How Costly Are Computer-Based Instructional Systems? A Look At Two Approaches

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Abstract: An increasing number of universities are investing in computer-based instructional (CBI) systems but the costs of operation are in dispute. Alpert and Biker's estimate of costs per student hour for PLATO has been challenged by Kearsley while Hofstetter attempts to demonstrate a more favourable cost for the University of Delaware's PLATO system. This paper demonstrates that the PLATO costs are higher than its proponents claim. A cost analysis of the VITAL microcomputer-based system is offered as an alternative to the high cost entry into CBI via mainframe systems. The major costs of computer-based instructional systems are not in the computing component, as costly as that is, but in the preparation and production of courseware. When compared to the cost of face-to-face classroom instruction, mainframe systems are at least four times more costly on a student hour basis even when using the large number of 500 students. Realistic instructional goals and clear priorities are argued to be the essential ingredients of effective computer-based learning rather than the expectation of efficiency and cost benefits.

INTRODUCTION

In the introduction to a series of working papers, *Computers on Campus,* Tucker (1983-84) names three American universities* which he states, "to my knowledge, outrank all others in the nation with respect to current scale of investment in information technology for instruction purposes -- close to $200,000,000 all told over the next few years." With costs of that magnitude, teachers in many other resource-starved North American universities may be excused if they think the bill for computers in education is too big. One Canadian university Vice-President remarked recently, "Don't talk to me about computing costs; it is just one big sink-hole." Systems predicted to cost pennies per hour of student contact time when purchased have shown a tendency to run into many dollars per hour. What are the costs which a teacher may expect to be incurred on liis or her behalf when using a computer-based learning system for instructional purposes? This paper will discuss large and small computer-based instructional systems and present an analysis of predicted

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and actual costs in two systems. It is offered as a contribution to clearing the air about the true costs of using computers for instructional purposes.

Philosophical and Historical Perspective

This article is written from the position that the computer in education is a tool, a means to an end, but that too frequently the hardware comes close to being viewed as an end in itself with the instructional application being left to someone else. The use of the computer in education should be seen as an integrated undertaking, including both the instructional application and the hardware. Such an integration is a complex process in that it draws first on theories of learning and instruction; second, on principles of instructional design; third, on matters of staff development and the adoption of innovations; fourth, on considerations of logistics and organization; and last, on the technical aspects of the hardware itself.

Many of us lived and worked through the heady decade of the 60's when communication technology was widely heralded as ushering in a transformation of education. The most spectacular example of the day was television with such massive projects, by the standards of the day, as Scarborough College's television teaching system (Lee, 1971). While television by the early 70's was beginning to be rejected, it did find its way into many classrooms in schools, colleges and universities. The question might be asked, "What makes computers in education in the 80's and 90's that much different from television in education in the 60's?" It can be argued that both represent instructional tools, and while they are different in their technical manifestations, they share an essential similarity as technical devices applied to education. Missing frequently in the 60's was adequate attention to the instructional design process along with satisfactory consideration of the impact on those with the instructional responsibility -- the teachers. It was not uncommon in the 60's to find those promoting educational technology to complain, with some derision, that education was the last remnant of the cottage industry and that it had to change to keep up with the times. Some of those sentiments are expressed in the 80's with reference to a different set of instructional devices.

Finally, it is the position of this paper that the only people who can effect change in instructional practices to incorporate the newer technologies are the professional educators themselves. This change will not come about by cajoling instructors or applying top-down administrative pressure but by an intrinsic belief that these new instructional devices offer something of value to learner and instructor alike.

Communication Technology and Computer-Based Instructional Approaches

Several parallels may be drawn between the use of television and computers in education. In the 60's the technology of the day required large central television production installations with a centralized coaxial distribution system. The use of such a system demanded major adjustments on the part of teachers and the yielding of large areas of control to the technical specialists. In the 70's this technology began to change with the appearance of low-cost half-inch video record and playback. machines and low-cost cameras. This enabled the teacher-user to regain some control over the instructional environment they had lost to the large central television system.

In the same decade of the 60's the first instructional applications of the computer began. The best known and perhaps the oldest established computer-based learning system in American and some international universities is PLATO. PLATO is considered by many to be the state-of-the-art system for computer-based instruction (CBI) providing a rich CBI environment with high-resolution graphics, student control keys, touch input screens and a large number of connections to external systems such as heart-rate monitors, slide projectors, videodisc players and speech synthesizers, to name only a few of the peripherals which may be connected to it. To support this range of features a computing resource of considerable size is required.

Computer-based instructional systems of the PLATO type require a highly centralized organizational structure which is removed from the normal academic environment in which most teachers find themselves. Without attempting to force the analogy between instructional television in the 60's and mainframe computer-based instruction, it is argued that both systems demand a high capital investment and a specialized operating establishment. If the instructional priorities require this type of system, then there can be no quarrel with the resulting costs and the technical and organizational infrastructures required to support it. A system such as PLATO works well in this environment and it is especially appropriate for the military or large industrial organizations.

However, one of the lessons of television in the 60's was that education required greater flexibility and more alternatives than the technology of the day allowed. That flexibility began to emerge in the 70's for video equipment with the rapid progress in the miniaturization of electronic components. The same process led to the development of microcomputers in the early 80's which now offer alternatives to the use of computer-based instruction. CBI is no longer restricted to the large mainframe or medium-sized mini-computer systems.

During the decade of the 60's another much heralded educational medium appeared on the instructional stage. It was the super 8mm camera and projection system. While its potential, as promoted, was never realized it did make one major contribution, later picked up by low-cost video recording equipment. It enabled teachers and students to work with a visual recording medium previously beyond their reach because of the high cost and technical sophistication of semi-professional 16mm equipment. Professor Lou Forsdale of Columbia University, a leading proponent of 8mm film in education, advised his audience to look upon the expenditures in 8mm film production as an investment in building experience and skill rather than an investment in equipment. That advice seems to be as true today in working with computer-based instruction as it was two decades ago in working with new visual communication media. There is an unfortunate tendency to await the latest technical improvements before committing even a part of one's instruction to a new medium. The trouble with that approach is that there will probably be no end to new developments, which only serves to justify procrastination. The large investments required for mainframe systems have tended to restrict the opportunity of the majority of teachers to explore the power of computer-based instruction. The advent of the microcomputer has changed this restriction by opening up alternatives which can be explored on today's budgets.

The computer hardware is only one piece of the picture. The essential requirement is that the system help students learn and this requires some content or courseware. Unless adequate arrangements can be made to provide for the teaching preparation time to create the materials or to acquire and adapt existing materials from a resource collection of courseware, the expenditure of funds on computer equipment could be a costly mistake.

One attempt to ease the burden of creating computer-based learning materials has been the development of course authoring systems. These are software packages which allow a person not sophisticated in computer programming to produce instructional sequences using

English and the simplified structures of the authoring system. These authoring packages may be compared to word processing, spreadsheet, or file management packages. They require the user to acquire a knowledge of the system to use its potential effectively, but they make it possible for the non-programmer to do useful work with the computer in a fraction of the time necessary to gain proficiency with a programming language. PLATO Tutor was developed as the authoring system for PLATO. NATAL and CAN7 are Canadian contributions for larger systems. PILOT in various versions - Apple Super PILOT, E-Z PILOT and Softcrates - are current authoring systems designed for the microcomputer.

A project at the University of Guelph has developed another authoring system using Telidon/NAPLPS* as the vehicle for creating and displaying the instructional materials. This project has moved away from Telidon as a unique equipment system requiring special purpose decoder terminals, to a computer based system ranging from a single microcomputer in a stand-alone configuration to a small network system of up to 24 student study stations. The system called VITAL (Versatile Interactive Teaching and Learning) incorporates a number of Canadian-designed features. These include the Telidon/NAPLPS computer code, software decoders for the microcomputer by FBN, Microstar and Microtaure and hardware electronics developed by NORPAK. VITAL is a software authoring package which integrates these elements to operate on an IBM PC or compatible equipment. (For a fuller treatment of VITAL, see Moore, 1986). The original contribution of VITAL, beyond integrating the various off-the-shelf elements, lies in the programming sequence which enables teachers or their assistants, without computer language skills, to create visual and text reference materials, tutorials and interactive quizzes with immediate judging and feedback capability. VITAL has been written in BASIC and operates on PC DOS although it could be converted to C to operate on UNIX making it suitable for a mini-computer environment approaching mainframe capability. However, its developers see its main contribution at the lower end of the cost/complexity scale to enable teachers and administrators to gain experience in the effective and efficient use of computer-based instructional applications while minimizing the expense normally associated with computer based instruction.

Cost Comparisons Between Two Systems

The two systems chosen for this analysis are PLATO and VITAL. PLATO was chosen since it is the most strongly established and widely recognized mainframe computer-based instructional system which incorporates audio visual devices in its display. VITAL was chosen for comparison since it provides a graphic visual display, multi-user capability, and record keeping functions, along with interactive programming and judging capability operating on a microcomputer-based network or single stand-alone study station.

Reported Costs for Operating PLATO

Hofstetter reported that at the University of Delaware the PLATO system installed in 1975 with 32 terminals had grown to 330 terminals with planned expansion to 560 terminals. The total investment in equipment for this system was reported to be $3,801,971 as of October, 1981 (Hofstetter, 1983). The annual operating cost for the system in 1981-82 was $3,164,698 of which $3,335,049 or 42 percent was derived form external grants and contracts, leaving a net operating cost to the University of $1,829,649 for its computer-

* NAPLPS - North American Presentation Level Protocol Syntax.

based instructional service. Both in terms of capital investment and in operating costs, the use of computers on the scale of PLATO makes major long-term demands on the instructional budget. At this level the costs are aggregated as a total budget expenditure for the institution.

It is also customary to analyze the costs on a per student contact hour basis. This is the figure which is frequently used to interpret the large total outlays. In 1970, Alpert and Bitzer (1970) projected a range of $0.34 to $0.68 per hour per student contact hour. When this projection is adjusted for inflation using a 14 year inflation factor of 2.63, those 1970 dollar costs become $0.89-$1.79 per hour, still a reasonable figure. However, Kearsley (1977) reported that the cost per hour for a single PLATO terminal leased on an annual basis would cost $7.20 per hour or 4 to 8 times the cost originally projected.

Hofstetter (1983) has analyzed the actual costs at the University of Delaware and argues that the costs are, in adjusted-for-inflation dollars, only twice the Alpert and Bitzer projection. His argument, however, is flawed in that he calculates an hourly cost in 1982 of $2.47 per hour using all 330 connected terminals for an annual per terminal cost of $3,816. He concedes that the actual average number of terminals in use at peak demand time is 140. If this is the average peak load then non-peak periods would be something below that. The average peak demand then is 42.4 percent of capacity. He uses Alpert and Bitzer's estimate of 2,000 hours of use per terminal per year in arriving at his cost of $2.47 per hour. A more accurate analysis would take into account actual student use rather than a projected capacity figure in calculating a per student hour cost. If one uses the 140 terminal per hour peak demand (the 190 non-used terminals are assigned an overhead status for redundancy or developmental purposes) the annual operating cost is $8,994 per student-used terminal or an hourly cost of $4.48 per student for the PLATO mainframe. To this must be added the amortized cost of the student terminal, annual maintenance costs on the terminal, and communication costs between the student terminal and the mainframe. Thus to the costs of the central system must be added a per hour cost for the student terminal of $1.51 per hour. The hourly cost per student, using a more realistic analysis in terms of student demand, becomes $5.99 or somewhat less than Kearsley's figure of $7.20 per hour. However, since this analysis has taken the average peak demand as the basis it may have erred on the generous side and one would be included to accept Kearsley's estimate of what the real costs are in terms of students served.

Thus far the discussion has been restricted to the costs of purchasing and operating the hardware system. Of equal, if not greater, importance is the cost of creating or procuring the course materials. Hofstetter (1983) gives evidence based on the University of Delaware's experience that the typical tutorial with good interaction takes 200 hours to produce -- 55-60 hours by the instructor and 140 by the programmer. Hourly costs for developing a lesson are given as $2,500 for material without graphics or judging features to $8,000 for a simulation. Other estimates for program preparation range from 100 hours per hour of instruction to 400 hours where graphics, sophisticated judging and simulations are required. There is no reason to dispute these high costs since they have been determined by experience.

Capital Equipment, Operating and Courseware Costs for VITAL

VITAL has been designed to operate on readily available MS-DOS equipment over a range of configurations from a single stand-alone unit to a small network system of up to 24 student terminals. This gives flexibility in terms of entry costs based upon the needs of the instructional program. It does not replace the power of large mainframe systems but it does provide the alternative of a decentralized facility while allowing advantages in the network mode not associated with single CPU licensed software on stand-alone units.

Courseware produced using the VITAL authoring system operates in any one of three modes -- a single stand-alone unit, a two station mini-network or a local network of up to 24 stations. It requires off-the-shelf equipment subject only to the installation of the appropriate colour graphics board and colour monitor. The use of Telidon/NAPLPS as the standard for computer storage and display enables a variety of student study stations to be chosen from videotex hardware units through a range of microcomputers from the Commodore 64, Apple IIe, Macintosh to MS-DOS compatibles.

The starter system comprises a Personal Computer with 256K of RAM, twin disc drives, a monochrome driver and monitor, colour card and an RGB monitor. The VITAL software for this single system costs $1,200. The combined hardware and software for this VITAL/Single-system costs approximately $4,000. This unit can be used to create the study materials and can also serve as a single student study station, A more efficient application is to equip any number of student microcomputers with a colour card, colour monitor and dual disc drives. A single floppy system disc called the TOAD (Teaching On A Disc) is loaded into drive A with the course files loaded from drive B. TOAD is designed to be purchased once per user at $49.95 and will operate any number of VITAL produced course files giving the same interactive branching and judging features as the network. TOAD, however, does not readily allow record keeping of student performance.

The next step up in providing increased capacity is the VITAL/Twin which uses a PC with a hard disc as the file server to drive two student terminals, Depending on the quality of the student terminals selected, the VITAL/Twin will cost between $8,600 and $11,200 for a two student station installation which includes a separate instructor course authoring station. VITAL/Twin provides a mini network with record keeping functions of individual student performance as well as summary records of all session activities,

The largest application of VITAL is in the network version which provides for up to 1000 student study hours per week for 48 weeks at 40 hours per week for an annual total of 48,000 hours. This configuration will accommodate up to 24 terminals which yields the lowest per hour unit cost of $1.21 on annualized costs of $57,781 for the system. The cost comparisons of the VITAL configurations are shown in Table 1 (see next page) which range from less than $10,000 for an authoring terminal and two student study stations to about $95,000 for a 24 station network. A single student station, using material produced elsewhere, costs $2,350 including the TOAD software. This is the unit suitable for home study or libraries and requires no running costs for telecommunication or data transmission apart from the mailing costs of the file discs for the courses being used.

The unit cost of using the VITAL system in a microcomputer environment, as shown in Table 1, will be influenced by the actual demand placed by students. However, the commitment of funds can be selected to fit within the requirements of the instructional program. While the smaller systems are more costly on a unit basis, they represent a much lower gross capital outlay. The microcomputer allows the institution or single academic department to *start small* and grow with experience and the needs of the instructional program.

A comparison of the VITAL microcomputer costs with the projection of Alpert and Bitzer in adjusted-for-inflation dollars reveals that these costs per student hour are comparable. In 1986 the Canadian dollar at 72 cents to the US dollar brings the Alpert and

TABLE 1
Capital Cost for Three Vital System Configurations

	Single	Twin	Network 10 Stations	Network 24 Stations
A. *System Purchase Costs*				
1. Authoring Terminal PC with colour card and 2 monitors	3,000	3,000	3,000	3,000
2. Server				
PC with 20 meg drive		2,250		
PC with 35 meg drive			8,000	8,000
3. Student Terminals				
2 x 2,300	4,600			
2 x 2,300		4,800		
10 x 2,300			23,000	
24 x 2,300				55,200
4. Network (10 terminals)			11,000	
(24 terminals)				21,460
5. Software				
VITALS	1,200			
VITAL/Twin		1,350		
VITAL/Net			8,000	6,000
VITAL/TOAD (2)	100			
Total Cost of Equipment and Software	8,900	11,200	51,000	*93,660*
B. *Annual Costs*				
Equipment amortized over 4 years	2,225	2,800	12,750	23,415
Maintenance @ 10% of Equipment Cost	760	985	4,500	9,366
Operator	2,500	5,000	12,500	25,000
Total Operating Cost	5,485	8,785	29,750	57,781
Cost per Student Station per year	2,743	4,393	2,975	2,408
Cost per Student Hour				
@ 2,000 hours per annum	1.38	2.20	1.49	1.21
@ 1,200 hours per annum	2.29	3.66	2.50	2.00

Bitzer figure ($1.79 US) to $2.50. The cost range for VITAL at 2000 hours per year is $1.15 to $2.20 depending on the configuration of the system or $1.92 to $3.66 for 1200 hours per year per student terminal. This is a favourable cost in contrast to Kearsley's figure of $7.20 US or $10.08 Canadian per student hour for PLATO.

The costs shown in Table 1, as in the case for PLATO, are related to the acquisition and operation of the equipment. The preparation of course materials adds a significant cost to the decision to use computer-based learning materials. The first element in the use of these materials is the instructor's time in the preparation, selection and supervision of the courseware production. In most established systems a trained programmer is essential to support the instructor. The VITAL system, using the simplified commands of Telidon/ NAPLPS and its own menu driven programming, eliminates the requirement for a computer programmer. Teachers and their teaching assistants are able to produce their own material without the need for such programmers. Where special graphic effects such as animation are desired the assistance of a trained graphic illustrator will enhance the visual elements, but such assistance is not essential for the bulk of the instructional programming.

The figure given by Hofstetter for the cost of producing computer based courseware ranges from $2,500 to $8,000 per student contact hour or $3,500 to $11,200 in Canadian dollars. Much of this cost is independent of the computer system used since it relates to academic time spent in planning the materials as well as to the technical time in programming or encoding the lessons. Any simplification of this process will introduce significant cost savings and enhance the prospect of expanded utilization.

Studies to date at the University of Guelph (Moore, 1986) indicate that the production time for creating instructional materials with VITAL ranges from 22 hours to 88 hours per hour of instruction or about one-third the time required for similar materials using traditional CAI approaches. Using an average cost of $30 per staff hour* in the preparation and production of computer-based courseware, VITAL shows a cost of $660 to $2,640 per student contact hour module or substantially less than that reported in the literature and by Hofstetter for traditional Computer-Assisted Instruction materials. A cost comparison between a comprehensive mainframe system such as PLATO and a less powerful but sophisticated authoring system such as VITAL on a microcomputer is summarized in Table 2 (see next page). It should be recognized that such comparisons are of limited value since the systems are different in capacity and capabilities. However, from the perspective of administrators providing funds and instructors wishing to explore the application of CBI, the comparison is valid in that it shows relative entry and operating costs. The microcomputer does provide for computer-based learning materials in the curriculum at lower cost and with minimal risk. Using standard microcomputers makes the equipment investment recoverable for other purposes.

To complete this analysis, the cost of courseware development must be combined with the costs of computer operations. Assuming 10 hours of computer-based material, class sizes of 30, 50, 100 and 500 students and life cycle of three years for the computer materials, Table 3 (see next page) provides an approximation of the hourly cost per student. In this table, the previously reported costs of $11,200 for PLATO and $2,640 for VITAL have been used. The data presented in Table 3 reveal that the major costs in using computer-based

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* This figure was arrived at by averaging academic, professional and technical annual staff salaries of $57,000, $37,000 and $27,000 respectively and using 1,350 applied hours per annum.

TABLE 2
Cost Comparisons Between PLATO and VITAL

		PLATO	VITAL
A.	*Capital Costs*		
	a) PLATO - mainframe facility with 330 installed terminals (Hofstetter, 1983)	$3,801,971	
	b) VITAL - local network with course authoring system and 24 student stations		93,660
B.	*Annualized Operating and Capital Costs*		
	PLATO - 7 year amortized equipment cost	543,138	
	VITAL - 4 year amortized equipment cost		23,415
	Operating Costs	1,829,649	34,366
Total Annual Costs		US$ 2,372,787	
		C$ 3,321,902	57,781
Hourly Cost of Operation per Terminal	2,000 hours per annum	C$ 8.37	1.21
C.	Courseware Preparation Costs in Canadian Dollars		
	PLATO - per student hour	3,500-l 1,200	
	VITAL - per student hour		660-2,640

TABLE 3
Courseware Development and Computer Operating Costs for PLATO and VITAL

	PLATO	VITAL
Materials production costs per hour of student instruction	11,200	2,640
Class Size		
30 students - instructional cost	124.00	29.33
- operating cost	8.37	1.21
Total Cost per Hour	132.37	30.54
50 students - instructional cost	74.70	17.60
- operating cost	8.37	1.21
Total Cost per Hour	83.07	18.81
100 students - instructional cost	37.35	8.80
- operating cost	8.37	1.21
Total Cost per Hour	45.72	10.01
. 500 students - instructional cost	7.46	1.76
- operating cost	8.37	1.21
Total Cost per Hour	15.83	2.97

instruction are not in the computer component but in the preparation of the instructional materials with the latter accounting for 80 to 90 percent of the total, The data further indicate that computer-based materials begin to approach a reasonable cost only when classes or class combinations have relatively large numbers of students. By way of comparison to face-to-face instruction, costs per student contact hour in university classes of 30, 50 and 100 students are $4.87, $2.92 and $1.46 respectively using an average salary of $57,000 and a teaching effort of 60 percent of a total faculty member's assignment for teaching, research and institutional service. From the data in Table 3 and the per student cost of face-to-face instruction, it can be seen that PLATO, even under conditions of very large student numbers, is approximately four times more costly than instruction in classes of 30 students ($15.83 and $4.87) while VITAL costs with 500 students are similar to face-to-face instruction in classes of 50 students, $2.97 and $2.92 respectively.

Summary and Conclusion

In this analysis a comparison has been made between the preparation and delivery of computer-based learning material in a mainframe system using PLATO and a microcomputer network system using VITAL. Costs of both systems are considerably more expensive than face-to-face instruction in class sizes generally found in most colleges and universities. Even with classes of 500 students, the cost of PLATO delivered instruction was found to be four times greater than the cost of face-to-face instruction in classes of 30 students. VITAL, on the other hand, was found to have hourly student costs similar to classes of 50 students when VITAL materials were given to 500 students.

The major implication of these findings is that computer-based materials cannot be justified on the basis of cost efficiency in the class sizes likely to be found in most institutions. The decision to develop and use these materials must be based on other factors which derive from a careful analysis of instructional requirements and student learning outcomes. Mainframe computer systems are likely to be too costly in the initial capital outlay and recurring operating costs to be widely used in most institutions. Microcomputer-based systems offer a less costly but acceptable alternative, one which can be phased in gradually with institutional priorities and available resources. However, such applications will require careful planning and realistic expectations to prevent disillusionment and frustration.

Naisbitt (1982) suggests five directions in which the adoption of technology is moving. These are:

Force Technology	High Tech/High Touch
Centralization	Decentralization
Institutional Help	Self-Help
Hierarchies	Networking
Either/or	Multiple Option

Upon reflection it may be seen that large scale systems such as mainframe instructional computer applications exhibit the characteristics on the left hand of Naisbitt's schema while smaller micro-based systems tend to be more compatible with the emerging factors on the right of the schema. This observation suggests that the exploration of microcomputer-based instructional systems is compatible with the prevailing forces in technological developments generally.

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