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Cost Analysis of Information Technology Projects in Education: Experiences from Developing Countries

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I. Introduction

1. **The New Information Age.** Revolutionary advances in information technology and communications are transforming the world economy and presenting new challenges to all countries. The challenges are to compete effectively in an emerging information-based economy in which computing and communications play a central role. They are also to take full advantage of the enormous potential of information and communications in advancing all aspects of economic, social, and cultural life. Electronic superhighways of broadband fiber optic lines, satellite channel capacity, data networks, and other essential information infrastructure are emerging in many countries. Likewise the increasing efficiency of data storage, improvements in the quality of software and steadily declining costs of production, are enabling more and more people to have access to computer and telecommunications technology at work, home, and in school. Indeed, today's $2,000 laptop computer is more powerful than a $10 million IBM mainframe computer of twenty years ago. Moreover, today's personal computer hard drives can hold 1.2 gigabytes whereas the IBM PC/XT first introduced in 1983 held 10 megabytes of information (Gates, 1995).

2. Today's computers are also relatively user friendly. For example, graphic user interfaces, exemplified by such systems as Windows and Mac OS have all but replaced character-based systems like MS-DOS. And, thanks to research by the Xerox Corporation, the "mouse" has become the vehicle for facilitating human-computer interactions. Over the past twenty years we have also seen an exponential growth in computer software of all kinds, including educational software. Students today can have access to very exciting educational software combining sound pedagogical qualities with multimedia applications. These new software packages give computers broad-based appeal serving students at all levels and with diverse learning styles and capabilities. Finally, advances in communications technology give students access to the world outside and to a rich array of information and other resources for learning heretofore unavailable. Telecommunications technology is becoming a common feature of classrooms and schools which have introduced computers into education. Using modems and telephone lines in their schools, students can now communicate via local and wide area networks as well as via the Internet.

3. **Computers in Education**. During the 1980s, most industrialized countries launched major programs for introducing computers into schools. In the OECD countries, there was both experimentation and controversy over the use of computers (Vickers and Smalley, 1995). In one group of countries, those with a strong "dual system" of apprenticeships—Austria, Germany, and Switzerland—computer science and computer literacy became compulsory subjects, but there was little use and integration of computers in other subjects. A second group of countries-the United States, the United Kingdom, Austria, and part of Canada - endorsed both computer literacy courses and integration into the curriculum from the beginning. However, these integrated approaches were slow to develop and hardware often found its way into schools before sufficient attention had been paid to curriculum development and teacher education. France was the first country to commit itself to integrating the use of microcomputers across the curriculum. In Norway, Scotland, and the Netherlands, governments mandated programs of integrated computer support and funded the creation of software and in-service teacher training.

4. Developing countries also introduced computers into their education systems during the past decade, although generally on a smaller scale and almost exclusively for the teaching of computer science and computer literacy. Many of these initiatives remained pilot projects, although there have been exceptions. In recent years, mainly due to the growing awareness of the need to prepare for the emerging information-based economy, some developing country governments have already launched or are in the process of initiating sizable programs to introduce computers in the education system. They are: Belize, Brazil, Colombia, Costa Rica, Chile, Grenada, Singapore, Argentina, Uruguay, the Philippines, Turkey, Egypt, South Africa, and Jamaica.

5. While in previous years governments had to be convinced of the importance of computers in education that is generally not the situation today. Policy makers and educators generally employ one or several of the following rationales in their decisions for adopting information technology: the *social rationale* which argues that schools need to provide students a "comfort level" with technology so they can live and work in a rapidly emerging society where information and telecommunications play an increasingly important role; the *vocational rationale* which follows from the social

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rationale, emphasizes the need to prepare students for future employment in information and telecommunications based economies; the *pedagogical rationale* argues that computers can improve the instructional processes and learning outcomes in schools; and, finally, the *catalytic rationale* is that computers can change schools for the better by accelerating educational innovations in the teaching learning which goes on in the classroom (Hawkridge, Jaworski and McMahon, 1990).

6. Despite significant cost reductions in recent years, information technology, as presently designed, is not going to be affordable for wide-spread use in most countries and school systems, any time soon. However, in a growing number of countries, policy makers and educators are still launching new pilot education technology projects, usually with the help of external and/ or extra-budgetary resources and strong community support. In fact, the experiences of the countries included in this study would suggest that affordability is a relative concept, not an absolute one. Even those countries which have yet to achieve universal primary education and have relatively low secondary school enrollments, government leaders at all levels have initiated pilot information technology projects. Even where schools lack other instructional inputs such as textbooks and/or have poor sanitation facilities, developing country educators and others are attempting to gain experience with computers. And in most of the countries, governments— often with significant contributions by the community— are making information technology accessible to children of all different socio-economic backgrounds, and in some, mainly to lower income students in rural areas.

7. A main tenet of this study is that the introduction of information and communications technology in education in developing countries should not wait until a country has reached some predetermined state of economic or educational development. Even in countries which do not believe in the cost effectiveness of information technology as a tool for mass education, it is important that they begin acquiring experience using this technology for educational purposes. Otherwise, educators in developing countries will be marginalized in the international dialogue on education. Short-term concerns for equity at the national level must be balanced by longer-term concerns for equity at the international level. The World Bank's recent publication, Priorities and Strategies for Education (1995) also notes that the failure to fully use cost-effective technologies to improve educational quality, "carries the risk of further increasing the gap between [developing] countries and industrial ones."

8. But what about the computer's promise of greater efficiency and productivity in education? Can governments expect to achieve these kinds of benefits from investments in technology? One of the more interesting and provocative observations about technology in education appears in Lewis J. Perelman's article "Closing Education's Technology Gap "Perelman, (1995). Reflecting on the high costs of education in the United States, Perelman has concluded there is a serious productivity crisis in education and insufficient research and development to come up with solutions to deal with this crisis. The failure to effectively exploit the instructional power of the computer is but one example of the resistance to change in education. There is little mystery as to the reasons for this failure, according to Perelman. They are the result of a lack of incentives, and disincentives common to government-owned, "bureaucratically administered monopolistic enterprises." To address these problems, Perleman calls for a major restructuring of schools with incentives for improving learning outcomes, and more and better funded educational R&D on learning technologies.

9. How much does educational technology cost? Is it affordable to most developing countries? Are there ways of reducing the costs and increasing the effectiveness of projects? What can we learn from the experience of other countries in designing cost-effective project inputs? These are the issues which motivate this study. There are certainly not new concerns. Several other writers have attempted to determine the costs of information technology as well as its effectiveness as input to improving educational quality such as Levin (1985), Jamison, Klees and Wells (1978) and Glick (Unpublished). Nonetheless, Anzalone (1991) noted there was no literature yet on the costs of in-school application of computers in developing countries and expressed the hope that pilot efforts would soon produce some usable data on costs, so that an attempt could be made to develop a projection for the costs of a "typical" application in a "typical" country.

10. **Purpose of Study.** This study aims to assist education policy makers and planners in analyzing the costs of programs to introduce and maintain information technologies in schools. The study has three main sections. In the first section, it provides background information on the instructional uses and inputs of information technology programs in the primary and secondary schools of several Latin American and Caribbean countries. The selected countries are: Belize, Chile, Costa Rica, Jamaica and Mexico. In the second, it highlights some of the key issues in cost analysis methodology used to calculate the costs, and assess the financial feasibility of proposed investments in information technology. This section also provides data, albeit, incomplete, on the costs of selected information technology programs. The final section contains the conclusion and recommendations of the study, which focus on how to reduce the costs and increase the benefits of proposed information technology programs.

11. This study is only a first step towards gaining greater understanding as to the costs and benefits of information technology in education. Further research is needed to learn more about individual country experiences and to test assumptions about the costs and benefits of different models of computer use. We would like to encourage other countries and researchers to join us in developing good empirical data on the costs of information technology

programs not only in Latin America and the Caribbean region, but in other regions of the world which might offer interesting contrasts or collaboration of the interim findings in this study. While the data we have managed to collect is incomplete and not totally reliable, it is the best we could obtain for now. And, despite these limitations, our data serves to define some of the key issues facing educators in analyzing the costs and benefits of educational technology investments.

12. **The Projects**. For this study, we attempted to obtain cost data from several information technology projects in execution in the Latin America and Caribbean region. These particular projects are, by no means, the only information technology activities underway in the schools of the particular countries. However, they are all significant pilots, and in two cases, "Enlaces" in Chile and the Computers in Education program in Costa Rica, are truly national in scope. We attempted to obtain cost information in three ways: directly from visits to the project sites, from IBM in Chile, Costa Rica and Mexico and from interviews with project consultants. As noted, we were only partially successful in our attempts to obtain detailed data on all the projects. However, we have utilized some qualitative and quantitative data obtained on the following projects:

13. **Belize**. Two information technology projects are on-going in Belize. One project at the primary level was started by a personal donation from Francis Ford Coppola in 1994; the other at the secondary was launched in the late 1980s and has been continued by the Michael Ashcroft Foundation. Working with the Apple Computer Corporation and in consultation with the World Bank, Mr. Coppola contributed about US$100,000 to equip a group of six primary schools with five computers, CD-ROMs, printers and other equipment all of which were placed in classrooms. The software consisted of ClarisWorks, Compton's encyclopedia, and a variety of other educational titles in science, graphics, environmental studies and reading. The second program provides computers and other hardware and software for laboratories in secondary schools. The major thrust of the program is on preparing students to use computer productivity software for employment in business and government. The schools are networked to a server at the Belize Teachers College which operates E-Mail.

14. **Costa Rica**. The Computers in Education Program is a national program that has been in operation since 1988 at the primary school level. The main funding has been provided by the Omar Dengo Foundation, created by the country's ex-President, Oscar Arias. Supplementary support to the program has been provided by USAID, the Inter-American Development Bank and other sources. The project has installed computer labs in some 127 primary schools reaching about 1 out of every 3 Costa Rican primary school students. The project was among the very' first in the region to use LOGO as its main instructional tool. Seymour Papert, LOGO's creator, and his colleagues from MIT, jointly with IBM, have delivered most of the project's hardware and software inputs. Beginning in 1994, a second project at the secondary level, funded by a World Bank loan, has installed 20 computer laboratories at a roughly estimated cost of $1.5 million. These schools are offering courses utilizing productivity tools as well as LOGO.

15. **Jamaica**. The Jamaica Computer Society Education Foundation (JCESF), with the support of the Business Partners for Education, the Ministry of Education, and the Heart Trust have been implementing two experimental pilot programs to improve the quality of education in Jamaica's schools through the introduction of computers. Under its first program known as Jamaica 2000, the JCESF and its partners mobilized US$4 million and installed computer laboratories in 51 secondary and community colleges. An additional 30 computer laboratories are scheduled to be installed by January, 1996. While originally intending to provide training in computer studies in secondary schools, Jamaica 2000 now seeks to increase literacy and numeracy through the use of computer-assisted instruction in reading and mathematics. A second pilot program recently initiated and known as EDTECH 20/20, is pursuing similar objectives within primary and all age schools and has successfully mobilized some 1.2 million, mainly from the Inter-American Development Bank, with the aim of installing 21 computer laboratories in 15 primary schools in four poor rural communities. Jamaica is also receiving US$.5 million from INFODEV in support of these initiatives.

16. **Mexico**. Two of Mexico's on-going information technology projects were examined. One, known as Genesis, is located in the state of Aguascalientes and is funded by the state from its own resources. Launched in the 1993-1994 school year, it includes all 61 secondary schools, 26 of 300 primary schools, and 3 normal schools. The project constructed laboratories with some 20 computers and trained some 400 teachers, and established a maintenance and repair service. LOGO is the predominant instructional tool, although the machines also have Microsoft Works installed and students use its word processing capabilities. The other project is located in the municipality of Puebla where secondary education is the responsibility of the Rector of the Benemerita Unversidad Autonóma de Puebla (BUAP). The BUAP-funded project has provided computer labs for eight secondary schools, in-service training for some 40 teachers, and technical and curriculum support from two US organizations, the Academy for Educational Development and the Center for Research in Education (INCRE).

17. **Chile**. There are two important information technology projects in Chile. One pilot project known as Genesis, is being carried out in the municipality of Ñuñoa, which is located in the greater Santiago metropolitan area. The project was launched in 1994 at the initiative of Mayor, Pablo Vergara, a strong advocate for both education and computers. The project has been implemented with the assistance of the Latin American Center for Research on Education (CLIE), an IBM technical support team, based in Mexico. The first phase of the project includes 13 of 21 schools.

Each school has been provided with computer labs containing some 20 PCs and given staff development training by CLIE. The main thrust of the project is teaching students thinking and problem solving skills using LOGO programming language. The second project, known as Enlaces, (Linkages) forms part of Chile's comprehensive educational reform program for both primary and secondary schools. Enlaces was launched in March 1993 with the goal of creating a national telecommunications and computer network among 100 Chilean primary schools and associated institutions by 1997. By mid-1995, Enlaces had substantially surpassed that target and by end 1995 had expanded the network to some 200 schools in the increasing the number of primary schools and incorporating an initial group of secondary schools. Enlaces is projecting to incorporate all public primary and secondary schools into the network. Enlaces is supported by the Government, the community and loans from the World Bank.

18. **Use of Computers**. What are the main applications of computers in schools and for what educational objectives? The information technology projects in the countries we have examined use computers for the following : teaching basic literacy and numeracy, use of productivity tools, LOGO programming, constructivist pedagogy, for communications networks, and for instructional enrichment.

(i) ***Basic Literacy and Numeracy***. Since the early 1980s, computers have been used to tutor students in basic literacy and numeracy through a variety of programs collectively known as Computer-Assisted Instruction (CAI) or Integrated Learning Systems (ILS). In CAI the computer provides text and multiple-choice questions or problems to students, gives and immediate response to the answers given, summarizes students' performance and generates exercises for worksheets and tests. CAI typically presents tasks for which there is only one correct answer; it can evaluate simple numeric or very simple alphabetic responses, but it cannot evaluate complex student responses. In ILS, computers are networked and equipped with software that provides a set of sequential lessons. Students work through these lessons as prescribed by the built-in management system, which tracks individual student progress. These systems are "integrated" in the sense that each lesson is connected with the next, all lessons are correlated with a set of objectives and all tests are matched to the lessons and objectives. As noted above, Jamaica is using ILS for teaching literacy and numeracy at both the primary and secondary levels. ILS is being used widely and effectively in the United States, and in tiny Grenada.

(ii) ***Productivity Tools***. Many schools today are teaching students to use a variety of computer productivity tools widely used in business and commerce: word processing, spread sheets, data bases, and e-mail. Inmost secondary schools, the purpose of this instruction is to equip students with marketable skills for employment. These classes are usually taught in computer labs which were formerly filled with typewriters but now include computers, an array of commercial software, printers and possibly modems. The students who take these classes obtain preparation for clerical jobs or in some cases for post-secondary technical and university education. These types of classes are commonplace in secondary schools in all countries and they fill a strongly felt need by educators and parents to prepare students for the labor market. In Puebla, Mexico where computers have been installed in eight municipal high schools, administered by the Benemerita Universidad Autonóma de Puebla students are being taught to use productivity tools for problem solving in their regular courses. Belize is using them in courses which prepare students for employment in private business and government.

(iii) ***Programming LOGO***. One of the most original and challenging applications of computers in education is the LOGO programming language. Logo has been used in schools all over the world since the early 1980s as a tool to promote thinking , problem solving, and creativity. It was widely popularized by Seymour Papert in his 1980 book, Mindstorms, a publication which, according to John Sculley, former Chairman and CEO of Apple Computer, Inc., started the computer revolution in schools. The two main premises on which Logo is based are that children can learn to use computers in a masterful way and that learning to use computers can change the way they learn everything else. Contrasting his approach to computer-aided instruction, Papert noted in Mindstorms that according to in his vision: rather than using the computer to " program the child, "it is the child who programs the computer and in doing so "both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building (Papert, 1980). Logo has been widely used in Latin America, Europe and to a lesser extent in United States schools.

(iv) ***Constructivist Pedagogy***. In a growing number of schools , particularly in the United States, computers are being used to support constructivist teaching (Means and Olson, 1995). The model of constructivist teaching draws on advances in cognitive psychology which have fostered our understanding of the nature of skilled intellectual performance and the environments conducive to learning. In schools where constructivist teaching is employed, teachers are working at creating learning environments in which students actively pursue knowledge rather than passively receive it, and where they can develop the advanced skills of comprehension, composition, reasoning, and experimentation. In constructivist classrooms, teachers serve as facilitators of learning , attempt to create authentic contexts for modeling expert thought processes, and seek ways to help students to achieve intellectual accomplishments they could not do on their own. In many of these areas, computers are providing effective interactive learning contexts consistent with constructivist instructional goals. In addition to the United States, Jamaica and Chile are expected to begin experimenting with these approaches in their computer programs in the coming years.

(v) ***Communication Networks***. In both the industrial and developing countries, a rapidly growing number of schools are using computers to connect their students with the world outside. By bringing telecommunications applications into their classrooms, teachers are able to create environments where students can communicate with other students via electronic mail, participate in collaborative projects with students from other schools, and come in contact with a rich array of information sources that broaden their horizons. Chile currently runs one of the few successful educational wide area networks (WAN) of any country in the world. Belize's secondary schools are also networked, but the network is not actively used. Other schools are able to link up to the Internet via telephone lines and local servers often located in universities. Where countries have fiber optic cables, as in Chile, plans are being made with local telephone companies for Internet connections and access to the World Wide Web. A number of school systems in developing countries are linked via the Internet to math and science networks such as the Global Laboratory project and National Geographic Kids Network science series developed at TERC with funding from the U.S. National Science Foundation.

(vi) ***Knowledge***. Educational courseware and reference materials such as stand along units of instruction in math, science, language and other subjects, as well as encyclopedias make up the largest number of titles on the market. They are available on diskette, but also increasingly on CD-ROM and in multi-media formats. They are used in the classroom to supplement and enrich teaching for practice and drill, independent study and research. The data which is now available on CD-ROM is larger and more diverse than is currently present inmost school libraries in developing countries, if they have them at all. Further, some of the new multi-media learning environments and formats offer students the opportunity to use those sensory skills which are most suitable for their individual learning styles.

II. Cost Analysis of Educational Computer Applications

Cost Analysis Methodology[1]

19. The purpose of cost analysis is to assist in making decisions about the use of scarce resources. The most general formulation of the concept of cost is that the cost of a set of resources (and the interventions they permit) is the maximum value of what they can alternatively be used to produce for the decision maker or the entity he or she acts for. If this entity is society as a whole, as is often the case in educational cost analysis, the usual assumption is that market prices and other equivalent money values can be used to evaluate the cost of resources, as long as they can be seen as representing the revealed preferences of society at large. Expenditure values are also used without adjustment where program managers aim to evaluate alternative expenditures out of given budgets, even though the budgeted sums do not reflect real economic value. Deviation of budgeted values from real economic ones arise for example, when programs can purchase equipment at a preferential exchange rate. In this case, cost comparisons using money values would not be appropriate for the decisions involving social efficiency. In one particular important case, one should generally not compare the purchase prices of program inputs that are to be bought at different times without adjusting for the time value of money .

20. **Cost-Benefit and Cost-Effectiveness Analysis**. Cost comparisons can be used to inform different kinds of decisions. If costs are measurable in terms commensurate with benefits, as they usually are in income generating enterprises and in some other contexts, they may fruitfully be compared with benefits in an integrated 'cost-benefit' analysis, using such summary measures as 'rate of return on investment'. When they are not measurable in terms commensurate with benefits, the cost comparison can be one of 'cost effectiveness', where the costs of alternative methods of achieving the same qualitative or quantitative benefit are compared. For instance, the cost of a 10% increase in reading scores may be calculated for several different interventions, such as a decrease in the student-teacher ratio, an increase in the quantity of teaching aids, or the placement of computers in classrooms. Even narrower cost comparisons are frequently useful. If the decision involves how to configure computers in a school, the cost comparison may involve the cost per student computer contact-hour of a computer laboratory configuration versus a classroom configuration. When more than one benefit results from a program, the lack of commensurateness among benefit indices can be overcome by weighting to form a single weighted benefit index (para. 31).

21. **Cost Data**. Cost data, of course, are used for accounting functions that are important in themselves, for instance, regulating cash flow, calculating taxes, deterring fraud or allocating budgets. Also, in budget documents, expenditure data often refer to planned expenditures rather than actual. These uses and aspects of cost data typically determine how it is aggregated and presented. For cost analysis to be useful to decisions, however, adjustments to accounting data are almost always necessary. For instance, the school technology budget may be aggregated across different technologies, may allocate the cost of long-lived equipment expenditures to a single year or may neglect to include the non-capital costs of technology programs in the technology account. Such data must be disaggregated over program and time, and data from personnel and other accounts obtained, before even crude estimates of the costs of a technology program can be obtained for decision-making.

22. **Marginal Cost**. Another way in which available cost data - usually average or total cost data - often need to be adjusted for

[1] The treatment here is necessarily brief. More extensive treatment of the methodology of cost analysis relevant to computer applications in education can be found in several excellent longer-length discussions: Henry Levin, *Cost Effectiveness: A Primer*, (Beverly Hills, Sage Publications, 1985) specifically treats the cost analysis of computer-assisted instruction; Dean T. Jamison, Steven J. Klees and Stuart J. Wells, *The Costs of Educational Media: Guides for Planning and Evaluation* (Beverly Hills, Sage Publications, 1978) treats the cost analysis of educational broadcasting; and Peter J. Glick, *Cost Analysis: Categories and Procedures* (Unpublished)

deciding on the allocation of resources is when marginal cost data are needed. Knowing the marginal cost (the extra cost) per additional student, for example, may be important for modeling the costs of different technologies or configurations, because certain of them may be more efficient at relatively lower or higher levels of utilization. Where appropriate, the marginal cost concept may be captured in a simple fixed-variable cost model. Many technology problems can be expressed in this model, because in many analyses the equipment, installation, software licenses, wages of laboratory instructor, etc. may be considered to be fixed costs regardless of the number of students served, and materials, electricity to run the computers and peripherals, teacher time, etc. are variable (marginal) costs that vary with the number of students served.

23. **Capital Costs.** Because most cost analyses are done for periods of a year or less, a special problem arises with the costs of long-lived assets, such as facilities, equipment, and training, where the expenditures are made in one period but the benefits reaped over the course of several other periods. When measured benefits are commensurate with costs and arrive at times different from costs, an analysis of the full streams of costs and benefits will be necessary, with all values converted to present values and summarized, if so desired, in an internal rate of return on investment.[2] In cost-effectiveness analysis, however, where benefits are not commensurate with costs, a simplified technique to "annualize" the costs of long-lived assets can be used (para. 32). It has the additional virtue of allowing the period of analysis to be coterminous with the budget period.

24. The costs of long-lived assets are generally of two types - depreciation and the financial cost of capital. Depreciation is that portion of the value of the capital good that is consumed over time, either through wear and tear or through obsolescence. Depending on the purpose, annual depreciation can be estimated in different ways. For example, it can be estimated as the average annual decrease in value over the life of the project or the asset or as a stream of values that differ in amount according to the age of the asset.

25. The second capital cost that must be considered is the financial cost of capital, which is simply the cost of tying up resources in a particular capital good, when they could be used for other expenditures. This cost is measured by the appropriate discount or interest rate for the entity bearing the cost. If the entity bearing the cost is considered to be "society", the appropriate discount rate is the "social discount rate", i.e., one that reflects the value society would have gained by using the financial resources for current consumption rather than tying them up in a piece of equipment or another long-lived asset for the purpose of producing consumption in future years. Since "society" cannot be interviewed directly, what society pays for capital, as measured by interest rates in private financial markets (when they are deemed to be functioning adequately), is the measure typically used to approximate the social discount rate. If the entity bearing the cost is considered to be the national government or a particular local government, the interest rate at which that government borrows can be considered to be its financial cost of capital.

26. Selecting the appropriate discount rate for a social investment project is, thus, somewhat tricky, and different analysts come up with different answers. To maintain consistency across different analyses, therefore, discount rates have become conventionalized in different contexts. Organizations often prescribe the particular discount rate that is to be used for projects under their jurisdiction. Alternatively, the analyst can use a range of discount rates to determine the sensitivity of total project cost to variation in the discount rate. In any case, analysts and users of their analyses need to understand that the "cost of money" is just as real a cost as the cost of teachers' salaries or supplies and cannot be neglected without biasing the analysis in favor of capital-intensive interventions.

27. **Sources of Funds and Costs.** Another guide to determining which costs to include in the analysis is to look at the sources of funds. If the goal is to determine the comparative educational efficiency of particular interventions, it is irrelevant who pays for them - governments at different levels, school fund-raising, teacher volunteers, parents and students, international donors, etc. All costs, however financed, need to be included in the analysis. If the issue is one of affordability from an educational budget, however, only the marginal budgetary costs of particular types of interventions need be considered. As for the other sources of funds, only their the sustainability would then be relevant. The danger of taking a narrow budgetary approach, however, is that efficiency considerations may be neglected with a resulting waste of scarce resources available to the system as a whole.

28. **Cost Comparisons.** Most cost analyses for program decisions involve comparisons, which are sometimes only implicit, of 'with-the-program' and 'without-it'. Carefully defining them is at the heart of an effective cost analysis. For instance, if the cost of a computer-assisted-instruction (CAI) program in a classroom configuration is desired, one clear cost element would seem to be the teacher time spent in planning, organizing and supervising classroom CAI activities. If the decision is to install the classroom CAI program only if it improves reading scores more cost-effectively than alternative methods, all of which use different amounts of teacher time, teacher time should be accounted for in the cost comparison. If the analysis is designed to examine whether a technology-intensive classroom could be designed to economize on teacher time and thus reduce total classroom costs, clearly, costing teacher

[2] Discussions of present value and internal rate of return can be found in any financial management textbook. Basically they involve 'discounting' values to the present by de-compounding them using a discount (interest) rate. In present value analysis, the discount rate is given; in internal rate of return analysis, the rate is calculated to bring future costs and benefits back to the present so that discounted costs and benefits are equal. See para. 32 for a discussion of the use of a discount rate to 'annualize' equipment costs.

time would be central to the analysis. However, if the decision is to ascertain the affordability of the classroom CAI program vis-à-vis the budget, it would not be appropriate to include teacher time in the calculation of cost, because the decision is not about the deployment of teacher resources. The steps in cost analysis should, therefore, be done in the following order: (i) clearly specify the decision, (ii) define the explicit or implicit cost comparisons and (iii) specify and develop data on the cost elements with and without the intervention.

Doing Cost Analysis of School Computer Applications

29. **Schematic Example.** The costs of different approaches to increasing reading and math skills are compared in a schematic cost analysis and serve as an illustrative example of how to go about doing a cost analysis. A hypothetical CAI program is compared with Alternative A, a program emphasizing math, Alternative B, a program emphasizing reading, and a fourth alternative, the simultaneous use of both A and B (Tables 1 and 2). The schematic example illustrates the importance of clear thinking about the decision involved, about the appropriate cost comparisons and about the relative importance of various benefits.

30. The first important decision that the cost analyst needs to make is to decide whether the comparison is on the basis of cost-effectiveness or affordability. In the sense used, cost-effectiveness means the impact of marginal resources on reading and math outcomes and measures the efficiency of resource use. Affordability means the impact of marginal budget expenditure on the same outcomes and is a measure of feasibility not efficiency. When the decision is to choose the most cost-effective program, the costs must include the opportunity cost of teacher time, since the alternatives use different amounts of teacher time, which could be used for other valuable teaching activities (Table 1). For this purpose, teacher time could be valued at teacher cost per hour or, in an attempt at greater realism, at some percentage of this, assuming that teachers would implement the new-programs using time that was less productive than their average. When the decision is to choose the most affordable program, teacher time should not be included as an expenditure, because there will be no change in the overall expenditures on teachers (Table 2).

31. When there is a single benefit, the analysis is straightforward. The cost-effectiveness index is simply the amount of the benefit per unit cost. When there is more than one non-commensurate benefit, like reading and math test scores, they must either be evaluated qualitatively or a weighted index constructed. Care in selecting weights should be taken, since program choice may be sensitive to the weights selected. When improvements in math and reading scores are given equal weighting in the schematic example, the CAI program is shown to be the most cost-effective of the four interventions(Table 1) but, with the same benefit weighting, also the least affordable (Table 2). The decision in this schematic example is shown to be sensitive to the benefit weights; when either reading or math is emphasized, the special reading and math programs are respectively more cost-effective and more affordable than the CAI program. Finally, unless the decision maker is prepared to forgo the chance of significant improvement in one or the other of reading and math, the choice needs to be restricted to those alternatives that can deliver significant improvements in both math and reading - the CAI program and the combination of the special reading and math programs. When only these two are considered, the CAI program is most cost effective in all relevant cases. Conversely, the combination program is usually tops when affordability is the criterion.

32. **Annualizing Capital Costs.** The special problems that arise with the cost analysis of long-lived assets, such as facilities, equipment and training, were discussed above. Because cost-effectiveness analyses are conveniently done on the basis of annual average cost, often to conform to the budget period, capital costs must usually also be expressed in annual terms. This is typically done by using a simple financial model available on standard spreadsheet programs, which can be used to provide an annualization factor to convert multi-period capital cost into an average annual cost.[3] This average annual cost combines depreciation and the cost of money in a single figure. Table 3 gives examples of this calculation for equipment of varying useful lives. As one example given in the table, a set of equipment with a purchase price of $150,000, no scrap value, and a useful life of 5 years would have an annualized capital cost of $41,611.

33. **Price Distortions and Taxes.** The treatment of price distortions and taxes in a cost analysis depends on whether the analysis is being carried out from the point of view of society as a whole or from that of a particular agency. When the analysis is being carried out from the point of view of a particular agency, and the focus is on financing out of a budget, the actual prices paid, distorted or not and the actual taxes paid, are relevant costs. On the other hand, when the analysis is being done from the point of view of society as a whole, the object is to find the efficient solution, which will allow society to gain maximum benefits from its available resources. This may require adjustments in the costs used in the analysis to take account of price distortions and taxes, since they do not repre-

[3] The model is mathematically the same as that used to calculate equal annual payments on an equipment loan with the cost of money equal to the interest part of the annual payment and the depreciation equal to the principal part of the payment. Annualized capital cost (or annual loan payments, when that is what is desired) can be calculated using the PMT function of any standard computer spreadsheet program or the formula $c[r(1+r)^n]/[r(1+r)^n-1]$, where c is the cost of the asset, r is the discount rate and n is the useful life of the asset. Since in this model the annual cost of money tied up at any particular time in the remaining value of the asset and the annual depreciation combine to form a constant annual amount, depreciation is by implication modelled as a moderately increasing function of time for relatively short asset lives and low interest rates. While this model is highly convenient and realistic enough in most cases, when asset lives are long-lived and interest rates very high, a model incorporating a more realistic depreciation profile may be indicated.

TABLE 1. Costs of Computer-Assisted Instruction (CAI) and Alternative Programs for Increasing Reading and Math Scores, Schmatic Comparison

Alternative Decision 1 : Invest in the Most COST-EFFECTIVE Among CAI, A or B

			CAI	Alternative A	Alternative B	Combined A & B	Most Cost-Eff. All Four	Most Cost-Eff. CAI v. A & B
SCOPE								
No. of Students Served			300	200	400	400		
COSTS								
INVESTMENT COST, ANNUALIZED								
Training			10,000	20,000	20,000			
Facilities			5,000	0	0			
Equipment & Prepaid Services			25,000	10,000	15,000			
Total Annualized Investment Cost			*40,000*	*30,000*	*35,000*			
RECURRENT COST								
Personnel Services								
CAI Coordinator (half time)			25,000					
Opportunity Cost of Teacher Time			10,000	25,000	40,000			
Other			5,000	5,000	5,000			
Subtotal Personnel Services			*40,000*	*30,000*	*45,000*			
Software and Supplies			15,000	5,000	10,000			
Maintenance and Technical Assistance			5,000	3,000	3,000			
Insurance and Other Recurrent			5,000	5,000	5,000			
Total Recurrent Cost			*70,000*	*48,000*	*68,000*			
Total Costs			*110,000*	*78,000*	*103,000*	*259,000*		
Total Cost Per Student			367	390	258	648		
BENEFITS								
Increase in Reading Score			10%	20%	1%	19%		
Increase in Math Score			15%	2%	15%	14%		
COST EFFECTIVENESS								
Cost Per Student per 10% Increase in Weighted Benefit Score								
	Benefit Weights Reading	**Benefit Weights** Math						
Equal Weights	50%	50%	293	355	322	392	CAI	CAI
Other Weightings:								
Reading Emphasized	67%	33%	315	277	458	373	A	CAI
Math Emphasized	33%	67%	275	491	248	414	B	CAI
Only Reading Valued	100%	0%	367	195	2,575	341	A	A & B
Only Math Valued	0%	100%	244	1,950	172	463	B	CAI

* Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs. See Text.

TABLE 2. Costs of Computer-Assisted Instruction (CAI) and Alternative Programs for Increasing Reading and Math Scores, Schmatic Comparison

Alternative Decision 2 : Invest in the Most AFFORDABLE Among CAI, A or B

			CAI	Alternative A	Alternative B	Combined A & B	Most Affordable All Four	Most Affordable CAI v. A & B
SCOPE								
No. of Students Served			300	200	400	400		
EXPENDITURES								
INVESTMENT, ANNUALIZED								
Training			10,000	20,000	20,000			
Facilities			5,000	0	0			
Equipment & Prepaid Services			25,000	10,000	15,000			
Total Annualized Investment			*40,000*	*30,000*	*35,000*			
RECURRENT								
Personnel Services								
CAI Coordinator (half time)			25,000					
Additional Paid Teacher Time			0	0	0			
Other			5,000	5,000	5,000			
Subtotal Personnel Services			*30,000*	*5,000*	*5,000*			
Software and Supplies			15,000	5,000	10,000			
Maintenance and Technical Assistance			5,000	3,000	3,000			
Insurance and Other Recurrent			5,000	5,000	5,000			
Total Recurrent			*60,000*	*23,000*	*28,000*			
Total Expenditures			*100,000*	*53,000*	*63,000*	*169,000*		
Total Expenditures Per Student			333	265	158	423		
BENEFITS								
Increase in Reading Score			10%	20%	1%	19%		
Increase in Math Score			15%	2%	15%	14%		
AFFORDABILITY								
Expenditure Per Student per 10% Increase in Weighted Benefit Score								
	Benefit Weights Reading	**Benefit Weights** Math						
Equal Weights	50%	50%	267	241	197	256	B	A & B
Other Weightings:								
Reading Emphasized	67%	33%	286	188	280	244	A	A & B
Math Emphasized	33%	67%	250	334	152	270	B	CAI
Only Reading Valued	100%	0%	333	133	1,575	222	A	A & B
Only Math Valued	0%	100%	222	1,325	105	302	B	CAI

* Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs. See Text.

sent resource costs to society as a whole, but merely the transfer of resources from one group to another. As an example, teacher wages can be seriously our of line with private labor markets for similar skills if they reflect the political power of public service unions to any great extent. As for taxes, import duties and sales taxes, which may be included in costs paid by even governmental organizations, are in reality a transfer from one group to another through the government budget and are not payments for resources used specifically in the production of the item purchased. Thus, they should be deleted from costs when societal efficiency is the objective of the analysis.

34. **Inflation.** Special care needs to be taken of the impact of inflation on costs. When the focus is efficiency in resource use, the best procedure is to adjust all costs to the money value of the date at which the project starts. That way, the same amount of resources is seen to cost the same amount of money at all times. If the focus is on budgetary affordability, however, the actual (inflated) prices expected to be paid may be the more appropriate ones to use in the analysis.

The Costs of Educational Computer Applications in Developing Countries

35. The large reductions in the cost of ever-more-powerful computers and peripherals and the attendant qualitative improvements in educational software are too recent for there to have been much experience with currently available educational computer applications in developing countries. Most of the experience with computers in schools in developing countries to date has been the unplanned acquisition of computers by secondary schools, often supported by parents interested in their children acquiring computer tool skills useful in future employment. The experience of Belize, which is analyzed in a somewhat outdated USAID consultant report, is illustrative of this and is discussed below. Nevertheless, as shown by the country survey presented in the first section of this paper, a considerable start has been made in a number of developing countries.

36. **Comparative Cost Analysis.** Unfortunately, the experience discussed above has not been accompanied as yet with effective efforts to do real world cost analysis, neither on the prevailing laboratory configuration nor on other configurations. The data which was obtained for this study, unfortunately, is also not complete for any of the projects. Both time constraints in country visits and the unavailability of reliable data, made it difficult to obtain the kind of information we would have liked to include in our cost analyses. Since no systematic benefit analyses are also available, it is also not surprising that little cost effectiveness analysis has been done. This needs to be rectified, because greater use of computers in education in developing countries will at some point need justifications based on costs and benefits. Despite the general lack of cost data that can be used to estimate the cost of information technology projects in developing countries, the Jamaica and Chile's Genesis

Table 3. Annualized Capital Cost

	Years of Useful Life /1	End of Year Annualized Cost /2	Annualization Factor /3
Cost of Equipment $ 150,000	(1)	(2)	(3)
	1	$ 168,000	1.120
	2	88,755	0.592
Discount Rate 12%	3	62,452	0.416
	4	49,385	0.329
	5	41,611	0.277
	6	36,484	0.243
	7	32,868	0.219
	8	30,195	0.201
	9	28,152	0.188
	10	26,548	0.177

1/ Number of years=NPER in the Excel spreadsheet function, see note 2.
2/ The Excel spreadsheet function is PMT(10%,NPER,150000). The Lotus 123 function is similar.
3/ Calculated by dividing column (2) by the cost of the equipment.

project examples described above have provided enough real world data about actual laboratory installations to tabulate along with the Belize data in comparative format (Tables 4-6). To round out the discussion, we also discuss the cost of computer-rich classroom configurations programs in the USA (Table 7).

37. **Equipment Costs.** Leaving aside the Belize data,[4] which are both outdated and deficient in other respects for comparative purposes, the first clear conclusion is that in the other three cases annualized investment costs, predominantly equipment costs, are about half or more of all costs when property protection costs are added in. Clearly, equipment costs do matter, and the cost declines of the last decade therefore also make a large difference. Cost in the three countries for computers, at least, appear to fall in a range from $1,600 to $2,000 for machines. While the capabilities of the various machines, particularly their communications and CD-ROM capabilities may vary somewhat, the data suggests that current computer costs are now similar in widely different countries.

38. **Market Differentiation.** This may not persist for long, however, if software and hardware interactions in the market allow a low-end market to develop to the advantage of developing countries. Because of the high investment costs, many programs in these countries would opt for low-end set-ups with less costly and less capable (but still educationally effective) inputs. For the last several years, the personal computer market has had a very simple structure, with basically two levels of capability - low-end processors, now in the Intel 486 capability range, and high-end processors, currently the Intel Pentium. Prices of computers at both levels have been declining, but not as fast as the price of computing power. In the process, the capability of even low-end hardware and software has risen very rapidly. A reasonable hypothesis is that sooner or later, the hardware market will experience much greater product differentiation with more levels than just low-end and high-end. Instead of the low-end simply being the high-end of two years ago, some of the increased productivity in the computer industry may then be channeled into large price declines rather than the increased capability that will undoubtedly continue in high-end computers. The educational software industry will also adapt to hardware differentiation with a parallel differentiation. If these market events occur, it will be good news for the mass extension of computer projects in developing country schools. In most cases, education officials in these countries will undoubtedly find that having a Ford-Escort type of program widely available is preferable to having a Mercedes-type program in a few schools.

39. **Software.** Initial and recurrent expenditures on software are less than 3 percent of total project costs in most developing countries, randomly reach about 5 percent of total project costs in the United States. Software expenditures are always going to remain relatively modest compared to other project inputs for a variety of reasons, cost being only one factor. First, there continues to be a shortage of high quality educational software that is culturally and linguistically appropriate for use in most countries. Despite the fact that there are over 13,000 educational software titles on the market in the United States, most developing country educators are reluctant to purchase educational software from other countries. The English-speaking Caribbean , Chile and Costa Rica, appear to be exceptions. Jamaica is using Autoskill's ILS for teaching literacy and numeracy, Costa Rica has trained teachers to use the Geometer's Sketchpad, U.S.-produced software for teaching geometry, and Chile's Enlaces project has invited software publishers to offer their educational software titles in Spanish for review and possible purchase. Second, in the Genesis projects in Mexico and Chile, the computer applications in schools have concentrated on the teaching of the LOGO programming language, so that the only software purchases required have been different versions of LOGO. Third, computer manufactures are bundling educational and productivity software into their computers so that country educators may not feel the need immediately to go to the market in search of other software.

40. **Professional Development.** The project data indicates that countries are allocating widely varying amounts on professional development, ranging from about 18 percent in the Genesis project in Chile 16 percent in Jamaica's new projects, and only 4 percent in the United States. Training costs are among the most difficult costs to analyze because they can vary widely depending upon how much training is needed, who does the training, and where it takes place. Some of the most effective professional development takes place outside the classroom when teachers learn from each other. Judging from the personal assessments made by teachers participating in projects and from classroom observations in Belize, Costa Rica, Chile and Mexico, there are clear indications that teachers have benefited from in-service training programs. Training has made teachers more knowledgeable of computers and generally confident in using them in certain learning situations. Many are also excited about the potential of the technology and would like to develop skills to enable them to use the technology more effectively in the classroom. Initial investments in training have also built up training capacity by "multiplicadores" in several countries so that there should be continuous training and support to teachers in the classroom. Likewise, in the Genesis projects in Chile and Mexico, CLIE technical support visits are programmed four times during the school year. These initial training efforts notwithstanding, there is reason to believe on the basis of recurrent cost allocation data, that most projects are not providing sufficient follow-up training for teachers and administrators which would permit them to use information and communications technology more effectively. After their first training event which lasts about two to three weeks most teachers do not obtain much additional training, ex-

[4] The computer cost was presented in annualized form in the source of the Belize data. Working backward, the implied cost per computer was a very low $1,115 (see Table 6). Certainly, this was not a commercial rate in 1987, so the relevance of the figure is limited at present. The argument in this paragraph, however, would suggest that such a figure may not be unrealistic in the not-too-distant future.

TABLE 4. Costs of Computer-Assisted Instruction, Laboratory Configuration, in Jamaica, 1995* (US$)

Cost Category	Item	Useful Life (Years)	Unit Description	No. of Units	Average Unit Cost	Investment Cost	Annualized or Annual Cost**	%
COSTS								
INVESTMENT*								
Facilities	Comput. Rm., Renovation	15	Contract	1	$ 3,000	$ 3,000	$ 394	1
	Airconditioning	7	Unit	1	1,700	1,700	349	1
	Contingency & Other	10	2% of Facil.	1		94	15	0
Equipment	Computers	5	Unit	15	2,000	30,000	7,914	30
	Peripherals	5	Set	1	1,200	1,200	317	1
	Power Protection	10	Unit	1	1,300	1,300	212	1
	Contingency & Other	8	5% of Equip.	1		1,625	305	1
Subtotal Facilities & Equipment						**38,919**	**9,506**	35
Software	Site Licenses	7	Set	1	3,200	3,200	657	2
Training (Upfront)	Lab Coordinator	7	Person Week	8	250	2,000	411	2
	Teacher Training	7	Training Day	5	285	1,425	293	1
Total Investment						**$ 44,119**	**$ 10,574**	39
RECURRENT**								
Personnel	Cluster Support		Pers. Wk.	3	80		$ 208	1
	Lab Coordinator		Pers. Wk.	52	80		4,160	16
	Fringe Benefits		15% Salaries	1			655	2
Maintenance	Equipment		Per Lab Chg	1	1,625		1,625	6
	Software		Per Lic. Chg	1	85		85	0
	Routine		Year	1	500		500	2
Insurance	Contract		5% of Equip.	1	1,625		1,625	6
Training			Training Days	12	285		3,420	13
Electricity			Month	12	200		2,400	9
Telecommunications	Telephone		Year	1	411		411	2
	Internet Provider		Year	1	343		343	1
Computer Supplies			Year	1	1,000		1,000	4
Total Recurrent							**$ 16,224**	61
Total							**$ 26,798**	100
						Recurrent	**Total**	
Cost Per Student (300 students)						**$ 54**	**$ 89**	
% of National Primary Per-Student Recurrent Expenditures (US$139)						**39%**	**64%**	
% of National Secondary Per-Student Recurrent Expenditures (US$315)						**17%**	**28%**	

Source of Basic Data: World Bank

* Estimated costs of 15-station computer laboratory for proposed World Bank-financed project, based on costs of similar facilities in the recently initiated EDTECH 20/20 project.

** Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs, using a 10% discount rate and with varying useful lives. Depreciation is included.

*** Does not include marginal costs for classroom teacher time and computer room space, which are assumed to be zero, since the focus of the analsysis is on affordability rather than cost-effectiveness.

TABLE 5 Costs of Computer-Assisted Instruction, Laboratory Configuration, in Chile, 1995* (US$)

Cost Category	Item	Useful Life (Years)	Unit Description	No. of Units	Average Unit Cost	Invest-ment Cost	Annualized or Annual Cost**	%
COSTS								
INVESTMENT**								
Facilities	Comput. Rm., Renovation	15	Contract	1	$ 5,000	$ 5,000	$ 657	2
	Furniture	10	Set	1	2,500	2,500	407	1
	Local Area Network	10	Unit	1	5,000	5,000	814	2
	Contingency & Other	10	2% of Facil.	1		150	24	0
Equipment	Server	5	Unit	1	2,100	2,100	554	1
	Computers	5	Unit	20	1,700	34,000	8,969	22
	Peripherals	5	Set	1	1,200	1,200	317	1
	Backup Generator	7	Unit	1	500	500	103	0
	Equipment Installation	5	Contract	1	1,000	1,000	264	1
	Contingency & Other	8	5% of Equip.	1		1,785	335	1
Subtotal Facilities & Equipment						**53,235**	**12,443**	30
Software	Site Licenses	7	Set	1	3,300	3,300	678	2
Training (Upfront)	Lab Coord. & Instructors	7	2yr.Vendor Supp.	1	19,250	19,250	3,954	10
Total Investment						**$ 75,785**	**$ 17,075**	41
RECURRENT***								
Personnel	Cluster Support		Share	1	$ 1,000		$ 1,000	2
	Lab Coordinator		Annual Salary	1	4,200		4,200	10
	Other Personnel Services		Annual Salary	1	5,700		5,700	14
Maintenance	Equipment		Annual Avg.	1	1,000		1,000	2
	Software		Per Lic. Chg	1	85		85	0
	Routine		Year	1	100		100	0
Insurance & Theft			Contract+$1,000	1	5,000		5,000	12
Training			Training Days	12	285		3,420	8
Utilities			Year	12	400		4,800	12
Telecommunications	Telephone		Year	1	100		100	0
	Internet Provider		Year	0			-	-
Computer Supplies			Year	1	130		130	0
Total Recurrent							**$ 24,535**	59
Total							**$ 41,610**	100
						Recurrent	**Total**	
Cost Per Student (400 students)						**$ 61**	**$ 104**	
% of National Primary Per-Student Recurrent Expenditures (US$)								
% of National Secondary Per-Student Recurrent Expenditures (US$)								

Source of Basic Data: IBM de Chile

* Estimated costs of 20-station computer laboratory in the municipality of Nunoa provided by IBM de Chile.

** Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs, using a 10% discount rate and with varying useful lives. Depreciation is included.

*** Does not include marginal costs for classroom teacher time and computer room space, which are assumed to be zero, since the focus of the analsysis is on affordability rather than cost-effectiveness.

TABLE 6. Costs of Computer-Assisted Instruction, Laboratory Configuration, in Belize, 1987* (US$)

Cost Category	Item	Useful Life (Years)	Unit Description	No. of Units	Average Unit Cost	Invest-ment Cost	Annualized or Annual Cost**	%
COSTS								
INVESTMENT*								
Facilities	Comput. Rm., Renovation	25	Contract	1			$ 474	3
	Furniture						-	-
	Local Area Network						-	-
	Contingency & Other		2% of Facil.	1			9	0
Equipment	Server						-	-
	Computers	6	Unit	10	[1,115]&	[11,150]&	2,486	16
	Peripherals	6	Set	1			658	4
	Power Regulator	6	Unit	1			268	2
	Equipment Install., Freight	6	Contract	1			361	2
	Contingency & Other	6	5% of Equip.	1			189	1
Subtotal Facilities & Equipment							**4,445**	29
Software	Acquisition Cost		Set	1			117	1
Training (Upfront)	Lab Teacher						-	-
Total Investment							**$ 4,562**	29
RECURRENT								-
Personnel	Support						$ -	-
	Lab Teacher		Annual Salary	1	9,180		9,180	59
	Fringe Benefits		Amount	1	172		172	1
Maintenance	Equipment		Annual Avg.	1	100		100	1
	Routine						-	-
Insurance & Theft							-	-
Training							-	-
Utilities & Supplies			Year	1	1,515		1,515	10
Telecommunications	Telephone						-	-
	Internet Provider						-	-
Total Recurrent							**$ 10,967**	71
Total							**$ 15,529**	100
						Recurrent	**Total**	
Cost Per Student (200 students)						**$ 55**	**$ 78**	
% of National Primary Per-Student Recurrent Expenditures (US$)								
% of National Secondary Per-Student Recurrent Expenditures (US$)								

Source of Basic Data: M.T. Rock, P.J. Glick and R.V.A. Sprout (1990)

* Estimated costs of 10-station computer laboratory at St. Johns College, Belize City, consultant's report for USAID. Cost data for four other schools were similar. Costs presented here are modified for purposes of comparison.

** Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs, in source. using a 9% discount rate and with varying useful lives. Depreciation is included.

& Annualized cost presented in source using assumptions there would imply cost per computer of only $1,115 per computer.

TABLE 7. Costs of Computer-Assisted Instruction, Classroom Configuration, in the United States, 1993* (US$)

Cost Category	Item	Useful Life (Years)	Unit Description	No. of Units	Average Unit Cost	Investment Cost	Annualized or Annual Cost**	%
COSTS								
INVESTMENT*								
Facilities	Wiring, Furniture, Etc.	10	School	1	$ 136,000	$ 136,000	$ 18,478	5
	Contingency & Other	12	2% of Facil.	1		2,720	324	0
Equipment	Computers	5	Unit	160	1,600	256,000	60,773	17
	Peripherals	5	Classroom	30	3,000	90,000	21,366	6
	Contingency & Other	5	5% of Equip.	1		17,300	4,107	1
Subtotal Facilities & Equipment						**502,020**	**105,049**	29
Software	Site Licenses	7	Set	1	75,000	75,000	13,435	4
Training (Upfront)	Lab Coord. & Instructors	7	Training Day	5	300	1,500	269	0
	Teacher Training	7	Program	1	2,000	2,000	358	0
Total Investment						**$ 580,520**	**$ 119,111**	33
RECURRENT**								
Personnel, Computer	Cluster Support		Share	1	$ 25,000		$ 25,000	7
	Technology Coordinator		Annual Salary	1	50,000		50,000	14
Personnel, Additional	To Allow Teach. Netwrk Time		Total Salaries	1	75,000		75,000	21
	To Allow Teach. to Use Tech.		Total Salaries	1	50,000		50,000	14
Training	Formal Staff Devel.		Year	1	13,000		13,000	4
Maintenance	Equipment		Annual Avg.	1	13,000		13,000	4
	Routine		Year	1	100		100	0
Telecommunications	Telephone + Internet		Year	1	12,000		12,000	3
Computer Supplies			Classroom	30	1,000		30,000	8
Total Recurrent							**$ 243,100**	67
Total							**$ 362,211**	100
Recurrent Cost Per Student (800 students)							**$ 304**	
Total Cost Per Student (800 students)							**$ 453**	

Source of Basic Data: Means and Olson, 1995
* Estimated costs of hypothetical US School, adapted from Means and Olson,1995, Table 7, p.99.
** Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs, using a 6% discount rate and with varying useful lives. Depreciation is included.
*** Does not include marginal costs for classroom teacher time and computer room space, which are assumed to be zero, since the focus of the analsysis is on affordability rather than cost-effectiveness.

cept in periodic summer workshops.

41. **Personnel Salaries**. Since the emphasis in this cost comparison is on the affordability of the programs rather than on their cost-effectiveness, the cost of teacher time (or of laboratory space) has not been included. The main personnel costs in Jamaica and Chile are those of the full-time laboratory coordinator and the technical support personnel shared with other clusters.

42. **Network and Communications**. Both the Jamaica and Chile cost data appear to have underestimated the cost of network communications, with $750 and $100 per year, respectively. This can be compared with $12,000 per year for US programs. Clearly, Internet and WAN costs need to be evaluated for cost-effectiveness. CD-ROM capability, valuable on its own, might be a partial lower-cost alternative to be evaluated against the Internet. Likewise, LAN capability alone might be evaluated against the combination of LAN and WAN capability.

43. **Infrastructural Support and Maintenance**. The Infrastructural support for computer facilities is well-developed in all the countries as are regular maintenance and repair services. Power outages are generally infrequent and thus not an insurmountable obstacle to the efficient functioning of computer labs. Likewise, all countries have regular maintenance and repair services which are mainly covered under standard service agreements for equipment. In Aguascalientes, Mexico a core maintenance and repair team functions along side IBM's, complementing and reinforcing services to schools. Belize's Ministry of Education appointed two full-time technicians to provide for routine mainte-

nance and minor repairs of the computers in the Belize Teachers College and the secondary and primary schools. Local dealers also provide hardware, parts and servicing in these countries, but experience has been mixed.

44. **Property Protection.** In many developing countries schools, security is a continuing difficult problem. Many have experienced incidents where most valuables have been stripped in a single night. This is one reason why many such schools have adopted extraordinary security precautions, such as having instructors take valuable equipment and tools home every afternoon. The security problem is also one reason why the laboratory configuration has been universally adopted in developing countries, since a single room can be better defended. Clearly, the security problem of computers left overnight in classrooms is serious, perhaps insurmountable. One alternative that has been given some attention is to have the investment for a classroom configuration made in notebook computers which would, like the tools mentioned above, be taken home every afternoon by the teachers or locked in some secure storage area at the end of school each day. In any case, property protection and its costs are not insignificant and need to be evaluated carefully. In the Jamaica and Chile cases, insurance and related costs alone are estimated at 5% and 9% respectively. In addition, a portion of facilities and equipment cost (e.g., for locks, security cables, and extra-strong walls and doors) should logically also be allocated to protection.

III. Conclusions and Recommendations: Strategies for Reducing Costs and Increasing Benefits

45. The conclusions and recommendations of this study point to a number of ways that countries and schools systems could improve the benefits and reduce the costs of projects to introduce information and communication technologies into education. While not all countries or schools systems will be able to benefit, there is little doubt that they should explore all available options to make technology in education more feasible and cost effective. Among these options, one that should be explored in some countries is the contracting out of instruction using computers to private tutors or private training institutions rather than having schools purchase equipment and assume responsibility for maintenance and professional development. The experiences of the countries and schools we have examined in this study suggest that some of the options for reducing costs and increasing benefits are not always immediately obvious. It is only after some passing of time and with good monitoring and assessment, do new and improved ways of maximizing resources become apparent.

Strategies for Reducing Costs

46. The main strategy for reducing costs involves substrategies for reducing the main cost elements: hardware, computer staff salaries and teacher training and support.

47. **Hardware and Software.** *Given the large costs of facilities,* equipment and software, it is clear that effective deployment, procurement practices, and payment arrangements are very important for cost reduction. Trade restrictions and other practices that prevent buyers from obtaining the best international prices are obviously counterproductive. Buyers should also attempt to exploit any tax exemptions that are available. Even pilot projects should attempt to negotiate 'best' prices with vendors, on the argument that more sales will be likely in the future.

48. **Computer Deployment in Schools.** Computer equipment costs average 25 to 35 percent in most projects. For most of the countries initiating information technology in education, the preferred option for deploying computers and related hardware has been to place them in computer labs or teaching resource centers. (With the exception of Chile, which has many small rural schools with only a few computers each, all schools in other countries have some 15 to 20 computers in each lab). The lab option has two strong arguments in favor of it. The first is that computers in labs, usually with 15 to 20 machines provide greater access to students at more affordable prices than do computers in classrooms. Second, schools can more easily protect computers from theft and vandalism when they are in one well-protected room rather than spread throughout a school building with poor security. Despite the almost exclusive preference for deploying computers in labs, there may be reason to question whether or not this should be the preferred option in all cases. As the cost simulation in Table 8 suggests, the deployment of inexpensive, capable and communications-ready portable computers in classrooms could prove to be a more cost effective and educationally advantageous option than the deployment of computers in labs. The easy portability of laptop/notebook computers from classroom to classroom would allow their collection at night in secure rooms (or in the possession of teachers at home) and thus make this deployment a feasible option in schools with security problems. For these reasons, classroom deployment of portable computers should be seriously investigated.

49. **Gain Market Knowledge.** Superior market knowledge will have an important role in cost reduction, especially in the next few years as the computer market becomes more differentiated (para. 38). The ability to use low-end hardware will also depend on the development of the software market. The recent explosion of educational software for today's low-end (486) machines will probably support the continued use of low-price software on cheaper low-end machines expected in the future. The key tactic for developing country buyers will be to successfully gain market knowledge of the opportunities in the more differentiated market. Retaining a high-priced international consultant may result in greater savings in this market than relying on vendor information even from several vendors. His or her knowledge of the international market would, first, be likely to result in significant hardware savings. Moreover, his or her specialized knowledge might include knowledge of computers that did not require air conditioning and special

protection against dust, resulting in facilities saving, and ones that could drive cost-effective software, resulting in software savings.

50. **Effective Procurement Procedures**. Effective procurement practices are very important for cost reduction. The world market for computer technology and software is highly competitive and offers countries and school districts opportunities for obtaining benefits from competition. Computer manufacturers wishing to penetrate markets for longer-term sales prospects are often willing to offer lower prices. For this reason, international competitive bidding procedures, will yield better prices than more limited local competition or direct purchasing. Likewise, procurement of equipment and services in bulk (e.g., for more than one school or one district), will produce economies of scale and the consequent price benefits. A two-step process recommended by the World Bank will bring better benefits than one step, if the system is large and complex. Following a two step process, a government would first invite companies to submit technical proposals and evaluate them based on criteria of soundness rather than cost. Bidders are permitted to adjust their technical proposals to produce the same performance. The financial viability of bidders and their capacity to implement the proposed solutions are also evaluated in this first stage. The second stage takes place after the government has chosen all qualified bidders and invites them to submit prices for the technical proposals approved in the first phase. The final selection is based on price. Chile's Enlaces project has followed this approach in its procurement of computers and related equipment with the result that both Apple Computer Corporation and IBM have won on different occasions with clear price advantages for the government.

51. **Lease vs. Purchase.** National governments and local school districts can obtain help from some of the large computer manufactures in putting together suitable packages for leasing or purchasing computer hardware and software. Not only may this help in financing projects that otherwise might be difficult to finance, but in some (probably a minority of cases) may even result in cost reductions, when all maintenance, insurance, technical assistance and training costs are considered. The Genesis projects in Chile and Mexico involve leases of equipment and training , backed up with support services from CLIE. Negotiating a lease is sometimes complicated by the fact that governments have to commit in advance annual contributions from their recurrent budgets to pay the leases, and that isn't easy for some governments to arrange. On the other hand, leases have their distinct advantages in that the companies retain ownership of the computers, which obligates them to obtain insurance on their computers and to make repairs of the technology if anything goes wrong. Secondly, upon termination of the lease, usually in about five years, the government is free to buy the equipment out right or return it to the seller and obtain upgrades. In an industry where there is constant improvements in technology, being able to return equipment to the manufacturer has its distinct benefits. The interest rates on leasing vary from country to country but generally reflect market conditions. Competition in the United States among computer manufactures has brought leasing prices down to levels where leasing can be an attractive alternative to purchase.

52. **Efficient Usage of Equipment.** Simply saving resources on the cost of hardware and software is only half the battle. Reducing the cost per student contact hour or, better, per unit of benefit by maximizing usage is the other half. This will mean especially careful attention to efficient scheduling by school principals and ministry officials, so that computers are continuously in use by children during and in many cases outside of school hours.

53. **Computer Staff Salaries**. Another potential major area for cost containment is in computer staff salaries, in particular, the full-time laboratory coordinator, who is an essential element in the laboratory configuration and other staff. In the laboratory configuration, the coordinator manages the operation and instructs both the teachers and students with or without paid assistants. When the lab is open to the community, he or she and/or assistants may manage the activity and handle the cost recovery. The main potential saving in these salaries would come from using an alternative configuration, probably a classroom configuration. In this configuration, the absence of the laboratory can allow a different and less expensive arrangement for technical and training support. Custodial, management and student teaching activities are the responsibility of teachers; technical support likewise becomes the responsibility of teachers generally, of teachers with specialized training, of technicians shared with other schools and of vendor-provided support teams. There is little experience with the classroom configuration in developing countries, however. Minimizing the security problem of the classroom configuration will probably require portable computers in many or most instances. Portability may also aid in maximizing usage. Developing country experimentation is urgently needed to determine whether the cost savings of feasible classroom configurations are both positive and significant. Investigating the relative cost-effectiveness of various laboratory and classroom approaches would also be essential. The extensive experience of developed countries in the classroom configuration should be analyzed to see what if any lessons learned can be transferred to the developing country context. The high resource commitment, however, reduces the usefulness of developed country cost data for developing country analysis (see Table 7). Developed country experience in how to train and motivate teachers to integrate technology in classroom activities, however, should be highly relevant to the third big cost category in the cost structure of educational computer applications, training and teacher support.

54. **Training and Teacher Support**. This category includes training of all kinds and released teacher time for teacher support activities. The conclusion of one study[5] is that schools in which exem-

[5] Becker, Hank (1993) as cited in Means and Olson (1995).

Table 8: Costs of Various Configurations of Educational Computers - Simulation

	10-Computers		20-Computers	
	Laboratory	Classroom Portable	Laboratory	Classroom Portable
PROGRAM SCOPE				
No. of Students Served	200	200	200	200
No. of Computers	10	10	20	20
No. of Classes	10	10	10	10
No. of Students Per Class	20	20	20	20
No. Students Per Computer	20	20	10	10
INTENSITY OF COMPUTER USE				
Average Hours Per Computer/Week	30	30	30	30
Avg. No. Students Working Together	2	2	2	2
Avg. Student Computer Contact Hrs./Wk.	3.00	3.00	6.00	6.00
Value of Use - Qualitative Adjustment	1.00	1.25	1.00	1.25
Avg. Quality-Adjusted Hours/Wk.	3.00	3.75	6.00	7.50
School Weeks Per Year	30	30	30	30
EXPENDITURES				
INVESTMENT, ANNUALIZED				
Facilities - Alteration, Air Con & Wiring	1,000	200	1,300	300
Use of Space - Opportunity Cost	1,900	-	3,800	-
Facilities - Communications Wiring	100	500	100	700
Computers & Prepaid Services	5,300	5,800	10,600	11,600
Peripheral Equipment	500	600	1,100	1,200
Software Site Licenses	1,500	1,500	3,000	3,000
Training (Upfront) & Tech. Assist. Contracts	8,000	5,000	10,700	6,700
Total Annualized Investment	18,300	13,600	30,600	23,500
RECURRENT				
Personnel Services				
Lab Coordinator	10,000	-	10,000	-
Technical Support	3,000	3,000	4,000	4,000
Program Support	3,000	3,000	4,000	4,000
Additional Paid Teacher Time	-	-	-	-
Other	-	-	-	-
Subtotal Personnel Services	16,000	6,000	18,000	8,000
Software and Supplies	1,000	1,000	1,300	1,300
Maintenance and Technical Assistance	1,200	1,000	1,600	1,300
Training and Teacher Release				
Insurance and Other Recurrent	1,700	1,900	3,500	3,800
Total Recurrent	19,900	9,900	24,400	14,400
TOTAL	38,200	23,500	55,000	37,900
Per Student	191	118	275	190
Per Student Contact Hour	2.12	1.31	1.53	1.05
Per Quality-Adjust. Student Contact Hour	2.12	1.04	1.53	0.84

NOTE: Discount rate = 10%

plary computer-using teachers work provide a strong social network of computer-using teachers and receive in-service training in computer software. The strong social network not only requires equivalently strong school leadership but also an allocation of time when teachers can interact with each other outside of their classrooms and also use computers. Doing this at the level costed in Table 7 would obviously use significant resources both for formal training activities and also for substitute teachers to cover for teachers having released time to confer with colleagues and experiment with computer applications and methods. Rather than seeing training and support activities as a source of savings, therefore, the imperative may be to use savings on hardware, software and personnel to efficiently augment teacher training.

55. **Interaction of Training with Cost Reduction Opportunities.** It will also be necessary to have effectively trained teachers in order to obtain the savings in these cost categories. Having trained teachers will help to maximizing the utilization of the hardware even in the laboratory configuration so as to reduce the cost of student contact hours. Certainly this will be the case in the classroom configuration. Effective, committed teachers will be even more essential in maximizing the educational effectiveness and the cost-effectiveness of technology applications. These interactions together with the large cost of training and teacher support will make these program aspects hardest of all areas to get right. Extensive experimentation with different models of training and teacher support is therefore indicated.

56. **Piloting Innovations**. One useful strategy for identifying cost reduction possibilities as well as efficiencies, is to undertake pilot programs before launching large-scale initiatives. Although this is rather obvious, educational policy makers and administrators are reluctant to undertake pilot projects because they often prove difficult to replicate on a larger scale. Pilot programs are also unattractive to officials who are looking for urgent responses to large-scale problems. Nonetheless, Chile has demonstrated the value of pilot projects in planning its national computer network project, Enlaces. During the past three years, Enlaces gained valuable experience and cost data to confirm the viability of it project concept , growing from an initial 14 schools in southern Chile to over 200 primary and secondary schools nationwide. The pilot phase has helped define hardware and software requirements, cost effective training solutions, and overall operating expenses of the network. While Enlaces is now a program of national scope, it continues to pilot different approaches such as the use of the Internet and the World Wide Web in selected schools.

Strategies for Increasing Benefits.

57. **Defining Instructional Objectives.** The introduction of information and communications technology into education should be guided by clear and relevant educational objectives. Experience indicates that quite often, technology has been introduced without specification of educational objectives, and thus its impact on teaching and learning in schools has failed to meet expectations. Likewise, educators need to have realistic expectations regarding the contributions to education which can be made by information technology. Viewing information technology as a valuable knowledge extension and instructional tool for use throughout the curriculum will enable teachers to employ many important applications to enrich teaching and could provide a powerful impetus to new forms of self-learning, cooperative learning, problem solving and higher-order thinking skills among their students.

58. **Intensity of Computer Usage.** The is little firm knowledge about what minimum weekly (or monthly) computer usage is necessary to obtain commensurate educational benefits. Judgments as to the minimum access required per student vary from one to three hours per week, depending upon how computers are used for instructional purposes. In Mexico, Chile and Costa Rica, students share computers from two to three hours per week. In Jamaica, the goal has been to provide students up to three hours per week of CAI. Even the goal of two hours per week of access is beyond the means of a good many education systems, at least initially. Thus they start with less, as has been the case of projects such as the one in Puebla, Mexico. However, after two years of operation, Puebla has plans to double the number of computers to enable students to have at least two hours of computer time weekly. Whatever the minimum usage decided on, it may be necessary in order to achieve this level for schools to limit access to certain grade levels, is done in Ñuñoa and Aguascalientes.

59. **Invest in Professional Development.** Teachers are the key change agents in education and play the crucial role in the deployment of information technology in the classroom. Computers are a powerful instructional tool and will become more so. But their potential will not be realized without teachers training in their use. There is an increasing need to give considerably more attention to the training of teachers in using computers effectively' in the classroom. Where feasible, teachers need to learn to use computers in their teaching when they are first trained. However, in-service training, combined with support in the classroom, enables practicing teachers to acquire the necessary knowledge and skills in computer use for teaching. Effective professional development will enhance investments, while the failure to invest will almost certainly limit the effectiveness of computers in achieving instructional objectives. The cost analysis of professional development in projects also indicates the need for governments to incorporate funding in their recurrent budgets to provide teachers regular training opportunities to upgrade their computer skills and familiarize themselves with the latest software on the market for teaching in their disciplines.

60. **Software**. The selection of good educational software is critical for maximizing the instructional benefits of information technology in schools. Nevertheless, teachers and administrators are generally handicapped in making informed judgments as to the best

software to support the learning outcomes in their curriculum. This handicap can be overcome in at least two ways. One way is to invite publishers to submit software for review by curriculum specialists and teachers before making selections and purchases. This may not be widespread industry practice, but should be pursued with those publishers willing to do so. A second way is to consult publications which review educational software. Two such guides for the U.S. market are High/Scope's Buyer's Guide to Children's Software and the ASCD's Only the Best: The Annual Guide To the Highest Rated Educational Software and Multimedia. Since producing quality software is costly and technically difficult, few companies in developing countries would be inclined to invest in new software publishing for their national markets. However, some firms are contracting with software publishers to translate and adapt exiting software code for use in different countries. Within IBM Corporation, there is an agreement which permits any geographic region of the company to have access to IBM software code for translations. These type of arrangements offer countries the opportunity to take advantage of other major up front software investments. Another option is for teachers to develop some of their own instructional materials, using one of the many authoring software packages on the market. Hypercard has been the most popular software among U.S. educators, but there are now other packages including ones which accommodate multimedia formats.

61. **Providing Benefits to the Community At-Large**. Programs to introduce computers into schools generally receive strong support from the school community. While parents might be reluctant to support other school programs, they are usually willing to contribute materials and labor for computers. While community members view school computers mainly as instructional tools, many quickly appreciate the benefits which computers offer to business and local government. Thus, in many communities in Mexico, Chile and Costa Rica where computers are installed in schools, community members have obtained access to them in the evenings, weekends, and other times when they are not being used for educational purposes. Using computers in this way, further maximizes their benefits although not exclusively for educational purposes. On the other hand, the benefits are reflected in tangible ways such as the user fees charged for the community use of computers, an increasingly common practice.

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