DOCUMENT RESUME

ED 319 357 IR 014 121

AUTHOR Levin, Henry M.; And Others
TITLE Cost-Effectiveness of Alternative Approaches to Computer-Assisted Instruction.
INSTITUTION Stanford Univ., Calif. Inst. for Research on Educational Finance and Governance.
SPONS AGENCY National Inst. of Education (ED), Washington, DC.
PUB DATE Nov 86
NOTE 81p.
PUB TYPE Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Cost Effectiveness; Effect Size; Elementary Secondary Education; *Mathematics Achievement; Meta Analysis; *Reading Achievement

ABSTRACT

Operating on the premise that different approaches to computer-assisted instruction (CAI) may use different configurations of hardware and software, different curricula, and different organizational and personnel arrangements, this study explored the feasibility of collecting evaluations of CAI to evaluate the comparative cost-effectiveness of several alternative CAI approaches. The analysis on which these evaluations are based was carried out in four stages: (1) a search was initiated for evaluations of different approaches to CAI that could be used for cost-effectiveness purposes; (2) each of the evaluations was reviewed in order to select those that met the criteria established for the study i.e., a single focus on CAI, common objectives, acceptability of evaluation methods, and availability of information for assessing costs; (3) effect sizes for the criterion of concern were estimated; and (4) the costs of each intervention were estimated. Analysis of eight K-12 CAI programs, in which the common educational outcome was that of reading and/or mathematics achievement, indicated great variation in effect size from study to study, and led to the conclusion that specific approaches to CAI and the realities of implementation account for differences in effectiveness. Data on the costs and effect sizes of each of the CAI programs selected for the study are provided in tables throughout the text and in the appendix of the report. (24 references) (GL)

IR

COST-EFFECTIVENESS OF ALTERNATIVE APPROACHES TO COMPUTER-ASSISTED INSTRUCTION

Henry M. Levin
David Leitner
Gail R. Meister

November 1986

Prepared for the National Institute of Education under a grant to the Institute for Research on Educational Finance and Governance, Stanford University. Henry M. Levin is a Professor in the School of Education and Department of Economics. David Leitner is in the Evaluation Department of the Portland (Oregon) Public Schools, and Gail R. Meister is a member of the professional staff of Research for Better Schools. Correspondence should be sent to Levin at CERAS Building, Stanford University, Stanford, CA 94305. Telephone 415 723 0840. The views expressed in this paper are those of the authors alone and do not reflect those of the institutions to which the authors are attached, Stanford University, or the U.S. Department of Education.

H. M. Levin, D. Leitner, and G. Meister
November 1986

COST-EFFECTIVENESS OF ALTERNATIVE APPROACHES TO COMPUTER-ASSISTED INSTRUCTION

I. INTRODUCTION

The instructional use of computers has spread rapidly among U.S. schools (Center for Social Organization of Schools 1986), and there is now a concerted effort to integrate them more effectively into the educational process. One criterion for evaluating the potential of the various approaches to computer-assisted instruction (CAI) is their cost-effectiveness, their costs for reaching particular objectives, such as raising student achievement in specific subjects. This paper reports some exploratory results from applying cost-effectiveness techniques to the evaluation of different approaches to CAI. It applies the same methodology that was used in comparing CAI with three non-CAI alternatives for raising student achievement in reading and mathematics (Levin, Glass, and Meister 1984 & 1987).

Most evaluations of educational interventions consider only the effects of alternatives and not their costs. But, all activities compete for available resources in addressing educational goals. The cost-effectiveness technique enables alternatives to be ranked according to their effe veness per unit of cost so that those alternatives can be chosen that maximize educational impact relative to an overall cost

constraint (Levin 1983).

Previously, a cost-effectiveness evaluation was undertaken of four educational interventions for raising mathematics and reading achievement among elementary school students (Levin, Glass, and Meister 1984 & 1987). The analysis revealed that peer tutoring was the most cost-effective approach, followed in decreasing order by a drill-and-practice version of CAI, reductions in class size, and an extension of the school day. The estimated effectiveness of peer tutoring relative to cost was four times as great as that of the CAI for mathematics, but about comparable for reading. Both approaches were considerably more cost-effective than reducing class size or extending the school day.

In a similar manner one can consider the cost-effectiveness of different approaches to CAI. Different CAI approaches may use different configurations of hardware, different curricula, and different organizational and personnel arrangements. Different applications also use different software for their instructional programs, even when they are addressing the same objectives. Some applications rely on minicomputers in which a central processing unit is linked to many student terminals, while others rely upon stand-alone microcomputers, and yet others link microcomputers electronically in local area networks. Sometimes the computers or terminals are located in computer laboratories, and sometimes they are dispersed among the classrooms of the school. Although all of these approaches are included under the

label of CAI, they represent different instructional interventions with potentially different costs and effects.

In this paper, several of these alternatives are evaluated according to their cost-effectiveness. The analysis on which these evaluations is based was carried out in four stages. First, we initiated a search for evaluations of different approaches to CAI that could be used for cost-effectiveness purposes. Second, we reviewed each of the evaluations in order to select those that met the criteria for inclusion in this study. Third, we estimated effect sizes for the criterion of concern, student achievement in mathematics and reading. Fourth, we estimated the costs of each intervention. Finally, we compared costs and effects among the interventions and explored their policy implications. The presentation that follows will review each of these procedures and their outcomes.

The search for CAI evaluations was based upon a three-part strategy. First, nationally prominent professionals in CAI were contacted by telephone and mail to obtain names of individuals or school districts that might have produced evaluations of CAI interventions. Requests were also sent to lists of participants at major national conferences on CAI. All responses were followed up, and successive nominations were sought from new respondents using a "snowball" sampling approach. Second, an appeal for evaluations was published in seven leading journals that specialize in the area of CAI. Third, a search was made among existing data bases that might provide references to

published and unpublished evaluations of CAI including ERIC and the Social Science Index.

The major purpose of this effort was to obtain studies that use recent computer and software technology. Accordingly, we were most interested in evaluations that had taken place in the 1980's rather than earlier ones from the 1960's and 1970's. The challenge of obtaining more recent evaluations is reflected by the fact that the most comprehensive study of the effectiveness of computer-based education in elementary schools, published in 1985, included 32 studies of which only five pertained to the 1980's (Kulik, Kulik, and Bangert-Drowns 1985). In a comparable study for secondary schools by the same authors, only five of 42 studies refer to the 1980's (Bangert-Drowns, Kulik, and Kulik 1985).

Our search yielded 88 evaluations (summarized in Leitner 1986). The evaluations ranged widely in terms of quality and focus. Of the 83 evaluations that indicated the year in which the CAI had been provided, 60 had been done in the years 1980-85. Almost three-quarters of the interventions had been implemented in elementary, middle, or secondary schools, and about one-fifth in colleges or universities. The remainder were taken from non-school sites such as workplaces and the military. About half focused on students of mixed-ability, one-third focussed on students of low ability, and the remainder addressed students of high ability. In terms of subject-matter, two thirds of the interventions pertained to reading or mathematics, with the

remainder distributed across a large number of diverse subjects.

Our purpose was not to do a cost-effectiveness analysis of all 88 evaluations, a task that would have been impossible, given the different educational levels, objectives, and variability in information. Rather, it was to select a reasonable sub-set that could be used for comparison purposes. Four criteria were used for selecting the evaluations that were eventually used for the analysis. These were: (1) a single focus on CAI, (2) common objectives, (3) acceptability of evaluation methods, and (4) availability of information for assessing costs.

(1) Single Focus on CAI

In many cases CAI is only a part of a larger intervention that includes other components in addition to CAI. It has been argued persuasively by Clark (1986) and Salomon and Gardner (1986) that evaluations of CAI have often overstated the unique effects of CAI by attributing both CAI and non-CAI impacts in such studies to the CAI. Many of the evaluations that we received were not designed to separate out the unique effects of CAI from those associated with other aspects of the instructional intervention. A good example of such a situation is the nationally-known Writing to Read program associated with IBM in where computers are used by young children to write words from which they learn to read (Murphy and Appel 1984). Since our research was designed to explore the cost-effectiveness of CAI alone, only those evaluations that were strictly limited to CAI were considered further.

(2) Common Objectives

Cost-effectiveness analysis is predicated upon a comparison of alternatives with common objectives. The reason for this is that policymakers are concerned with choosing those alternatives with the lowest cost for achieving any given result. Accordingly, evaluations of programs aimed at a variety of or different objectives are not easily comparable for policy purposes. We limited our analysis to those interventions that were designed to improve reading and/or mathematics achievement at the elementary and secondary levels. We chose these criteria because of the importance of these outcomes in public policy and because of the substantial availability of studies that addressed them.

(3) Acceptability of Evaluation Methods

Cost-effectiveness analysis requires reliable information on effectiveness that has been generated by a study that meets reasonable evaluation standards. Since we wished to study the effects of CAI on student achievement, acceptable evaluations had to provide information on achievement gains as calculated through the use of experimental or quasi-experimental designs (Cook and Campbell 1979). We were concerned not only with the purported achievement gains associated with CAI, but also the method by which those gains were ascertained. Of particular concern were the random assignment of students to experimental and control groups or the use of appropriate statistical controls in quasi-experimental approaches. Only those that met minimum criteria

for evaluation design and procedures were selected for further consideration.

(4) Availability of information for Assessing Costs

Our cost methodology requires specific and detailed information on the types and quantities of resources used in the intervention such as personnel, equipment, facilities, supplies, and so on (Levin 1983). However, relatively few of the evaluations had detailed and comprehensive descriptions of the interventions. Most provided only cursory information. In all but one case, it was clear that additional data would have to be gathered from the sites at which the interventions had taken place. Accordingly, we limited further consideration to those studies with good evaluations that showed some promise of providing useful data on resources through a follow-up. This meant that recent studies were favored over older ones. Older programs posed problems of locating knowledgeable personnel after a lapse of several years and risking errors inherent in human retrospection in constructing information from memory in the absence of documentary evidence. Even among newer studies we found that there was often little availability of systematic information on resources.

INTERVENTIONS USED IN THIS STUDY

Only eight of the evaluations, met all of the criteria that we set out. Table One provides a summary of the characteristics of the CAI interventions that are included in this study. For each intervention the table shows the year, the number of

TABLE ONE

Characteristics of CAI INTERVENTIONS

District Name	Year	No. Students	Subject		Grade Level			Hardware		Minutes Per Week
			Reading	Math	Elem.	Middle	High School	Micro	Mini	
Asbury Park	79-80	121		0			9-12		HP	20
Chelmsford	80-81	683	0		2-6	7-9			CCC	50
Kindersley	84-85	39		0	3; 5			Apple		50
Lafayette	80-81	200		0	3-6				CCC	50
Newark	83-84	440	0		2-6	7-9			CCC	50
		740		0	2-6	7-9	10-11			
Omaha	83-84	66	0		4			Apple		12
Pasco	82-83	429		0	3; 6				CCC	50
Salt Lake City	81-82	100	0		3	7		Apple		75 180

students that participated, subjects, grade levels, type of hardware, and configurations of microcomputers or computer terminals. Each of the interventions is described, briefly, below:

Asbury Park, New Jersey (1979-80)

The program in Asbury Park focused on secondary school mathematics (De Talvo and Pastuzyn 1982). It served 121 students in grades 9-12 in an ethnically and socioeconomically mixed urban high school. Computer software was integrated into the regular curriculum for four courses: Algebra I, Algebra II, Trigonometry and General Mathematics. The computer software consisted of 30 units that were developed locally and cross-referenced to the mathematics texts in current use. Computer instruction was provided through 16 terminals connected by telephone lines to a Hewlett Packard minicomputer located in the central office of the school district.

Computer activities included simulations, tutorial exercises, and basic programming. One to three computer sessions were provided for each software unit, and all such sessions were held in the computer laboratory of the school. Typically, the students' classroom teacher made the presentation on a specific topic. This was followed by a 20 minute student session at the computer that was supervised by the teacher for the computer laboratory. The sequence was completed by a class discussion on the presentation and computer lesson. Total computer time for a student in one of the CAI courses averaged about 500 minutes,

based upon 25 twenty-minute sessions over the year.

Chelmsford, Massachusetts (1980-81)

The Merrimack Education Center in Chelmsford provided CAI to disadvantaged students under Title I funding in 6 Massachusetts school districts (Metric Associates, Inc. 1982). The 16 school sites housed 4 terminals each for a total of 64 terminals connected to a minicomputer in Chelmsford. The hardware and curriculum were provided by Computer Curriculum Corporation (CCC) and included CCC's standard 10 minutes a day of drill-and-practice in mathematics and reading. In 1980-81, 683 students in grades 2 through 9 participated in the CAI reading program, and 346 from grades 1 through 6 participated in the mathematics.

Kindersley, Saskatchewan (1984-85)

This intervention consisted of using CAI as a drill-and-practice adjunct to the traditional mathematics instruction from January to May, 1985 (Hawley 1985). Twenty students from the third grade and 19 students from the fifth grade participate, using six Apple microcomputers that were placed in the classroom. While the rest of the class worked on other activities, five students at a time spent an average of 10 minutes a day on exercises that their mathematics teacher had chosen to comport with the topic and level of difficulty appropriate to each. (A sixth comp[illegible] was available as a spare.) The software utilized was Milliken's "Math Sequences." Third graders worked on addition, subtraction or multiplication, and fifth graders worked on multiplication, division, fractions, decimals, percents, and

measurement formulas.

Lafayette Parish, Louisiana (1980-81)

This program provided remedial mathematics instruction for disadvantaged students in grades 3 to 6, using the drill-and-practice curriculum of the Computer Curriculum Corporation (CCC) (Joint Dissemination Review Panel 1982). In 1980-81 the program was implemented in 2 schools for 200 Title I students. These students were pulled out of the regular classroom for 50 minutes a day for individually-prescribed mathematics activities of which 10 minutes a day was alloted to CAI. The CCC system was based on the use of a minicomputer with terminals and represents one of the most widely used systems for drill-and-practice across the nation.

Newark, New Jersey (1983-84)

The Newark CAI program that is included in this study consists of both reading and mathematics instruction for large numbers of students drawn from various ability groups, depending on the individual school site (Newark School District 1984). (Newark also had bilingual and enrichment CAI programs, but these were not considered in this study). In 1983-84 some 440 students in grades 2 through 9 and at 8 different school sites participated in the reading program during the school year. In the same year 740 students in grades 2 through 12 at 11 school sites participated in the mathematics program. Hardware and software were provided by CCC, using its drill-and-practice curriculum. The minicomputer provided by CCC was located in the

district headquarters, and terminals were connected through telephone lines to the participating schools. Each school had from 4 to 16 terminals. Hardware and personnel configurations varied among schools, but in all cases, students received 10 minutes of CAI a day for each subject in which they were enrolled.

Omaha, Nebraska (1983-84)

This intervention is based upon an experiment that employed CAI as a supplement to the traditional, basal reading approach in use in Omaha's elementary schools (Bryg 1984). Data from 66 fourth grade students in 5 classrooms were collected, although all students in those classes used computers. Over a period of 15 weeks, each student took one weekly 12 minute session on an Apple IIe computer located in the classroom. At the start of a new CAI lesson, the teacher spent 10 minutes introducing the CAI lesson to the class. Commercially available drill-and-practice software was used.

Pasco, Washington (1982-83)

Pasco's CAI program in mathematics served 429 students in third through sixth grades at an elementary school (Mc Connell 1983). Five terminals were linked through telephone lines to a minicomputer and CCC curriculum in Portland, Oregon. Students received 10 minutes a day of CAI in those areas of mathematics individually diagnosed as needing reinforcement. These were selected from among CCC's 14 available mathematics strands. The intervention that is evaluated lasted for one semester with 55-65

sessions per student at the computer and staffing by a full time paraprofessional.

Salt Lake City (1981-82)

Salt Lake's "Basic Literacy Through Microcomputers" was inaugurated in 1981-82 to improve reading and enhance typing skills for 60 third grade and 40 seventh grade students from one elementary and one junior high school (Reid Foundation 1983). Students walked in class groupings to a computer facility that was leased to the schools.

Third graders attended three one-hour sessions per week in the course of a semester for a total of 54 hours of computer use. Seventh graders attended three 25-minute sessions for a total of 22.5 hours over the semester. Software was prepared for the project by an independent producer. The resulting CAI curriculum was based upon a mastery approach to controlled reading where students were directed to type and verbalize a given set of letters, sounds, and words, and then move on to typing phrases, sentences, and stories. The students' regular classroom teachers presented lessons that reinforced the exercises that were presented on the computer.

Replicability of the Studies

Since we are considering the cost-effectiveness of different approaches to CAI, we are also concerned with the replicability of the results of the evaluations. That is, we want to be reasonably sure that if the intervention were adopted at another site, the results of the evaluation would be approximations of

those that would be produced. Four of the interventions (Chelmsford, Lafayette, Newark, and Pasco) are based upon the hardware, software, and utilization of the Computer Curriculum Corporation (CCC). These have been applied in hundreds of different sites over a number of years and are likely to be replicable in the forms used by the four sites in this study.

However, the four other interventions were established under circumstances that do not suggest that the results should be readily replicable at other sites. The Kindersley intervention was designed by and implemented under the Superintendent of Schools of the district who had a special interest in the procedures and outcomes, since they served as the basis for his doctoral dissertation. The Omaha study was also implemented and evaluated by a doctoral student for purposes of a thesis. In both Asbury Park and Salt Lake City, the design and implementation of the instruction was undertaken by those responsible for evaluation.

Bangert-Drowns, Kulik and Kulik (1985) showed that when evaluators were involved in secondary school CAI interventions, the effects were almost 80 percent higher than when they were not involved; Kulik, Kulik, and Bangert-Drowns (1985) found that the "evaluator bias" was almost 40 percent at the elementary level. We will include these studies in the comparison, but we will consider this bias in reviewing them.

EFFECTIVENESS OF THE INTERVENTIONS

Cost-effectiveness analysis requires that the measurement of

effects and costs be comparable among alternatives. To obtain comparable measures of effectiveness, we estimated the effect sizes on mathematics and/or reading of the intervention. Each of the evaluations was based upon comparisons between a CAI group and a control group. The difference in test score gains between the two groups after the intervention represents the effects of the CAI, providing that the two groups are strictly comparable. In some cases, the design was based upon random assignment of students to groups. In others, a matching non-CAI group was chosen for comparison. In the latter case, statistical analysis was used to assure that the two groups were statistically similar or to control for differences that might affect the achievement outcomes (Cook and Campbell 1979).

Following Glass, McGaw, and Smith (1981) the difference in test score gains was converted into an effect size that was comparable across interventions. The effect size is generally defined as the post-intervention difference in test scores between the two groups, divided by the standard deviation of the control group. Glass, McGaw, and Smith (1981) provide a number of methods for estimating effect sizes from different information bases, and we followed these procedures in this study. A similar approach was taken in the earlier analysis of cost-effectiveness of CAI and other interventions (Levin, Glass, and Meister 1984). The same method was also used by Kulik, Kulik, and Bangert-Drowns (1985) and Bangert-Drowns, Kulik, and Kulik (1985) in their comprehensive meta-analyses of computer-based education in

elementary and secondary schools.

Table Two shows the effect sizes for the eight CAI interventions included in this study. The first point of interest is the large range of effects among the different interventions, both across and within subject areas. Even if one considers only positive effects, the range varies from .16 to .72 for reading and from .09 to .66 for mathematics. The variation in results for Newark among the different levels in each subject and between remedial and non-remedial students is startling, with negative as well as positive effects. Although the actual effect sizes for Asbury Park, Kindersley, Omaha, and Salt Lake City are shown, these may be biased upwards by 40-80 percent (based upon the literature) relative to what might be found in an impersonal replication, given that the evaluators were also the implementors.

Average effect sizes across all sites and grade levels were .23 standard deviations for mathematics and .33 for reading. These can be compared with the results from a larger base of studies analyzed by Kulik and colleagues (Kulik, Kulik, and Bangert-Drowns 1985: 71) in which they report average effect sizes for CAI on student achievement in all subjects as .47 standard deviations at the elementary level, .36 at the secondary level, and .26 at the college and university level. Our data contain few observations above the primary level, but it does appear that declining effects are found between primary and middle schools in reading.

TABLE TWO

Effect Sizes for Eight CAI Projects

Project	Years	No. of Students	Subject Read	Subject Math	Level Prim	Level Middle	Level Secon
ASBURY PARK	79-80	55(21)		0.66			0.66(M)
CHELMSFORD	80-81	444					
Reading							
Prim.		186(172)	0.36		0.36(R)		
Mid.		85(70)	0.56			0.56(R)	
Math		173(151)		0.09	0.09(M)		
KINDERSLEY	84-85	42(39)		0.40	0.40(M)		
LAFAYETTE	80-81	200(94)		0.23	0.23(M)		
NEWARK	83-84						
Remedial							
Reading							
Prim.		(38)	0.72		0.72(R)		
Mid.		(31)	-0.17			-0.17(R)	
Math							
Prim.		(35)		0.30	0.30(M)		
Mid.		(89)		0.41		0.41(M)	
Sec.		(185)		0.18			0.18
Non-Remed							
Reading							
Prim.		(68)	0.13		0.13(R)		
Mid.		(67)	0.21			0.21(R)	
Math							
Prim.		(120)		-0.01	-0.01(M)		
Mid.		(52)		0.03		0.03(M)	
Sec.		(30)		-0.02			-0.02(M)
OMAHA	83-84	66(66)	0.20		0.20(R)		
PASCO	82-83	91(73)		0.23	0.23(M)		
*SALT LAKE	81-82	60(24)	0.59		0.59(R)		
AVERAGE EFF. SIZE			0.33	0.23	R: 0.40 M: 0.21	R: 0.20 M: 0.22	M: 0.27

* - Third Grade only

The contrast between studies merits closer attention. Kulik and colleagues found much larger effects sizes for CAI interventions at the elementary level than those we found for these eight studies. There are several possible reasons for these differences. One possibility is that students in the average study reviewed by Kulik and colleagues were receiving more exposure to CAI during the period of the intervention. While Kulik, Kulik, and Bangert-Drowns (1985) say nothing about this issue in their study of elementary schools, in their study of secondary schools they report that their typical CAI implementation involved 20 minutes a day of computer-based tutoring or drill-and-practice for a period of 16 weeks Bangert-Drowns, Kulik, and Kulik 1985: 63). That means that students were taking about 100 minutes a week of CAI.

As Table One shows, the weekly exposure to CAI varied from only 12 minutes in the case of Omaha to 180 minutes in the case of third graders in Salt Lake City. The typical amount of CAI time among our studies was only 50 minutes a week as in the case of the CCC sites, and other than the third graders in Salt Lake City, no group had more than 75 minutes per week. Thus, the Kulik et al. results appear to be based upon twice as high a weekly exposure to CAI as our results, which could explain the higher effect sizes that they derive.

But there is an additional explanation for the fact that the effect sizes in our studies are smaller than those found in the more general meta-analyses. Studies with careful evaluation

designs are likely to show smaller effects than those with weaker designs. Since we used the adequacy of the evaluation as a criterion for selecting studies, it would not be surprising to find smaller effect sizes. A review of CAI evaluations used in meta-analyses found that three quarters of the studies that were used had evidence of serious design flaws and that there was a tendency for these to overstate effects (Clark 1986: 258-9). Among the 40 percent of such studies which used the same teacher for both CAI and control groups, providing better teaching method and content controls, the effect size of the CAI was only .09 (Clark 1986).

A direct test of the possible bias due to less stringent criteria for evaluation design can be made by comparing the effect sizes that Kulik and colleagues found for CCC interventions with that of the most rigorous evaluation for this approach. Between 1976 and 1980, the National Institute of Education sponsored a four year experiment using the CCC approach to CAI in the Los Angeles schools. The intervention was designed and evaluated by an external evaluator, the Educational Testing Service. By virtually all standards, the evaluation was considered to be unusually comprehensive and sophisticated (Ragosta, Holland, and Jamison 1982).

Further, the results were reanalyzed by one of the originators of the meta-analysis technique, Gene Glass (1984). Glass concluded that the CCC effect sizes in the Los Angeles experiment were .13 for mathematics and .23 for reading. These

compare with an average effect size of .24 and .26 for mathematics and reading among the four CCC interventions in the present study (Chelmsford, Lafayette, Newark, and Pasco) and .46 for 15 studies using the CCC approach as reported in the meta-analysis of Kulik, Kulik, and Bangert-Drowns (1985:69). Clearly, our results are much closer to those of the Los Angeles experiment, reinforcing our belief in their validity.

COSTS OF THE INTERVENTIONS

Just as the effectiveness measure must be comparable across interventions to perform cost-effectiveness analysis, so must the costs. In this section, a standard methodology for estimating costs is applied to the interventions. This approach has been used to assess the costs of CAI (Levin and Woo 1981) and other interventions (Levin, Glass, and Meister 1984, 1987). The overall goal is to ascertain the costs for replicating each of the CAI approaches. The procedure for estimating the cost of an intervention is based upon the "ingredients" approach (Levin 1983).

This approach entails several steps. First, the ingredients or resources that are needed for an intervention are specified. That is, the personnel, equipment, facilities, materials, and other necessary ingredients to replicate the intervention are identified in sufficient detail that both their quantities and qualities are specified. Second, a cost is attached to each resource according to its market value or a procedure which approximates market value. Since we will be comparing costs on

an annual basis, all costs will be converted to yearly amounts. Finally, the costs of all of the ingredients will be added and divided by the number of students who participate in the intervention. This will provide an annual cost per student for each of the alternatives which can then be combined with the effectiveness data.

Ingredients

In order to identify the ingredients needed to replicate each intervention, it is necessary to have a close familiarity with the intervention and its implementation. Unfortunately, most evaluation reports do not provide much detail on the intervention. Information on the precise resources used such as the characteristics or qualities of personnel and associated personnel time are rarely identified. Requirements for administrative support are usually omitted as is delineation of other resources that are necessary for replication. Further, some resources that are identified either are unnecessary for replication or are inappropriate. For example, some projects may be overstaffed during their developmental phases, or they may use suboptimal or outmoded equipment that would not be used in a replication. An example of the latter can be found in one or our cases where Asbury Park used terminals linked by telephone lines to the school districts's business computer in 1979-80, while microcomputers or a school based mini-computer could do the same task more efficiently today.

Accordingly, we followed a number of steps in identifying

ingredients. We reviewed carefully the evaluation reports and accompanying documentation for each intervention. Where these proved insufficient for our purposes, telephone calls and written requests were made to each site for clarification and additional data. In some cases, additional documentation was provided to us, and in other cases the questions were answered by telephone (within the limits of memory of available personnel). In several instances, many different personnel had to be contacted to obtain the missing information.

We found that evaluations often lacked detailed knowledge of how the intervention was actually undertaken, so we had to contact the personnel who had been directly involved in implementing the intervention. In a few cases sufficient detail on some ingredients was not available. This problem was typically associated with an inability to recall details, conflicting accounts among different respondents or the turnover of staff who had been involved. These difficulties usually arose over relatively minor ingredients, so we sketched a "reasonable" scenario based on our experience with CAI interventions, and we estimated costs from that scenario.

It is important to note that partial and incomplete information characterized all 88 evaluations in our larger population, and descriptions of interventions in the detail needed for cost analysis are rarely found among educational evaluations of any sort. Although our cost estimates were done carefully and systematically, their accuracy clearly depends upon

the quality of the underlying information that we were able to uncover. Accordingly, we believe that the cost results should be viewed as approximate rather than definitive.

Costs of Ingredients

Costs were estimated in the following way. First, in order to obtain cost comparability among interventions done at different times, we used 1980 cost data for all ingredients except computer hardware and software. Given the substantial decline in costs of these inputs, we used costs from late 1985 to provide a realistic picture. To the degree that costs of other ingredients such as personnel have risen since 1980, our cost estimates will be low in absolute terms. but the relative costs of the interventions should still be representative. Further, we used estimates of national costs for each ingredient, in order to provide comparability on a national basis. The costs and their documentation are found in Appendix A. Detailed cost analyses for each intervention are found in Appendix B and C. To the degree that someone wishes to ascertain costs for a particular locality or region, the local or regional costs should be substituted for national ones in these tables.

Second, all costs for facilities and equipment are stated in terms of annual values. Classrooms and other facilities and furnishings and equipment last for many years. The standard procedure is to estimate their annual costs on the basis of depreciation and interest on the undepreciated investment for each year. A simple procedure enables one to estimate the

"annualized" cost of such a resource over its lifetime (Levin 1983:67-72).

Costs Per Student

A final adjustment that is necessary is the division of the overall costs per intervention by the number of students that it accommodates. In most of the cases, the resources were underutilized, resulting in higher costs per student than had they been fully used. It is not appropriate to assume that replications of the approaches should be characterized by underutilization. That is, there is nothing intrinsic to the interventions that suggests that some should be underutilized and others more fully utilized. Accordingly, we expressed all per student costs in terms of both their actual utilization and their full capacity utilization.

Based upon extensive experience in the Los Angeles experiment with the CCC approach, full utilization meant that some 23 sessions of 10 minutes duration could be accommodated in a six hour day. This figure is based upon the actual amount of time used for instruction. The remaining time consists periods in which machines are not functioning properly or in which routine maintenance is taking place, time between sessions in which students are moving in or out of the computer laboratory, and spare time at the beginning and end of periods and the school day. Time is also needed for the computer to be used to prepare reports on student progress. Using this information, full utilization for the non-CCC interventions is assumed to be

approximately equal to a continuous utilization rate of about two-thirds of the school day.

Full utilization costs were derived by assuming that the computers, software, and facilities would be used to their full capacity. For some of the interventions, this meant increasing personnel to accommodate an all day program. For this reason, the total costs under full utilization assumptions would also increase somewhat, even though the per pupil costs would be less as the costs of fixed components are divided over more students.

Per student costs were obtained by dividing total costs by the numbers of students who were accommodated by the evaluation or who could be accommodated under full utilization. The numbers of students in the evaluations were smaller than the number who benefitted from the intervention, primarily because of student turnover. That is, evaluative data on some students was lost through their leaving during the year, even though other students took their place.

Cost Estimates

Table Three shows the cost per student for the CAI interventions under actual utilization and full utilization. The actual utilization costs are based upon the number of students serviced by the interventions, and the full utilization costs are based upon the assumptions set out above. The pattern of costs shows great variability with the maximum actual cost of $431 per student in Newark, which is five times the minimum cost of $78 per student in Omaha.

TABLE THREE

Cost Per Student for CAI Interventions

Project	Actual Cost Per Student	Full Utilization Cost Per Student
ASBURY PARK	$ 382	$ 100
CHELMSFORD	164	113
KINDERSLEY	98	67
LAFAYETTE	334	305
NEWARK		
Teacher	431	232
Aide	273	150
OMAHA	78	77
PASCO	375	242
SALT LAKE CITY	217	166
Average	$ 294	$ 182

The full utilization cost range is almost as great, with a per student cost of $305 in Lafayette, but only $67 in Kindersley. On average, the full utilization cost per student is about one-third less than the actual utilization cost. In some cases, the cost reductions are dramatic. For example, per pupil costs in Asbury Park are reduced by almost 75 percent, and those in Newark are reduced by almost half. Only in Omaha is there no ostensible change.

The fact that the cost per student can be lowered substantially, by fully utilizing the interventions suggests that

an important potential way to increase cost-effectiveness is to reduce costs through higher utilization rates. This strategy will be addressed below.

Finally, separate estimates are made for using teachers and teacher aides in Newark. The Newark intervention used both types of personnel. Unfortunately, it was not possible to tie specific effect sizes to the choice of personnel. The cost of the intervention using teacher aides was about 40 percent less than using teachers. Although the cost-effectiveness tables will assume the teacher model, the result could be considerably more cost-effective if teacher aides were shown to be as effective as teachers.

One final point that should be stressed is the composition of costs. Contrary to popular views, hardware costs represent only a small portion of total costs. As the tables in Appendix B and C show, hardware costs are often in the range of about one-tenth of the total costs. Personnel costs typically account for half or more of the costs of delivering CAI services, with the balance composed of software, maintenance, materials, facilities, and other minor categories. Accordingly, even drastic reductions in the costs of hardware will do little to reduce the overall costs of CAI. For example, even a 50 percent reduction in hardware costs would only reduce the per-pupil cost of CAI by 5 percent, if hardware accounts for 10 percent of costs.

COST-EFFECTIVENESS OF THE INTERVENTIONS

Table Four shows the cost-effectiveness ratios of the eight CAI interventions as they were implemented with their actual

TABLE FOUR

Cost-Effectiveness Ratios of Eight CAI Projects
(Actual Utilization Costs)

Project	Cost Per Student	Subject Read.	Subject Math	School Level Prim.	School Level Mid.	School Level Sec.
ASBURY PARK	$ 382		.17			.17(M)
CHELMSFORD	164	.23		.23(R)		
		.34			.34(R)	
			.06	.06(M)		
KINDERSLEY	98		.41	.41(M)		
LAFAYETTE	334		.07	.07(M)		
NEWARK (Teacher)[a]	431					
Remedial						
Reading		.17		.17(R)		
		-.04			-.04(R)	
Math			.07	.07(M)		
			.10		.10(M)	
			.04			.04(M)
Non-Remedial						
Reading		.03		.03(R)		
		.05			.05(R)	
Math		.00		.00(M)		
		.01			.01(M)	
		.00				.00(M)
OMAHA	78	.25		.25(R)		
PASCO	375		.04	.04(M)		
SALT LAKE CITY	217	.21		.21(R)		
Average	$ 294	.11	.12	.18(R)	.12(R)	
				.11(M)	.06(M)	.07(M)

[a]Cost-Effectiveness for Newark is based on the use of teachers. If the same result could be obtained with aides, the cost-effectiveness results would be about 1.5 times as large.

levels of utilization. In order to provide a uniform metric, we have presented the results in terms of effect sizes for each $100 cost per student. The average cost-effectiveness was an effect size of .11 for each $100 of cost per student for reading and .12 for mathematics. The variance in results was substantial with a range of negative or no effects to an effect size of .34 in reading and a range from .04 to .41 in mathematics.

To the degree that the results for Asbury Park, Kindersley Omaha, and Salt Lake City are biased upwards by the fact that the evaluators were also the implementors, their effect sizes are likely to be overstated relative to what they would be in an impersonal replication. However, even if the upward bias is 80 percent as cited in one of the surveys, the studies would still show results that are at the average or above of the eight sites. These results can be compared to cost-effectiveness ratios for CAI in the Los Angeles experiment of .19 for reading and .10 for mathematics.

Table Five shows the results at full rates of utilization with resultant lower costs per student. The average cost-effectiveness ratio rises to .23 for reading and .17 for mathematics, both higher than the results from the Los Angeles experiment. However, for the reasons set out above, there is reason to believe that the results for Asbury Park, Kindersley, and Omaha are considerably larger than they would be in a replication.

TABLE FIVE

Cost-Effectiveness Ratios of Eight CAI Projects
(Full Utilization Costs)

Project	Cost Per Student	Subject Read.	Subject Math	School Level Prim.	School Level Mid.	School Level Sec.
ASBURY PARK	$ 100		.66			.66(M)
CHELMSFORD	113					
Reading		.33		.33(R)		
		.50			.50(R)	
Math			.08	.08(M)		
KINDERSLEY	67		.60	.60(M)		
LAFAYETTE	305		.08	.08(M)		
NEWARK						
(Teacher)[a]	232					
Remedial						
Reading		.31		.31(R)		
		-.07			-.07(R)	
Math			.13	.13(M)		
			.18		.18(M)	
			.08			.08(M)
Non-Remedial						
Reading		.06		.06(R)		
		.09			.09(R)	
Math			.00	.00(M)		
			.01		.01(M)	
			.00			.00(M)
OMAHA	77	.25		.25(R)		
PASCO	242		.10	.10(M)		
SALT LAKE CITY	166	.35		.35(R)		
Average	$ 182	.23	.17	.26(R)	.17(R)	
				.17(M)	.10(M)	.25(M)

[a]Cost-Effectiveness for Newark is based on the use of teachers. If the same result could be obtained with aides, the cost-effectiveness results would be about 1.5 times as large.

What is noteworthy, nevertheless, is that cost-effectiveness doubled for reading and rose by half for mathematics, simply by increasing the level of use from the actual one to full utilization. It demonstrates that cost-effectiveness can be increased dramatically by more fully utilizing existing CAI resources.

These results suggest the earlier finding that present approaches to CAI are superior in cost-effectiveness in imparting mathematics and reading achievement to extending the school day or reducing class size (Levin, Glass, and Meister 1984 & 1987). However, the earlier study shows that an exemplary peer tutoring program is considerably more cost-effective for mathematics and about comparable for reading.

Comparison of CCC Sites

Since four of the sites used the drill-and-practice approach of CCC, it is possible to do a careful comparison of the cost-effectiveness results for those sites and for the Los Angeles experiment which also used the CCC approach. The latter was the basis for an unusually careful and comprehensive evaluation by the Educational Testing Service in behalf of the National Institute of Education (Ragosta, Holland, and Jamison 1982). The CCC intervention uses a mini-computer that is connected to student terminals to provide 10 minute sessions of drill-and-practice on a daily basis. Since the CCC approach is largely self-contained with a curriculum, standard procedures, training, and so on, it is as close to a "plug-in" approach to CAI as one

might find. The CCC site comparison is also attractive because the design and implementation are based upon the package that CCC provides rather than being developed by the evaluators as in the other four sites.

TABLE SIX

Cost-Effectiveness Analysis of Four CCC Interventions at Primary Level

	Effect Size		Actual Cost			Fully Utilized Cost		
	Math	Read.	Cost Per Student	CE M	CE R	Cost Per Student	CE M	CE R
CHELMSFORD	.09	.36	$ 164	.05	.23	$ 113	.08	.33
LAFAYETTE	.23	-	334	.07	-	305	.08	-
NEWARK	.42	.15	431	.10	.04	232	.18	.07
PASCO	.23	-	375	.06	-	242	.10	-
AVERAGE	.24	.26	$ 326	.07	.13	$ 223	.11	.20
LOS ANGELES EXPERIMENT	.12	.23	$ 119	.10	.19	$ 119	.10	.19

The four sites using the CCC instructional system were Chelmsford, Lafayette, Mississippi; Massachusetts; Newark, New Jersey; and Pasco, Washington. All programs were devoted primarily to educationally disadvantaged students, those eligible for services under Chap. I of the Education Consolidation and Improvement Act of 1981. Table Six shows a comparison of cost-effectiveness results for these sites and for the Los Angeles

experiment. We have restricted the comparison only to the results for the primary grades in contrast to an earlier comparison that used results for higher grades as well for Newark. The effect size for Newark is an average for remedial and non-remedial groups.

The first column on the left shows effect sizes for reading and mathematics. In the case of Lafayette and Pasco, the evaluations did not include reading. At the elementary level, an effect size of .1 is equivalent to about a month of test score gain in a 10 month year. Therefore, an effect size of .4 is equal to a four month gain over an instructional year beyond students who were not exposed to the intervention.

One claim that is sometimes made for CAI systems is that they are self-contained and "teacher-proof" so that a particular CAI approach should produce comparable gains in diverse settings. Certainly, the CCC system is largely self-contained in this sense. Accordingly, it is surprising to find the wide variance in effect sizes among the four sites. The largest effect size for mathematics (Newark) was over four times the smallest size (Chelmsford). Average effect sizes for the four sites were considerably higher for mathematics than those found in the four year Los Angeles experiment, but they were only slightly higher for reading. A tentative conclusion that might be reached from this comparison is that local implementation of a particular CAI approach can account for large differences in effectiveness, even for systems that are as automated and non-interactive as that of

CCC.

The middle column reports the actual, annual cost per student for CAI for each of the two subjects and the cost-effectiveness in terms of effect size per $100 of cost per student. Cost per student also varies substantially. For example, the highest cost is about three times as great as the lowest cost per student.

There are two principal reasons that costs vary so greatly from site-to-site. The first is that some of the sites used more personnel than others and personnel of a higher quality such as teachers rather than teacher aides. The second is that the utilization rate varied from site-to-site.

The cost-effectiveness (effect size per $100) was remarkably uniform for mathematics among the four sites, suggesting that differences in resource use and costs largely accounted for differences in effectiveness. This uniformity is quite dramatic relative to the heterogeneity of mathematics effects sizes in the first column. However, the cost-effectiveness for the two reading sites is even more disparate than the effectiveness measures alone. When one looks at average cost-effectiveness among the four sites, it appears that the Los Angeles experiment was considerably more cost-effective.

The third column adjusts the costs to a "fully-utilized" level. In this case, the annual cost per student per subject declines by about $100 or 30 percent on the average, with different patterns for each site. Although the fully-utilized

cost per student of $223 is higher than for the Los Angeles experiment, effectiveness is also higher. When expressed in terms of cost-effectiveness, the fully-utilized interventions would be almost identical in cost-effectiveness to those of the Los Angeles experiment. This suggests that investments in personnel resources made in conjunction with CAI can increase the effectiveness of CAI and provide results that are as cost-effective as when less is spent on personnel.

But, even more intriguing is that the average cost-effectiveness for the four sites under full utilization was almost identical to the results of the Los Angeles experiment. This suggests a rather remarkable robustness, given the fact that the four sites represented completely independent applications of the intervention.

SUMMARY

This report explores the feasibility of collecting evaluations of CAI to evaluate the comparative cost-effectiveness of different CAI approaches. It was successful in obtaining 88 evaluations of CAI of which over 60 pertain to the 1980's. This is a much higher proportion of recent studies than the available meta-analyses of CAI. However, in order to do a cost-effectiveness analysis, a number of criteria must be met. These include a single focus on CAI, common goals, acceptable evaluation methods, and adequate information on required resources. Only eight of the evaluations met this standard, where the common educational outcome was that of reading and/or

mathematics achievement.

Cost-effectiveness is a decision-oriented tool which focusses on criteria that are pertinent to decision-makers. Accordingly, we also were concerned that the interventions and their results would be likely to be replicable beyond the initial setting. Only five of the studies seemed to meet this criterion.

Among the eight studies, effects varied greatly from study to study. This suggests the rather plausible conclusion that specific approaches to CAI and the realities of implementation make a big difference in effectiveness. Further reinforcement of this interpretation is provided by the separate analysis of the four CCC sites. Given that the CCC approach is so fully packaged and comes as close to a "plug-in" version of CAI as one might find, it is remarkable that large differences in effect sizes were found among sites doing the same ostensible activity. In part, these differences seem to relate to differences in the quality and quantity of personnel among the four sites. This suggests that even with a relatively "mechanical" approach to CAI, differences in personnel and implementation can make for substantial differences in results.

This interpretation is also consistent with intensive observational studies of computer-based drill and practice by Nira Hativa (1986). She found that the better students adjust more readily to the special requirements of working with computers than low achievers. Clearly, the problems that she identified could yield to the provision of greater personnel

inputs where such children could be assisted to overcome the obstacles that they encounter rather than being constrained by them.

Differences in costs among the different approaches to CAI as well as within the CCC approach were also substantial. For example, both actual costs and those estimated for fully utilized systems differed by a factor of 4 between the lowest cost and highest cost interventions. Even the per student costs among the 4 CCC sites with their common approach showed a ratio of 3 to 1 between the most costly and least costly. But, at least for the CCC sites, differences in costs seem to be correlated with differences in effectiveness, so the cost-effectiveness values among sites are much more nearly uniform than the effect sizes.

Most of the sites were characterized by substantial underutilization of their CAI capacity. This is hardly a surprise to even casual school observers who often see micro-computers and associated equipment sitting idly. But, it does have important cost implications. Among the eight sites it was found that by moving from actual levels of utilization to full utilization would have reduced the cost per student by about one-third. This finding suggests that there may be great potential for increasing cost-effectiveness of a given intervention by fuller utilization rather than seeking alternative interventions that may be more cost-effective. On the average, cost-effectiveness among the 4 CCC sites was raised by 50 percent by fully-utilizing the CAI intervention.

A final concern is the need for better evaluations and more complete descriptions of interventions so that their cost consequences can be established. The need for better evaluations is obvious, given the large number of evaluations that do not use acceptable experimental or quasi-experimental techniques. Some do not even report the variances in achievement in the student groups, but only pre- and post-test scores. Many make no effort to use co-variate controls, even though treatment and comparison groups are not matched. Moreover, many of the evaluations are experimental in nature rather than replications of a "standard" approach. Better evaluations and evaluations of replications are called for to improve the data base for cost-effectiveness studies.

Difficulties in estimating costs also suggest [illegible] more attention to the details of interventions and their resource requirements. The time investment required to identify the details of the interventions and resource requirements for the eight interventions that were assessed in this study exceeded by a factor of 20-30 the time required to estimate effect sizes. Future cost-effectiveness analysis would benefit greatly from a detailed and comprehensive description of the CAI interventions and the types and amounts of personnel and other resources that were used.

Finally, it is important to bear in mind that the results in this study should not be used to draw conclusions about future approaches to CAI. Although micro-computer hardware is already

BIBLIOGRAPHY

Bangert-Drowns, James A. Kulik, & Chen-Lin C. Kulik. (1985, Summer). Effectiveness of computer-based education in secondary schools. Journal of Computer-Based Education, 12(3), pp. 59-68.

Bryg, Virginia. (1984). The effect of computer-assisted instruction upon reading achievement with selected fourth-grade children. Unpublished doctoral dissertation, University of Nebraska, Lincoln, Nebraska.

Center for Social Organization of Schools. (1986, June). Instructional uses of school computers. Baltimore: The Johns Hopkins University.

Clark, Richard E. (1985, Winter). Evidence for confounding in computer-based instruction studies: Analyzing the meta-analyses. Educational Technology and Communication Journal, 33(4), pp. 249-262.

Cook, Thomas D., & Donald T. Campbell. (1979). Quasi-experimentation. Chicago: Rand McNally.

Glass, Gene V. (1984). The effectiveness of four educational interventions, IFG Project Report No. 84-A19. Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University.

Glass, Gene V., Barry McGaw, & Mary Lee Smith. (1981). Meta-analysis in social research. Beverly Hills, CA: Sage Publications.

Hativa, Nira. (1986, April). Computer-based drill and practice in arithmetic--widening the gap between high and low achieving students. Tel Aviv: Tel Aviv University, Unit for Communication and Computer Research in Education--School of Education.

Hawley, David E. (1985). The costs, effects, and utility of microcomputer assisted instruction in a rural school division in Canada. Unpublished doctoral dissertation, College of Education, University of Oregon, Eugene.

Joint Dissemination Review Panel, U.S. Department of Education. (1982). Title I mathematics laboratory with computer assisted instruction, Lafayette, Louisiana. Washington, DC: JDRP, Department of Education.

Kulik, James A., Chen-Lin C. Kulik, & Robert L. Bangert-Drowns. (1985). Effectiveness of computer-based education in

highly sophisticated, the "big breakthroughs" in instructional software are yet to be made. Accordingly, it is necessary to constantly update evaluations and cost-effectiveness comparisons of CAI in order to ascertain what the latest possibilities might be.

elementary schools. Computers in Human Behavior, Vol. 1, pp. 59-74.

Leitner, David. (1985). Summary of 88 studies of CAI. Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University.

Levin, Henry M., Gene V. Glass, & Gail R. Meister. (1987, February). Cost effectiveness of computer-assisted instruction. Evaluation Review.

Levin, Henry M. (1983). Cost-effectiveness: A primer. Beverly Hills, CA: Sage Publications.

Levin, Henry M., & Louis Woo. (1981, Winter). An Evaluation of the costs of computer-assisted instruction. Economics of Education, 1(1), pp. 1-26.

Levin, Henry M., Gene Glass, & Gail Meister. (1984). Cost-effectiveness of four educational interventions, Project Report No. 84-A11. Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University.

McCarnell, Beverly B. (1983). Evaluation of computer assisted instruction in math, Pasco School District, final report. Pasco, WA: Pasco School District.

Metrics Associates, Incorporated. (1982). Evaluation of the computer-assisted instruction Title I project, 1980-81. Chelmsford, MA: Merrimack Education Center.

Murphy, Richard T., & Lola Rhea Appel. (1984, June 30). Evaluation of the writing to read instructional system, Second Year Report. Princeton, NJ: Educational Testing Service.

Newark School District. (1984). C.A.I. Program Evaluation Report, 1983-1984, Division of Research, Evaluation, and Testing, DRET Report No. 21. Newark, NJ: Newark School District.

Ragosta, Marjorie, Paul W. Holland, & Dean T. Jamison. (1982, April). Computer-assisted instruction and compensatory education: The ETS/LAUSD study. Final Report, Project Report No. 19. Princeton, NJ: Educational Testing Service.

Reid Foundation. (1983). Basic literacy through microcomputers (BLTM). Salt Lake City: Reid Foundation.

Salomon, Gavriel, & Howard Gardner. (1986, January). The computer as education: Lessons from television research. Educational Researcher, 15(1), pp. 13-19.

de Talvo, Jack, & Karen Pastuzyn. (1982). Utilizing computers in the teaching of secondary mathematics. Asbury Park, NJ: Asbury Park School District.

APPENDIX TABLE A-1
AVERAGE COSTS 1980

Ingredient	Description	Components	Cost
PERSONNEL			
Teacher	Elementary & secondary, regular service	Salary(a) and fringe benefits(b) = $ 17,500 + $ 4,375	$ 21,875/yr
Teacher	Elementary & secondary, extra service	Hourly rate(c) =	$ 20.25/hr
Substitute Teacher	Elementary & secondary, observer	Daily rate(d) =	$ 50.00/day
Principal	Elementary	Salary(e) and fringe benefits(b) = $ 28,000 + $ 7,000	$ 35,000/yr
Supervisor	Elementary & secondary, central office	Salary(f) and fringe benefits(b) = $ 20,000 + $ 5,000	$ 25,000/yr
Consultant	Inservice trainers	Daily rate(d) =	$ 100/day
Parapro-fessional	Teaching aide, tutor manager, clerk	Hourly rate(d) =	$ 5.00/hr
Parapro-fessional	Adult tutor	Hourly rate(g) =	$ 4.25/hr
Student	Elementary	Hourly rate(h) =	$ 0.00/hr
FACILITIES			
Classroom Construction	Elementary & secondary	Cost per square foot(i) for classroom space(j) = $ 50 X 900 sq. ft. annualized at 10% interest over 30 years(k)	$ 45,000/rm $ 4,775/yr
Classroom Renovation	Elementary & secondary, for computer laboratory	Actual costs annualized at 10% interest over 10 years(k)	$ 18,500/rm $ 3,010/yr

Ingredient	Description	Components	Cost
Office space	Central office (equivalent to 1/2 classroom)	1/2 cost for classroom space(j,j) annualized at 10% interest over 30 years(k)	$ 2,388/yr
EQUIPMENT			
Classroom Furnishings	30 student desks & chairs, 1 teacher desk & chair, 2 30" X 72" folding tables, 2 bookcases	Market price(l) = $ 3,000 annualized at 10% interest over 10 years(k)	$ 488/yr
Office Furnishings	1 desk & chair, filing cabinet, telephone	Price(d) = $ 500 annualized at 10% interest over 10 years(k)	$ 82.00/yr
OTHER			
Classroom Maintenance & Utilities	Routine maintenance, utilities and insurance	Annual rate(d)	$ 1,000/yr

(a) "Estimated average annual salary of classroom teachers in public elementary and secondary schools: United States 1959-1960 and 1980-81", Digest of Education Statistics 1982, p. 56; and Education Research Service, ERS Report: Salaries Paid Professional Personnel in the Public Schools 1980-81.

(b) Assume at 25% of salaries on basis of examination of representative rates in 1980.

(c) Computed from average teacher wage, assuming a 180-day, 6-hour day teacher year.

(d) Representative rate used in sample of school districts in 1980.

(e) Based on Education Research Service, ERS Report: Salaries Paid Professional Personnel in the Public Schools 1980-81.

(f) Based on "Average annual salary on instructional staff", Digest of Education Statistics 1982, p. 58; and mean salary information of assistant principals as listed in "Salaries of Assistant Principals per pupil expenditure for 1979-80", Standard Education Almanac 1980-81, pp. 64-65. Assume supervisor salary is average of both.

(g) Based on actual cost in Boise model, where Adult Tutors are paid at a lower rate than Tutor Managers.

(h) Assume no opportunity cost.

(i) Paul Abramson, "Educational Construction: Seventh Annual Cost Report", American School and University, April 1981, p. 54.

(j) Estimate from American Registry of Architects, exclusive of hall space.

(k) Louis Woo, "Table 4.1: Annualization Factors for Determining Annual Cost of Facilities and Equipment for Different Periods of Depreciation and Interest Rates", in Henry M. Levin, Cost-Effectiveness: A Primer, Beverly Hills: Sage, 1983, p. 70.

(l) Based on estimate from Palo Alto Unified School District, deflated for 1980.

APPENDIX TABLE B-1
Actual Utilization Costs

Asbury Park, New Jersey: "Utilizing Computers in the Teaching of Secondary Mathematics"

1979-80

Mathematics for 126 students in one secondary school.

Annual Costs	Ingredients
	PERSONNEL
$ 5,000	1 Supervisor of Instruction at 20% time at $ 20,000 per year, plus fringe benefits.
$ 21,875	1 math lab teacher at $ 17,500 per year, plus fringe benefits.
$ 3,281	3 regular math teachers at 5% time for planning and coordination at $ 17,500 per year, plus fringe benefits.
$ 2,000	1 principal at 5% time at $ 32,000 per year, plus fringe benefits.
	FACILITIES
$ 5,775	Classroom for CAI laboratory (includes $ 1,000 for utilities and routine maintenance).
$ 163	Classroom rewiring for CAI laboratory at 16/32 of $ 2,000, annualized at 10% over 10 years.
$ 1,155	Office for Supervisor of Instruction at 20%.
	EQUIPMENT AND MATERIALS
$ 3,655	16 Apple IIE microcomputers at $ 995, annualized at 10% over 6 years.
$ 471	Protection equipment (includes 16 fans at $ 40 each, 16 mats at $ 59 each, 5 surge suppressors at $ 117 each), annualized at 10% over 6 years.
$ 184	1 Epson FX-100 dot matrix (220 cps) printer with cable at $ 800 (discounted), annualized at 10% over 6 years.
$ 603	30 diskettes at $ 50, annualized at 10% over 3 years.

$ 36	9 teachers' manuals at $ 10 per manual, annualized at 10% over 3 years.
$ 244	Classroom furnishings (includes teacher desk and chair and 16 student desks and chairs), annualized at 10% over 10 years.
$ 16	Office furnishings at 20% of $ 500 at 10% over 10 years
$ 1,600	Supplies at $ 100 per microcomputer.
$ 200	Transportation for Supervisor of Instruction.
	OTHER
$ 641	Training time for 1 math lab teacher and 3 regular math teachers at 30 hours at $ 20.25 per hour, annualized at 10% over 5 years.
$ 132	Consultant to provide training at 5 days at $ 100 per day, annualized at 10% over 5 years.
$ 1,120	Maintenance at $ 70 per microcomputer per year.
$ 48,151	TOTAL COST PER YEAR
$ 382.15	COST PER STUDENT (N=126)*

* This is based on the number of students they actually served this first year of operation.

APPENDIX TABLE B-2
Actual Utilization Costs

Kindersley School Division #34, Saskatchewan: Mathematics CAI

1984-85

Mathematics for 41 third and fifth grade students at one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 101	2 teachers at 2.5 hours at $ 20.25 per hour.
$ 50	1 district coordinator at 4 hours at $ 100 per day.
$ 1,750	1 principal at 5% time at $ 28,000 per year, plus fringe benefits.
	FACILITIES
$ 141	Classroom rewiring in 2 classrooms at 6/32 X $ 2,000, annualized at 10% interest over 30 years.
$ 21	3 double computer tables at $ 44, annualized at 10% over 10 years.
	EQUIPMENT AND MATERIALS
$ 918	6 Apple IIE microcomputers at $ 995, annualized at 10% over 6 years, at 67% instructional use.
$ 190	Protection equipment (includes 6 fans at $ 40 each, 6 mats at $ 59 each, 2 surge suppressors at $ 117 each), annualized at 10% over 6 years.
$ 526	6 copies of 6 diskettes in Milliken Math Sequences at $ 218 per set, annualized at 10% over 3 years.
$ 8	2 teacher' guides at $ 10, annualized at 10% over 3 years.
	OTHER
$ 21	Training for 2 teachers at 2 hours at $ 20.25 per hour, annualized at 10% over 5 years.
$ 281	Maintenance at $ 70 per microcomputer.

$	5	Transportation for District Coordinator.
$	4,012	TOTAL COST PER YEAR
$	97.85	COST PER STUDENT (N=41)*

*This refers to the number of students who started the program. If the number of students for which data is available is used, then N=39 and the cost per student is $ 102.87.

APPENDIX TABLE B-3
Actual Utilization Costs

Lafayette, Louisiana: "Title I - Mathematics Laboratory with Computer-Assisted Instruction"

1980-81

Mathematics for 90 third to sixth graders in one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 1,750	1 principal at 5% time at $28,000 per year, plus fringe benefits.
	FACILITIES
$ 2,888	Classroom for CAI laboratory at 1/2 classroom (includes $ 500 for utilities and routine maintenance of space).
$ 1,505	Classroom renovation for CAI laboratory at 1/2 classroom.
$ 122	Furnishings (teacher desk and chair and 16 student chairs) at $ 1,500, annualized at 10% over 10 years.
$ 1,444	Room for CPU at school site at 50% of 1/2 includes ($ 250 for utilities and routine maintenance of space).
	EQUIPMENT AND MATERIALS
$ 2,950	1 Microhost CPU with 1 Mb memory and 40Mb storage and software at 50% of $ 25,760, annualized at 10% over 6 years.
$ 7,714	16 Computer Curriculum Corporation terminals (includes software) at $ 2,100, annualized at 10% over 6 years.
$ 556	1 dot matrix (120cps) printer console (includes controller for CPU) and software at $ 2,422, annualized at 10% over 6 years.
$ 595	Installation (includes 50% of CPU at $ 1,500, 16 terminals at $ 100 each, a printer at $ 140, 1/2 of 2 modem pairs at $ 100 each) at $ 2,490, annualized at 10% over 6 years.

$ 181	1/2 of 2 modem pairs at $ 790, annualized at 10% over 6 years.
$ 440	1/2 of 2 telephone lines (estimated at $ 358 fee and $ 35 labor for installation), annualized at 10% over 6 years, plus $ 35 monthly fee for 10 months.
$ 3,200	Curriculum rental at $ 200 per terminal per year.
$ 1,500	Supplies.
	OTHER
$ 64	Training time for 1 teacher at 12 hours at $ 20.25 per hour, annualized at 10% over 5 years.
$ 115	UNIX license fee at 50% of $ 1,000, annualized at 10% over 6 years.
$ 5,015	Maintenance (includes CPU at 50% of $ 4,050; terminals at $ 160; printer at $ 310; 1/2 of $ 240 for 2 modems).
$ 30,039	TOTAL COST PER YEAR
$ 333.77	COST PER STUDENT (N=90)*

*Since there were never more than 15 students in lab for 30 minute period.

APPENDIX TABLE B-4

ACTUAL UTILIZATION COSTS

Chelmsford, Massachusetts Merrimack Education Center
Reading and Math CAI

1980-81

Reading and math for 64 students in one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 1,563.00	1 CAI coordinator at Merrimack Education Center @ 1/16 time at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
376.00	Classroom renovation @ 4/32 of $18,500, annualized at 10% over 10 years
180.00	Room for CPU @ 4/64 of 1/2 classroom, annualized @ 10% over 30 years (includes $31 for utilities and routine maintenance)
180.00	Office space for CAI coordinator @ 1/16 of 1/2 classroom, annualized @ 10% over 30 years (includes $31 for utilities and routine maintenarce)
	EQUIPMENT AND MATERIALS
455.00	1 Microhost CPU with 2 Mb memory and 40 Mb storage and software @ 4/64 of $31,700, annualized at 10% over 6 years
1,928.00	4 Computer Curriculum Corporation terminals and software @ $2,100, annualized at 10% over 6 years
556.00	1 dot matrix (120 cps) printer console and software (includes controller for CPU) @ $2,420, annualized at 10% over 6 years

APPENDIX TABLE B-4 (continued)

Annual Costs	Ingredients
168.00	Installation (includes 4/64 of CPU @ $1,500; 4 terminals @ $100; printer @ $140; modem @ $100), annualized at 10% over 6 years
181.00	1 modem @ $790 annualized at 10% over 6 years
440.00	1 telephone line (estimated at $358 fee plus $35 labor for installation, annualized at 10% over 6 years, plus $35 monthly fee for 10 months)
31.00	Classroom furnishings (includes teacher desk and chair and 4 student chairs), annualized at 10% over 10 years
5.00	Office furnishings for CAI coordinator @ 1/16 of $500, annualized at 10% over 10 years
800.00	Curriculum rental @ $200/terminal per year
375.00	Supplies @ 4/32 of $3,000
63.00	Transportation
	OTHER
48.00	Training time for 1 Title I teacher @ 9 hours at $20.25/hour, annualized at 10% over 5 years
50.00	UNIX license fee @ 4/64 of $3,500, annualized at 10% over 6 years
1,361.00	Maintenance (includes 4/64 of $4,650 for CPU; 4 terminals @ $160; printer @ $310; modem @ $120
$10,510.00	TOTAL COST PER YEAR
$ 164.22	COST PER STUDENT (N=64)

N's calculation is based on 1983-84 reports that terminals were used at 80% full capacity. Full capacity for Merrimack is defined as 80 students. Thus N = .8 x 80 = 64.

APPENDIX TABLE B-5

ACTUAL UTILIZATION COSTS

Newark, New Jersey: "Regular Reading CAI"

1983-84

Reading for 96 students at one elementary school (program at 8 sites).

Annual Costs	Ingredients
	PERSONNEL
$21,875.00	1 Chapter I teacher @ $17,500 plus fringe benefits per year
OR	
6,750.00	1 teacher aide @ 1,030 hours/year at $5.00/hour plus fringe benefits
1,042.00	1 CAI Reading Coordinator @ 1/8 (for one of eight sites) of 1/3 time (the Coordinator's commitment to the whole program) at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory, annualized at 10% over 30 years (includes $1,000 for utilities and routine maintenance)
753.00	Classroom renovation @ 8/32 of $18,500, annualized at 10% over 10 years
525.00	Room for CPU @ 8/44 of 1/2 classroom, annualized at 10% over 30 years (includes $91 for maintenance)
120.00	Office space for CAI Coordinator @ 1/8 of 1/3 of 1/2 classroom, annualized at 10% over 30 years (includes $21 for utilities and routine maintenance)

APPENDIX TABLE B-5 (continued)

Annual Costs	Ingredients
	EQUIPMENT AND MATERIALS
1,323.00	1 Microhost CPU with 2 Mb memory and 40 Mb storage and software @ 8/44 of $31,700, annualized at 10% over 6 years
3,857.00	8 SLS-11 Computer Curriculum Corporation terminals and software @ $2,100, annualized at 10% over 6 years
181.00	1 pair modem @ $790, annualized at 10% over 6 years
440.00	1 phone line (estimated at $358 fee plus $35 labor for installation, annualized at 10% over 6 years, plus $35 monthly fee for 10 months)
556.00	1 dot matrix (120 cps) printer console (includes controller for CPU) and software @ $2,420, annualized at 10% over 6 years
301.00	Installation (includes 8/44 of CPU @ $1,500, 8 terminals @ $100, printer @ $140, 1 modem @ $100) annualized at 10% over 6 years
61.00	Classroom furnishings for CAI laboratory (includes teacher desk and chair and student chairs) annualized at 10% over 10 years
3.00	Office furnishings for CAI coordinator @ 1/8 of 1/3 of $500, annualized at 10% over 10 years
	OTHER
48.00	Training time for 1 Chapter I teacher @ 9 hours at $20.25/hour, annualized at 10% over 5 years
146.00	UNIX license fee @ 8/44 of $3,500, annualized at 10% over 6 years
2,555.00	Maintenance (includes 8/44 of CPU @ $4,650; 8 terminals @ $160; printer @ $310; modem @ $120)
42.00	Transportation
$41,353.00	TOTAL COST PER YEAR FOR PROGRAM WITH TEACHER
$ 430.76	COST PER STUDENT FOR PROGRAM WITH TEACHER

APPENDIX TABLE B-5 (continued)

Annual Costs	Ingredients
$26,180.00	TOTAL COST PER YEAR FOR PROGRAM WITH AIDE
$ 272.71	COST PER STUDENT FOR PROGRAM WITH AIDE

N=96

N reflects the maximum capacity of program with 8 terminals using the Newark model. According to this model, students come to Chapter I room every 40 minutes, and spend 20 minutes of time on computer. Thus, there are 16, ten-minute sessions every 40 minutes (i.e., 8 x 2 = 16). Assuming there are 6 working periods during the day, maximum capacity is 6 x 16 = 96.

APPENDIX TABLE B-6

ACTUAL UTILIZATION COSTS

Omaha, Nebraska: Reading CAI

1983-84

Reading for 66 fourth grade students in 5 classrooms in three elementary schools.

Annual Costs	Ingredients
	PERSONNEL
$ 6,250.00	1 reading specialist @ 25% time for project coordination at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
723.00	Office space for reading specialist @ 25% of 1/2 classroom (includes proportion of maintenance)
	EQUIPMENT AND MATERIALS
1,142.00	5 Apple IIe microcomputers @ $995 annualized at 10% over 6 years
36.00	5 computer tables @ $44 annualized at 10% over 10 years
248.00	Protection equipment (includes 5 fans @ $40; 5 mats @ $59; 5 surge suppressors @ $117) annualized at 10% over 6 years
12.00	5 digital clocks @ $10 annualized at 10% over 6 years
202.00	10 diskettes @ $50 annualized at 10% over 3 years
500.00	Supplies @ $100/microcomputer
20.00	Office furnishings for reading specialist @ 25% of $500, annualized at 10% interest over 10 years

APPENDIX TABLE B-6 (continued)

Annual Costs	Ingredients
23.00	Adapters and extension cords @ $100 annualized at 10% over 6 years
	OTHER
186.00	Training for 5 teachers @ 7 hours on software at $20.25/hour, annualized at 10% over 5 years
350.00	Maintenance @ $70/microcomputer
250.00	Transportation for reading specialist @ 25% time
$11,692.00	TOTAL COST PER YEAR
$ 77.95	COST PER STUDENT
	N=150
	N represents 6 classes times 30 students per class

APPENDIX TABLE B-7

ACTUAL UTILIZATION COSTS

Pasco, Washington: Mathematics CAI

1982-83

Mathematics for 91 third through sixth graders at one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 6,750.00	1 teacher aide @ 1,080 hours/year at $5.00/hour plus fringe benefits
4,688.00	1 CAI supervisor @ 25% of 3/4 time, at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance)
470.00	Classroom renovation @ 5/32 of $18,500, annualized at 10% over 10 years
723.00	Office space for CAI supervisor @ 25% of 1/2 classroom (includes $125 for utilities and routine maintenance)
	EQUIPMENT AND MATERIALS
922.00	1 Microhost CPU with 1 Mb memory and 40 Mb storage and software @ 5/32 of $25,760, annualized at 10% over 6 years
2,411.00	5 SLS-11 Computer Curriculum Corporation terminals and software @ $2,100, annualized at 10% over 6 years
556.00	1 dot matrix (120 cps) printer console (includes controller for CPU) @ $2,420, annualized at 10% over 6 years

APPENDIX TABLE B-7 (continued)

Annual Costs	Ingredients
224.00	Installation (includes 5/32 of CPU @ $1,500; 5 terminals @ $100; 1 pr. modem @ $100; printer @ $140) annualized at 10%
6,184.00	Phone line (estimated for analog/data line; $800 installation annualized over 6 years, plus $600/month x 10 months) over 6 years
76.00	Classroom furnishings (includes teacher desk and chair and student chairs) annualized at 10% over 10 years
20.00	Office furnishings for CAI supervisor @ 25% of $500, annualized at 10% over 10 years
1,000.00	Curriculum rental @ $200/terminal per year
469.00	Supplies @ 5/32 of $3,000
188.00	Transportation for District Coordinator
	OTHER
36.00	UNIX license fee @ 5/32 of $1,000, annualized at 10% over 6 years
1,862.00	Maintenance (includes 5/32 of $4,050 for CPU; 5 terminals @ $160; printer @ $310; _____?_____
$34,104.00	TOTAL COST PER YEAR
$ 374.77	COST PER STUDENT (N=91)[1]

[1]This figure is a calculation which is based on the number of experimental students for whom test data was available (N=73), and the average percent (.90) of student in both the control and experimental groups for whom test data was available who had started the program. Thus, 73 ÷ .90 = 91, N=91.

APPENDIX TABLE B-8

ACTUAL UTILIZATION COSTS

Salt Lake City, Utah: "Basic Literacy Through Microcomputers"

1981-82

Reading (and typing) for 60 students in one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 1,667.00	Director .33 of .20 of $20,000 plus fringe benefits
2,250.00	1 teacher aide as lab manager @ 1,080 hours at $5.00/hour plus fringe benefits (x .1/3
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
1,925.00	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance of the space (x 1/3)
71.00	Classroom rewiring for CAI laboratory @ $2,000 annualized at 10% over 30 years (x 1/3)
	EQUIPMENT AND MATERIALS
2,437.00	32 Apple IIe microcomputers @ $995 annualized at 10% over 6 years (x .1/3)
314.00	Protection equipment (32 fans @ $40, 32 mats @ $59, 8 surge suppressors at $117) annualized at 10% over 6 years (x 1/3)
81.00	1 Epson FX-100 dot matrix printer (220 cps) printer with cable at $800 (discounted), annualized at 10% interest over 6 years (x 1/3)
80.00	1 curriculum binder @ $198 annualized at 10% over 3 years

APPENDIX TABLE B-8 (continued)

Annual Costs	Ingredients
257.00	32 sets of backup disks @ $60 annualized at 10% over 3 years (x 1/3)
163.00	Furnishings (teacher desk and chair and student desks and chairs) annualized at 10% over 10 years (x 1/3)
1,067.00	Supplies
	OTHER
192.00	Training time for 6 elementary teachers @ 6 hours x $20.25/hour, annualized at 10% interest over 5 years
4.00	Rental of training videotape at $15 annualized at 10% interest over 5 years
747.00	Maintenance (includes microcomputers @ $70/year x 1/3)
$13,005.00	TOTAL COST PER YEAR
$ 216.75	COST PER STUDENT (N=30)

Note: Students walking to center 3 times/week to spend 1 hr/time takes time from other learning. This cost is not charged.

Note: We assume that this school has 2 classrooms that use one of the center's 5 rooms part of the time. We also assume that the school uses the classroom 1/3 of time.

APPENDIX TABLE C-1

FULL UTILIZATION COSTS

Asbury Park, New Jersey: "Utilizing Computers in the Teaching of Secondary Mathematics"

1979-80

Mathematics for 480 students in one secondary school.

Annual Costs	Ingredients
	PERSONNEL
$ 5,000.00	1 Supervisor of Instruction @ 20% of $20,000 plus fringe benefits per year
21,875	1 math lab teacher @ $17,500 plus fringe benefits per year
3,281.00	3 regular math teachers @ 5% time for planning and coordination at $17,500 plus fringe benefits per year
2,000.00	1 principal @ 5% time at $32,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance)
163.00	Classroom requiring for CAI laboratory @ 16/32 of $2,000, annualized at 10% over 10 years
1,155.00	Office for Supervisor of Instruction @ 20%
	EQUIPMENT AND MATERIALS
3,655.00	16 Apple IIe microcomputers @ $995 annualized at 10% over 6 years
471.00	Protection equipment (16 fans @ $40, 16 mats @ $59, 5 surge suppressors @ $117) annualized at 10% over 6 years

APPENDIX TABLE C-1 (continued)

Annual Costs	Ingredients
184.00	1 Epson FX-100 dot matrix (220 cps) printer with cable @ $800 (discounted), annualized at 10% over 6 years
603.00	30 diskettes @ $50 annualized at 10% over 3 years
36.00	9 teachers' manuals @ $10/manual annualized at 10% over 3 years
244.00	Classroom furnishings (includes teacher desk and chair and 16 student desks and chairs) annualized at 10% over 10 years
16.00	Office furnishings @ 20% of $500 at 10% over 10 years
1,600.00	Supplies @ $100/microcomputer
200.00	Transportation for Supervisor of Instruction
	OTHER
641.00	Training time for 1 math lab teacher and 3 regular math teachers @ 30 hours at $20.25/hour, annualized at 10% over 5 years
132.00	Consultant to provide training @ 5 days at $100/day, annualized at 10% over 5 years
1,120.00	Maintenance @ $70/microcomputer per year
$48,151.00	TOTAL COST PER YEAR
$ 100.31	COST PER STUDENT (N=480)

APPENDIX TABLE C-2

FULL UTILIZATION COSTS

Kindersley School Division #34, Saskatchewan: Mathematics CAI

1984-85

Mathematics for 60 third and fifth grade students at one elementary school.

As Is	Annual Costs	Ingredients
		PERSONNEL
$ 101.00	$ 101.00	2 teachers @ 2.5 hours at $20.25/hour
50.00	50.00	1 district coordinator @ 4 hours at $100/day
1,750.00	1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
		FACILITIES
141.00	141.00	Classroom rewiring in 2 classrooms @ 6/32 x $2,000, annualized at 10% interest over 30 years
21.00	21.00	3 double computer tables @ $44 annualized at 10% over 10 years
		EQUIPMENT AND MATERIALS
918.00	918.00	6 Apple IIe microcomputers @ $995 annualized at 10% over 6 years at 67% instructional use
190.00	190.00	Protection equipment (includes 6 fans @ $40; 6 mats @ $59; 2 surge suppressors @ $117) annualized at 10% over 6 years
526.00	526.00	6 copies of 6 diskettes in Milliken Math Sequence @ $218 per set annualized at 10% over 3 years

APPENDIX TABLE C-2 (continued)

As Is	Annual Costs	Ingredients
8.00	8.00	2 teachers' guides @ $10 annualized at 10% over 3 years
		OTHER
21.00	21.00	Training for 2 teachers @ 2 hours at $20.25/hour annualized at 10% over 5 years
281.00	281.00	Maintenance @ $70/microcomputer
5.00	5.00	Transportation for district coordinator
$4,012 00	$4,012.00	TOTAL COST PER YEAR
$ 97.85*	$ 66.87	COST PER STUDENT (N=60)

*N=41

This refers to no. of students who started program. If the number of students for which data is available is used, then N=39, and cost per student = $102.87.

APPENDIX TABLE C-3

FULL UTILIZATION COSTS

Lafayette, Louisiana: "Title I Mathematics Laboratory with Computer-Assisted Instruction"

1980-81

Mathematics for 96 third to sixth graders in one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
2,888.00	Classroom for CAI laboratory @ 1/2 classroom (includes $500 for utilities and routine maintenance of space)
1,505.00	Classroom renovation for CAI laboratory @ 1/2 classroom
122.00	Furnishings (teacher desk and chair, and 16 student chairs) @ $1,500 annualized at 10% over 10 years
1,444.00	Room for CPU at school site @ 50% of 1/2 (includes $250 for utilities and routine maintenance of space)
	EQUIPMENT AND MATERIALS
2,950.00	1 Microhost CPU with 1 Mb memory and 40 Mb storage and software @ 50% of $25,760, annualized at 10% over 6 years
7,714.00	16 Computer Curriculum Corporation terminals (includes software) @ $2,100, annualized at 10% over 6 years
556.00	1 dot matrix (120 cps) printer console (includes controller for CPU) and software @ $2,422, annualized at 10% over 6 years

APPENDIX TABLE C-3 (continued)

Annual Costs	Ingredients
572.00	Installation (includes 50% of CPU @ $1,500; 16 terminals @ $100; printer at $140) at $2,490, annualized at 10% over 6 years
3,200.00	Curriculum rental @ $200/terminal per year
1,500.00	Supplies
	OTHER
64.00	Training time for 1 teacher @ 12 hours at $20.25/hour, annualized at 10% over 5 years
115.00	UNIX license fee @ 50% of $1,000 annualized at 10% over 6 years
4,895.00	Maintenance (includes CPU @ 50% of $4,050; terminals @ $160; printer @ $310)
$29,275.00	TOTAL COST PER YEAR
$ 304.95	COST PER STUDENT (N=96)

APPENDIX TABLE C-4

FULL UTILIZATION COSTS

Merrimack Education Center, Chelmsford, Massachusetts: Reading and Math CAI

1980-81

Reading and math for 92 students in one elementary school

Annual Costs	Ingredients
	PERSONNEL
$ 1,563.00	1 CAI coordinator at Merrimack Education Center @ 1/16 time at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
376.00	Classroom renovation @ 4/32 of $18,500, annualized at 10% over 10 years
361.00	Room for CPU @ 4/32 of 1/2 classroom annualized @ 10% over 30 years (includes $63 for utilities and routine maintenance)
180.00	Office space for CAI coordinator @ 1/16 of 1/2 classroom annualized @ 10% over 30 years (includes $36 for utilities and routine maintenance)
	EQUIPMENT AND MATERIALS
739.00	1 Microhost CPU with 1 Mb memory and 40 Mb storage and software @ 4/32 of $25,760, annualized at 10% over 6 years
1,928.00	4 Computer Curriculum Corporation terminals and software @ $2,100 annualized at 10% over 6 years
556.00	1 dot matrix (120 cps) printer console and software (includes controller for CPU) @ $2,420 annualized at 10% over 6 years

APPENDIX TABLE C-4 (continued)

Annual Costs	Ingredients
167.00	Installation (includes 4/32 of CPU @ $1,500; 4 terminals @ $100; printer @ $140) annualized at 10% over 6 years
31.00	Classroom furnishings (includes teacher desk and chair and 4 student chairs) annualized at 10% over 10 years
5.00	Office furnishings for CAI coordinator @ 1/16 of $500 annualized at 10% over 10 years
800.00	Curriculum rental @ $200/terminal per year
375.00	Supplies @ 4/32 of $3,000
63.00	Transportation
	OTHER
48.00	Training time for 1 Title I teacher @ 9 hours at $20.25/hour annualized at 10% over 5 years
29.00	UNIX license fee @ 4/32 of $1,000 annualized at 10% over 6 years
1,456.00	Maintenance (includes 4/32 of $4,150 for CPU; 4 terminals @ $160; printer @ $310)
$10,427.00	TOTAL COST PER YEAR
$ 113.34	COST PER STUDENT (N=92)

APPENDIX TABLE C-5

FULL UTILIZATION COSTS

Newark, New Jersey: "Regular Reading CAI"

1983-84

Reading for 184 students at one elementary school (program at 8 sites)

Annual Costs	Ingredients
	PERSONNEL
$21,875.00	1 Chapter I teacher @ $17,500 plus fringe benefits per year
OR	
6,750.00	1 teacher aide @ 1,080 hours/year at $5.00/hour plus fringe benefits
1,042.00	1 CAI Reading Coordinator @ 1/8 (for one of eight sites) of 1/3 time (the Coordinator's commitment to the whole program) at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory annualized at 10% over 30 years (includes $1,000 for utilities and routine maintenance)
753.00	Classroom renovation @ 8/32 of $18,500 annualized at 10% over 10 years
120.00	Office space for CAI Coordinator @ 1/8 of 1/3 of 1/2 classroom annualized at 10% over 30 years (includes $21 for utilities and routine maintenance)
	EQUIPMENT AND MATERIALS
1,475.00	1 Microhost CPU with 1 Mb memory and 40 Mb storage and software @ 8/32 of $25,700 annualized at 10% over 6 years

APPENDIX TABLE C-5 (continued)

Annual Costs	Ingredients
3,857.00	8 SLS-11 Computer Curriculum Corporation terminals and software @ $2,100 annualized at 10% over 6 years
556.00	1 dot matrix (120 cps) printer console (includes controller for CPU) and software @ $2,420 annualized at 10% over 6 years
302.00	Installation (includes 8/32 of CPU @ $1,500; 8 terminals @ $100; printer @ $140) annualized at 10% over 6 years
61.00	Classroom furnishings for CAI laboratory (includes teacher desk and chair and student chairs) annualized at 10% over 10 years
3.00	Office furnishings for CAI coordinator @ 1/8 of 1/3 of $500 annualized at 10% over 10 years
48.00	Training time for 1 Chapter I teacher @ 9 hours at $20.25/hour, annualized at 10% over 5 years
57.00	UNIX license fee @ 8/32 of $1,000 annualized at 10% over 6 years
2,603.00	Maintenance (includes 8/32 of CPU @ $4,050; 8 terminals @ $160; printer @ $310)
42.00	Transportation
$42,669.00	TOTAL COST PER YEAR FOR PROGRAM WITH TEACHER
$ 231.90	COST PER STUDENT FOR PROGRAM WITH TEACHER (N=184)
$27,544.00	TOTAL COST PER YEAR FOR PROGRAM WITH AIDE
$ 149.70	COST PER STUDENT FOR PROGRAM WITH AIDE (N=184)

APPENDIX TABLE C-6

FULL UTILIZATION COSTS

Omaha, Nebraska: Reading CAI

1983-84

Reading for 150 fourth grade students in 5 classrooms in one elementary school.

Annual Costs	Ingredients
	PERSONNEL
$ 6,250.00	1 reading specialist @ 35% time for project coordination at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
723.00	Office space for reading specialist @ 25% of 1/2 classroom (includes proportion of maintenance)
	EQUIPMENT AND MATERIALS
1,142.00	5 Apple IIe microcomputers @ $995 annualized at 10% over 6 years
36.00	5 computer tables @ $44 annualized at 10% over 10 years
248.00	Protection equipment (includes 5 fans @ $40; 5 mats @ $59; 5 surge suppressors @ $117) annualized at 10% over 6 years
12.00	5 digital clocks @ $10 annualized at 10% over 6 years
202.00	10 diskettes @ $50 annualized at 10% over 3 years
500.00	Supplies @ $100/microcomputer
20.00	Office furnishings for reading specialist @ 25% of $500, annualized at 10% interest over 10 years

APPENDIX TABLE C-6 (continued)

Annual Costs	Ingredients
23.00	Adapters and extension cords @ $100 annualized at 10% over 6 years
	OTHER
347.00	Training for 5 teachers @ 13 hours (includes 7 hours on software and 6 hours on hardware) at $20.25/hour, annualized at 10% over 5 years
350.00	Maintenance @ $70/microcomputer
250.00	Transportation for reading specialist @ 25% time
$11,853.00	TOTAL COST PER YEAR (N=150)
$ 79.02	COST PER STUDENT

APPENDIX TABLE C-7

FULL UTILIZATION COSTS

Pasco, Washington: Mathematics CAI

1982-83

Mathematics for 115 third through sixth graders at one elementary school

Annual Costs	Ingredients
	PERSONNEL
$ 6,750.00	1 teacher aide @ 1,080 hours/year at $5.00/hour plus fringe benefits
4,688.00	1 CAI supervisor @ 25% of 3/4 time, at $20,000 plus fringe benefits per year
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance)
470.00	Classroom renovation @ 5/32 of $18,500 annualized at 10% over 10 years
723.00	Office space for CAI supervisor @ 25% of 1/2 classroom (includes $125 for utilities and routine maintenance)
	EQUIPMENT AND MATERIALS
922.00	1 Microhost CPU with 1 Mb memory and 40 Mb storage, and software @ 5/32 of $25,760 annualized at 10% over 6 years
2,411.00	5 SLS-11 Computer Curriculum Corporation terminals and software @ $2,100 annualized at 10% over 6 years

APPENDIX TABLE C-7 (continued)

Annual Costs	Ingredients
556.00	1 dot matrix (120 cps) printer console (includes controller for CPU) @ $2,420 annualized at 10% over 6 years
201.00	Installation (includes 5/32 of CPU @ $1,500; 5 terminals @ $100; printer @ $140) annualized at 10% over 6 years
76.00	Classroom furnishings (includes teacher desk and chair and student chairs) annualized at 10% over 10 years
20.00	Office furnishings for CAI supervisor @ 25% of $500, annualized at 10% over 10 years
1,000.00	Curriculum rental @ $200/terminal per year
469.00	Supplies @ 5/32 of $3,000
188.00	Transportation
	OTHER
36.00	UNIX license fee @ 5/32 of $1,000 annualized at 10% over 6 years
1,743.00	Maintenance (includes 5/32 of $4,150 for CPU: 5 terminals @ $160; printer @ $310)
$27,778.00	TOTAL COST PER YEAR
$ 241.55	COST PER STUDENT (N=115)

APPENDIX TABLE C-8

FULL UTILIZATION COSTS

Salt Lake City, Utah: "Basic Literacy Through Microcomputers"

1981-82

Reading (and typing) for 180 students in one elementary school

Annual Costs	Ingredients
	PERSONNEL
$ 6,750.00	1 teacher aide as lab manager @ 1,080 hours at $5.00/hour plus fringe benefits
1,750.00	1 principal @ 5% time at $28,000 plus fringe benefits per year
	FACILITIES
5,775.00	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance of the space)
212.00	Classroom rewiring for CAI laboratory @ $2,000 annualized at 10% over 30 years
	EQUIPMENT AND MATERIALS
7,310.00	32 Apple IIe microcomputers @ $995 annualized at 10% over 6 years
942.00	Protection equipment (32 fans @ $40, 32 mats @ $59, 8 surge suppressors at $117) annualized at 10% over 6 years
184.00	1 Epson FX-100 dot matrix printer (220 cps) printer with cable at $800 (discounted), annualized at 10% interest over 6 years
80.00	1 curriculum binder @ $198 annualized at 10% over 3 years
772.00	32 sets of backup disks @ $60 annualized at 10% over 3 years

APPENDIX TABLE C-8 (continued)

Annual Costs	Ingredients
488.00	Furnishings (teacher desk and chair and student desks and chairs) annualized at 10% over 10 years
3,200.00	Supplies
	OTHER
192.00	Training time for 6 elementary teachers @ 6 hours x $20.25/hour annualized at 10% interest over 5 years
4.00	Rental of training videotape at $15 annualized at 10% interest over 5 years
2,240.00	Maintenance (includes microcomputers @ $70/year
$29,899.00	TOTAL COST PER YEAR
$ 166.11	COST PER STUDENT (N=180)