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ABSTRACT

This study employs meta-analysis and cost-effectiveness instruments to evaluate and compare cross-age tutoring, computer assistance, class size reductions, and instructional time increases for their utility in improving elementary school reading and math scores. Using intervention effect studies as replication models, researchers first estimate costs, then compute cost-effectiveness ratios (size of effect for each $100 of cost per pupil). Among alternatives in the area of math achievement, for example, two tutoring interventions show the largest effects per $100 of cost per pupil, while increasing instructional time by one-half hour daily has the smallest effect per cost. Peer tutoring and computer assistance reveal almost equivalent cost-effectiveness ratios for reading. Conversely, increasing instructional time appears to be a poor choice for both. Such results should serve as guidelines--not absolutes--for considering alternative interventions. A bibliography and appendixes conclude the report. (KS)

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SCHOOL OF EDUCATION STANFORD UNIVERSITY

Project Report No. 84-A11

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INSTITUTE FOR RESEARCH ON EDUCATIONAL FINANCE AND GOVERNANCE

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Abstract

In order to assist decisionmakers in considering different approaches to improving mathematics and reading performance of elementary school children, four different educational interventions are subjected to a comparative cost-effectiveness analysis. The four interventions include: reducing class size, increasing the length of the school day, computer-assisted instruction, and peer and adult tutoring. Using the tools of meta-analysis and cost effectiveness, each intervention is evaluated and compared according to its cost-effectiveness in improving reading and mathematics scores. A discussion of the cost-effectiveness ranking of the interventions and implications is provided. In general, tutoring approaches are found to be the most cost-effective, while reducing class size and increasing the length of the school day are found to be the least cost-effective. Computer-assisted instruction ranks between these two extremes.

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I. INTRODUCTION

The last few years have witnessed numerous calls for reform of elementary and secondary education in the United States. Some of the reports make general recommendations for improvement, while others focus on such specific interventions as changes in curriculum and teacher training, increasing time in learning, and the rapid implementation of computers in schools.

Although the policy thrust of these reports may appear to be clear, such is not the case. First, many of the recommendations are so broad that they actually comprise a number of very different approaches. For example, time for learning can be increased through various combinations of extending the school day or the school year, or increasing time allocated to specific subjects. There are also myriad approaches to improving teacher training and retraining. Second, a sensible response in each of these areas must be tailored to particular needs of schools rather than designed as a broad-brush approach to reform. Different priorities may be salient in different educational situations, and the feasibility of successful implementation will also vary from context-to-context.

Many of the proposed reforms are likely to be costly, but the reports do not indicate what they will cost and who should pay for them. Clearly, the adoption of all of the items on the reform agenda would consume more resources than states and local schools have at their disposal, but the reports do not indicate how priorities should be set among them. Nor is guidance found from other quarters on costs and on the contributions of the proposed changes to the educational effectiveness of the school program.

The absence of such crucial data for the school reform agenda is not a simple oversight. Such data are only rarely available in any form; when available, the specific information is not immediately applicable to an assessment of policy alternatives. The problem arises in part because of the lack of evaluations of the educational alternatives. And because the most promising alternatives are often those with which we have little or no experience, one can only speculate about their effectiveness.

Even when there are instances of applications of a specific educational intervention, they are often so idiosyncratic that generalization to other situations is hazardous. A project for disadvantaged third graders in one school district, for example, may be difficult to replicate with similar results for other groups of students in other school districts. Not only do particular student groups differ from one another in various ways, but organizational settings and adaptations of interventions within them also differ.

Finally, cost information is rarely available because most evaluations neglect to consider the costs of potential interventions. Evaluators are not usually trained in cost analysis, and school sites and districts do not have systematic methods of ascertaining the costs of specific interventions. When school budgets are used to estimate costs, the estimates tend to be incomplete or misleading (Levin 1983: 50-51).

The result of these gaps in information is that there is little to guide policymakers or school districts in choosing among school reforms that will account for both the costs and effects of educational interventions. Consider a hypothetical example. Assume that a district would like to improve student performance in reading and mathematics at the primary level. Alternatives include increasing the length of the school day, retraining teachers to increase instructional time, introducing computer-aided instruction, or reducing class size. Assume further that by reallocating resources and receiving higher allowances from the state, the school district will have about $200 per student to spend on the interventions. How should the $200 allocation per student be used to maximize reading and mathematics achievement?

The school district will wish to obtain the maximum increase in mathematics and reading scores that is possible with an expenditure of an additional $200 per student. One way of addressing the problem is to ascertain both the cost and effectiveness of each alternative for increasing mathematics and reading scores. The cost-effectiveness ratios which result enable the district to rank alternative mathematics and reading programs in terms of their contribution to improving scores relative to their costs. Those alternatives with the largest effects relative to costs are the most cost-effective and should presumably have the highest priority. By selecting the interventions with the highest cost-effectiveness ratios, the district can expect to obtain the largest effect from the additional $200 for each student.

The purpose of this report is to provide a cost-effectiveness evaluation of four prominent educational interventions for improving reading and mathematics proficiencies: reducing class size, using computer-assisted instruction, increasing the instructional time devoted to mathematics and reading, and employing cross-age tutoring. Each of these approaches represents an intervention that schools might consider for raising students' mathematics and reading achievement.

Ideally, an experiment would be conducted in which students were randomly assigned to each of the four interventions in order to ascertain how their proficiencies in mathematics and reading improved. However, no such experimental data are available. An experiment of this kind would require massive coordination, resources, and time. Further, there are significant obstacles to creating a "clean" experiment and to generalizing from its results. A more feasible approach is to pool the large number of existing studies on each intervention into a synthesis of findings. In this way, we can estimate the effects of each intervention and integrate them with costs estimated by a uniform cost methodology. That is the approach taken in this study.

Meta-analysis is one means of synthesizing the findings of many studies on a topic (Glass 1976, 1978; Smith and Glass 1980; and Glass, McGaw, and Smith 1981). As Glass, McGaw, and Smith (1981) define it: "The essential character of meta-analysis is that it is the statistical analysis of the summary findings of many empirical studies" (p. 21). On experimental questions, it seeks to determine the effect of a specific treatment, influence or intervention from a large variety of individual studies on a particular subject.

In order to obtain cost-effectiveness results, it is necessary to combine effectiveness measures with data on the costs of alternative interventions. Only recently have cost analyses begun to enter the evaluation literature systematically. Often, even when cost information is provided, it is unclear how the data were derived. In this study we will draw upon the "ingredients" method to determine the costs of each intervention (Levin 1975, 1983). This method makes explicit the ingredients and prices included in cost estimates. Data on effectiveness and costs will be combined to compare the cost-effectiveness of the four instructional interventions: cross-age tutoring, computer-assisted instruction, reducing class size and increasing time in learning.

The next section of the report will describe the general nature of the interventions that are under consideration, characteristics of the specific models, and the manner in which they were chosen. This will be followed by sections on the assessment of effectiveness, estimation of costs, and the construction and evaluation of cost-effectiveness ratios.

II. INSTRUCTIONAL INTERVENTIONS

Several criteria were used to choose the set of alternative instructional interventions that might be considered for the cost-effectiveness analysis. (1) The interventions had to be designed to improve mathematics and/or reading; (2) they had to be supplemental in nature; (3) they had to be readily replicable; and, (4) sufficient statistical evidence for an acceptable evaluation had to be available. Each of the criteria will be explained below.

Cost-effectiveness comparisons can only be made among alternatives that have similar types of outcomes (Levin 1983: Chap. 1). Improvement in mathematics and reading scores was chosen as the outcome because of the prominence of these basic subjects on the educational reform agenda and among schools' priorities generally. An overriding concern of our study was the potential applicability of the results. In this respect, it is easier to achieve incremental change in school programs than fundamental restructuring. Accordingly, we chose to consider only interventions that would supplement existing school offerings.

An intervention's replicability was also a selection criterion. Some highly successful programs may be unique to a particular set of circumstances and cannot be duplicated with similar results in other settings. For example, in our early analyses, a specific study of individually-prescribed-instruction (IPI) (Sinks 1969) showed the best results relative to costs of all of the interventions in the comparison. Discussions with a knowledgeable expert, however, suggested that this result was unique to the study and could not be easily duplicated elsewhere. In addition, the totally individualized approach in the model we examined actually constituted restructuring instead of supplemental change. By contrast, the interventions we chose met our feasibility criterion by being both supplemental and replicable. Finally, our criteria included the requirement that adequate evidence was needed to draw conclusions about the effectiveness of each approach.

While these criteria are useful for present purposes, they represent limitations in a broader consideration of alternatives for school reform. Our results will be limited to reading and mathematics: they should not be generalized beyond these subjects. Moreover, our criteria exclude both alternatives that would fundamentally transform the school and those on which little or no evidence is available. It is possible, for example, that a fundamental restructuring of schools would be more efficient than incremental improvement. It is also possible that certain instructional alternatives would be shown to be more cost-effective than the one in this study, if the evidence were available. Of course, these limitations apply to virtually all studies of educational reform. Despite them, we believe that the specific interventions that we have chosen are salient ones for educational policy.

The four interventions that were chosen for this study include cross-age tutoring, computer-assisted instruction (CAI), reduction in class size, and increases in daily instructional time. A meta-analysis was carried out for each of the general interventions in order to estimate the range of effect sizes on mathematics and reading achievement. In order to do a cost analysis, the exact ingredients needed for a particular application of an intervention must be specified. Accordingly, with the exception of the reduction in class size, a specific study was chosen that was representative of each intervention's general approach and was typical of its effect size. Both the effect sizes used in this analysis and the costs are derived from these studies.

Criteria for choosing a representative study included: an approach that was representative of the class of interventions; an effect size that was representative of the typical effect found in a meta-analysis of many studies of the intervention; a clear description of the intervention and its ingredients; the availability of a careful and reliable evaluation; and the promise of replicability. With the exception of reducing class size, these choices enabled us to obtain a more precise picture of costs and other conditions conducive to replication than would have a generalized version of an intervention based upon a meta-analysis alone. With respect to the reduction in class-size, the nature of the intervention and its cost are so straightforward that we were able to draw on the meta-analysis results without singling out a representative study. A description of each of the interventions, as well as the specific study that was used for more precise cost and effectiveness analysis, follows.

Cross-Age Tutoring

Cross-age tutoring has a long informal history in American education. In one-room schools, older students routinely helped teach younger students. The benefits of such an arrangement have been commented on at least since the 19th century. For example, Ehly and Larsen cite John Comenius (published 1849) and Andrew Bell (1832) who both noted that the one who teaches also learns. More contemporary studies confirm this view. A compendium of reported benefits of successful peer tutoring efforts includes achievement gains, increases in self-esteem and enhancement of academic motivation, often for tutors and tutees (Ehly & Larsen, pp.12-17 and pp.21-23). (Some of these reports are based more upon anecdotal evidence than on findings from rigorously disciplined studies, however.) Researchers hypothesize that peer tutoring programs work in part because the tutees are motivated to model the tutors' behavior, and because tutees feel more relaxed with a child tutor, and are therefore better able to concentrate (Ehly and Larsen, p.21).

The need for tutoring often arises because individual students may not be well-served by group instructional methods. Peer tutoring (or any one-to-one tutoring arrangement) in essence assigns an individual surrogate teacher to the tutee. The policy importance of tutoring turns on the fact that when a child or paraprofessional, instead of a certificated teacher, fulfills this role, the individualized instruction costs less. Perhaps even more important, the tutor is expected to benefit from the experience along with the tutee.

Assuming older children will tutor younger ones, a peer tutoring program implies the need to select tutors and tutees, coordinate activities between at least two classrooms, and provide adequate training and supervision for the student pairs. The tutoring intervention we have selected utilizes all these elements. The peer tutoring component is one in which younger children were tutored by older children, whom adults trained and supervised. A tutoring program by adult paraprofessionals parallels this peer tutoring, and provides help mainly for upper-grade children.

The cross-age tutoring intervention used in this study is based upon the Cross-Age Structured Tutoring Program for Reading and Mathematics in the Boise (Idaho) Schools (The Independent School District of Boise, no date (a) and (b) and 1983). For a school of about 300 to 400 students, an adult tutor manager in reading, an adult tutor manager in math, and an adult tutor in reading and one in mathematics--who are all paraprofessionals--along with upper grade student tutors, provide tutoring for second and third grade children needing help in reading and mathematics. The adult tutors and tutor managers are trained and supervised by a Tutoring Program Specialist, a central office administrator, whose responsibility covers 14 schools. The student tutors at each site are trained and supervised by the tutor managers in each subject. Typically, a tutor manager oversees 30 tutoring pairs, and an adult tutor works regularly with twelve or thirteen individual tutees. Tutoring sessions with both adult tutors and student tutors last approximately 20 minutes a day.

All the tutoring pairs (adults and students) use a commercially-available curriculum, which includes a manual for each adult in each subject (as well as an audiotape in reading). Student tutors are trained with a locally-produced manual. As part of their work with tutees, they distribute locally-purchased awards and certificates. Both student tutors and adult tutors find otherwise unused space around the school for the tutoring sessions, such as an available classroom, hallways, a cafeteria, or a small office. Thus, one school in the range we are considering hosts sixty student tutors and their sixty tutees, as well as 26 other tutees who work with the adult tutors, for a total of 146 children participating in the tutoring program.

The effects of the Boise tutoring program, then, are principally those of the peer tutoring component for students in grades 2 and 3, and the adult tutoring component for students in grades 4, 5 and 6. Pupils in the lower grades are not tutored exclusively by students, however. When a younger child cannot work with a student tutor, that child may be assigned to the tutor manager (or to the adult tutor). Or, when a student tutor is absent, an adult tutor might substitute in the peer tutoring component. The division of lower-grade students being tutored by peers, and upper-grade students by adults holds true on the whole, and tutor managers do devote the majority (from 85% to 90%) of their time to coordinating the peer tutoring.

Computer-Assisted Instruction

Although computer-assisted instruction (CAI) has been available for at least two decades, the drastic decline in the costs of computer hardware and the sharp increase in capability of microcomputers have engendered large growth in the use of computers for instruction. The growth of CAI is also due to the ubiquity of computers in the workplace, and the explicit call of national educational reports for greater use of computers in instruction and more widespread "computer literacy" among students. Typical applications of CAI include drill and practice (exercises to reinforce conventional classroom instruction) and the teaching of specific subjects such as computer programming, languages, design, and technical topics (Center for Social Organization of Schools 1983).

Use of computers in instruction is growing very rapidly, but relatively few evaluations of the effects of CAI over a full academic year or longer exist. And those evaluations of the effects of CAI on mathematics and reading achievement are generally limited to drill and practice. The CAI model whose costs and effects are evaluated in this study stays within the limits of a specific drill and practice approach as set out by one of the pioneers in the field, the Computer Curriculum Corporation (CCC). The advantages of selecting this particular approach are that it is one of the most important applications of CAI; it has the longest history of CAI use; and it has been the subject of one of the best instructional evaluations of a long-term (four year) intervention.

The specific CAI approach that we have used to construct cost-effectiveness data was sponsored by the Educational Testing Service and Los Angeles Unified School District (ETS/LAUSD) in 1976-80 with funding from the National Institute of Education (Ragosta, Holland, and Jamison 1982). Elementary students were provided with ten-minute daily sessions of drill and practice in mathematics, reading, and language arts. Some students had more than one daily session, and the combinations of subjects to which students were assigned differed so that a child studying reading and language arts by computer could serve as a control for assessing the benefits of mathematics instruction by another child studying reading, language arts and mathematics. Since the experiment ran for four years, it was also possible to make comparisons among students with up to four years of CAI and with different combinations of subjects as well as between students who received CAI and those who did not.

The approach evaluated in the ETS/LAUSD study requires a separate classroom with 32 terminals that are connected to a minicomputer. (A similar type of delivery system can be constructed using personal or microcomputers that are arranged in a network with a hard-disk storage device.) The minicomputer holds all computer curricula for all elementary grades and curriculum areas as well as student records on the number of sessions that students have taken and their progress.

Students sign in at their terminals and begin the session where they left off in the previous session. A problem is displayed, typically in a multiple-choice or a "fill in the blank" format. For instance, a student might be given a problem in arithmetic operations such as vertical addition or subtraction and asked to type in the answer. Or the student might be asked to fill in the correct form of a verb in a sentence. The computer program indicates on the display screen whether the answer is correct or incorrect. In either case, a new problem appears on the display. When a student achieves proficiency on a particular part of the curriculum--as evidenced by a high proportion of correct answers--the system provides either problems of the same type at a higher level of difficulty or a new type of problem. The curriculum is not designed to introduce new curricular material as much as it is to provide an opportunity to apply concepts that have already been taught.

Reducing Class Size

One of the oldest methods of improving educational outcomes is to reduce class size. The reduction of class size is not an intervention that is designed to increase achievement directly. Rather, it is expected to influence what goes on in the classroom, how teachers interact with students, and what the students themselves do or are allowed to do. It is especially favored by teachers and parents who feel that smaller classes will mean more individual attention for pupils. The differences in classroom processes resulting from reduced class size, in turn, influence outcomes like student achievement, student attitudes, and teacher morale. In this indirect fashion then, a class size reduction opens the way for improving classroom processes and, hence, achievement. Glass and Smith (1979) attempted to integrate the extensive literature on the relation between class size and achievement, and their results are used as the basis for calculating the effect sizes in this study. Cost-effectiveness comparisons will be made for reducing class size successively from 35 to 30 students, 30 to 25, 25 to 20, and 35 to 20.

Increasing Instructional Time

Although the reduction of class size has been the most prominent traditional intervention for improving schooling in the past, increasing instructional time has become more recently the rallying point for educational reform. National reports argue for increases in the amount of time devoted to instruction by lengthening the school day and school year, assigning more homework, and using existing time more effectively (National Commission on Excellence in Education 1983: 29; Task Force on Education for Economic Growth 1983: 38).

The evidence behind these policies derives from comparisons of time in instruction between U.S. schools and those of other industrialized nations as well as studies of the effects of time in learning on achievement. The typical U.S. school day lasts 5-6 hours, while a 7 hour day is common in other industrialized countries such as Japan. Further, while a 180-day school year is the norm in the U.S., 220- to 240-day sessions are found in other nations. Empirical studies suggest that more instructional time as well as greater amounts of "time-on-task" or "engaged learning" will improve educational achievement (Karweit 1983).

The data that are used here to measure the effectiveness of increased learning time derive from the Beginning Teacher Evaluation Study (BTES), which is the most important data source on the subject (Fisher et al. 1980; Denham and Lieberman 1980). The BTES research team carefully observed selected students in a number of second and fifth grade classrooms in 1976-1977 at the same time that teachers in those classrooms kept detailed logs of instructional content in mathematics and reading and time spent on those activities for an 85-day period. Student achievement was assessed by tests geared to the specific content taught.

More time alone does not necessarily translate directly into more learning time and higher achievement. Extraneous factors, such as clerical tasks, attention to group processes, and interruptions for discipline and field trips , all claim some available time. Additional factors, such as fatigue, might also undermine the effectiveness of some of the additional time. Equally important, theoretical models of learning suggest that classroom instructional processes and environment, student aptitudes and behavior all contribute to students' classroom learning. This learning is inferred from student behavior, which may be on- or off-task, engaged or unengaged in learning. The idea behind informed recommendations for better use or extension of school time is that the more time allocated to instruction and the more student engagement during that time, the more learning will take place.

Thus, the variable of interest to policymakers should emerge as engaged time or time-on-task. Engaged time may be increased by restructuring learning activities, reducing distractions and interruptions, or by increasing the total amount of time available for instruction; but it is important to reiterate that clock time is not equivalent to learning time. The BTES stressed the importance of Academic Learning Time. In adapting the BTES findings to a time intervention for second and fifth grade reading and mathematics, we therefore assumed that only a portion of available time will be actual academic learning time. We estimate that to lengthen the school year of 180 days by one hour a day will add only 150 hours to instruction, instead of 180 hours.

III- EFFECTS OF INTERVENTIONS

In this section we will present the estimated effects of the four interventions. Details on the meta-analysis of effects for each intervention are reported separately in Glass (1984), so we will provide only the basic method and overall results here. For each of the interventions, we searched the literature to locate pertinent studies. Each of the studies was scrutinized to determine that it met the minimal conditions for inclusion outlined above, such as having a reasonable evaluation design and outcome measures that could be placed in a standardized or common metric.

Effects of the interventions were converted into standard scores or effect sizes in terms of standard deviation units. For experimental studies this was generally estimated as the average test score difference between treatment and control groups divided by the standard deviation of the control group (Glass, McGaw and Smith 1981). In the case of quasi-experimental research (research in which statistical controls were used to adjust for differences among subjects), the effect size was derived by dividing the increase in test scores associated with the regression coefficient for the intervention by the standard deviation of test scores in the sample. Thus, the effectiveness of an intervention was viewed as the increase in test scores associated with the intervention in standard deviation units.

The general strategy was to array the different studies relating to each intervention to ascertain the range of results and to explore explanations for differences in results such as differences in testing format, grade level, student population, or variations of the intervention. Once a range was established, a specific study was chosen towards the middle of the range that also met the criteria of replicability and adequate detail on the nature of the intervention and its resource ingredients. Many studies lacked details about the

TABLE ONE--EFFECT SIZES PER YEAR OF INSTRUCTION FOR FOUR EDUCATIONAL INTERVENTIONS

		Mathematics						Reading					
			Grade						Grade				
Intervention		Mean	2	3	4	5	6	Mean	2	3	4	5	6
CROSS-AGE TUTORING	Combined Peer and Adult Program	.79[c]	1.02	.91	.79	.68	.55	.42[c]	.50	.46	.42	.39	.35
	Peer Component	.97[a]	1.02	.91				.48[a]	.50	.46			
(Boise Model)	Adult Component	.67[b]			.79	.68	.55	.38[b]			.42	.39	.35
COMPUTER ASSISTED INSTRUCTION	Overall	.12[c]	.13[a]			.12[b]		.23[c]	.23[a]			.23[b]	
		Computation	.30[a]			.25[b]		Vocabulary	.25[a]			.25[b]	
(10 Minute Daily Session on Mini-computer)		Concepts	.00[a]			.00[b]		Comprehension	.20[a]			.20[b]	
		Application	.10[a]			.10[b]							
REDUCING CLASS SIZE	From 35 To 30	.06						.03					
	From 30 To 25	.07						.04					
	From 25 To 20	.09						.05					
	From 35 To 20	.22						.11					
INCREASING INSTRUCTIONAL TIME (Additional 30 Minutes a Day for Each Subject)		.03	.02			.04		.07	.08			.07	

LEGEND: a = average for grades 2 and 3
b = average for grades 4, 5 and 6
c = average for grades 2 through 6

intervention, so they did not meet these criteria. Further, we scrutinized the evaluations on which our effectiveness results were based to ensure that they met reasonable standards. In the case of class size reductions, it was not necessary to single out a particular study for establishing replicability and resource requirements.

A summary of the effects of each intervention on mathematics and reading achievement is presented in Table One. All effects are based upon the assumption of a full school year of intervention. For a detailed treatment of the derivation of effect sizes for the four interventions, see Glass (1984).

Effects of Cross-Age Tutoring

The cross-age tutoring approach used in Boise, Idaho, consists of children in the upper elementary grades tutoring students in grades 2 and 3 and adults tutoring students in grades 4, 5, and 6. Other adults were responsible for training student tutors and for overall coordination of the tutoring program. Comparable achievement gains were found for both tutors and tutees for the student tutoring. Table One separates the breakdown by peer and adult components as well as by an overall summary of the combined program.

Overall tutoring effects were substantial, with average effect sizes of .97 and .48 for mathematics and reading, respectively, in the peer component and .67 and .38 for mathematics and reading in the adult tutoring component. Average effect sizes in the combined peer and adult program were .79 for mathematics and .42 for reading. Although the effect sizes are lower at each successive grade level, it is not possible to ascertain if this is intrinsic to the tutoring intervention, if the adult tutoring approach used in the upper grades is less effective than the peer approach used in the earlier ones, or if the difference is due to a measurement artifact.

Effects of Computer-Assisted Instruction

The drill and practice approach of the Computer Curriculum Corporation is the most-widely used CAI intervention of its type. Effect sizes are based upon reanalysis of the results of the four-year experiment carried out by the Educational Testing Service in the Los

Angeles Unified School District from 1976-80. Effect sizes are associated with each ten minute daily session in a subject. Table One reports both estimated mean effect sizes as well as results for grades 2 and 5. The mean effect size is .12 for mathematics and .23 for reading. The mean score in each area is based upon an equal weighting of the three mathematics sub-tests and two reading sub-tests. The largest effect size in mathematics is for computation, with a smaller effect for application and virtually no effect for concepts. The two sub-scores (vocabulary and comprehesion) for the reading effect are in much closer agreement.

Effects of Reducing Class Size

The effect of reducing class size is based upon a refinement of the results of a meta-analysis of 77 studies (Glass and Smith 1979). After evaluating the different studies and exploring unique effects of a variety of mediating factors in those studies, it was found that the relation between class size differences and learning effectiveness can be estimated by the following relation:

$$\hat{\Delta}_{S-L} = \hat{\beta} \log_e(L/S)$$

where $\hat{\Delta}_{S-L}$ is the estimated effect size for achievement in changing from a large class size of L pupils to a small class size of S pupils, and $\hat{\beta}$ is a constant determined by fitting the model to the data by least squares. The value of $\hat{\beta}$ is about .40 for mathematics and .20 for reading. On this basis, the effect sizes for reducing class size in Table One were estimated for sequential reductions of 5 students from a class size of 35 until a class size of 20 was reached. An estimate was also made for reducing class size directly from 35 to 20. The typical effect sizes associated with a class size reduction of 5 students is about .07 in mathematics and about half that in reading. For a reduction in class size from 35 to 20, the expected increase in effect size is about .22 standard deviation units for mathematics and .11 for reading.

Increasing Instructional Time Effects

The estimate of effectiveness for increasing instructional time was based on adding one hour to the elementary school day, divided equally between mathematics and reading. Although this would add 180 hours a year--90 for mathematics and 90 for reading--we also assume that only about 80 percent of the time would actually be used for instruction. Results were taken from the Beginning Teacher Evaluation Study (BTES) which carried out a detailed analysis of classroom time over a 56-day period. For example, extrapolating to a 180-day year, we estimated that about 186.5 hours and 232.6 hours were devoted to reading at grades 2 and 5 respectively in the BTES classrooms. The corresponding hours of mathematics instruction were 102 hours at grade 2 and 133 hours at grade 5. An additional 75 hours of instruction a year in each subject would therefore increase the amount of time devoted to reading by about 40 percent at grade 2 and 32 percent at grade 5, and would increase learning time in mathematics by about 74 percent in grade 2 and 56 percent at grade 5. These represent substantial increases in instruction.

The effect sizes for increasing instructional time are estimates from the BTES data. It is important to mention that the fifth grade mathematics result for the BTES data was suspect in that it was highly inconsistent with the other results and seemed to be due to an anomalously large effect for a single sub-test, fractions. Accordingly, the result was adjusted to provide a result that was more nearly consistent with the other sub-tests, scores and other studies in the literature (Glass 1984). Effect sizes were relatively small, with a mean estimated effect of only .03 for mathematics and .07 for reading.

Table One shows only the effect sizes, a measure of effectiveness, for each intervention. Before considering a ranking of the interventions for possible implementation, we also need to know their costs. The next section presents the cost of each of the interventions.

IV- COSTS OF INTERVENTIONS

The goal of the cost portion of the analysis was to ascertain the costs for replicating each intervention so that comparisons across interventions could be made. Replication refers to the ability to undertake the same intervention with similar effects at a different site. Accordingly, the replication costs include only those required to reproduce the intervention in new settings but not the costs associated with initial development activities or evaluations that created and assessed the intervention.

The procedure for estimating the cost of an intervention is based upon a three-stage approach (Levin 1983). First, the ingredients for replicating a program are specified in sufficient detail. Second, an annual value or annual cost is placed upon each ingredient. The summation of these costs provides an estimated total annual cost for each intervention. Finally, a cost per student is derived by dividing the total annual cost figure by the number of students served.

It is important to emphasize that all of the four interventions represent instructional supplements rather than replacements of basic instructional services. Accordingly, the costing strategy addresses only the additional resources or ingredients required to replicate these supplemental interventions. For each intervention we identified the ingredients by consulting documents and, where necessary, expert practitioners, to obtain descriptions of the interventions at an appropriate level of detail to permit cost estimates of the resources required. These were classified according to numbers and types of personnel, facilities and equipment, materials, and other required ingredients.

Assigning a cost to the ingredients entailed a number of steps. First, to obtain a consistent set of costs for a specific year, 1980, an attempt was made to set out average "national" costs for 1980. This table of costs is found in Appendix Table A-1 with a reference to both the source of each as well as the method of calculation. For example, whenever a full-time classroom teacher is used in an intervention, the cost is established as $21,875 per year on the basis of an average salary for 1980 of $17,500 and fringe benefits of $4,375. Similar calculations are made for other personnel, facilities, and all equipment with the exception of computer hardware. In the case of computer hardware, the rapid decline in costs since

1980 suggested that we obtain the most recent cost information. Thus, the costs of computer hardware are based upon prices to schools in the spring of 1984.

By using cost data for the same year, it is possible to obtain a uniform basis for comparisons. Even though costs have risen since 1980, this is unlikely to affect the relative cost patterns with the exception of costs for computer hardware (which have been updated to 1984 costs in this study). In order to obtain a cost per student, the total cost of each intervention was divided by the number of students. Details of the costing process for each of the interventions follows. In summary, all costs were estimated on the basis of national averages for 1980 with the exception of computer hardware.

Moreover, certain costs in our estimates were annualized, i.e., converted into a cost per year (Levin 1983: pp.67-71). Personnel costs are normally incurred and calculated on an annual basis, so they do not need to be annualized. In contrast, the use of facilities or equipment typically includes ingredients that have a life considerably longer than a year. To ascertain the costs of such ingredients that should be charged to programs for each year of use, a formula was used that takes account of depreciation and interest costs. Essentially, this approach considers the replacement cost, lifetime, and appropriate interest rate as bases for calculating an annualized cost estimate. The cost of each ingredient and the overall or total cost assigned to each intervention thus represent a cost for one year of operation.

All cost estimates used here are based upon the concept of "opportunity costs" or the value of the resources in their best alternative use, regardless of who paid for them (Levin 1983: 48-50). Thus, the complete costs of personnel and facilities are accounted for, even if some of the personnel were volunteers and facilities were provided "free" or without charge by other units of government. That is, for purposes of comparability, we ascertained the full cost of each intervention. Since the ingredients, costs and cost sources for each intervention are contained in tables in the appendix, analysts at any particular site can adjust and update our estimates to make their own cost estimates for their own particular sites. Such adjustments might include substituting local for national figures and current for 1980 prices. To the degree that any potential decisionmaker can reduce costs through obtaining volunteers or donated facilities, equipment, and supplies, those adjustments can also be made in any specific case.

In a few cases we identified ingredients for particular interventions for which we did not attribute costs. Generally, these were cases where the ingredients were truly "costless" in the sense that they were slack resources that had no alternative use other than the intervention at the time that they were employed. For example, the cross-age tutoring model is able to draw upon nooks and crannies in halls, cafeterias, gymnasiums, auditoriums, resource centers, lounges, and vacant classrooms at times when these spaces would not be used for their normal functions. In a few other instances, there appeared to be minor ingredients whose cost was likely to be small, but the exact amount could not be identified. Turning again to the cross-age tutoring intervention as an example, we recognized that it probably required some attention from teachers to select and keep records on tutors and tutees, but the precise amount was not documented in the reports. In this case, we felt that omission of a very small--but unknown--quantity of teacher time (e.g., probably less than 1 percent of the time for each teacher affected) would hardly affect the accuracy of the estimates.

Details of the costing process for each of the interventions follow.

Costs of Cross-age Tutoring

From the various evaluation reports for the tutoring program as well as detailed inquiries and interchanges with the Boise School District, we identified the various ingredients for the entire cross-age tutoring program and its separate peer and adult components. A typical school, with 60 tutors and 60 tutees for the student or peer tutoring component and 30 tutees for the adult tutoring component, was used as the unit of analysis. Appendix Tables A-2, A-3, and A-4 show the ingredients and costs for the combined peer and adult tutoring program, the peer component alone, and the adult component alone, respectively.

Personnel costs for each school include 1/14 of the costs of the tutorial supervisor who is responsible for all 14 schools in the tutoring program; the costs of the 2 tutor managers, 2 adult tutors, and an estimated 5 percent of the principal's time as well as a small amount of time of inservice consultants for training. The clerk who records and reports test data (a primary way to determine tutees' eligibility) is also included in the personnel cost.

Facilities required for replicating the Boise model may be conceptually separated into office space and tutoring space. The adult tutoring staff needs minimal office space in the school to maintain records (at least a desk and file cabinet for each), and the Tutoring Program Specialist needs an office in the administration building. In addition, all those who tutor require some space to meet with their tutees. Because the tutoring takes place in available space throughout the school and because the adults on site typically do not have full-sized offices for their exclusive use, we assumed that these two elements together amount to one classroom. Only an appropriate portion (1/14) of the cost of the Specialist's office is assigned to the cost of the replication at the single site.

Equipment and materials include learning materials and furnishings. We included the purchase of curriculum and supplies, but excluded materials required for the eligibility testing itself (except for the additional reporting having to do with the tutoring program), because it is part of the on-going school program. As we have partitioned cost assignment for the space, we have also partitioned cost assignment for furnishings. However, we assumed slack resources re available for furnishings during tutoring sessions.

Except for the staff developers' time, we have not included any costs for training. We assumed that adults who provide tutoring will be paid for training as part of their wage, and we further assumed that there is no market value or monetary opportunity cost for elementary student tutors' time. Neither have we assigned a cost for training and travel for tutees' parents one to three nights a year for meetings. We assumed that the voluntary parent meetings simply replace already-established parent conferences.

The total costs of the complete tutoring program (peer and adult components combined) were estimated at $41,433 for the 150 tutees or a cost per student of about $276. Since the peer tutoring approach for grades 1 and 2 and the adult tutoring approach for grades 4, 5 and 6 were separable, estimates were made for separate components based on each model in Appendix Tables A-3 and A-4. The peer approach showed a cost of $212 per student participant (which included tutors and tutees), and the adult tutoring approach showed a cost of about $827 per student.

The substantial difference in costs was primarily due to two factors. First, the peer tutoring component provides achievement gains for both tutors and tutees and both are counted as student participants, while the adult tutoring component provides achievement gains only for the tutees so that costs are divided by the smaller number of students affected by adult tutoring. Accordingly, the costs are distributed over twice as many students for the peer component. Second, the peer tutoring model assumes no cost for the time of elementary students in terms of market opportunities or lost learning. Tutoring activities do not compete with other mathematics and reading opportunities. In contrast, the time of adult tutors is costly, and each adult can tutor only a limited number of students. Thus, the personnel cost for the adult model is higher and it is distributed over fewer student participants, resulting in a much higher cost per student for the adult component by itself.

Costs of Computer-Assisted Instruction

The ingredients for the CAI approach are based upon the application in the Los Angeles Unified School District under the ETS/LAUSD evaluation (Levin and Woo 1981). However, the costs of computer hardware, software, and maintenance were updated to March

1984, and all other costs are based upon 1980 data to make them consistent with the costs of the other interventions. The purpose of providing the most recent hardware costs was to take account of the drastic declines in such costs over the last few years.

The basic model is one in which a Microhost minicomputer and 32 terminals are incorporated into a computer laboratory in a single classroom. The minicomputer serves as the central processing unit (cpu), and the terminals are used to interact with the cpu, but have no independent capability for memory or processing. Students take ten minutes of drill and practice at each session in either mathematics or reading, although other subjects can also be introduced into this system. The Los Angeles experience suggested that each terminal could be used for 23 sessions a day so that the laboratory had a capacity of 736 sessions a day.

Personnel costs for replicating the CAI intervention include a coordinator, two teaching aides, and a small portion of the time of the principal. The CAI coordinator is responsible for the overall functioning of CAI including scheduling and coordination of instruction, reporting to teachers on student progress, and monitoring of equipment functioning and maintenance. This role is served by a classroom teacher who is trained in an intensive one and one-half day program. Teaching aides monitor the performance of students and assist them in understanding the CAI problems and solving them.

Facilities include a classroom for the CAI laboratory; renovation for built-in counters, chairs and other furnishings, air conditioning, and security devices. Equipment and materials include the minicomputer, 32 terminals, a printer, curriculum rental, and supplies. All of the hardware and software costs are based on prices quoted by the provider, Computer Curriculum Corporation, in March 1984. Finally, there are training costs, maintenance, and insurance. Details on most of these ingredients and the costing procedures are found in Levin and Woo (1981), but are summarized in Appendix Table A-5.

The total cost per school for a fully-equipped computer laboratory, personnel, and other requirements (based on 736 sessions per day for one year) are about $87,000 a year for an annual cost per student per 10 minute daily session, of about $119 at 1980 prices. In 1978 the cost of a similar system was estimated at $136 per student (Levin and Woo 1981), so a combination of 1984 hardware and software costs and 1980 costs for other ingredients reduced the overall cost per student by only about 12 percent, despite a large drop in the cost of hardware. Some analysts assume that declines in hardware costs will substantially reduce the costs of CAI. But hardware costs represent only about 25 percent of the total estimated costs of our CAI intervention. That is, three quarters of the cost for delivering the CAI services are not associated with the hardware, so even drastic declines in hardware costs would not reduce the overall cost per student by very much. For example, even if the cost of the hardware were to decline by 50 percent, the cost per student would decline by less than 13 percent--assuming that all other costs remained the same. Since other costs are rising over time, it is conceivable that the overall cost reduction in this scenario would be at least partially offset by higher costs for personnel and other inputs. What is important to keep in mind is that the CAI intervention requires considerably more than hardware to provide CAI services.

Since 1978, many schools have acquired microcomputers. Accordingly, we decided to ascertain the hardware costs of a microcomputer approach to compare with the minicomputer approach used in this evaluation. This comparison is especially relevant because it has been asserted that a shift in technology over time from a centralized system based on a minicomputer to a decentralized one based on microcomputers has resulted in a cost reduction of two-thirds (Pogrow 1983: 80-81). Although the software used in the CAI intervention is not presently available for microcomputers, we thought it would still be useful to compare the costs of hardware required to deliver similar instruction with a networked system of microcomputers.

A review of recent surveys and discussion with experts suggested that a common configuration would be the use of Apple IIe microcomputers linked in a Corvus network known as Omninet (Piele 1984). Basically, such a system must provide the opportunity both for instruction and for the storage and reporting of pupil programs. This configuration requires 32 Apple IIe computers for the students and one through which the teacher monitors the local network. In addition to the storage capacity of each of the microcomputers, memory is provided through an 18.4 megabyte hard disk device for systems programs and student records. Unlike the minicomputer approach with its central storage of curriculum, each student is provided with a diskette containing the curriculum and a record of progress that is inserted in the disk drive to "load" the information into the microcomputer at the outset of each student session. Periodically (e.g., weekly), the coordinator will transfer these records to the hard disk storage device to prepare student reports for classroom teachers.

Appendix Tables A-6.1 and A-6.2 show the hardware and maintenance costs of the comparable minicomputer and microcomputer network approaches, respectively. Lifetime of the equipment was assumed to be identical in both cases, although our casual survey of users suggested that heavy use of the microcomputers and local network might limit its life to a shorter period rather than the six years over which we annualized the cost. Of special concern here is the durability of terminals. The terminals used in the minicomputer configuration are commonly used in offices for data input and processing and are designed to stand up to constant use in the workplace. The Apple IIe was not designed to be used for such a purpose, and there are particular problems with the keyboard and disk drive that seem to emerge under heavy use.

In the spring of 1984 the costs of the two systems were roughly comparable, with a slight edge given to the minicomputer approach. This small cost advantage of the minicomputer hardware configuration over the microcomputers and local network would probably be substantially greater if one were to account for all of the ingredients and their cost, and especially differences in personnel needs. Experience with both approaches suggests that the microcomputer network, at present, is complex and unpredictable enough to require substantially greater surveillance and knowledge of the system by the coordinator than does the minicomputer approach. Such a person would need greater training and experience with computers than the coordinator for the minicomputer version, so personnel costs would also be higher. This gap in personnel needs may narrow in the future as local instructional networks become simpler and more reliable, but it is a consideration that must be incorporated into cost comparisons at the present time.

In addition, the fact that elementary school students must "load" their own diskettes for each session suggests a heavier use of teaching aides than the minicomputer approach where pupils need only "sign-in" by typing in their names to initiate a session. Finally, the fact that the Apple IIe is relatively slow to load a program means that a ten-minute instructional session may actually take 12 minutes or longer, lowering the capacity for each terminal from the 23 sessions a day under the minicomputer approach. Although all of these problems might be overcome with a more sophisticated network and the addition of greater storage capabilities, such changes would add substantially to the cost of a microcomputer network. It is our judgment that when all of these factors are taken into account, a microcomputer instructional system as presently available that could deliver the CAI instruction we evaluated would be more costly than the minicomputer approach that was actually used.

Costs of Reducing Class Size

A reduction in class size requires the availability of more teachers with additional classrooms and furnishings. Accordingly, the cost per student rises with any reduction of class size, because the overall cost of a classroom, furnishings, and teacher must be divided over fewer students. For ease of presentation, we start with the fixed costs of a classroom, and then show how costs change when the number of students served by that classroom decreases. A classroom for our purposes includes the physical space, furnishings, energy needs, insurance, maintenance and a teacher. The cost of any specific reduction in class size can be calculated by simply ascertaining how many additional classrooms with furnishings and teachers will be needed. As Appendix Table A-7 shows, one classroom in this model costs $28,138 annually or a cost per student of $804 when class size is 35.

Decreasing class size from 35 to 30 pupils would require an increase of $135 or about 14 percent in cost per student for that classroom. Similarly, reducing class size from 30 to 25 pupils raises costs by an additional $188 per student or about 17 percent. A decrease from 25 to 20 will entail an increase in costs of $281 per student or 30 percent. Finally, a reduction in class size from 35 to 20 implies an increase in per pupil costs of $603 or about 43 percent.

However, each of these figures represents the total estimate of additional cost per student for reducing class size, not the additional cost per subject. That is, overall reduction in class size is an educational intervention that should affect all of the educational activities during the school day, not just the teaching of mathematics and reading. Consequently, only a portion of the additional cost should be viewed as an educational intervention to improve mathematics and reading. We therefore assumed that about one-third of the school day is devoted directly or indirectly to mathematics at the elementary level and one-third to reading, with the remaining one-third devoted to other areas. Although our time-in-learning analysis indicated that formal instruction in mathematics and reading takes up less than 2/3 of the school day, we assumed that the benefits of smaller classes for mathematics and reading should also be conferred from other activities such as social studies, writing, and science. Accordingly, the total additional cost per student for a given reduction in class size was divided by three to obtain an estimated cost per subject.

Costs of Increasing Instructional Time

The cost of increasing the length of the school day is estimated in a straightforward manner. We have assumed that the only additional cost is derived from higher salaries and fringe benefits associated with additional teacher time. This additional cost was calculated by increasing teacher salaries and fringe benefits by one sixth to accommodate an additional hour of instruction beyond a normal six hour requirement. We have assumed that such an intervention would not entail additional costs for administration, library, maintenance, or curriculum materials and supplies. We have further assumed that no additional facilities will be required (and that no activities will be displaced). Given an average class size of 30, the annual cost of this intervention, then, is estimated at $61 per student per subject as shown in Appendix Table A-8. For smaller class sizes, the costs would be proportionately higher.

V- COST EFFECTIVENESS RESULTS

From the data on both effects and costs, it is possible to calculate cost-effectiveness ratios to rank the alternative interventions. Table Two provides estimates of the cost per student per subject for each of the four interventions as well as effect sizes for each $100 of cost per pupil. The effect size for each $100 of cost per pupil is our cost-effectiveness ratio. It is computed by dividing each effect size by the pertinent cost per student and multiplying by 100. The $100 figure serves as a standard unit of expenditure which allows us to compare the derived cost-effectiveness ratios across interventions. Clearly, the larger the effect size on this standard expenditure level, the greater the educational impact of resources on achievement. Let us consider the results for reading and mathematics separately.

Interventions for Raising Mathematics Achievement

Among the alternatives for increasing mathematics achievement, two tutoring interventions--the combined cross-age approach and the peer component--show the largest effects per $100 of cost per pupil, with .29 for the combined program and .46 for the peer component.

TABLE TWO--COST PER STUD[illegible]R SUBJECT AND COST-EFFECTIVENESS RATIOS [illegible]OUR INTERVENTIONS

(Effect Size for Each $100 Cost Per Student)

Intervention		COST PER STUDENT (Per Subject)	COST-EFFECTIVENESS RATIOS: Mathematics Mean	Mathematics Grade 2	3	4	5	6	Reading Mean	Reading Grade 2	3	4	5	6
CROSS-AGE TUTORING (Boise Model)	Combined Peer and Adult Program	$276	.29[c]	.37	.33	.28	.25	.20	.15[c]	.18	.16	.15	.14	.13
	Peer Component	$212	.46[a]	.48	.43				.22[a]	.23	.21			
	Adult Component	$2[illegible]7	.08[b]			.09	.08	.07	.05[b]			.05	.05	.04
COMPUTER ASSISTED INSTRUCTION (10 Minute Daily Session on Minicomputer)	Overall	$119	.10[c]	.11[a]			.10[b]		.19[c]	.19[a]			.19[b]	
			Computation	.25[a]			.21[b]		Vocabulary	.21[a]			.21[b]	
			Concepts	.00[a]			.00[b]		Comprehension	.17[a]			.17[b]	
			Application	.08[a]			.08[b]							
REDUCING CLASS SIZE	From 35 To 30	$ 45[d]	.14						.07					
	From 30 To 25	$ 63[d]	.12						.06					
	From 25 To 20	$ 94[d]	.10						.05					
	From 35 To 20	$201[d]	.11						.06					
INCREASING INSTRUCTIONAL TIME (Additional 30 Minutes a Day for Each Subject)		$ 61	.05	.04			.06		.12	.12			.11	

LEGEND: a = average for grades 2 and 3
b = average for grades 4, 5 and 6
c = average for grades 2 through 6
d = cost per student per subject is one-third of reducing class size across all subjects

This means that the combined Boise tutoring program provides almost one-third of a standard deviation in test score gain per $100 cost per pupil, while the peer component provides almost half a standard deviation gain per $100. The adult component with its higher costs and smaller effects provides a much smaller effect relative to cost.

CAI and reducing class size show about equal cost-effectiveness ratios for mathematics, although the initial reduction (from 35 to 30 pupils) shows somewhat higher cost-effectiveness than successive reductions. However, in both cases the effect sizes relative to cost are only about one-fourth of that for peer tutoring and less than one-half of that for the combined tutoring approach. Finally, increasing instructional time by one half hour a day in mathematics has the smallest effect per unit of cost: about half that of CAI and reduced class size, one-sixth that of the combined tutoring approach, and only one-ninth that of the peer tutoring component.

Thus, the most preferred alternative among the four interventions for increasing mathematics achievement is the peer tutoring model, followed by the combined tutoring model, CAI, reducing class size, and increasing instructional time. It is interesting to compare these results with those for reading.

Interventions for Raising Reading Achievement

With respect to reading achievement, peer tutoring and CAI show almost equivalent cost-effectiveness ratios. The peer tutoring model at .22 appears to be slightly more cost-effective than CAI at .19, though the combined tutoring program at .15 is estimated to be slightly less effective. The relatively more expensive adult tutoring model is one of the least cost-effective of the alternatives in reading, along with reducing class size. Increasing instructional time for reading is about twice as cost-effective as reducing class size, a reversal of the results for mathematics.

In summary, the results for reading suggest that the most cost-effective approach is also peer tutoring, followed closely by CAI. Increasing instructional time follows with the reduction of class size being the least cost-effective alternative for raising reading scores.

Cost-Effectiveness for Both Subjects

Because the cost-effectiveness rankings for the four interventions differ by subject, the decisionmaker may be confronted with a dilemma. In some cases, different alternatives can be used for different subjects. An example might be to use peer tutoring for mathematics and CAI for reading. However, in other cases such as the reduction of class size, it may be more difficult to mix interventions. That is, a reduction in class size is likely to be difficult to implement for a single subject, so one must consider the implications of each intervention for both subjects. It is useful for this reason to average the cost-effectiveness ratios for the two subjects to determine if an unambiguous ranking that combines both mathematics and reading emerges.

Table Three shows the cost effectiveness ratios for each intervention averaged across mathematics and reading. The peer tutoring component and the combined tutoring approach show the best result, while reducing class size, increasing instructional time, and the adult tutoring component show the poorest cost-effectiveness ratios.

The differences in cost-effectiveness are substantial. For example, the same cost outlay would provide almost four times as large an effect on reading and mathematics achievement through peer tutoring as through reducing class size or increasing instructional time. Further, although the adult tutoring approach in itself has the poorest cost-effectiveness result among all of the interventions, the high cost-effectiveness of peer tutoring contributes to a combined cost-effectiveness of the peer and adult approach that still exceeds considerably the second best alternative, CAI.

VI SUMMARY

The purpose of this report was to address the cost-effectiveness of four important interventions for improving mathematics and reading

TABLE THREE--AVERAGE COST-EFFECTIVENESS RATIOS OF FOUR INTERVENTIONS FOR TWO SUBJECTS
(Average of Mathematics and Reading Effect Sizes for Each $100 Cost Per Student Per Subject)

		Cost-Effectiveness Ratio
Cross-age Tutoring	Combined Peer and Adult Program	.22
	Peer Component	.34
	Adult Component	.07
Computer Assisted Instruction		.15
Reducing Class Size	from 35 to 30	.11
	30 to 25	.09
	25 to 20	.08
	35 to 20	.09
Increasing Instructional Time		.09

achievement at the elementary school level. Tutoring, computer-assisted instruction, reducing class size, and increasing instructional time were evaluated according to their costs and effectiveness in raising mathematics and reading achievement. In some ways the results are surprising. For example, a traditional and labor-intensive approach, peer tutoring, appears to be far more cost-effective than a widely used CAI approach. Moreover, the centerpiece of many of the calls for educational reform, increasing instructional time, appears to be a relatively poor choice for both reading and mathematics from a cost-effectiveness perspective.

Equally interesting is the contrast between the analysis of effects alone and the cost-effectiveness results. Table One shows that the adult tutoring model is associated with one of the largest effect sizes, .67 for mathematics and .38 for reading. Yet, the costs of the adult tutoring approach are so substantial that it yields one of the lowest cost-effectiveness ratios in mathematics and the lowest one in reading. Moreover, as Table Three shows, the adult tutoring component has the poorest average cost-effectiveness across both subjects. Accordingly, an evaluation of effectiveness alone might provide highly misleading implications for the policymaker concerned with how to allocate additional resources in the most efficient way for improving mathematics and reading achievement. To retain the strong cost-effectiveness advantages of tutoring at the upper-elementary grades, it might be desirable to consider the use of seventh and eighth grade students from local middle schools instead of adult tutors.

In using the results of these computations, a number of cautions should be noted. First, each of the results is drawn from a particular version and application of a general class of interventions, so the results should not be used to draw a general conclusion for all possible versions of the intervention. While we attempted to select specific forms of interventions that were tested, replicable, based upon substantial experience, and which had effects that were representative of that class of interventions, there may be other examples that are potentially more cost-effective. There are many approaches and forms of implementation of CAI, for example. Our test of a prominent one for drill and practice should not be a basis for assessing the cost-effectiveness of other CAI applications. Moreover, future declines in the cost of CAI and increases in its effectiveness may be reasonable possibilities. It should be noted, however, that the large proportion of non-hardware costs in CAI suggests that decreases in hardware costs alone may not substantially reduce the cost of CAI services. This case illustrates that one should not use the results of our analysis to make an all-time generalization about all possible versions of each of the interventions. Second, our results pertain to mathematics and reading achievement, so they should not be applied to other outcomes.

Third, both costs and effects of interventions may vary from one school to the next, depending on variations in conditions that were not studied here. For example, at some schools and for some interventions, it may be possible to obtain volunteers and donations of facilities and equipment. In those cases, the costs to the sponsor may be reduced and local cost-effectiveness ratios altered in favor of those interventions. In other cases, a long tradition of working with a particular intervention may make it especially cost-effective.

The most appropriate use of these results is to provide guidelines for consideration of alternative interventions for increasing mathematics and reading achievement in elementary schools. Four prominent interventions were compared according to their cost-effectiveness properties. Both the methods and the results of this comparative analysis provide a framework for assessing specific interventions that a state or local educational agency should find useful.

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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/year
Teacher	Elementary & secondary, extra service	Hourly rate[c] =	$ 20.25/hour
Substitute Teacher	Elementary & secondary, observer	Daily rate[d] =	$ 50/day
Principal	Elementary	Salary[e] and fringe benefits[b] = $28.000 + $7,000	$35,000/year
Supervisor	Elementary & secondary, central office	Salary[f] and fringe benefits[b] = $20,000 + $5,000	$25,000/year
Consultant	Inservice trainers	Daily rate[d] =	$ 100/day
Paraprofessional	Teaching aide, tutor manager, clerk	Hourly rate[d] =	$ 5/hour
Paraprofessional	Adult tutor	Hourly rate[g] =	$ 4.25/hour
Student	Elementary	Hourly rate[h] =	$ 0/hour
FACILITIES			
Classroom Construction	Elementary & secondary	Cost per square foot[i] for classroom space[j] = $50 x 900 sq. ft.	$45,000/room
		annualized at 10% interest over 30 years[k]	$ 4,775/year
Classroom Renovation	Elementary & secondary, for computer laboratory	Actual costs	$18,500/room
		annualized at 10% interest over 10 years[k]	$ 3,010/year

APPENDIX TABLE A-1: AVERAGE COSTS 1980
Page Two

Ingredient	Description	Components	Cost
Office space	Central office (equivalent to 1/2 classroom)	1/2 cost for classroom space[i,j] annualized at 10% interest over 30 years[k]	$ 2,388/year
EQUIPMENT			
Classroom Furnishings	30 student desks & chairs, 1 teacher desk & chair, 2 30"x72" folding tables, 2 bookcases	Market price[l] = $3,000 annualized at 10% interest over 10 years[k]	$ 488/year
Office Furnishings	1 desk & chair, filing cabinet, telephone	Price[d] = $500 annualized at 10% interest over 10 years[k]	$ 82/year
OTHER			
Classroom Maintenance and Utilities	Routine maintenance, utilities and insurance	Annual rate[d]	$ 1,000 year

[a] "Estimated average annual salary of classroom teachers in public elementary and secondary schools: United States 1959-60 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 percent 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 of 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 A-2: CROSS-AGE TUTORING INGREDIENTS AND COSTS
COMBINED PEER AND ADULT PROGRAM

Number of Students: 150 (includes 30 tutoring pairs for each tutor manager, 13 tutees for each adult tutor, and 2 additional tutees for each tutor manager)

Annual Cost	Ingredient
	PERSONNEL[a]
$ 1,800	1 tutorial supervisor (over 14 schools) at $20,000 plus fringe benefits per year (1/14 for each school)
16,500	2 tutor managers for 30 tutoring pairs and 2 individual tutees each at $5.00/hour x 6 hours/day x 22 days/month x 10 months = $13,200 plus fringe benefits per year.
14,025	2 adult tutors for 13 tutees each at $4.25/hour x 6 hours/day x 22 days/month x 10 months = $11,220 plus fringe benefits per year
1,750	1 principal @5% time at $28,000 plus fringe benefits per year
21	6 inservice training consultants (over 14 schools) @ 1/2-day at $100/day
540	1 clerk at 5% time to identify tutees
	FACILITIES
171	Office space for tutorial supervisor (equivalent to 1/2-classroom; cost spread over 14 schools)
5,775[b]	Office space for tutor managers and adult tutors[b]
	Tutoring space[b]
	Training space for tutor managers, tutors, and parents[b]

APPENDIX TABLE A-2: CROSS-AGE TUTORING INGREDIENTS AND COSTS
Page Two
COMBINED PEER AND ADULT PROGRAM

Annual Cost	Ingredient
	EQUIPMENT AND MATERIALS
120	Tutoring curriculum at $30/adult
300	Student tutoring manual, locally produced, at $5.00/manual
100	Recordkeeping and award supplies
325	Office equipment for tutor managers and adult tutors
6	Office equipment for tutorial supervisor (cost spread over 14 schools)
slack	Furniture for tutoring pairs
	OTHER
in salary	Training for tutor managers and adult tutors
slack	Training and travel for parents (assumed to be equivalent to existing parent conferences)
$41,433	TOTAL COST PER YEAR
$ 276	COST PER STUDENT

[a] It is possible that some time of the classroom teachers is needed for communicating with tutor managers and adult tutors. However, we have no information on this ingredient, so we have not included it in the intervention.

[b] Office space, tutoring space and training space together are assumed to be equivalent to one classroom. Cost of classroom space includes $1,000 for utilities and routine maintenance.

APPENDIX TABLE A-3: CROSS-AGE TUTORING INGREDIENTS AND COSTS
PEER COMPONENT

Number of Students: 120, includes 60 tutors and 60 tutees

Annual Cost	Ingredient
	PERSONNEL[a]
$ 1,800	1 tutorial supervisor (over 14 schools) at $20,000 plus fringe benefits per year (1/14 for each school)
14,850	2 tutor managers @ 90% time for 30 tutors and 30 tutees each at $5.00/hour x 6 hours/day x 22 days/month x 10 months = $13,200 plus fringe benefits per year
1,750	1 principal @ 5% time at $28,000 plus fringe benefits per year
21	6 inservice training consultants (over 14 schools) @ 1/2 day at $100/day
540	1 clerk @ 5% time to identify tutees (equivalent to 1/2 month per year)
	FACILITIES
171	Office space for tutorial supervisor (equivalent to 1/2 classroom; cost spread over 14 schools)
5,775[b]	Office space for tutor managers[b]
	Tutoring space[b]
	Training space for tutor managers, tutors and parents[b]
	EQUIPMENT AND MATERIALS
60	Tutoring curriculum at $30/tutor manager
300	Student tutoring manual, locally-produced, at $5.00/manual
100	Recordkeeping and award supplies

Annual Cost	Ingredient
	EQUIPMENT AND MATERIALS (continued)
163	Office equipment for tutor managers
6	Office equipment for tutorial supervisor (cost spread over 14 schools)
slack	Furniture for tutoring pairs
	OTHER
in salary	Training for tutor managers
slack	Training and travel for parents (assumed to be equivalent to existing parent conferences)
$25,536	TOTAL COST PER YEAR
$ 212	COST PER STUDENT

[a] It is possible that some time of the classroom teachers is needed for communicating with tutor managers and adult tutors. However, we have no information on this ingredient, so we have not included it in the intervention.

[b] Office space, tutoring space and training space together are assumed to be equivalent to one classroom. Cost of classroom space includes $1,000 for utilities and routine maintenance.

APPENDIX TABLE A-4: CROSS-AGE TUTORING INGREDIENTS AND COSTS
ADULT COMPONENT

Number of Students: 30 (includes 13 for each Adult Tutor and 2 for each Tutor Manager)

Annual Cost	Ingredient
	PERSONNEL[a]
$ 1,800	1 tutorial supervisor (over 14 schools) at $20,000 plus fringe benefits per year (1/14 for each school)
1,650	2 tutor managers @ 10% time for occasional direct tutoring at $5.00/hour x 6 hours/day x 22 days/month x 10 months = $1,320 plus fringe benefits per year
14,025	2 adult tutors for 13 students each at $4.25/hour x 6 hours/day x 22 days/month x 10 months = $11,220 plus fringe benefits per year
700	1 principal @ 2% time at $28,000 per year plus fringe benefits
21	6 inservice training consultants (over 14 schools) @ 1/2 day at $100/day
216	1 clerk @ 2% time to identify tutees
	FACILITIES
171	Office space for tutorial supervisor (equivalent to 1/2 classroom; cost spread over 14 schools)
5,775[b]	Office space for tutor managers and adult tutors[b]
	Tutoring space[b]
	Training space for tutor managers and parents[b]

APPENDIX TABLE A-4: CROSS-AGE TUTORING INGREDIENTS AND COSTS
Page Two ADULT COMPONENT

Annual Cost	Ingredient
	EQUIPMENT AND MATERIALS
120	Tutoring curriculum at $30/adult
20	Recordkeeping and award supplies
325	Office equipment for tutor managers and adult tutors at $500 each, annualized
6	Office equipment for tutorial supervisor (cost spread over 14 schools)
[illegible]	Furniture for tutoring pairs
	OTHER
in salary	Training for tutor managers and adult tutors
slack	Training and travel for parents (assumed to be equivalent to existing parent conferences)
$24,829	TOTAL COST PER YEAR
$ 827	COST PER STUDENT

[a] It is possible that some time of the classroom teachers is needed for communicating with tutor managers and adult tutors. However, we have no information on this ingredient, so we have not included it in the intervention.

[b] Office space, tutoring space and training space together are assumed to be equivalent to one classroom. Cost of classroom space includes $1,000 for utilities and routine maintenance.

APPENDIX TABLE A-5: COMPUTER ASSISTED INSTRUCTION INGREDIENTS AND COSTS MINICOMPUTER SYSTEM

Number of Students: 736 (includes 23 sessions per terminal per day for 32 terminals)

Annual Cost	Ingredient
	PERSONNEL
$25,000	1 CAI Coordinator at $20,000 plus fringe benefits per year
6,000	2 teaching aides @ 600 hours at $5.00/hour
1,750	1 principal @ 5% time at $28,000 plus fringe benefits per year.
	FACILITIES
5,775	Classroom for CAI laboratory (includes $1,000 for utilities and routine maintenance of the space)
3,010	Classroom renovation for CAI laboratory
244	Furnishings (includes teacher desk and chair and student chairs only)
	EQUIPMENT AND MATERIALS
4,982[a]	1 Microhost (CPU) with 1 Mb memory and 40 Mb storage at $21,700, annualized at 10% interest over 6 years[a]
4,857[a]	32 Computer Curriculum Corporation terminals at $21,152, annualized at 10% interest over 6 years[a]
207[a]	1 dot matrix (120 cps) printer at $900, annualized at 10% interest over 6 years[a]
11,434[a]	Software at $49,800, annualized at 10% interest over 6 years[a]

APPENDIX TABLE A-5: COMPUTER ASSISTED INSTRUCTION INGREDIENTS AND COSTS
Page Two MINICOMPUTER SYSTEM

Annual Cost	Ingredient
	EQUIPMENT AND MATERIALS (continued)
1,102[a]	Installation at $4,800, annualized at 10% interest over 6 years (includes CPU at $1,500, terminals at $3,200, and printer at $100)[a]
6,400	Curriculum rental per year
3,000	Supplies
	OTHER
40	Training time for coordinator @ 1 1/2 days x $100/day, annualized at 10% interest over 5 years
855	Training time for 40 teachers @ 4 hours x $20.25/hour, annualized at 10% interest over 5 years
9,720	Maintenance (includes CPU at $3,600, terminals at $5,760, and printer at $360)
3,000	Insurance
$87,376	TOTAL COST PER YEAR
$ 119	COST PER STUDENT

[a]Costs quoted by Computer Curricululm Corporation as of 3/16/84.

APPENDIX TABLE A-6.1: COMPUTER ASSISTED INSTRUCTION MINICOMPUTER SYSTEM--HARDWARE AND MAINTENANCE ONLY

Number of Students: 736 (assumes 23 sessions per terminal per day for 32 terminals)

Annual Cost	Ingredient
	EQUIPMENT (Hardware only)
$ 4,982[a]	1 Microhost (CPU) with 1 Mb memory and 40 Mb storage at $21,700, annualized at 10% interest over 6 years[a]
4,857[a]	32 Computer Curriculum Corporation terminals at $21,152, annualized at 10% interest over 6 years[a]
207[a]	1 dot matrix (120 cps) printer at $900, annualized at 10% interest over 6 years[a]
1,102[a]	Installation at $4,800, annualized at 10% interest over 6 years (includes CPU at $1,500, terminals at $3,200, and printer at $100)[a]
	OTHER (Maintenance only)
9,720	Maintenance (includes CPU at $3,600, terminals at $5,760, and printer at $360)
$20,860	SUBTOTAL COST PER YEAR
$ 28	SUBTOTAL COST PER STUDENT

[a]Hardware only, exclusive of software. N.B.: Costs of hardware quoted by Computer Curriculum Corporation as of 3/16/84.

APPENDIX TABLE A-6.2: COMPUTER ASSISTED INSTRUCTION MICROCOMPUTER SYSTEM--HARDWARE AND MAINTENANCE ONLY

Number of Students: 736 (assumes 23 sessions per student microcomputer per day for 32 microcomputers)

Annual Cost	Ingredient
	EQUIPMENT (Hardware only)
$ 3,813[a]	Corvus OMNINET local area network with 18.4 Mb. storage, interface with video cassette recorder, disk server, print server (for up to 3 printers), 33 transporters, tap cables, network cables, tap boxes and installation guides at $16,605 (includes 30% discouont off list price), annualized at 10% over 6 years[a]
7,539[a]	33 Apple-IIe (32 student and 1 teacher) microcomputers with with 64K memory, disk drive, green monitor and 80-column card at $32,835 (discounted), annualized at 10% interest over 6 years[a]
184[a]	1 Epson FX-100 dot matrix (220 cps) printer with cable at $800 (discounted), annualized at 10% interest over 6 years[a]
1,061[a]	Protection equipment (includes 33 microcomputer fans, desktop anti-static mats, 9 high quality, 4-outlet surge suppressors with on/off switch, cord, and 1[a] stand-by power unit for the hard disk system) at $4,620, annualized at 10% interest over 6 years[a]
	OTHER (Maintenance only)
9,432	Maintenance (includes network at $3,311 and microcomputers at $5,621, computed at 18%); printer at $500 (computed at $42 per month)
$22,029	SUBTOTAL COST PER YEAR
$ 30	SUBTOTAL COST PER STUDENT

[a]Hardware only, exclusive of software. N.B.: Costs of hardware as of May 1984.

APPENDIX TABLE A-7: REDUCING CLASS SIZE INGREDIENTS AND COSTS

Number of Students: From 35 To 30; From 30 To 25; From 25 To 20; and From 35 To 20 per classroom

Annual Cost		Ingredient
		PERSONNEL
$21,875		1 classroom teacher at $17,500 plus fringe benefits per year
		FACILITIES
5,775		1 classroom (includes $1,000 for utilities and routine maintenance)
		EQUIPMENT
488		Classroom furnishings
$28,138		TOTAL COST PER CLASS PER YEAR
804	260[a]	COST PER STUDENT FOR 35 STUDENTS PER SUBJECT[a]
134	45[a]	Incremental cost for reducing from 35 to 30 students per subject[a]
938	313[a]	COST PER STUDENT FOR 30 STUDENTS PER SUBJECT[a]
188	63[a]	Incremental cost for reducing from 30 to 25 students per subject[a]
1,126	375[a]	COST PER STUDENT FOR 25 STUDENTS PER SUBJECT[a]
281	94[a]	Incremental cost for reducing from 25 to 20 students per subject[a]
1,407	469[a]	COST PER STUDENT FOR 20 STUDENTS PER SUBJECT[a]
603	201[a]	Incremental cost for reducing from 35 to 20 students per subject[a]

[a]Cost per subject, estimated at one-third of annual cost for all subjects.

APPENDIX TABLE A-8: INCREASING INSTRUCTIONAL TIME INGREDIENTS AND COSTS

Number of Students: 30

Annual Cost	Ingredient
	PERSONNEL
$ 3,645	Additional classroom teacher time for 180 hours/year (equivalent to 1 hour/day)
$ 3,645	TOTAL COST PER YEAR
$ 122	COST PER STUDENT
$ 61	COST PER STUDENT PER SUBJECT