DOCUMENT RESUME

ED 039 727 56 EM 008 060

AUTHOR Speagle, Richard E.
TITLE The Costs of Instructional Technology.
INSTITUTION Academy for Educational Development, Inc., Washington, D.C.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO BR-8-0571
PUB DATE [70]
NOTE 36p.; This is one of the support papers for "To Improve Learning; a Report to the President and the Congress of the United States by the Commission on Instructional Technology", ED 034 905

EDRS PRICE EDRS Price MF-$0.25 HC-$1.90
DESCRIPTORS *Cost Effectiveness, Expenditure Per Student, *Instructional Technology, Program Budgeting, Resource Allocations, Student Costs

ABSTRACT

In order to communicate a feeling for the costs of the new instructional technology tools, the author presents an estimated annual cost table for three major instructional technologies--instructional television, computer access, and computer assisted instruction (CAI). He builds a model school district of 100,000 elementary and secondary students and discusses the costs of various configurations of media for the district. He identifies eight key variables which are critical in making these estimates, and points out ways in which they may be manipulated to reduce the costs of instructional technology. The question of whether instructional technology will be used in addition to conventional teaching methods, or whether it will become a substitute for some of them, he predicts, will be answered by comparing costs per student hour. (JY)

The Costs of Instructional Technology

by Richard E. Speagle*

Part I: An Overview

The potential of instructional technology to bring about a revolution in education can no longer be questioned, but anyone with the idea it might come cheap is in for a rude awakening. In the present state of the art, costs run from the high but affordable to the astronomical.

The general adoption of a sophisticated, multi-purpose computer configuration, and this on an introductory basis only, could easily double the annual $25 billion that the United States spends today on the operation of public elementary and secondary schools. This does not include colleges and universities.

On the other hand, one billion dollars a year could bring the computer into every school district in the country for a limited teaching and administrative load.

In the more modest budget price range, instructional technology could be introduced into most schools as part of present programs for about a quarter of a billion dollars a year. The figures are shown in Table. A. The number of options in between is legion.

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*Richard E. Speagle is professor of finance at Drexel Institute of Technology.

Table A

Cost Estimates of Major IT Media

/16,000 school districts in larger populated states representing 75-80 percent of elementary and secondary public school population in 1966/

Mode and Quality	Annual Cost 1/ (In billions of dollars)
ITV	
Utility Model	$ .3
Intermediate Quality	.8
Top Quality	1.5
Computer Access	
Batch-Process	.9
Time Sharing	1.2
CAI	
Drill-and-Practice	9.0
Tutorial	24.0

1/Current and amortized capital costs.

Source: C.N. Carter and M.J. Walker, Costs of Installing and Operating Instructional Television and Computer Assisted Instruction in the Public Schools, Chicago, Ill.: Booz, Allen and Hamilton; General Learning Corporation, A Feasibility Study of a Central Computer Facility for an Educational System, Final Report, Washington, D.C.: U.S. Department of Health, Education and Welfare, Office of Education, February 1968; Academy for Educational Development.

Cost estimates here and now for instructional technology, which is as primitive in its development and limited in its application as the automobile was at the turn of the century, obviously do not do justice to the situation likely to exist at a more mature stage. Many factors will impinge on instructional television costs, and their collective impact is almost entirely in one direction -- down. For a realistic appraisal of future costs . . .

. . . These eight factors should be studied	. . . because
(1) Heavy inherent overhead and fixed expenses	they are subject to economies of scale and of greater intensity of use.
(2) Cost-saving technology	under which smaller and cheaper devices, like transistors and printed circuits, deliver a higher and more reliable performance as time goes on.
(3) Geographic concentration of the student population	greater student density spells savings in transmission costs.
(4) Cooperation among schools, districts, and systems	fosters the sharing of central facilities and the pooling of programs.

(5) Machinery for evaluating the quality and effectiveness of teaching techniques and materials...	promotes standardization and multiple uses of hardware.
(6) Level and type of teaching program desired...	the higher the demand for "quality" of instruction, the greater will be the required dollar input of software, hardware, and training.
(7) Rate of learning under innovative techniques...	faster learning and fewer repeaters and drop-outs shorten the duration and therefore cost of instructional technology relative to student achievement.
(8) Possibilities of replacing traditional teaching with instructional technology...	such substitution reduces demand for new faculty, and releases space.

One further observation is of vital importance: instructional technology in the sense of the most advanced media is almost entirely a matter of hardware costs. The expenses of producing and installing programs, once the media enjoy widespread adoption, are trivial on a per student basis -- a dollar per year and less. Prior to such an adoption however higher research as well as development costs of software remain a serious hurdle, much like the River Jordan was in biblical time for the children of Israel. It had to be crossed before they could reach the Promised Land.

A Brief Buyer's Guide

Before pulling out his checkbook, the education buyer must ask himself three basic questions:

(1) How much does it cost?

(2) What am I getting for my money in the way of equipment, materials, and personnel?

(3) What is it going to do for me and members of my family in providing better and more effective education?

These are simple questions which have complex answers. The present Part I of this chapter as well as the more detailed Part II address themselves to the first two questions, the "price tag" and the "merchandise." The third question--about quality and effectiveness--leads to complications and is dealt with separately in a chapter on cost-benefit analysis.

The cost figures cited here are good enough for working purposes. They serve to give the reader something to go on while realizing that inflation and rapid changes in technology are making them obsolete and subject to reevaluation. Figures that give costs on a per student basis will be found in Part II below. Cost per student-hour is a term that, although familiar to economists, has not yet entered the working vocabulary of school officials. For that reason no direct use has been made of the concept in this presentation.

Part II: The Meaning of the Cost Figures

The Costs of Major Media

When people ask about the costs of IT they are not concerned with abstract definitions. They see children in a classroom using all sorts of modern equipment, from television sets to computers, while a teacher stands by monitoring the proceedings, giving advice or leading a discussion. Blackboards, chalk and inexpensive teaching aids are taken for granted by the average citizen and so they will be here.

This is not to downgrade the evident benefits of slide projectors, tape recorders, film strips and audio-visual devices in stimulating students and enriching the course content of the curriculum. Whatever the difficulties of these artifacts of IT they lie not in their cost of acquisition--it is modest--but in making full use of their potentialities.

In order to present the multi-faceted evidence about IT costs briefly and intelligibly, the analyst is forced to simplify.

One way is to consider the new media serially, one at a time, and to make the question of combining or mixing them to a separate point.

The most exciting and talked-about possibilities of IT center around television and computers. Table B illustrates the cost structure of these media at several levels of "quality"--measured by the amount of care and elaboration that go into their application to the school system. At the bottom of the price range, the lowest-cost medium one could get away with and still transform the classroom stituation in a technologically radical fashion is represented by instructional television (ITV); the most expensive plan calls for the full-fledged installation of a system approaching computer-managed instruction (CMI). These and intermediate options of ITV and CMI technologies are illustrated in Table B below.

There is still another alternative, bracketed in the medium-cost range and moderate in its technical demands, while of great possible importance to the de elopment of an educational strategy towards IT. It is a type of installation that might be called a "computer access system." One of its virtues lies in getting the computer on to the school grounds while harnessing it to administrative tasks and, at the same time and at an increasing rate, to problem-solving by students.

Table B

Estimated Annual Costs of Major Instructional Technologies

Mode and Quality	Annual Costs Per 100,000 Students			
	Hardware	Software	Other	Total
	(in millions of dollars)			
ITV				
Utility Model*	$ .8	b/	---	$ .8
Intermediate Quality*	.8	1.6	---	2.4
Top Quality*	2.2	2.4	---	4.6
Computer Access				
Batch Process	2.2	n.a.	.7a/	2.9
Time Sharing	2.9	n.a.	.9a/	3.8
CAI				
Drill-and-Practice*	20.0	.8	6.4	27.2
Tutorial*	50.0	4.6	17.2	71.8

n.a. = not applicable.

a/ Estimated at 30 percent of hardware.

b/ Less than $100,000.

Source: C.N. Carter and M.J. Walker, Costs of Installing and Operating Instructional Television and Computer Assisted Instruction in Public Schools, Chicago: Booz, Allen and Hamilton, 1968. General Learning Corporation, A Feasibility Study of a Central Computer Facility for an Educational System, Final Report, Washington, D.C.: U.S. Department of Health, Education and Welfare, Office of Education, February, 1968. Academy for Educational Development.

Cost Estimates through Model Building

Estimates of the cost of instructional technology should come with imaginary labels saying "Caution! Use at your own risk!" so as not to inspire unwarranted confidence in their precision. Cost projections in the complex education area depend on critical assumptions that must be identified and in a practical case changed to fit actual necessities.

In particular, the starred programs in Table B constitute a "family" of estimates derived from an example of typical model-building procedures. All assume the addition of ITV or CAI techniques to enrich conventional classroom teaching. Few if any elements of substitution or replacement of existing modes of instruction are contemplated, a premise of the model designers that will be subject to examination below.

Briefly, the postulated environment in which variations of the ITV and CAI modes are costed out has the following characteristics:

(1) a school district with 100,000 students in grades 1 through 12;

(2) 152 schools, half elementary and half secondary. containing respectively 720 students, 30 per classroom, and 600 students, 25 per classroom.

(3) a typical six-hour instructional day in a 150 day school year;

(4) one hour, or 16 percent, of each school-day taken up by either ITV or CAI.

Buyer's Options in the ITV Model

Investment in ITV divides into two major parts, software or live and film programs, and hardware or equipment. Programing labor and materials are estimated to run from $50 per hour for a simple televised lecture to $6,000 for an hourly presentation conducted by a TV professional with visual aids and props. Ultra-high quality spectaculars, say, of a reenactment of the Battle of Gettysburg, would carry a budget of perhaps $500,000 per hour of running time, but commercial video-tape copies might be rented at about $50. In all cases, the use of staff teachers avoids incurring additional personnel costs.

Hardware for this school-system module consists mainly of a central studio and transmitter plus peripheral receiving gear, inclusive of two 27" black-and-white TV sets per classroom. Costs start at $600,000 annually for four-channel, closed-circuit microwave - a standard component of all versions of the proposal - and run up to $2.2 million for an airborne transmission system. Estimates assume ten-year lives, and maintenance and power costs equal 11 percent of initial equipment expense.

The total annual outlay in the modular system depends on the particular software-hardware selection. Costs range from $800,000 for the simplest pattern, closed circuit and ordinary televised lessons, up to $4.6 million for airborne programs of professional caliber.

Buyer's Options in the CAI Model

Unlike ITV, the major CAI cost categories are three: instruction material, equipment, and a cadre of computer technicians. As to the first, the more comprehensive and ambitious the teaching approach taken, the more intricate becomes program design and installation.

Least expensive is drill-and-practice material, as used in mathematics or reading courses, where in-house production runs to about $5,000 per program-hour and rental of similar material from a commercial source to about $35. The more demanding tutorial mode of CAI raises the cost figures to $30,000 and $210 respectively.

Estimating the life of software at three years, the model specifies no more than one-third of annual programs content to be new, distributed in a ratio of 3:1 between rented and campus-produced courses. For the 100,000 student universe, the annual bill for software comes to $800,000 for the drill and $4.6 million for the tutorial approach.

Basic CAI hardware consists of a central data processing and storage facility (Central Processing Unit or CPU) linked with a set of student terminals which may range from simple typewriter-like devices to elaborate consoles with cathode ray tubes (CRT), light pens, keyboards, image projectors and audio gear.

A drill-and-practice hardware configuration would involve an annual rental of $2,400 per terminal, including the pro-rated cost of a CPU capable of handling up to 200 units. With 16,700 terminals needed to serve 100,000 students, total equipment costs would run to $40 million, although mass production of terminals might halve this figure to $20 million.

A tutorial mode of CAI runs the bill up sharply, based on the price tags of standard equipment now available. Here, each CPU accomodates no more than 32 student stations which boosts the pro-rata charge and the total cost per terminal to $6,000 a piece. Again, volume production might slash the $100 million outlay to an annual $50 million per system.

CAI occasions a third type of expense that puts an override of perhaps 30 percent on top of hardware costs--the expense of operating and administrative personnel, supplies, utilities, and the lease of telephone-computer transmission lines. Additional estimated disbursements amount to $6 million for the drill mode and $17 million annually for the tutorial mode. Still omitted are training costs and space costs, surely not negligible, but maintenance costs would be absorbed by the lessor of the equipment.

The Computer Access System

A different assignment for the computer, reflected in sharply lower costs, is represented by a "computer access system". It is not a pure teaching approach because administrative uses of computer facilities are expected to carry a large part of the expense burden. The design of a proposal for such a system to HEW was modular and hence turned out to be comparable with the rest of the instructional technology models presented here. Specifications called for:

(1) a system of fifty educational institutions, within a 50 mile radius, having a total enrollment of 100,000 students;

(2) grades from 9 to 16, but excluding major universities offering post-graduate work;

(3) users of services including:

  (a) students of computer programming;

  (b) students and faculty performing teaching and research calculations;

  (c) administrative personnel processing operating data.

The computer system design focussed on two technical options: a time-sharing mode, which affords simultaneous access to multiple users; and batch-processing, which assigns multiple access acording to a prearranged time schedule. The capability specifications for the two techniques were derived from a survey of actual rates of usage in selected currently operative computer installations around the country.

Because of the still scant use of digital computers in schools, that approach gave the projections a distinctly upward bias in estimating expenses. Annual hardware costs, based on production models and a conservative 40 month life, came to $2.2 million for the batch-process and $2.9 million for the time-sharing technique. Although personnel, utility, and other expenses were not specified, one may estimate them at roughly 30 percent of hardware costs. Software expenses, however, also left out of the picture, are probably trivial considering the simple nature of the tasks to be performed and the availability of standard programs from commercial sources.

It is not straying too far from the mark then to estimate the total annual costs per standard 100,000-student module at $3 million for a batch-processing and $4 million for a time-sharing installation. Transferred to the wider canvass of 16,000 public school systems, the nation-wide bill for adopting a "no-frills" computer access system, at the present state of the arts, would come to $900 million and $1.2 billion respectively.

Cost Reduction

Advanced versions of IT, leaving aside the issues of effectiveness and implied institutional change, face a formidable economic obstacle: they are too expensive in relation to what Americans are accustomed to pay for education. Any factor which can reduce costs to "realistic" proportions is bound to raise IT's competitive edge vis-a-vis traditional teaching methods, and make it financially more attractive to prospective backers. The same goes, to a lesser degree, for sophisticated "far-out" IT proposals.

As shown earlier in tabular form, eight key considerations are critical for the estimating procedures of IT costs, no matter what the underlying hypothetical model. Appropriate changes in these key variables--jointly if possible!-- would do much to reduce the money hurdle. The vast potential impact in terms of lower future costs of IT makes a close inspection of these aspects well worth the trouble. What, in other words, must be done to make such potential savings a reality?

The Scale of Operations

Few principles are more fundamental to the practical application of instructional technology than the economics of overhead costs. When any cost is fixed for a given scale of operations -- industrial, education, or whatever -- a rise in the level of activity causes a reduction in the cost per unit. The fixed cost, a constant, becomes the enumerator of a fraction in which the denominator, units of output, is permitted to expand. In accounting language, overhead costs are being spread by the rise in volume, resulting in "economies of scale" that allow lowering the price for the good -- or instructional technology service!

Five specific types of economies are achievable:

- At the factory level, those due to
  - (1) mass production of equipment
  - (2) a less than proportionate rise in the CPU's cost per unit of capacity (measured, say, in statements per second) as the size of equipment is increased.
  - (3) the design of special-purpose educational computers.
- At the school level, when
  - (4) the number of students or tasks per installation expands.
  - (5) the duration of equipment use is lengthened.

While interrelated, these factors lends themselves to separate discussion.

Quantity production of television sets, video tape, and audio-tape units, to name only a few standard ITV components, is bound to reduce present price tags. The same holds true for computers and especially for student terminals in the various CAI modes. One informant, as noted earlier, projects a 50 per cent cut in cost, from \$2,400 to \$1,200 per terminal, once industry went into large-scale production of the drill configuration.

Larger models of computers require a larger initial investment or total annual lease cost, but they come cheaper in terms of unit of capacity -- whether measured by data storage, output of statements per second, or student terminals serviced. The last-mentioned aspect is shown in Table C.

Table C

Size and Cost of Computer Installation:
Tutorial Mode of CAI

Size and Type of CPU	Annual Rental	Number of Terminals	Annual Rental per terminal
"Small" -- IBM 1500	\$180,000	32	\$5,550
"Large" -- PDP-10	650,000	448	1,450

Source: F.F. Kopstein and F.J. Seidel, "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics," AV Communications Review, Vol. 16, No. 2, Summer 1968, pp. 155-8.

In ITV, cost per student may be expected to be cut similarly when more powerful transmitters -- airborne or satellite -- and larger receiving equipment are employed.

An increase in the number of students in the audience, ITV plainly demonstrates, need not occasion anything like a proportionate increase in unit costs. While the ratio of viewers per TV-set, or even per classroom screen, may be subject to a ceiling, so that more viewers means more purchases of sets, the cost of airborne equipment and communication satellites is fixed and largely independent of the size of the audience. The more viewers, the lower the potential "entrance fee".

In CAI, potential cost reductions from accomodating more students and hence putting in more student terminals, are considerable up to the maximum of CPU capacity. However economies of scale, once each CPU carries a full load, are less dramatic as the number of installations multiplies. At that point, it is the fixed software overhead that suggests the widest possible student participation in order to lower unit costs, as shown in Table D.

Mention should be made of an intriguing possibility, the "pairing"of two students to work simultaneously at one terminal, which promises virtually to halve per-student cost. Experiments

Table D

Size of Student Body and Instructional Television Cost Per Student

Number of Students in System	ITV		CAI			
	Medium Quality[a] [b]		Drill Mode	[b/]	Tutorial Mode	[b/]
	Hourly	Annual	Hourly	Annual	Hourly	Annual
10,000	$1.67	$250	$2.27	$340	$7.53	$1,130
100,000	.21	30	1.81	272	4.79	718
500,000	.08	12	1.77	265	4.27	640

[a] Based on CCTV and $6,000 per hour programs.

[b] Assumes 150 student hours of exposure per school year.

Source: C.N. Carter and M.J. Walker, Costs of Installing and Operating ITV and CAI in Public Schools, Chicago: Booz, Allen and Hamilton, 1968.

point to little if any loss in learning efficiency -- the use of the "buddy system" might even heighten learning motivation!

An obvious case of instructional cost reduction follows an expansion of the number and types of tasks assigned to one computer installation -- say, accounting, record-keeping and research calculations. The situation is almost equivalent to a lengthening of the time period of computer use, discussed below.

Unused capabilities of computers engineered for industrial purposes but applied to instruction mean high costs. For example, the IBM 1500 system was designed for such tasks as process control of cracking towers in petroleum refineries and consequently has many expensive features not needed in elementary or secondary schools. Once an educational market of sufficient width is created it becomes feasible to design special purpose computers for education that will have lower price tags because of more limited data processing features.

Duration of equipment use becomes a factor wherever IT confronts substantial fixed costs. A longer use of the equipment during the day or over the calendar year brings obvious economies. In ITV, such restrictive initial assumptions as one hour's use per six-hour instructional day over a 150-day school year must be relaxed once the televised lesson is more widely accepted.

Similarly in CAI, running the computer round-the-clock means significant savings per student-hour. One could even visualize night shifts for students, now commonplace for scientific researchers working on expensive devices like the cyclotron. However, fairly continuous utilization of the computer could accrue simply from batch-processing administrative data during off-hours and at night -- like posting accounting data and updating student records. Research problems of faculty and graduate students also could be scheduled to coincide with slack time on the input terminals. Such flexibility would not come cost-free because additional expenses are incurred in "marrying" the time-sharing and batch-processing modes within the same computer complex.

Cost-saving Technology

The productivity of modern technology does not only rest on turning out more volume at a lower cost per peice by making the machine bigger. It rests increasingly on getting the same unit cost effect by making devices smaller and cheaper. The post-war history of the digital computer, a keystone of advanced IT, provides perhaps the most telling example, as shown in Table E.

Table E

Computer Progress:
Reduction in Cost of Computation

/Costs are estimates based on reasonable assumptions about computer configurations and use/

Equipment	Technical Innovation Involved	Time to do one multiplication	Cost of Machine per hour	Cost of 125 million multiplications
Desk Calculator	Mechanical	10 secs.	$ 0.20	$2,150,000
Harvard Mark I	Electro-mechanical	1 sec.	12.50	850,000
	Electronic	10 ms.	25.00	12,800
UNIVAC 1103 (type C)	Magnetic Core	500 mu's.[a/]	70.00	1,420
Stretch (IBM 7030) (type A)	Parallel Circuits	2.5 mu's.[a/]	320.00	29
IBM 360 (model 85)	Monolythic Buffer Storage	5.0 nsec[b/]	550.00	5
CDC 7600	Remote Peripheral Process Units	1.4 nsec[b/]	972.00	5

a/ mu = microseconds or one millionth of a second.

b/ nsec = nanoseconds or one billionth of a second.

Source: President's Science Advisory Committee, Computers in Higher Education, Washington, D.C., 1967, p. 60; Academy for Educational Development.

Cost Effects of Student Density

The concentration of students in a given geographic area has noticeable cost effects because under either ITV or CAI the leasing of the requisite communication cables and the transmission of signals is a function of distance. As Table F illustrates for the ITV mode, sparsely populated areas and rural sections of the country involve a considerable larger cost burden than, say, the Boston-Washington corridor. To the extent that the shift of population to the larger metropolitan areas will continue and smaller schools consolidate, transmission costs may well drift downward.

Table F

Population Density and Unit Cost of ITV

	ITV Costs Per Student Hourly	ITV Costs Per Student Annual
Montana	$ .35	$52
Mid-Atlantic States (N.Y., N.J., Pa.)	.06	9
	Instructional Material Costs Per Student[a/]	
National Average	$ .02	$ 3

a/ Includes books and supplies.

Source: C.N. Carter and M.J. Walker, Costs of Installing and Operating Instructional Television and Computer Assisted Instruction in the Public Schools, Chicago, Ill.: Booz, Allen and Hamilton; Academy for Educational Development.

Cooperation Among Schools

Advances in computer capabilities have outstripped individual user requirements and are likely to keep on doing so in the future. Banking and industry have drawn the logical conclusion from this development by entering into mutual time-sharing arrangements to spread the overhead. There is no reason why the same efficient pattern might not be suitable in the schools. All that is needed is a spirit of cooperation and flexibility to follow the promptings of economic sense, whether this leads to a crossing of political boundaries or to a bridging of institutional differences in order to find appropriate partners for computer services.

Standardization

There is not only safety but economy in numbers through the widest possible participation of schools in a common pool of audio, television, and computer materials. The more schools can agree on the validity of a given program, as they now informally agree on the best-sellers on text book publishers' lists, the cheaper will be student costs.

But there is a difference. In the still underdeveloped IT area, agreement on competing teaching devices and materials presupposes a common ground on educational goals and techniques.

This does not yet exist and awaits progress in the R and D of learning theory and teaching effectiveness. Here is one instance more, in the economics of overhead costs, where R and D turns out to be a critical factor in the adoption of advanced IT.

Eventually, some testing association may be created to evaluate new materials, and to "accredit" them with its stamp of approval. This does not require monolithic uniformity. The tremendous breadth of the education market, in the United States alone, would permit "many flowers to grow" in the program field at the same time that sufficient adoptions for a given mode could guarantee a tolerable cost burden.

Importance of Teaching Mode

Both the level and quality of instruction have a cost impact. For ITV as well as for CAI, the higher the quality specified, the greater the expense. This follows from three inputs:

(1) more elaborate software.

(2) more sophisticated hardware.

(3) the need for more highly trained professionals to run the system.

In ITV, the cost difference between utility and high quality software is dramatic. However it tends to disappear when the student audience becomes very large -- at that point the two unit cost curves converge at a very low level. Hardware costs similarly are sensitive to program quality -- one need only note the difference between the price of color as against black-and-white television equipment and production. Whether the price gap will disappear is still questionable.

For CAI, a high-quality, audio-visual tutorial mode is sharply more capital-intensive, both in hardware and in the associated program pool, than is mere drill-and-practice. The resulting cost differential between these two modes is likely to persist, but advances in computer design, languages, and programing techniques are bound to lower costs at all levels of sophistication..

The Rate of Learning

The speed at which a student absorbs instructional material may turn out to be the most significant cost consideration of all. One management consultant asserts that the learning rate is the most important factor, on the basis of a carefully constructed accounting model.

Up to now, costs have been analyzed as if the learning achievement of the U. S. school population were a constant, distributed over a given time-span of faithful classroom attendance. This assumption puts ITV and CAI in the context of whether they might be able to match traditional levels of teaching performance at a comparable cost.

Once that hidden limitation is brought to light and relaxed, the way is open to think about a possible acceleration of "educational production" -- the rate at which students acquire the skills and knowledge, at specified achievement levels, to qualify for a standard diploma or degree, society's measure of scholastic accomplishment. Should the average student aided by IT be able to master a given curriculum at, say, only three-quarters of the time imposed on him now by a fairly rigid schedule, his cost of education would automatically drop by a similar proportion.

A speeding up of the "learning process" could spell tremendous potential savings in public outlays and in human self-investment, and probably constitutes the greatest challenge facing instructional technology today. There is no good reason why some of these savings in certain situations could not be passed on to the student based on the speed at which he attained a given level of achievement, to reward him and spur him on to greater effort. Of course, the conventional tuition formula would have to be transformed into a variable dependent on the duration of school attendance.

Instructional Technology: Addition or Substitution?

Another and highly important part of the package of assumptions by which the models arrived at their respective cost figures was that ITV and CAI would simply be additions to the arsenal of educational tools, without disturbing existing patterns of student-teacher and student-administrator ratios. Such a premise may be prudent for making reasonable estimates in a practical world of established institutions, but it cannot be maintained in talking about the future of education and the longer-range leverage that instructional technology promises in the future.

The thrust of technology in the Western World is for machine inputs to be substituted for the human factor in the production process -- whether of goods or services. That does not mean that teachers will be out of work any more than other people as long as national policies aim at full employment -- it merely means that teachers will do new things and perform their special roles differently than they did before.

While model-builders generally have shied away from discussing substitution effects, some costing techniques that take account of them have been worked up. It is too early, however, to appraise these accounting techniques except in their theoretical aspects. Further discussion will be found under the heading of cost-benefit and systems analysis.

Cost of Improving Availability of Conventional Media

The traditional media have not been standing still, resigned to being displaced by more advanced teaching instruments. Organized and collected in a modern "media center", books, magazines, maps, film strips, slides, films, and recordings are clamoring for additional funds which a recent proposal by ALA and NEA targets at 6 percent of school operating costs. The price tag of this proposal nationwide for public elementary and secondary schools would come to $1.6 billion annually or about half a billion dollars more than is now being spent on instructional materials (Table G).

A Look at Annual Costs Per Student

One dimension of costs that needs emphasis because of its paramount practical interest to school administrators is the expense per student of the various innovative media. Such figures form the starting point for them in computing the costs per school on their home grounds.

This focus has additional advantages here because it allows the inclusion of a wider range of data, some not previously considered. It further illustrates an important proposition: the significant costs are those of hardware, because the costs of programmed materials shrink to insignificance once a new medium spreads across the nation.

Table G

Cost of Upgrading Traditional Instruction Media to ALA-NEA Standards

/Public elementary and secondary schools/

Expenditures for Instructional Materials (1966 basis)		Amounts (Millions of dollars)
(1)	Free textbooks	$221
(2)	School library books	117
(3)	Supplies and other	541
(4)	Total	$879
	(1968 basis)	
(5)	ALA-NEA target for "media centers"1/	$1,596
(6)	Total in (4) adjusted2/	1,080
(7)	Required additional cost to meet ALA-NEA target	$516

1/ 6 percent of current operating expenditures of $26.6 billion.

2/ Raised by 23 percent, the rate of increase in current operating expenditures 1965-6 to projected 1968-9.

Source: ALA-NEA Report (Draft), Standards for School Media Programs, Washington, D.C.: 1968; U.S. Department of Health, Education and Welfare, Office of Education, Projections of Educational Statistics to 1976-77, p. 78; U.S. Department of Health, Education and Welfare, Office of Education, Education in the Seventies, Washington, D.C.: May, 1968, p. 28.

Finally, it serves to put these costs side by side with average current expenditures per student today. If widely accepted, a low cost ITV mode could be installed for an extra 1 percent of current student outlays, as shown by Tables H and I below. The lowest cost CAI configuration now on the horizon would raise average current annual student costs in public schools by 13 percent and those in institutions of higher learning by 6 percent.

For hardware, what is new in Table H is the consideration of powerful computing equipment that may well lend itself to future educational use. If so, it promises to slice the hardware and eventually the total cost of a sophisticated tutorial CAI system by as much as three-quarters.

Confidence in this added group of cost projections is heightened by the fact that data on a tutorial IBM 1500 system, when suitably adjusted, closely match a second independent estimate for the same configuration.

The adjustment of all data to similar assumptions is of course crucial. One such assumption is the use of each television set and of each terminal by a typical student one hour a day, five days a week, for an annual 150 hours of exposure to the respective medium. For a six hour instructional day this works out to 900 hours of active use of the average TV set or terminal per year. Stepping up intensity of use by a second shift of

Table H

Annual Hardware and Operations Costs of ITV and CAI per Student

[Each terminal shared by six students for a total use of 900 hours per year]

System and Investigator	Terminals[a]	Hardware	Operations	Total
ITV				
Booz, Allen & Hamilton				
Closed Circuit TV				$ 8
Airborne System				22
CAI				
Booz, Allen & Hamilton				
Drill-and-practice	200	$200	$ 64	$264
Tutorial	32	480	172	652
HumRRO[b]				
IBM 1500	32	480	172e	652e
PDP-10 (Teletype)	448	60	18e	78e
PDP-10 (CRT)	448	115	35e	150e

e Estimates based on 30 per cent of hardware costs.

a/ Per Central Processing Unit.

b/ Figures adjusted to reflect potential 50 per cent saving due to mass production for comparability with Booz, Allen data.

Source: C.N. Carter and M.J. Walker, Costs of Installing and Operating Instructional Television and Computer Assisted Instruction in Public Schools, Chicago: Booz, Allen and Hamilton, 1968; F.F. Kopstein and F.J. Seidel, "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics," AV Communications Review, Vol. 16, No. 2, Summer 1968, pp. 153-9; Academy for Educational Development.

students and adding some use on Saturday would cut the costs shown by more than one-half across the board.

Operating expenses are of special importance for computer systems but the degree varies according to the investigator. In one case, such costs were estimated at no more than 4 percent of hardware while in another case as much as 30 percent was estimated to be the true expense ratio. The difference seems to lie in the inclusiveness of this expense category as well as in the status assumed for the operation. The leasing of telephone lines to link remote terminals to central computers alone runs to 30 percent of equipment costs.

In the case of the low estimate the only operating cost mentioned was operator pay whereas the other study cited personnel, utilities, training, consultants and other related expense items. Furthermore, the low estimate was made on the basis of a going computer operation whereas the high estimate reflected actual school experience in what amounts to CAI experiments.

It would be wise to conclude that operating costs will start in the 30 percent-of-hardware range, and that only with the gain of operating experience would schools find costs descending along the so-called learning curve.

Software for CAI includes the outlays of instructing the computer in what to do and those of designing appropriate course materials. The programing costs run from $250 per student annually on the IBM 1500, if distributed over ten CAI installations, to about $18 for the PDP-10, since one system of the former can accomodate only 192 as against 2,688 students for the latter. Each stepwise addition of ten more installations would successively reduce these costs by one half.

Expanding the student body exposed to CAI to 100,000, the figure used in the original module, would bring computer programing costs, regardless of hardware used, down to only $0.48 annually per student. Further possible savings, as acceptance of CAI spreads, are easily extrapolated since costs drop proportionately with every rise in the number of students.

Instruction materials for CAI cost $29 per student annually if spread over a single IBM 1500 installation, and $2 annually for a PDP-10 configuration. Expanding the student population to 100,000 would distribute the investment in course materials over a far larger number of users and reduce costs per student to as little as $0.06 a year.

A second set of estimates of programing costs is far less optimistic but the eventual outcome is the same. Here the annual per-student cost of programed materials would be $0.77 for drill-and-practice and as much as $4.60 for the tutorial mode. Since a further expansion of the student body would again reduce annual costs proportionately, it would not take long before instruction material expenses would become quite insignificant.

What is true for relatively expensive CAI course materials holds even more true for films and live presentations in ITV. No formal discussion of this point is needed since the mathematics of costs work in the same direction.

In sum, the analyst of the economics of the new media is back with hardware and operating costs. These may be compared with average annual current costs per student in the conventional classrooms and laboratories to evaluate their relative magnitude.

The $8 to $22 range of annual ITV hardware costs per student seem small indeed if it can be proven that the medium can "deliver" an at least proportionately higher rate of learning achievement.

It is also apparent that a $78 annual cost per student for a PDP-10 teletypewriter installation is not an outlandish figure when put next to the corresponding current outlay per student in the nation's schools today (Table I). The IBM 1500 system, by contrast, with a price tag of $652 a year per student, seems prohibitive.

The cost figures in the table further make clear that the logical entry path of the hardware-intensive media into the educational system is through colleges and universities where they will be cost-competitive much sooner than in public schools. Strategists planning to introduce instructional technology into the educational establishment would be well advised to give this factor their closest attention.

Table I

Projected Current Expenditures per Student in the U.S.: 1968

Item	Public Schools K-12	Higher Education[1/]
Fall enrollment	44.7 million	7.4 million
Current expenditures	$26.6 billion	$9.4 billion
Average current expenditure	$593	$1,270

1/Total resident and extension degree-credit and nondegree-credit institutions.

Source: Projection of Educational Statistics to 1976-77 (1967 Edition), Washington, D.C.: U.S. Department of Health, Education and Welfare, Office of Education, 1968, pp. 9, 11, 77-78.