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Estimated Costs of Computer Assisted Instruction for Compensatory Education in Urban Areas

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Introduction

As this paper goes to press, a number of institutions in the United States will have acquired several years' experience using computer assisted instruction for compensatory education in both urban and rural areas. Our purpose in this paper is to discuss, on the basis of this experience, the short-term potential for using CAI in urban schools. Our discussion will focus almost entirely on the drill-and-practice programs developed for grades K through 6 in elementary arithmetic and beginning reading at Stanford University's Institute for Mathematical Studies in the Social Sciences. The reason for this focus is that the curricular content of these courses has already undergone a number of phases of development, and is now in a position to be readily implemented by any of a number of different computer systems.

Before proceeding to that discussion, however, we feel it important to place in context the potential role of CAI in the urban schools. Research over the last four or five years has given us rather systematic evidence about three aspects of that urban context. These are:

1. Information concerning the costs and effects of a number of compensatory education programs, primarily those financed by Title I of the Elementary and Secondary Education Act of 1965.
2. Information concerning the relationship between school inputs and various measures of school performance; this is information obtained primarily from the data in the 1964 Equality of Educational Opportunity Survey.
3. Further information from the EEO Survey concerning the state of inequality of educational opportunity by social class and race.

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We shall discuss each of these briefly in turn in order to place in perspective the potential role of CAI in urban compensatory education.

For a number of years, over a billion dollars a year has been spent by the federal government on compensatory education. The reasoning behind this large expenditure is that, as President Nixon (1970) put it, "... the most glaring shortcoming in American education today continues to be the lag in essential learning skills in large numbers of children in poor families." Unfortunately, however, as the President goes on to say "... the best available evidence indicates that most of the compensatory education programs have not measurably helped the poor children catch up." The President's assessment is shared by a large number of members of the academic community. For example, Arthur Jensen (1969) begins his well-known article on IQ and scholastic achievement by asserting that "Compensatory education has been tried and it apparently has failed." Jensen then supports this assertion by a number of references to studies by the federal government. H. Piccariello (1969), in concluding a large-scale evaluation of 1966-67 and 1967-68 Title I funded reading programs, found that in these programs a child had a 69 percent chance of no significant change over a peer in a control group in terms of his reading ability and, given that he did show a significant difference, that he only had a slightly better probability of having that difference be positive rather than negative. The programs that Piccariello evaluated were those that had been funded at a higher than average level.

There are, however, two lines of argument against those who would conclude from such studies that we have accomplished little or nothing by our Title I programs to date. J. Hunt (1969), in a rebuttal to Jensen, argues that the instances of compensatory education being examined by Jensen (notably the Head Start program) were not appropriate types of compensatory education. Hunt argues that, in this case, compensatory education did not succeed because it was not tried. If instead of the type of play school that Head Start seemed to represent typically, the students had been given intensive drills in cognitive skills, Hunt feels that there would have been enduring gains in achievement on the part of initial underachievers. Hunt's arguments are supported by Professor H. Kiesling's (1970) study of a number of successful compensatory education programs in California. Kiesling's approach was to examine in detail those compensatory education programs in California (funded by ESEA Title I and California Senate Bill 28) that had proved very successful. What he hoped to do was to isolate characteristics common to all those programs that would differentiate them from less successful compensatory education programs. What Kiesling found was that there are three aspects of the successful programs that appear over and over again—(1) thorough planning and program coordination, (2) thorough inservice training of teaching personnel with respect to local instructional problems, and (3) individualization of instruction. The implication of Kiesling's finding is simply that, while compensatory education may on the average in the past have been unsuccessful, there is no reason to continue the average practices of the past. We should instead tailor our future compensatory education programs around those that have *shown success* in the past. Kiesling then presents a number of paradigmatic compensatory programs for both reading and arithmetic and provides a detailed cost analysis of those programs. We shall return to his cost and effectiveness estimates in a later section of this paper in order to compare the more traditional compensatory education techniques that he considers with computer assisted instruction.

A reason that compensatory education may have been a failure on the average, other than, as Kiesling argues, that generally it was incorrectly organized, is that what goes on in the schools has very little effect on achievement of students. Arthur Jensen in the article previously cited is implicitly making this point when he argues that the reason for the failure of compensatory education for black students is that they have been equipped genetically with a lower IQ. The importance of IQ in learning is, he argues, sufficiently large so that additional schooling resources devoted to disadvantaged students do not show a large or lasting effect. The U.S. Office of Education report on the *Equality of Educational Opportunity* prepared under the leadership of James Coleman (and popularly known as the Coleman Report) also comes to the conclusion that what goes on in the schools is of secondary importance compared to what happens to the child outside of school. The Report's somewhat discouraging conclusion is that various school inputs such as teacher skills and classroom facilities have relatively little impact on the achievement of the child. These conclusions have been subject to vigorous debate in the four or five years since their initial publication; for an overview and rebuttal to this literature, see Coleman (1968). Nevertheless, since publication of the Report there has been an increasing consensus that the input factors in the schooling process, as traditionally defined, have a good deal less effect on the outputs than had been thought previously. This has caused a focus of attention on outputs and what causes outputs to change instead of, as before, simply trying to improve schooling by increasing the quantities of traditional inputs.

While the somewhat pessimistic findings of the Coleman Report concerning the potential of affecting student performance by changing school inputs would seem to argue against large-scale expenditures on something like computer assisted instruction, there are good reasons to believe that the range of inputs considered in the Report was not sufficiently broad to enable us to say anything definite at all about important changes in instructional technique. For example, in their criticism of the Coleman Report, Bowles and Levin (1968) assert: "The findings of the Report are particularly inappropriate for assessing the likely effects of radical changes in the level and composition of resources devoted to schooling because the range of variation in most school inputs in this sample is much more limited than the range of policy measures currently under discussion."

A third important aspect of the context into which CAI would be put for compensatory education in urban areas is the widespread inequality of opportunity for students in those areas. Various notions of the meaning of the word "inequality" and the extent of its existence are examined in some detailed in a recent study by Stephan Michealson. Michealson's results are summarized in a recent paper (1970). Michealson used data gathered by the Coleman Survey for one large eastern city—which he calls Eastmet—and argues very persuasively that there is large-scale inequality in educational resources devoted to blacks as opposed to whites and, within either racial group, an increasing level of resources devoted to children of increasingly high social class. An important purpose, clearly, of CAI in an urban context would be to reduce these racial and social class differences in access to educational opportunity.

In our preceding comments we have briefly surveyed what is now known about the effects of compensatory education, about the relation of educational inputs to educational outputs, and about the extent of inequality of educational opportunity in the urban United States. We conclude that while there does exist large-scale inequality in access to educational opportunity, we now know enough to be able to provide a reasonable level of compensatory education for those who have been subject to discrimination in the past. While from the Coleman Report we have probably learned that varying the levels of traditional educational inputs probably scarcely affects the level of output, we cannot conclude from that Report that new compensatory techniques—either of a conventional variety or utilizing a technology such as CAI—would be ineffective. In what follows we shall report on some of our previous experiences to show, on the contrary, that the arithmetic drill-and-practice program developed at Stanford University has proved to be effective as a compensatory education device. While it has not produced the very dramatic achievement gains that the best programs surveyed by Kiesling have, its cost on an operational basis in the relatively near future appears to be markedly less. These cost projections will be discussed in the final section of this paper. Before turning to a more detailed discussion of CAI we would, however, like to discuss requirements for providing the financial resources (on the order of $100 per student per year) that would make its introduction possible on a wide scale.

Financing CAI for Compensatory Education

Kiesling (1970) estimated that his paradigm compensatory education programs would cost between $212 and $354 per student per year, depending on whether an appreciable amount of the compensatory program had to be carried on outside the regular classroom. In the final section of this paper we estimate that the cost of providing arithmetic CAI to a student would be about $50 per year; to provide both arithmetic and reading would cost a little over $100 per year. These figures represent increments in the cost of educating a student that amount to appreciable fractions of the initial amount spent. In a time of tight budgets in general, and particularly for school systems, it is important to address the question of where the money will come from.

A very natural possibility is to reduce the amount of time the student spends in contact with a professional classroom teacher. One to three hours of the child's school day could be spent on organized play, unorganized play, watching *Sesame Street*, listening to music, sports, etc. These are all activities requiring only a paraprofessional monitor (perhaps a mother working half time, or a college student) and having a large student-to-monitor ratio. The students would be faced with frequent decisions about how to spend their own time, and encouraged to follow their interests.

Simple and obvious as such an approach to cost reduction appears, it would no doubt entail major and difficult administrative restructuring. We bring it up here for the following reasons:

1. The Coleman Report and subsequent related research consistently suggest the ineffectiveness of traditional school inputs in producing scholastic achievement. Yet few people seem willing to act on the implication of those results—that *cutting back on these traditional inputs is unlikely to seriously impair production of scholastic achievement.*

2. In order to increase our understanding of how school inputs affect achievement, we need both to vary those inputs downward as well as upward and to provide means for altering the mix of inputs to include new technologies.

3. The most important reason is the one we began this section with: Education's budget is stationary and compensatory education, costly. *Only by cutting back on some school inputs can we increase the level of others;* it is incumbent on those who propose any compensatory education program to face this problem squarely.

Another approach to financing CAI or other new technologies of education is to monitor and evaluate with much greater care the programs supported under the Elementary and Secondary Education Act of 1965, especially Title I. For the short term, effective use of these funds seems to be the most realistic possibility for a major implementation of new educational technologies.

Operational CAI in New York City: Cost and Effectiveness

Our purpose in this section is to present results from an ESEA Title III funded ($2.5 million) program in CAI in New York City. The New York system used an RCA Spectra 70 computer that served 192 student terminals located at 15 elementary schools in Manhattan, Bronx and Brooklyn. About 6,000 students were involved and the curriculum used was a commercial successor of the elementary arithmetic drill-and-practice program developed at Stanford University's Institute for Mathematical Studies in the Social Sciences. A detailed evaluation of this project may be found in Weiner, *et al.* (1969) and an extensive discussion of the complexities of implementation is given by Butler (1970). Here we shall simply present a summary view of the cost and performance of this particular system in order to place in context the next section containing our projections for the short-term future.

This analysis will derive tentative cost-effectiveness values for the experimental and control groups according to three different sets of assumptions which are summarized as the median case, the best case and the worst case. To obtain cost estimates on a per-student basis we make separate estimates of overall system cost and utilization rate. The effectiveness of the system is considered only in terms of arithmetic achievement test scores. Use of a single measure of this sort has obvious shortcomings; we feel, nevertheless, that the information it provides is the best single measure of system effectiveness. It should be noted that use of this single measure is likely to understate the overall benefits from using the system because improved achievement in one area is likely to increase motivation and achievement in other areas; see Levin (1970).

Cost of the New York CAI System

We will present only summary cost information here; a detailed breakdown and justification of these costs may be found in Butler (unpublished). We present two separate cost figures—those actually incurred in the 1968-69 school year and those anticipated for 1970-71. The cost reductions included for 1970-71 are only those felt very likely to be possible, and our cost-effectiveness estimates are based on this cost. Table 1 presents a cost summary.

Table 1

Costs of New York City CAI System[a,b]

Category	1968-69 (actual)	1970-71 (projected)
Hardware	190	190
Curriculum	20	20
Administrative staff	80	52
Paraprofessionals	60	75
Telecommunications	130	70
Teacher training	15	13
Miscellaneous	20	8
TOTAL	515	428

[a] Costs are in thousands of 1969 dollars.

[b] Costs of classroom space and students' time are not included.

Since the total projected cost for 1970-71 is $428,000 and the system serves 192 terminals, the per terminal cost is $2,230 per year. We shall indicate in the final section of this paper that available technical advances can reduce this cost by about 50 percent.

Utilization of the New York CAI System

Median case. The rate of utilization in the median case is based on expected system use in 1970-71. This rate assumes that the elimination of familiarization problems of the first year of operation, plus the publication and circulation of the first year's student performance data showing the benefits of CAI, will effect a rate equal to the highest rate achieved in the first year by one school, 25 pupils per terminal per day.

Best case. The rate of utilization in the best case includes the same assumptions as for the median case. It assumes also that a significantly higher rate will be attained when all schools can establish an optimal utilization schedule at the start of the school year. In the year's activities analyzed in this study, technical problems of the CAI system prevented the schools from using the system every day, until February. At that time school administrators were reluctant to create new schedules that would use all of the available system time. (Administration of the urban school is notably inflexible and even more so in a system trying to regain equilibrium after the longest teachers' strike in its history.)

Utilization rates in the best case also take into account the fact that students will be able to complete lessons in a shorter average time, and that therefore more lessons will be completed. This expectation is based on the following: (a) the students will be more familiar with the terminals and the structure of the lessons, and (b) teachers will improve the degree to which their in-class instruction will precede the related CAI lessons, thereby reducing the number of incorrect responses and time-outs by students.

In the McComb, Mississippi and Waterford, Michigan projects, the average daily utilization rate is above the 30-pupil rate chosen for the best case in this study. Both projects use a curriculum and a student terminal virtually identical to those used in the NYBE CAI project; the "next" students are in the terminal room before the prior students finish their lessons, thereby keeping all terminals in constant use. Utilization rates as high as 60 per day have been attained in Ohio by using the terminals after school hours. At the present time in New York the paraprofessionals return one group of students to their classroom before escorting the next group to the terminal room.

Worst case. The utilization rate for the worst case is the rate attained by the clustered schools in the first year of operation (18 pupils per terminal per day). The rate assumes the opposite of the assumptions used to derive the rate for the best case; i.e., the significant student gains of the first year will not be an inducement to schedule a larger number of students; the nonrecurrence of the political events of 1968-69 will not permit better planning; the ability of the system to accommodate 192 terminals simultaneously from the beginning of the school year will not encourage a schedule of maximum utilization; the increased confidence of teachers to integrate the in-class and CAI parts of the curriculum will not reduce the average length of a lesson, or the schedules will not take advantage of such reductions by scheduling more students.

Student Achievement in the CAI Group

Median case. Student achievement gains for the median case, shown below, are based on the assumption that the amount students learn increases with the amount of their instruction, and that appropriate testing instruments, properly administered, will indicate such increases. It is also assumed that, over the time periods we are considering, student gains increase linearly with

Table 2

Average Grade-Placement Scores on the Stanford Achievement Test: Mississippi 1967-68[a]

Grade	Pretest[b] Experi-mental	Pretest[b] Con-trol	Posttest Experi-mental	Posttest Con-trol	Posttest-Pretest Experi-mental	Posttest-Pretest Con-trol	t	Degrees of Freedom
1	1.41 (52)	1.19 (62)	2.55	1.46	1.14	0.26	3.69[c]	112
2	1.99 (25)	1.96 (54)	3.37	2.80	1.42	0.84	5.23[c]	77
3	2.82 (22)	2.76 (56)	4.85	4.04	2.03	1.26	4.64[c]	76
4	2.26 (58)	2.45 (77)	3.36	3.17	1.10	0.69	2.63[c]	131
5	3.09 (83)	3.71 (134)	4.46	4.60	1.37	0.90	3.43[c]	215
6	4.82 (275)	4.36 (160)	6.54	5.48	1.72	1.13	5.18[c]	433

[a] Data from Suppes and Morningstar (1969), p. 342.

[b] Values in parentheses are numbers of students.

[c] $P < .01$.

the increase in the amount of instruction. In the median case it is assumed therefore that a pretest-posttest interval of nine months would demonstrate student gains 80 percent greater than those actually observed in the NY project with a five-month test interval.

Best case. Student achievement data from CAI projects in California and Mississippi that used a similar curriculum to that used in New York City form the basis of this study's best case values. The Mississippi project used the Stanford Achievement Test; in New York City, the Metropolitan Achievement Test was used. Tables 2 and 3 show achievement data from these schools. The CAI schools of the California group were also tested in the previous year. Although comparison of the results for these schools in the two years is impossible, for reasons indicated by Suppes and Morningstar (1969), significant improvement for the CAI students in 1966-67 in comparison with the 1967-68 results is clearly indicated.

For the best case, therefore, the identical result reported by Suppes and Morningstar (1969) for the contrasting student populations in Mississippi and California will be used. On the basis of a 15.3-month achievement gain in a seven-month test interval, and also assuming a linear increase in student achievement with an increase of test interval, an increase of 19.8 months would be produced in a nine-month test interval.

Worst case. Student achievement gains for the worst case will assume that a nine-month test interval would indicate the same student gains as were indicated using a five-month test interval. Such a failure to produce further student gains could be attributed to the teachers' failure to continue to select appropriate CAI lessons for the students, or to a deterioration of the environment in the terminal rooms, or to a reduction of student enthusiasm in the CAI mode of instruction. (Each of these assumptions is contrary to present indications in the project.)

Student Achievement in the Control Group

Median case. The value used for student achievement in the median case is based on the assumption that the gains that would be demonstrated using a nine-month test interval would be 80 percent greater than those demonstrated using a five-month test interval, i.e., a gain of nine months. (The 80 percent increase is the

Table 3

Comparison of MAT Arithmetic Computation Raw Scores Earned by Students in the Eight Schools Matched by the Board of Education[a]

Grade	Pretest							Gains						
	CAI			NCAI				CAI			NCAI			
	N	Mean	SD	N	Mean	SD	P	N	Mean	SD	N	Mean	SD	P
2	82	16.71	6.02	79	18.44	5.97	N.S.	82	7.15	5.12	79	3.50	4.51	<.01
3	106	17.49	6.14	98	19.96	6.17	<.01	106	12.92	5.65	98	9.31	5.34	<.01
4	190	25.32	9.16	93	31.36	8.60	<.01	190	8.02	6.35	93	6.10	6.75	<.05
5	208	15.75	8.24	49	21.61	10.16	<.01	208	7.57	6.71	49	2.89	8.09	<.01
6	136	22.77	10.02	23	35.34	7.63	<.01	136	4.28	7.99	23	2.69	7.44	N.S.

[a]Data from Weiner *et al.* (1969), p. 24.

same as that used in the median case for CAI plus Traditional Instruction (TI) and is derived from the same assumptions as used in that case.)

Best case. The student achievement value used in the best case is based on the assumption that a control group more closely matched with the experimental group would have achieved larger gains than the control group used in the experiment. (In every grade the mean pretest score for the control students was higher than that of the corresponding experimental students, thus providing the control students a smaller range of potential improvement, as indicated by the standardized test.) The best case for TI students will assume a gain of ten months, or one month more than the gain used in the TI median case.

Worst case. The worst case value for TI student achievement is based on the assumption that the control group selected was provided a more intensive mathematics program because of the awareness of the control schools that they were part of the experiment. This is precisely what occurred in one school in the California CAI evaluation conducted by Suppes and Morningstar. The worst case value for TI student achievement will be eight months, or one month less than the gain used in the TI median case.

Table 4, below, summarizes the achievement gains to be expected from having CAI in addition to TI as opposed to simply having TI.

These achievement test scores from New York City are averaged across all students participating, not just those needing compensatory education. Data in Suppes and Morningstar (1969) clearly indicate that CAI does relatively more for low-performing students; thus the median information in Table 4 would probably tend to understate the expected value of CAI for compensatory instruction.

Cost-Effectiveness Data for the New York CAI System

We are now in a position to combine the cost and performance information discussed thus far. Immediately following Table 1 the annual per terminal cost for 1970-71 operation in New York City was estimated as $2,230. The best, median and worst case figures for student utilization of the terminals were 30, 25 and 17.75 students per terminal per day. Table 5 summarizes this information and combines it with data from Table 4 to obtain estimates of cost per month of achievement gained by use of CAI. We emphasize that

Table 4

Achievement Gains from CAI[a]

Group	Median case		Best case		Worst case	
	5 month[b]	9 month[c]	5 month[b]	9 month[c]	5 month[b]	9 month[c]
(1) CAI + TI	8.4	15.1	8.4	19.8	8.4	8.4
(2) TI only	5.0	9.0	5.0	10.0	5.0	8.0
Achievement gain: (1) - (2)	3.4	6.1	3.4	9.8	3.4	0.4

[a]Achievement gains are measured in months of achievement.

[b]Actually measured gain.

[c]Projected gain.

these costs cannot be extrapolated to achievement gains much larger than those shown in Table 4.

The cost-effectiveness figures in Table 5 obviously do not in themselves enable a school decision-maker to decide whether to implement CAI. He must also have an estimate of the value of improving low performers' arithmetic scores and estimates of the cost-effectiveness of alternative compensatory education techniques in arithmetic. It is beyond the scope of this paper to discuss the value of improving arithmetic scores. However, the study of Kiesling (1970) previously cited does contain estimates of performance as well as cost for alternative compensatory techniques, and we feel it would be worthwhile to mention his findings here.

Kiesling surveyed the most successful compensatory programs in California, including in his study projects that "... exhibit gains that are approximately double (at least) the expected gains (in cognitive achievement test scores) for children from the same background ..." (p. 3). For the median case of the New York City CAI project, the gain with CAI was about two-thirds again the gain without it; thus the CAI project was slightly less successful than the programs Kiesling surveyed. On the other hand, its cost per student per year is only about one-third Kiesling's estimates of the cost of replicating the projects he studied.

We conclude that the New York City CAI program in elementary arithmetic is a highly cost-effective compensatory education technique.

Future CAI Costs

There are two quite different lines along which CAI technology is evolving. One is that of a small low-cost computer serving a small number of student terminals (5-20) at a single location. The other is for a single high-capacity computer to serve a large number (several hundred or more) terminals over a broad geographical region.* Bitzer and Skarperdas (unpublished) have made estimates of the cost of a future high-capacity CAI system that they call PLATO IV. Their design is for a 4,000-terminal system having an initial cost of $13.5 million. They estimate that PLATO IV would achieve a cost of approximately $.34 per student contact-hour (about 10 percent of the cost per

*A critical aspect of the economic viability of the latter approach is the cost of communication. Current methods of communication between computer and terminal make use of an individually strung wire (for very short distances) or use of voice-grade phone lines to carry a number of multiplexed signals from teletype terminals. We at Stanford are considering an alternative to these communication techniques: use of geostationary communication satellites. Use of satellites is particularly attractive for long distances and therefore for rural schools, since cost is independent of distance up to about 10,000 miles. On May 18 of this year we made our first experimental test using a satellite to distribute CAI. Nine terminals at a single elementary school usually served by a phone line were run through NASA's ATS-1 experimental communication satellite with no difficulties. In many respects the future cost of satellite communication facilities depends on complex administrative and political decisions more than direct economic or technical considerations.

Table 5

Cost of One Month's Achievement Gain with CAI

Terminal utilization rate (students/day)	Cost/student/yr.[a]	Cost of the one month's achievement gain		
		Median case	Best case	Worst case[b]
30	$ 74.00	$12.00	$ 7.50	$185.00
25	89.00	14.50	9.00	223.00
17.75	124.00	20.00	12.50	310.00

[a]These cost figures assume that the terminals are unused during the summer; if the terminals are used during the summer, these figures should be about 25 percent less.

[b]The worst-case cost estimates are so high because the nine-month estimated gain of CAI + TI over TI alone is only 0.4 months.

contact-hour of the New York City CAI system described in the preceding section, although they assume about three times the utilization rate obtained in the New York project). Problems of finances, communications, curriculum preparation and utilization must be overcome before PLATO IV becomes a reality, so what we would like to discuss here are cost reductions feasible in the very near future.

The system we shall describe is at the other end of the spectrum from PLATO IV; it is small, special purpose, has simple terminals, and utilizes existing curriculum. The first CAI system of this type will be produced by Computer Curriculum Corporation (CCC) of Palo Alto, California late in 1970. It is an eight-terminal system that will be used for drill and practice in arithmetic (grades 1-8). While this particular system is special-purpose for arithmetic, similar but slightly more expensive systems are being designed for drill and practice in reading, and for tutorial work in foreign languages.

The CCC arithmetic system has two practical advantages. First, it is a "stand-alone" system in the sense that the computer requires no operator but can be simply placed in a classroom and plugged in. Normally all eight terminals would be located in close proximity to the computer, although, at some additional cost, provision can be made for remote location. Second, the system is low in cost. Let us now detail the cost of this system for comparison with the costs given in Table 5 of the preceding section. We should emphasize that the initial purchase cost and the maintenance cost are current price quotations from CCC.

The selling price of the system will be between $30,000 and $40,000 and the monthly maintenance cost will be $250 ($25/teletype + $50 for the central processor). The (conservatively estimated) lifetime of the system is eight years. We can obtain the imputed annual cost, p, of the system from its initial cost, I, its lifetime, n, and the prevailing annual interest rate, r, by means of the following standard formula:

$$p = \left[\frac{r(1 + r)^n}{(1 + r)^n - 1} \right] I ;$$

We have I = $30,000 or $40,000 and n = 8. Table 6 shows p for I = $30,000 and several different values of r and for n = 10 as well as n = 8.

Table 7 gives an estimate of the total annual cost to a school district of using the CCC arithmetic system under the assumptions that n = 8 and r = .10. Table 7 has the same format as Table 1, though entries that appear in Table 1 have been omitted from Table 7, if we believed their value to be close to zero. The estimates of costs for paraprofessionals and teacher training are based on the estimates of Table 1 scaled down proportionally to an eight-terminal system.

For a sale price of $30,000, the total cost per year is $9,940 (it would be 15 percent less with a ten-year lifetime and 5 percent interest) for a per terminal cost of $1,240 per year. With a utilization rate of 25 students per day and no system use during summer school, the system costs $50 per student per year for

Table 6

Imputed Annual Hardware Cost of CCC Arithmetic System[a]

System lifetime (n)	Annual interest rate (r)		
	.05	.10	.15
8	$3,650	$4,640	$6,690
10	3,240	4,890	5,970

[a] If I = $40,000 instead of $30,000, values in this table must be increased by one-third.

Table 7

Total Annual Cost of CCC Arithmetic System

Category	Annual Cost	
	I = $30,000	I = $40,000
Imputed annual hardware cost	$4,640	$ 6,190
Maintenance (12 mos. @ $250/mo.)	3,000	3,000
Paraprofessionals	1,500	1,500
Teacher training	500	500
Miscellaneous	300	300
TOTAL	$9,940	$11,490

instruction in a single subject matter.* This is only slightly more than half the $89 per year that the New York City system costs; as that system already only costs about one-third as much as alternative compensatory systems of about the same quality, it appears that CAI can markedly reduce the cost of compensatory education in the near future.

We believe that the assumptions made to compute the annual student cost of the eight-terminal system are conservative. Improvements in technology in the next five years can be anticipated, and there is every reason to think that the cost of CAI relative to other forms of instruction will continue to decrease.

As in the past, so today the manner, style and substance of education is a subject of great controversy in our society. In this paper we have not attempted any deep-running defense of CAI, but have restricted ourselves to certain sharply defined measures of achievement and the associated costs of producing such measured achievements. We believe that CAI provides an unparalleled opportunity for moving some of the past and present controversies about education from the arena of great generality to one of data analysis and confrontation of theories with facts. However, we cannot pursue these matters in greater detail here. □

*Use of the system during summers would reduce this per-student annual cost by about 20 percent. The possibility (as yet unproved) of having 12 or even 16 terminals run from basically the same system would further reduce costs.

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