks 1-2)	Phase II (Wks 1-4)	Phase III (Wks 5-6)
Experimental	CAI	CAI	CI
Control	CI	CI	CI

Figure 2

Training Mode for Experimental/Control Groups

obtained representing the two study groups. Since the CAI pool was quite limited in size, a matched CI counterpart for every CAI student was selected from the larger CI pool on the basis of the predicted score indicated above.

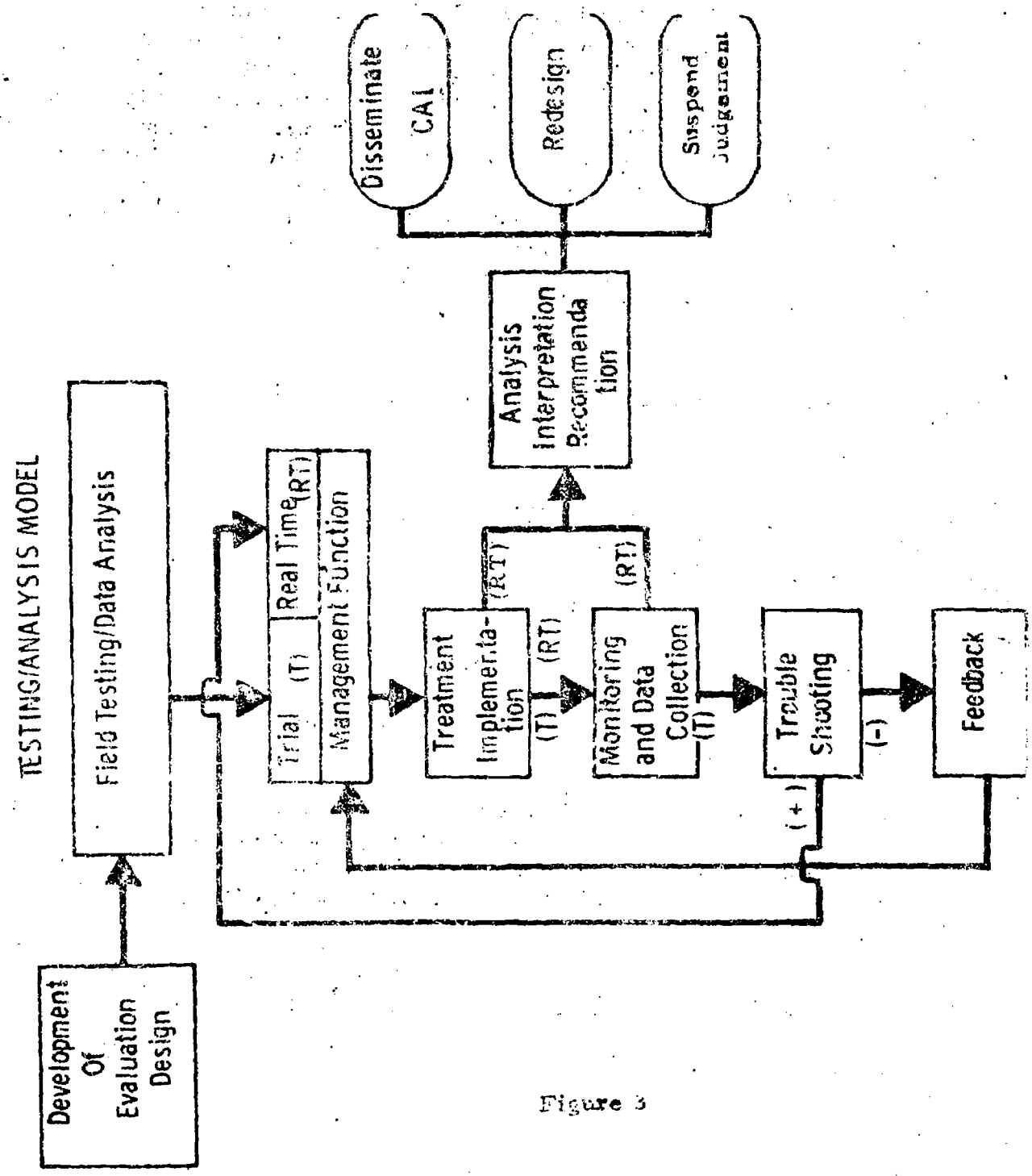

Figure 3

For the sake of administrative expediency, this matching process was conducted "after the fact" (after training). Lastly, the data analyses for all the separate studies was represented by 2 basic statistical models: the fixed effects analysis of variance (ANOVA) and the t test for equivalent groups (matching by pairs), as appropriate. Thus, in summation, subsequent to the development of the CAI course material and the evaluation design, the CAI material was subjected to testing, analysis and appraisal as indicated in Figure 3.

This included trial testing of CAI material both by the instructional programmers and small representative samples of students, troubleshooting and debugging as necessary, and then real-time field testing with a random selection of incoming draftees and Regular Army students. On the basis of an analysis and interpretation of these results, recommendations are made as appropriate (disseminate, redesign, suspend judgement).

Basic Findings

The subject matter of the several studies to be discussed encompassed the first four weeks of Army basic electronics in varying degrees. As each week of electronics material was programmed for CAI, a separate comparative analysis of the total cumulative amount of CAI material versus its counterpart CI block of material was conducted. Thus, between the feasibility study (Wk 1) and the final summative evaluation (Wks 1-4) there were many interim evaluations representing increased sampling of course material and students. For the purposes of this paper, only the more salient cumulative evaluations will be discussed.

I Feasibility Results (Wk 1)[2]

The initial CAI feasibility study was based on the first week of basic electronics material taught by the Common Subjects Branch of the Department of Specialist Training, USASCS, Fort Monmouth. The basic design and results are contained in Tables 1-4. As indicated in Table 1, the feasibility study

Table 1

Experimental Design

Aptitude Levels	Instructional Methods			
	CAI	TV	IC	
High	6	6	6	18
Medium	6	6	6	18
Low	6	6	6	18
N	18	18	18	54

considered 3 training methods (CAI/TV/IC) at 3 aptitude levels (Hi/Med/Lo). (N.B., IC = Instructor Controlled). With 6 replications of the experiment, this yielded an n of 18 per method and a total N of 54. An analysis of the pretest and post test data (Tables 2, 3) indicated that all 3 treatment groups exhibited equivalent achievement both prior to and after their respective treatments.

Table 2

Analysis of Pretest Data

Source	d.f.	Mean Square	F Ratio	p
Instructional Method	2	97.02	1.19	n.s.
Aptitude level	2	3044.02	37.49	.001
IM x AL	4	39.80	0.49	n.s.
Residual	45	81.20		
Total	53			

This result held true across all three aptitude levels, as indicated by a non-significant interaction effect. As expected, the aptitude level differences in both situations were significant.

Table 3

Analysis of Post Test Data

Source	d.f.	Mean Square	F Ratio	p
Instructional Method	2	90.39	1.27	n.s.
Aptitude Level	2	5037.56	70.86	.001
IM x AL	4	64.11	0.90	n.s.
Residual	45	71.09		
Total	53			

A summary of the CAI students completion time for Week 1 material is contained in Table 4. In comparison with the fixed instruction time of 11.25 hrs for the TV and IC methods, the CAI group demonstrated a mean time of 10.03 hrs, a 10.8% reduction in training time.

Table 4

Summary of CAI Student's Course Time

Aptitude Group	Mean (Hrs)	Range (Hrs)
High	5.69	3.92 - 6.60
Medium	9.35	7.02 - 11.00
Low	15.00	9.65 - 17.85
Total Group	10.03*	3.92 - 17.85

*This represents a 10.8% time savings as compared with 11.25 hrs for conventional instruction. Later CAI program refinements indicate greater time savings to be possible.

II Feasibility Study Follow-up (Wk 1)[3]

Subsequent to the feasibility study, a follow-up study (Longo, 1969) was conducted on a slightly revised version of the Week 1 (11.25 hrs) course material. Based on feedback obtained during the conduct of the feasibility study, a few lessons were consolidated for clearer presentation. The primary results of this follow-up study are contained in Table 5. As illustrated, based on an N of 278 per study group, there was no significant difference between the mean achievement scores for the two study groups. Thus, the two groups were equivalent on achievement. However, with respect to completion time, the CAI group showed a substantial reduction of 20.1% relative to a matched group of CI students. These results essentially replicate the main effects of the feasibility study regarding test achievement and completion time.

Table 5

Achievement/Time: CAI vs CI
(Week 1)

Criteria	N	CAI $\bar{X}$	CAI SD	CI $\bar{X}$	CI SD	Evaluation
Achiev. (Scores)[3]	278	61.92	13.25	62.44	12.84	Equiv.[1]
Time (Hrs)	278	9.99	3.02	11.25	—	20.1% reduction

[1] t test (matched groups)

[2] Fixed time for all S's: no variation

[3] Criterion test: 85 items

III Interim Results (Wks 1-2)[1]

As more weeks of basic electronics material were programmed and made operational, a series of interim evaluations was conducted. Since many of the evaluations were intermediate, based on increasing tabulated N's, only the results based on the final tabulated N's will be discussed. The next logical cumulative break in course material came at the end of Wk 2. The first set of interim results (paper by Giunti and Longo, 1971) are contained in Table 6. Based on an N of 155 per study group, the test achievement results indicated a significant mean difference (t: $<.05$ level) in favor of the CAI group on the Phase I (Wks 1-2) performance test and final average score. However, no significance was obtained for the written test mean difference. This represented a slight improvement over prior results on test achievement. With respect to test failures, the results demonstrate a significant difference (X^2: $<.01$ level) in the rate of failures on the performance test, again in favor of the CAI group. However, the two groups had equivalent failure rates on the written test and total Phase I failure incidence. Again, with respect to completion times, the CAI group exhibited a substantial reduction of 29% relative to an equated group of CI students. As before, it was concluded that these interim results replicated the essential findings of the feasibility study, with even greater time reduction for the CAI group.

Table 6

Achievement/Failures/Time
CAI vs CI: Phase I
(Weeks 1-2)

Criteria	CAI (N-155)		CI (N-155)		Differ.	t/X^2	p
	$\bar{X}$	SD	$\bar{X}$	SD			
PRED. SCORE[1]	102	10.6	102	10.6	-	N.S.	
ACHIEVEMENT[2]							
WRIT	101	19.4	100	19.1	1	N.S.	
PERF.	107	16.9	103	18.1	4	2.34	.05
PH I AVG.	104	16.9	101	17.3	3	2.03	.05
FAILURES[3]							
WRIT.	24		30		6	N.S.	(20% reduct.)
PERF.	13		31		18	8.50	.01
PH I	26		33		7	N.S.	(21% reduct.)
TIME	HR:MIN		HR:MIN				
	29:55		42:00		12:05	(29% reduction)	

[1] MATCHING VARIABLE

[2] STANDARD SCORES

[3] INCIDENCE

IV Interim Results (Wk 3)[1]

The end of Week 3 provided the next logical break in the course material. The results for this phase pertain to Week 3 achievement only. This second set of interim results (presented in the above same paper) is contained in Table 7. Based on an N of 121 per study group, the mean difference between the two treatment groups on the written achievement test was not significant. However, the

Table 7

Achievement/Failures/Time
CAI vs CI: Phase II
(Week 3)

Criteria	CAI (N=121)		CI (N=121)		Differ	t/X^2
	$\overline{X}$	SD	$\overline{X}$	SD		
PRED. SCORE[1]	104	9.3	104	9.3	-	N.S
ACHIEVEMENT Writ.	114	16.3	111	21.3	3	N.S
FAILURES[2]	N		N			
	0		7		7	
TIME	HR:MIN		HR:MIN			
	23:02		30:00		6:58	(23% reduction

[1] MATCHING VARIABLE

[2] INCIDENCE

results were in favor of the CAI group. Furthermore, it is noteworthy that the CAI failure rate was zero in contrast with seven failures for the CI group. Lastly, in regards to time to complete training, the CAI students completed Week 3 training in 23% less time than required for the CI group.

V Final Results (Wks 1-4)[4]

After the instructional programmers had developed the fourth week of basic electronics for CAI, plans for a formal evaluation of all four weeks of instruction were implemented. The formal evaluation was conducted between Mar and Dec, 1971. The results were published recently in a technical report at USASCS (Longo, 1972). The basic results of that study are summarized in

Tables 8-11. As in the prior studies, the final formal evaluation was a comparison between CAI and CI on the accepted criteria of test achievement, attrition, completion time and attitudes. The study was comprised of 3 course phases (Wks 1-6) which entail 102 hours of instruction. As indicated earlier, the design basically called for a four week comparative evaluation between two different methods (CAI/CI) and a follow-up of both methods into two weeks of conventional training only.

The test achievement results for the two study groups are contained in Table 8. Based on two equally matched groups with N's of 139 (CAI) and 142 (CI), the mean differences between the two groups were all in favor of the CAI group. Two of these mean differences (Ph I performance/Ph III Written) were statistically significant.

Table 8

Test Achievement
CAI vs CI: Phases I - III
(Wks 1-6)

	Matching Score	Ph. I			Ph. II			Ph. III**		
		N	WT	PT	N	WT	PT	N	WT	PT
CAI	102	139*	77.4	80.9	120	78.2	84.5	116	78.5	82.6
CI	102	142	76.4	78.7	126	77.2	82.6	119	76.4	80.7
Diff			+1.0	+2.2		+1.0	+1.9		+2.1	+1.9
Sig Level			NS	.05		NS	NS		.05	NS

*3 Admin drops in Ph. I

**CAI S's took CI in Ph. III

Bearing in mind that the CAI group was subjected to CI training in Phase III (Wks 5-6) after 4 weeks of CAI, the follow-up results lend support to the statistical integrity in the trend of the mean differences in favor of CAI and suggest that a satisfactory degree of retention and transfer of learning is attainable via CAI.

The results on the incidence of academic attrition are contained in Table 9. Again a comparative analysis between the two study groups was performed. Based on the total entering N's of 142 per group, the CAI group exhibited, in absolute percent reduction terms, a 21% reduction in attrition

relative to the CI group. Another salient aspect of the attrition data suggests that CAI identifies academic failures much earlier in the training pipeline.

Table 9

Phase Attrition
CAI vs CI: Phases I - III
(Wks 1-6)

Phase	CAI			CI		
	Nt	Na	%a	Nt	Na	%a
I & II	142	21	15	142	20	14
III	116*	2	2	119*	9	8
Totals	114	23	16	110	29	20

*Excludes Ph I/II admin drops

Key: Nt = # of S's entering Phases
Na = # of academic drops
%a = Percent attrition $\left(\frac{Na}{Nt}\right)$

The next data of crucial importance is that of completion time which is illustrated in Table 10. Based on N's of 139, 142 for the two study groups respectively, the results show a significant difference (t: .01 level) in completion time in favor of CAI, for both Phases I/II. Again, using CI as a base, the CAI group demonstrated approximately 35% reduction in training time for the basic four week block of electronics instruction. It should be noted that this is the first time wherein the results reflect recycling of students within CAI.

Student recycling in CAI is analagous to student setbacks in conventional training. Therefore, these time results more truly reflect the time parameters for a real-time CAI training system. The cumulative time reduction for Ph. I/II combined was 36.9% for the select group who successfully completed Phase II. As explained earlier, the CAI group took CI training in Phase III along with the CI group. Thus, the almost equivalent completion times for the two groups in Phase III is understandable.

Table 10

Training Time
CAI vs CI: Phases I - III
(Wks 1-6)

	N	Ph. I (Wks 1-2)	N	Ph. II (Wks 3-4)	N	Ph. III (Wks 5-6)
CAI	139	34.76	120	46.08	116	66.21
CI	142	53.83	126	71.43	119	70.08
Diff		19.07		25.35		3.87
% Reduction		35.4		35.5		5.5

Norm: CI Base Time

Ph I - 42 hrs
Ph II - 60 hrs
Ph I - 60 hrs

The last topic of discussion and very much of interest concerns student attitudes toward CAI. It is not sufficient that a product merely work but that it be esthetically appealing to the consumer. Therefore, the assessment of student attitudes toward CAI has been given due focus along with the above evaluation considerations. An attitude questionnaire composed of 22 Likert type items was constructed to ascertain overall student preference toward/against CAI. The questionnaire consists of two parts: (a) Part I contains 11 items comparing CAI with CI; (b) Part II contains 11 items relating to the CAI

environment alone. In order to determine the reliability of the attitude index, a pre-post CI attitude measure was obtained. Thus, the questionnaire was administered at the end of CAI (Wk 4) and again at the end of CI (Wk 6). The attitude results are contained in Table 11. Based on N's of 138 (Wk 4) and 121 (Wk 6), (not all failures were available for retesting), the results show that the CAI students generally favor CAI on both parts of the questionnaire and at both points in time (before and after being exposed to CI).

Table 11

CAI Group Attitudes
(Ph. I-III: Wks 1-6)

Phase	N	Part I $\bar{X}$	Part II $\bar{X}$	EVALUATION
Ph. I/II Wks 1-4	138	43	44	Pro-CAI
Ph. III Wks 5-6	121	39	43	Pro-CAI

Score Norms

55 = Maximum Pro-CAI
33 = Neutrality
11 = Maximum Pro-CI

These attitude results are in complete agreement with all interim attitude measures obtained at the end of each week of training during the development of the CAI material. Thus far, increasing amounts (up to 102 hrs) of CAI material has not had any deleterious effect on overall student attitudes toward CAI.

Resume

The above results are intended first to provide a snapshot of the more salient CAI evaluation findings obtained at USASCS. For more detail, of course, the reader is referred to the original reports listed in the reference section at the end of this paper. Further, on the level of main experimental effects, the second aim of this paper is to illustrate, in reference to the initial feasibility study, the high degree of replication obtained across several interim studies and the final summative evaluation, despite increasing amounts of instructional material encountered by each sequential evaluation. The generality of the findings across these reports clearly indicates that CAI is as effective as CI in teaching Army basic electronics, and further demonstrates the capability of CAI to reduce training time to a significant degree (approx. 35%). Similarly, the favorable average findings on student attitudes toward CAI remained essentially unchanged across all interim and final reports, also unaffected by the amount of CAI material administered. When considering that the differential in training material across these studies ranges from 11 1/4 hrs to 102 hrs, the significance of the obtained parallel findings (achievement/time/attitudes) greatly dispels any notion that the results obtained thus far have been fortuitous or novelty effects.

Direction

The favorable results attained from the development and applications of CAI at USASCS has been received with much interest by the Department of the Army. Recently, the US Continental Army Command established a Task Group to investigate the cost effectiveness and academic justification for the application of CAI to those installations where technical training was emphasized. Among other things, the major recommendation of the Task Group was that the Army continue to expand its CAI capability by conducting a prototype development, test and evaluation of a large scale CAI system which encompasses a multiprocessor minicomputer concept.[5] The Signal School, Fort Monmouth, has just been selected as the prototype site. In conjunction with support from the Human Resources Research Office (HumRRO) and a system contractor yet to be selected, the prototype task will be accomplished, in several phases, over a period of four years. It is anticipated that a systematic prototype development will affirm the positive findings obtained thus far, and contribute substantially to the evolution of CAI in the US Army.

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