

Introduction: Why use computers in classrooms in developing countries?

The idea of computers in developing country classrooms may seem incongruous to some at first glance. Why put computers in places where there are few textbooks, no electricity, or where the teacher rarely comes to school? And it is true, computers will not suddenly or magically solve everything that plagues an educational system. Computers can be used, however, to address several pressing problems facing educational institutions. Today computers are used to improve data processing, administration, and teaching and learning. Most arguments in favor of computer use to improve the quality of teaching and learning in K-12 schools hinge on three key areas: skills, content, and pedagogy.¹ Appendix 1 reviews the literature related to the effectiveness of computers in developed countries.

The skills argument suggests that computer-related skills are valuable in their own right. Students report that word-processing, spreadsheet, web-browsing, and more advanced skills such as database design, computer programming, and computer maintenance and repair, contribute to their ability to be hired (WorLD evaluation 1999). In short, increasingly computerized economies pay for technology skills. And a computer literate population can have even broader economic implications. Costa Rican leaders are active in making their country a leader in technology. Their Computers in Secondary Education program is part of this strategy. "The decision by INTEL to build a \$300 million microprocessor plant in Costa Rica, which will generate 3,500 jobs as well as billions of dollars in future export revenues, is one result of this strategy" (Wolff 1999).

Computers, either with specialized software, CD-ROMs, or through the Internet can also provide rich and engaging resources that can be valuable in educational settings. Not just an encyclopedia at a student's fingertips, for example, but an encyclopedia with animation, sound, and easy cross-referencing. In places where print is either expensive or not easily distributed, computers, perhaps with wireless connectivity, dangle the possibility of mass distribution copies at the push of a button and at a relatively low marginal cost per copy.

Finally, some research suggests that teachers can and often do teach differently with the support of computers. Computers are vehicles for simulation and exploration, and computers readily support an activity-based curriculum. With such a curriculum, students are "actively exploring phenomenon, instead of being passive recipients of information" (Osin 1998). Where email is possible, classrooms need no longer be isolated places. Students and teachers can share materials, experiences and support. Many students become enthusiastic about sharing with an audience beyond the classroom. Others report that computers can contribute to a student's ability to present and process information (Osin 1998)

¹ A more detailed discussion of quality improvements, including technology for administrative and access purposes can be found in Wright 2000.

The objectives stated in the policy documents of programs in developing countries reflect many of these aspects of computer use. Table 2 presents some of the stated objectives of computer-projects in selected developing countries.²

Table 2: Objectives for School-based Computer Use

Country	Objectives for School-based Computer Use
Barbados	<ul style="list-style-type: none"> • To provide better motivation for both teachers and students; • To enable schools to provide better educational management; • To assist students in mastering the requisite skills and competencies of a computerized world; and • To enhance the teaching of subject matter of the various curricula offered.
Chile	<ul style="list-style-type: none"> • To promote cooperative learning, higher-level thinking skills, data management, and communication skills.
Costa Rica	<ul style="list-style-type: none"> • To contribute to the improvement in the quality of education; • To provide access to technology to children in rural and marginal urban areas; and • To stimulate creativity, cognitive skills and collaborative work. • To rekindle teachers' interests in teaching • To provide students with new learning environments and opportunities.
Egypt	<ul style="list-style-type: none"> • To improve the quality and relevance of education through improved access to information for teachers and students and work-related skills; and • To provide a means of communication within the education system.
Jamaica	<ul style="list-style-type: none"> • To integrate technologies into the curriculum; • To foster literacy and numeracy acquisition through computer-assisted instruction in primary schools; • To electronically network rural schools; and • To expand software available to educators
Turkey	<ul style="list-style-type: none"> • To promote active involvement of students in individual and collaborative work; • To enrich institutional activities through various kinds of multimedia instructional software and web-based materials; • To enrich of interaction among students, teachers and other schools; • To promote multidisciplinary and authentic tasks, covering more than one course and real-life applications • To integrate of IT skills into the existing curriculum.

Where computers are used effectively, they often are used many ways simultaneously as the computer acts as a catalyst for broader reform. One longitudinal study of computer's effects on classroom

² These six countries have been selected because they are among the best documented, large-scale K12 computer projects in the formal education sector in developing countries.

practice "observed profound changes in the nature of instruction, learning, assessment and the school culture itself" (Dwyer 1994). With so much promise, it is important to look at evaluations of the cost-effectiveness of computer use in K-12 classrooms. In the next section, we review the current state of research on the effectiveness of computers for teaching and learning in K-12 education.

Once the decision to invest in computers is made, what can projects be expected to cost? Much depends on what individual countries and schools want to accomplish with computers, how they are used and how intensively, and what the total and unit costs of projects are likely to be.

Methodology: Estimating the Costs of Computer Projects.

Total Cost of Ownership (TCO) is a concept used among American businesses today to estimate what a computer is likely to cost over the life of the investment. (Appendix 2 offers a review of costing terms and additional information about costing methodologies). It has also been applied to technology projects in education, although rarely to the unique set of circumstances facing developing countries. In the cost tables presented here, expenditures in four countries, Barbados, Turkey, Chile, and Egypt, are cited most often because it was for these countries that the most detailed information was available. The first two countries, Barbados and Turkey, are grouped together because the percentages are of total project costs. The estimates were developed from the perspective of the central ministry. Estimates in the second two countries, Chile and Egypt, are from the perspective of individual schools, and so do not include centralized costs. The analysis for these two countries therefore excludes central management and planning or monitoring and evaluation. When percentages are included they are of these school-based costs, not total project costs. All estimates, unless otherwise specified, assume that the majority of computers are grouped in a single "laboratory" or classroom.

Where data was available, detailed cost models of projects were constructed for analytical purposes. (See Appendices 3 - 6 for detailed summaries of the costs of computer projects in Barbados, Chile, Egypt and Turkey.) Estimates for the costs of Turkey's project were gathered specifically for this report; secondary sources are used in all other cases. Turkey data was gathered through site visits, interviews, planning and policy documents. In the case of Barbados, Costa Rica, Egypt, planning and policy documents were the principle source of data.³ Published reports and internal World Bank documents were the primary source of data for Chile and Jamaica. Documents from projects in other countries were also used to supplement the analysis, although detailed cost information was not available. In most cases, the costs of classroom space are not included. Most investments are amortized over 5

³ Planning documents have particular limitations. The use of planning budgets can distort cost analysis to the degree that they do not reflect actual expenditures or the inevitable unbudgeted items. Of course, poor expenditure coding can mean records of actual expenditure are not reliable either.

years with a 10% opportunity cost.⁴ This data is also compared to cost analysis of computer projects in US schools, where both computer investments for schools and the documentation of experiences tend to be the strongest.

All currencies were converted into US\$ using exchange rates that were either the average exchange rate for the year of expenditure or a current exchange rate for on-going, recurrent, or contemporary expenditures. Using the ingredients approach specified in Levin (1983), inputs for each project were specified, and then market prices were associated with each item. Capital and other investment costs were annualized at a rate of 10% (more information about cost analysis is available in Appendix A).

Overview of Total Costs.

The projects incorporated into the analysis presented here had compatible objectives; all addressed issues related to computer use as an instrument of curricular reform. In most cases, computer technology was introduced for some combination of three purposes: to increase technology skills, to reform pedagogy and curriculum, and to increase access to resources and information. Despite these common objectives, the computer projects incorporated into the analysis presented here varied considerably in scope and scale, and as a result in total and unit costs. Table 1 summarizes the allocation of costs by category as was as reports total, per school, per student, and per computer, costs for the four countries for which the data was available.

Table 1: Summary of Cost By Project

Cost Category	National Estimates		School-based Estimates	
	Barbados (1998)	Turkey (1999)	Chile (1995)	Egypt (1998)
Central Management (planning and recurrent)	11%	2%	N/A	N/A
Hardware (annualized investment per school)	33% (\$150,000)	31% (\$ 6,800)	49% (5,540)	24% (\$ 10,950)
Software (annualized investment per school)	13% (\$ 56,000)	6% (\$ 1,240)	2% (\$ 171)	2% (\$ 749)
Facilities and Renovation (annualized investment per school)	19% (\$ 85,000)	5% (\$ 985)	3% (\$ 350)	7% (\$ 3,100)

⁴ While 10% might appear high for many countries, it is becoming a somewhat standard proxy in the field of cost analysis.

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Connectivity (recurrent)	10% (\$ 85,000)	5% (\$ 960)	10% (\$ 1,165)	6% (\$ 3,000)
Maintenance and Tech Sup (recurrent including personnel)	18%	42%	N/A	4%
Professional Development (annualized investment and recurrent)	4% (\$ 18,430)	2% (\$ 535)	13% (\$ 1,445)	29% (\$ 13,275)
Total Annual Cost	\$30,279,100	\$54,206,336	N/A	N/A
Total Annual Cost Per School	\$ 451,930	\$ 21,685	\$ 11,215	\$ 45,045
Total Annual Cost Per Student	\$ 646	\$ 32	\$ 56	\$ 75
Total Annual Cost Per Computer	\$ 1,938	\$ 1,280	N/A	\$ 2,048

One of the interesting facts that emerges from this analysis is that over time, countries appear to be purchasing computers in the \$1,000 - \$2,000 price range, despite decreases in computer prices, holding computer power constant. Further, annual costs per computer also hovered in the \$1,000 – 2,000 range, suggesting that initial hardware costs represent only a fraction of total, annual project costs. A successful computer project must budget for additional costs beyond the price of hardware and software.

Discussion of Findings by Category

The following discussion provides further detail by cost category about both how these costs were derived and the implications for these findings. The discussion focuses on six main cost categories: central management, hardware, software, facilities renovation and connectivity, support and maintenance, and professional development.

Central Management

We have little information about personnel and resources devoted to the planning, operation, and evaluation of computer projects in schools. We do, however, have some information about the costs of planning and the costs of monitoring and evaluation.

The costs of planning are often overlooked and underestimated, but they are essential.⁵ Costs of planning are quite dependent on the scope and scale of the initiative as well as on salary rates in a particular country. Although discussions of how and what to plan are beyond the scope of this paper, planning activities must be adequately budgeted in terms of financial, human, and time resources. Resources typically include staff salaries and benefits, travel, equipment and supplies, and telephone

⁵ Valuable planning resources can be found on the World Wide Web. See for instance: <http://www.ncsa.uiuc.edu/edu/nie/overview/handbook/handbook.html>, <http://www.microsoft.com/education/vision/roadmap/default.asp>, and <http://www.cvu.cssd.k12.vt.us/k12tech/howcover.htm>.

charges, and might support focus groups, conferences, and other planning mechanisms. Project planning and preparation costs were only available for the Barbados project, despite their centrality to any sustainable initiative. Barbados estimated that US\$11,379,204 was necessary for project preparation. Since planning costs are in essence investments in the project, they are also amortized like other investment costs. Annualized investments in project preparation in Barbados equal a little more than \$3 million or about 10% of the annualized total budget at a 10% opportunity cost. To estimate the cost of resources required to plan and support the national project in Turkey, the costs of two senior managers, 15 staff members, and 4 part-time consultants were added to costs of computers, paper, supplies, office space, telephones, etc. This came to a total of \$634,000 per year, and project planning is estimated as having taken two years for a total of \$1,268,000, which accounts for less than 1% of the annualized total costs (see Appendix 2).⁶

Monitoring and Evaluation is an important element of project oversight and can affect on-going planning efforts. "International experience indicates that good, credible evaluations are expensive, often 10% to 15% of a project's budget ... (excluding civil works)" (Cobbe and Klees 1998). Monitoring and evaluation in Chile's Enlaces program, for instance, has several facets. The program monitors network operations and has conducted evaluations on the role and impact of computers in teaching and learning. The program has employed a full-time researcher who is responsible for monitoring and evaluation activities (Potashnik 1996). Unfortunately, no cost estimates of these activities were available. While Barbados budgeted for ongoing monitoring and evaluation at the school level, Turkey did not provide funds for on-going monitoring evaluation. Barbados planned to incorporate monitoring and evaluation activities as well. Barbados budgeted approximately \$245,000 for the first five years of the project and about \$76,000 for the next five years. Initial planning documents indicated a comprehensive evaluation, both formative and summative, at all levels of the education system, from within schools to the national level (Cobbe and Klees 1998). Evaluations would also explore the effect of computer use on students' cognitive skills as well as cooperative skills and attitudes. To accomplish these ends, Barbados expected to hire 3.5 full-time professionals, although project reviewers anticipated that a larger staff would be necessary (Cobbe and Klees 1998). Project monitoring and evaluation activities should also include cost analysis, although this is seldom done in practice.

Hardware

⁶ The model analyzed in this report includes costs for only the first phase of Turkey's national project, which is intended to reach 2,400 of Turkey's more than 10,000 basic education schools. Per student and per school costs are expected to remain somewhat consistent, although total costs will be larger by a factor of 5 once all schools are included in the project.

Equipment costs consume from 17% - 49% of total project costs in the 4 detailed developing country models compared in this study, NOT including servers and connectivity hardware, which are included in section titled: Facilities Renovation and Connectivity (see Table 2 for a breakdown of hardware costs by project).⁷ Hardware costs typically include computers for students, teachers, and/or administrators, printers, cd-roms, and scanners.

Table 2: Total Hardware Costs

Country	Annualized Per School Cost	% of Total Cost
Barbados	\$150,000	33%
Turkey	\$ 6,800	31%
Chile	\$ 5,540	49%
Egypt	\$ 10,950	24%

The largest proportion of these hardware costs is for student computers. Student computers specifically represented between 14 - 32% of total project budgets (see Appendices 2 - 5). Perhaps surprisingly, this number is actually a bit lower than some estimates for schools in the United States.¹ One might expect that the higher salary rates in the United States would take up a larger share of the budget and thus hardware would consume a smaller percentage of total resources than where salary rates are low. It appears that the much lower computer-student ratio in the United States, resulting from greater numbers of purchased computers, is responsible for driving up total hardware costs in the United States (see Table 2). A 1995 study of 8 hi-tech schools in the United States found that schools were spending between 30 - 67% on hardware (Keltner and Ross 1995 as cited in Melmed, A et al 1995).

Schools should be prepared to replace a computer every five years. The rapid evolution and relatively short life of computers suggest that they become a line-item in recurring budgets. The short-life of computers and software also suggest that if computers are not available later in school-life, lower school investments are not likely to be valuable. Issues that affect the exact cost of hardware include: functionality of hardware, how many units, and the configuration of units.

The functionality of a computer -- processor speed, hard drive space, and memory -- affect unit cost of a computer. Age indirectly affects costs because older computers often have lower functionality. What kinds of computers are necessary for a given project depend on the type and intensity of use. High-powered computers cost more, although high powered computers are not always necessary. Typical use of

⁷ The World Bank has constructed a website (www.worldbank.org/html/fpd/telecoms/procurement/hw_config.htm) with equipment specifications which can be used in preparing bidding documents for procurement under World Bank guidelines. The pages also contain direct links to vendors in the information technologies industry.

computers in K-12 schools does not require state of the art hardware.⁸ While it has been conventional wisdom for several years to talk about the declining costs of hardware and computing power, evidence suggests that institutions consistently pay between \$1,000 - 2,000 per computer, at least over the last 5 years. While the computers being purchased today for \$1,500 may be more powerful than the computers purchased 5 years ago for \$1,500, off the shelf software applications often require newer hardware without providing measured educational improvements. Two alternatives to this dilemma are emerging although neither has been widely tested: "New Deal Software," which takes advantage of lower-grade computers and "networked computers." New Deal Software is discussed in the next section, software, and networked computers are discussed here.

Networked Computers. Some efforts are being initiated to use low-cost equipment such as Network Computers (NCs, also known as thin clients and dummy terminals). Network computers do not have hard drives, so are unable to store data or applications on the computer. Instead, NC users access both through their local server or, in some cases, the Internet. NC's have three major advantages. One is their relatively lower cost than personal computers; another is that they require very little maintenance or technical support since they are much simpler machines; and finally, they do not need to be discarded and replaced by newer, more powerful computers every few years. Instead, upgrades are simply provided to the server. There are three main drawbacks to network computers. One drawback is the need for more technically proficient network administrators, although fewer network administrators may be needed overall. Another drawback is that processing speed of terminals are greatly reduced when network traffic is heavy, as is likely to be the case when a class goes to the lab for an organized computer session. Finally, should the server go down, all computers connected to the server lose almost all functionality, rather than just networked services. The impact of NCs on project costs are not well yet documented, although several projects are underway. A South African distance education consortium has started using Sun's NCs for its computer centers, and Sun also is working with a number of school districts in the United States to pilot their NC systems. Sun's thin client is currently retailing at about \$499 and can be leased in the United States for \$9.99 per month with a 5 year contract.

Student-computer ratios. Total number of computers purchased also influence the magnitude of total project costs. Student-computer ratios in developing countries differ dramatically. In Costa Rica, the reported average was about 53 - 73 students per computer, and in Chile the ratio was much higher

⁸ The World Bank has compiled generic procurement specifications for hardware at http://www.worldbank.org/html/fpd/telecoms/procurement/hw_config.htm. Although not education specific, the pages may be helpful in that they "contain equipment specifications that World Bank borrower's can use in preparing bidding documents for procurement under World Bank guidelines. They also contain direct links to the offerings of the IT industry. As equipment specifications and product life cycles are quite short in the IT industry, we propose that the industry commits to review the generic specifications and suggest changes that may be due from

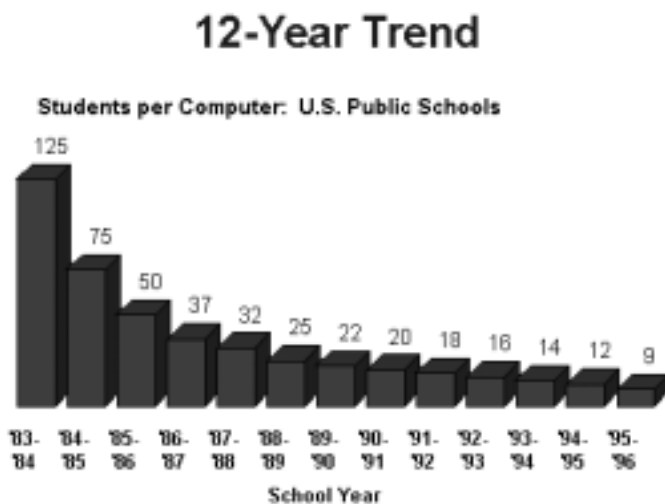
with 68 to 137 students per computer reported (Alvarez et al 1998). The range for in-country estimates depend on several factors influencing how computers are allocated. Where computers are provided centrally, laboratory size is often set at given increments. In the case of Chile, for example, 3 computers were offered to schools with under 100 students, 6 computers to schools with under 300, and 9 computers to all schools larger than 300 students. These computer-student ratios are not equivalent. Often times, localities are expected to provide some computers, and these instances, poorer and/or remote localities fall predictably behind. Thus, planners of large-scale projects should pay particular attention to addressing needs of poor and rural in order to encourage equity among K12 schools. In Egypt, the planned student to computer ratio was 27 to 1 (computed from Secondary Education Enhancement Project PAD), and in Turkey the ratio is 40 to 1. Barbados planned on the lowest student-computer ratio at an eventual 3:1, see Table 3.

Table 3: Student-Computer Ratios in Developing Country Projects.

Country	Student-Computer Ratio
Costa Rica	68-137:1
Chile	53-73:1
Turkey	40:1
Egypt	27:1
Barbados	3:1
Jamaica	n/a

In the United States, student-computer ratio has been consistently falling for at least the last 15 years. Figure 1 shows the steady decline of student-computer ratios from 125:1 in 1983 to 9:1 in 1996.

Figure 1:



time to ti
 on actual Copyright © 1995 QED National Education Database



Bank borrowers can find information
 g purposes)."

There are few guidelines available to help determine optimal computer-student ratios. A general tendency has been "the more the better." Administrators can estimate the likely need for computers by assessing what students will do with computers, how long it will take them to do it, whether students will work alone or in groups, and the number of hours that computers will be available in a school day or week. Where only a few computers are to be deployed in a school, administrators and the library are generally the first recipients. Where these few computers are used for instructional purposes, they are generally used as presentational aids.

In addition to the specific type and number of computers, how computers are configured will impact on cost. The choice is typically between a centralized, "laboratory" model and the more diffuse "classroom" model. Computer labs typically have from 10 - 50 terminals. They are well-suited to centralized instruction, maintenance, and security. It has been argued that a centralized model does not encourage curricular integration among classroom teachers and so many valuable uses are lost. In a 1995 McKinsey & Co. study, found that classroom model with a computer for every 5 students and a high-speed T-1 connection would cost about four times as much as computer lab model in up-front investments and a little more than 3 times the per student recurrent cost. Project analysis in Egypt found that significant economies of scale were possible if larger laboratories were used. Increasing laboratory size to 22 computers from 14 resulted in 28% lower total per student costs and 35% less recurrent costs (Project Appraisal Document, p. 40, 1999).

Beware of Donations. It is important to note that donated computers are not free. Donations are likely to incur expenses, although very little has been documented in this area. Many donated computers are likely to require memory and hard drive upgrades to run newer software. Such upgrades can be expected to cost between \$50 - 500 per computer. Further, at least one country in Africa has charged much as \$200 per donated computer for Import Duties.

Software and Content

The intended uses of the computer will also dramatically impact upon software costs. A library of software resources can allow teachers greater flexibility in their use of technology. But hosting a wide-range of software applications can increase not just the amount spent on software, but the amount needed for training and support as well. At one end of the spectrum, "freeware" for generic applications exists and much of it can be found on the Internet at little direct cost to potential users (except telephone charges for downloading material as they may apply in specific countries). At the other end, there is custom-made and/or specialized software. Specialized software, such as those for scientific purposes, is typically very expensive with some packages costing thousands of dollars. Similarly, software in languages other

than English are more difficult to obtain. Countries interested in using computers in other languages may face linguistic hurdles, and thus incur additional costs for translation and new programming. Economies to scale can be realized by centralizing the storage of CD-ROM's and other resources in a library or other place for use by many classrooms or sometimes across schools. Jamaica, for instance, created "Software Centers," within a reasonable distance of several schools. The Software Centers were used for teacher training and as a means of trying out new software before local purchase.

In the United States, experts have recommended that school systems allocated approximately \$100 per student for software (President's Committee of Advisors on Science and Technology 1997). Schools typically fall well short of this figure, although Barbados estimates hit it precisely. Quality Education Data reports that the average school in the United States spent about \$11.00 per student on instructional software in the 1998-1999 school year. Other research in the United States suggests that 10% or less of a school's technology budget is typically spent on software (Melmed et al 1995, and International Data Corporation www.apple.com/education/k12/leadership/LSWTF/IDC1.html). Costs in developing countries for software appear to also fall within this lower range. Table 4 shows the total annualized per school software cost and software costs as a percent of annualized total costs. Per school estimates vary considerably; additional work will need to be done to determine the causes of such dramatic fluctuation.

Table 4: Total Annualized Software Costs

Country	Annualized Per School Cost	% of Total Cost
Barbados	\$56,000	13%
Turkey	1,240	6%
Chile	171	2%
Egypt	749	2%

These software estimates are made of two types of investments: software for instruction and network, server and other administrative software. Instructional software is usually a much greater expense than administrative software. In Barbados, investments in instructional software are expected to account for 9% of total expenditures, where as in Turkey software expenditures appear less than 1%. Turkey continues to investigate the costs of creating specialized software and appears inclined to rely on basic "office packages" and freeware at least in the short-term. Similarly Egypt and Chile software expenses are reported at around 2% of total project costs, or US\$2,000 and \$350 per school, respectively. Chile's program benefited from freeware, most notably "La Plaza" a graphical interface for mail, document storage, and other computer applications (Potashnik 1996).

Budgeters and planners must also keep in mind the need for network software. Although smaller, administrative software costs are not negligible. Estimates for networking software also range considerably, from \$700 per school (Egypt) to \$16,000 per school (Barbados). No specific estimates for networking software were found for other projects.

Facilities Renovation and Connectivity

All of the projects in developing countries reviewed for this paper included funds to connect computers within a school and to connect computers across schools through the Internet. The costs of connectivity rely heavily on three factors: the cost to prepare a building for connectivity, the costs of equipment and installation, and recurrent connectivity charges.

Some of the costs necessary to prepare a building for connectivity would also be necessary for computer projects that did not have connectivity -- such as heating, ventilation and air conditioning as well as security and power requirements. We group them here under one heading because they are often inter-related. "Several studies [in the United States] have projected the cost of building local area networks and wiring classrooms to the Internet to be roughly about \$500 per student per year. However, many factors, including the age of physical plant and previous technology investments, [school size and computer student ratio] will determine the precise figure," (Taking TCO to the Classroom, available at www.cosn.org/tco). Preparing a school for connectivity will often require renovations within a building. A building must have sufficient electrical capacity, from available power to number of outlets, adequate temperature control and ventilation, and security. These costs can often be reduced if they are considered when new buildings are being constructed. There are also a wide range of wireless solutions emerging (discussed in greater detail below), which could further reduce the burden of some wiring costs.

In developing countries, the costs of renovation, also known as retrofitting, varied considerably. Table 5 shows this variability by project.

Table 5: Annualized Costs of Renovation

Country	Annualized Per School Cost	% of Total Cost
Barbados	\$ 85,000	19%
Turkey	985	5%
Chile	350	3%
Egypt	3,100	7%

Equipment costs associated with connectivity depend heavily on the type of connectivity made available to schools. Low-bandwidth connections are generally less expensive but by definition reduce

the capacity of the network and how it can be used. Downloading materials in a slow network can be very costly in staff time. The California Department of Education has produced a document to help planners determine the level and costs of connectivity called "Going Beyond your Local Area Network and available at <http://www.cde.ca.gov/ftpbranch/retdiv/k12/ISDN.html>. In Egypt, connectivity and telecommunications equipment cost an estimated \$4,600, or \$1,200 in annualized costs per school, and 3% of total school costs. In Barbados, where budgeting was done for the entire national project, \$8.8 million was planned for networking equipment, or \$2.3 million in annualized costs, and 8% of total project costs. Although these figures were not reported by school, it appears that about \$34,000 in annualized costs was budgeted per school.

Telephone companies often charge for the use of a telephone line in many countries, even for a local call. Thus schools will be paying two different types of charges: one for the use of a telephone line and another for Internet service provision. Where telecommunications are still operated by monopolies, these prices can be quite steep. The additional cost of the telephone line can dramatically influence total costs. For instance, in Turkey, a single, dedicated telephone line per school is likely to incur charges of \$80 per month, resulting in an estimated \$2,400,000 per year (or 4% of total annualized project costs). The World Links Project in Ghana reports that schools are paying an average of about \$86 a month per school in telephone dial-up charges for the internet in addition to an internet subscription fee of \$100 per school. Planners in contexts such as these must think carefully about how many telephone lines per school are needed and balance cost and performance issues.

Table 6: Annual Costs of Connectivity

Country	Annualized Per School Cost	% of Total Cost
Barbados	\$ 85,000	19%
Turkey	\$ 960	4%
Chile	\$ 1,165	10%
Egypt	\$ 3,000	6%

Strategies to provide low-cost internet access are emerging. Some costs may be mitigated, at least in the short term, during the bidding process. For instance, firms supply free internet service for one year as part of arrangement in Turkey. Further, the major investment necessary for access---country gateways and university nodes---already exists in most countries. For a relatively small additional investment, the benefits of connectivity can be vastly expanded. Michigan State University has designed a low cost, low bandwidth system to provide faculty/grad student access to the Internet, and it is likely to facilitate scholarly exchange and build capacity within the African continent as well as among Americans and African research institutions, teachers and scholars (see Table 6). The first of these systems was installed in November 1999 at the West African Research Center (WARC) in Dakar, Senegal. WARC

serves as a key research base for Americans as well as Senegalese researchers and students. By installing the laboratory and server at WARC, the capacity of Senegalese research institutions and universities is increased and visiting scholars are supported as well. Through a virtual domain at WARC, websites and online databases, journals and archives can be seamlessly mirrored onto machines in the United States that are on the fastest part of the Internet backbone. The sites maintain .sn domains (and are thus identified as Senegalese). This speeds user access to these websites both within West Africa and around the globe, while maintaining domains that are distinct to the West African organizations. Experience suggests that educators are extraordinarily eager for the type of interaction that WARC provides. This laboratory configuration can provide a cost-effective model for providing significant faculty Internet access that can be replicated elsewhere.

Table 7: Low-Cost Internet Connectivity Model

PROJECT DIRECT EQUIPMENT COSTS

(Funding for this project was provided by USIA grants and Michigan State University.)

UNIX server with a MSU-programmed web-based interface **\$ 5,000**

(Using a UNIX system with a web-interface enables remote technical support while permitting local staff to manage the server through an user-friendly web interface that requires minimal training to operate and navigate.)

Total cost of the workstations, laser printer and flatbed scanner **\$10,000**

(Dedicated computer laboratory equipped with five Dell workstations to serve the local academic and research community. Software on the machines will serve a range of email, word processing, data processing and web-creation needs.)

Radio ethernet link from WARC to University of Dakar Campus **\$ 7,500**

(Includes antenna, router and amplifier at both WARC and the local university. At a fraction of the cost required to use a dedicated phone line, the radio transmission system provides high speed, reliable access to the WARC laboratory at a significantly reduced cost.)

TOTAL DIRECT EQUIPMENT COSTS **\$22,500**

Using this model, additional service points at other research centers or institutions in Dakar could be added for around \$3,200 USD

Wireless is also emerging as a viable solution. Wireless systems can be terrestrial, when radio frequencies are used, or by satellite. High-speed data-links can cost less than \$2,000 for a simple point to point connection over a mile or two, and these links can cost less for lower-bandwidth (Jensen 1999). Cost-components of a wireless system include: capital costs, recurring costs, and usage costs. Jensen (1999) offers the comprehensive checklist to "ensure the success of a project including wireless", including:

- How much traffic needs to be transported?

- How reliable does the link have to be?
- Are there any other potential users of the system in the area that can help defray the set-up or operating costs?
- What are the characteristics of the terrain where the equipment is to be used?
- What is the required distance of the link?
- Is a license required?

The answers to these questions have cost implications. (For greater detail see, Jensen (1999) available at <http://www3.sn.apc.org/africa/wireless.doc> and Puetz (1996).

Support and Maintenance

Once computers are installed in schools, users will need regular support, and hardware and software will require regular maintenance. The number of support staff required depends on several factors, including the number of computers, the number of software applications, and the ability of users. Schools and ministries have often been innovative in the way they provide support and maintenance. In Chile, technical support was provided largely by engineering school faculty from a near-by University. Maintenance costs were estimated at 10% of equipment costs, or 9% of the total annualized budget per school. Turkey has included maintenance in its hardware bids. Bidding vendors have budgeted for between 3 and 7% of total hardware costs over a 5 year contract. Similarly, a flat rate of 5% of equipment costs was budgeted for maintenance costs in the Barbados project. No information was available regarding how these funds would be deployed. In Egypt, maintenance costs were anticipated at 4% of total costs, or \$300 per machine per year. Again, no information was available regarding how these funds would be deployed. Jamaica estimated that \$25,220 was spent to maintain computers in 23 schools over two years, or about \$550 per school per year.

Students and their parents also have a role to play in maintaining equipment. PTA's have played a role in successful computer projects around the world. Their role is typically to raise funds for computer up-grades, computer personnel, and supplies. In both Chile and Costa Rica, "parents and other private individuals or locally-based companies have provided telephone lines, air conditioning, and other equipment free of charge to the schools" (Alvarez 1998, p. 9). In addition, students have contributed to basic trouble-shooting and can be trained to participate in the upkeep of computers. "The Chilean computer program has encouraged schools to appoint older students with a special interest in computers as 'monitors' or computer assistants" (Alvarez 1998, p. 15).

Inadequate support costs schools too. A detailed cost analysis was undertaken in Fairfax County, VA. "Fairfax County is a large district in the suburbs of Washington, DC, with 155,000 students and 26,000 employees. It calculated that if every teacher spends at least one hour a week trying to fix their

own computer problems, that equals 307 full-time equivalent positions, at a cost to the district of \$15.3 million in lost teaching time. In addition, if 5 percent of teachers are regarded as 'technical wizards' by their peers, and are asked to provide 1.5 hours a week of informal support, that equals 23 full-time equivalent positions, at a cost of \$1.2 million. Thus, the district concluded that its 'hidden' costs for technical support could amount to an estimated \$16.5 million" (CoSN, <http://www.cosn.org/tco/checklist/support.html>).

Professional Development

Professional development is an essential part of any educational technology project. It is vital for teachers to understand why technology is being adopted and how they can integrate it into their instruction. Professional development activities might also include basic technical skills, discussions of pedagogy, and modeling activities. There is no proven formula for knowing how much training is enough for a technology project. Costs will also vary according to how and when teachers participate in professional development activities. Does the budget include money for travel, per diems, substitutes, trainers and materials? Very often teachers will require a period of free-time to rework the curriculum for the first time when technology becomes available. Is there money available for substitutes to cover teaching periods while teachers design integrated curriculum? Another often overlooked aspect of professional development is the availability of incentives for teachers to adopt new practices. Time and resources should be spent to assure that technology use is incorporated into job descriptions and job assessments.

Computer technology projects in education typically roll out training and professional development in two phases. The first phase usually consists of a project orientation and basic skills training. In the models analyzed here, the term "up front training" is used with this content in mind. On-going training, as it is referred to in the models, is usually weekly, monthly or intermittently, and helps address problems and concerns that teachers engage while working on the project. Chile's Enlaces program, for instance, made training available on Fridays for interested teachers. On-going training often focuses on the more difficult task of integrating curriculum into the mainstream curriculum.

"If there is a single overarching lesson that can be culled from research about teacher professional development and technology, it is that it takes more time and effort than many anticipate" (US Dept of Ed available at www.ed.gov/Technology/Plan/NatTechPlan). And as a result the US Dept of Ed recommends that 30% of technology budgets be set aside for training and development activities. According to the *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*, a 1993 survey of U.S. schools found that "only 15% of the typical computer system budget is in fact devoted to staff instruction (President's Committee of Advisors on Science and Technology

1997, p. 48). Quality Education Data, Inc. estimates that the average U.S. school district spends 6% of its technology budget for teacher training.

Estimates for training in computer projects in developing countries also have considerable variation. Preliminary budgets for training in Turkey allocate just 2% of total project costs, more than 1% for up front training and less than 1% for on-going training. The Barbados documents did not differentiate between types of training and allocates 4% of total costs for this purpose. Of the school based models, Chile allocates approximately 18% and Egypt has planned for 28% of total costs. Part of the reason for this apparent difference in training costs by program is that the Turkey and Barbados estimates include costs for entire system, while the Chile and Egyptian figures focus only on costs at the school level.

Table 8: Annualized Professional Development Costs

Country	Annualized Per School Cost	% of Total Cost
Barbados	18,430	4%
Turkey	535	1%
Chile	1,445	13%
Egypt	13,275	29%

Once teachers have gained some minimum threshold of technology skills, the technical infrastructure can often be used to provide on-going support. Internet-based support includes webpages, databases, and communication spaces available to share curriculum, problems and solutions. Once an infrastructure is in place, webpages can be relatively inexpensive to construct, newsgroups and listserves are near free, and databases can be costly but invaluable administrative tools. Use of the infrastructure for training purposes can improve on-going support by increasing interactivity and timeliness of information while also reducing travel and per diem costs. For these reasons, corporate training on-line is increasingly pervasive, and the approach is of likely utility to education systems with Internet access.

Financing Models

The integration and financing of technology in education, whether it be used in formal or informal settings or for conventional or distance education, cannot be viewed as separate from the main system and be sustainable. Many of the general financial reforms proposed for educational systems in Sub-Saharan Africa are also suitable here. The use of student fees, public/private partnerships,

consortium, and donor relations are explored in this section. The use of technology can both benefit from and encourage the successful implementation of these reforms.

Countries can devise investment strategies that spread costs over time. A project can be phased over several years. In the model suggested here, all schools are to be equipped over a 5 year period, where a total of \$10 million is necessary, and recurrent costs are expected to total \$2.5 million. Thus, 20% of schools might be equipped and trained each year, requiring only a \$2 million investment each year. Similarly the burden of recurrent costs (approximately 45% of the total costs in this example) can be more slowly incurred while institutional capacity is developed. Each year an additional US \$ ½ million would be required to cover recurrent costs, so that in the first year total project costs would be approximately US \$2.5 million, in the second year they would be US\$ 3.0 million and so on until in year 5 when costs would plateau at about \$5 million. After 5 years, all schools will have been equipped. If a revolving fund is established, then school upgrading can begin in year 6.

Establish mechanisms for cost recovery: Funding sources can be diversified in at least four ways: student fees, consortiums, public/private partnerships, and donors.

Student fees. Fees from students, if used in addition rather than to replace government funds could be an important source of revenue for higher education.⁹ A World Bank survey of 15 sub-Saharan African universities found that only half charged user fees, which accounted for a minor portion of their recurrent budgets (World Bank 1995a). However, other work has suggested that fee recovery for student housing and meals is gaining acceptance, at least in Anglophone Africa (Saint, 1992). Use of educational technology and the development of distance education programs can be important catalysts for redesigning the financing schemes of educational institutions and systems.

Build Consortiums. Educational consortiums and similar partnerships allow education institutions to share resources. Where appropriate, sharing development costs and curriculum materials can benefit all participants. Consortiums, as they are now emerging in developed countries, often allow institutions to share students. Where enrollments in a single institution might be too low to offer a particular course, aggregating students across institutions can allow students a wider array of course options while also containing costs. Consortium arrangements need to be carefully arranged to stipulate accreditation, administration, support services to students, and fee collection.

Explore Public/Private Partnerships. Depending on the regulatory frameworks in place in a country there may be at least two goals of effective partnership with the private sector: negotiating resource contracts and income generation through entrepreneurial activity. Telecommunications

⁹ User fees in primary education should probably be avoided because they are often used in place of government funding and can strongly dissuade student attendance (Mehrota 1998).

providers are often willing to subsidize cost of Internet in schools because they view it as a business development opportunity. Even if affordable, enhancements with high unit costs such as intensive computer and internet use may be particularly difficult to sustain in primary school systems, where unit costs are typically at their lowest in the education system. Thus, the high unit costs of a technology project will seem particularly high in comparison. Income generation through entrepreneurial activity might take the form of “contract training” or other customized services to industry. Other entrepreneurial activities include renting facilities or equipment or providing Internet access. As yet there is little information available regarding willingness to pay among Africans for various technological services. It is also unclear to what degree exposure to technology in higher education might stimulate hardware and software markets more generally.

Improved donor collaboration. Policy-makers everywhere need more solid information about models of technology deployment in education and their related costs. Donor collaboration can contribute to deeper understanding of the total costs of learning material projects, greater international awareness of best practices, and possible improvements in the efficiency of financial allocations to education. The apparent paucity of good, comparable data on donor financing of technology projects and their impact suggests a fruitful area for future donor collaboration. Research activities ought to seek answers to three primary questions. What are the investment and recurrent costs associated with the use of learning materials in formal education systems around the world today? How are these costs likely to vary across regions and countries at different stages of development? What do we know about the relative cost-effectiveness of learning materials in particular settings?

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Appendix 1: Effectiveness of Computers in K12 Education

The effect of computer use in education has been studied over the past several decades, yet experts lack agreement on whether or how it measurably improves learning. There are several limitations associated with most existing evaluations of technology projects, and educational interventions more generally. Many technology projects serve multiple objectives and involve multiple reform principles, and few studies isolate the impact of technology specifically and apart from pedagogical, professional development, and administrative reforms. The technologies are changing rapidly; discoveries associated with their appropriate use are also evolving. Many believe the most potent use of computers exist in their ability to support authentic, real-life inquiries by students engaged in multi-disciplinary, project based learning. While the broadly used multiple-choice assessments are generally considered reliable and valid, some suggest that these methods do not capture the benefits of student-centered instruction. Alternative measurements of the effects of "active" education are still considered nascent. Further, evaluations tend to be small-scale and short-term.

In order to determine the impact of computer use, the objectives, project characteristics, student body and subject matter must first be clarified. Computers and related educational technologies can be used in multiple ways throughout a school. Some uses are associated with improved academic performance and school climate, while other uses are not. In general, computers are most effective when they are used to serve clear educational goals (Harrington-Lueker 1997). Further, teachers need to be trained and supported in order to use technology successfully. Becker (1994) found that those teachers who use computers effectively are more likely to be in schools that offer high levels of professional development and have technology coordinators to assist with technical problems.

The earliest uses of computers included "drill and practice" programs (also known as "computer-aided instruction") that repeatedly test a student's factual knowledge. Questions are typically posed within a multiple choice framework. Students receive immediate feedback from the computer, and questions are often posed as a consequence of student performance on prior questions. Computer-aided instruction (CAI) is by far the most studied application of computers (see President's Committee of Advisors on Science and Technology 1997; Kulick 1994; Burns and Bozeman 1981). Research generally supports the following findings. When CAI was used as the sole basis of instruction, results were mixed. However, when CAI is used to supplement traditional instruction with frequent (3 - 4 times a week), short (10 - 20 minute) sessions, it can be more effective than traditional instruction alone. Most studies report positive changes in student attendance and motivation, and many show that CAI reduces the time needed for instruction. Very few studies have explored whether CAI is cost-effective compared to alternative interventions. One of the more commonly cited studies suggests that this type of computer use was not cost-effective compared to other interventions (Levin, Glass and Meister 1984).¹ In this

experiment, peer tutors were the most cost-effective method of improving math scores, although computers were more cost-effective than lengthening the school day or reducing class-size.

Computer applications for teaching and learning have since evolved to include simulations, data collection and management apparatus, and writing tools. While many of these applications can be used to support traditional instructional methodologies, the real excitement in the education field is in the potential for computers to facilitate student-centered, "constructivist" education models.¹ Constructivism is an educational philosophy that asserts children must construct knowledge for themselves in order to acquire deep understanding of principles and concepts. They construct knowledge best through activities that allow them to experience phenomenon first hand. The role of the teacher often changes considerably. Teachers are no longer solely responsible for content delivery, but become more supportive of the child's independent inquiries. For instance, one teacher reports that she would have taught her first grade class about animals by sitting students down and giving them information orally. With computers, she reports directing students to one of five computers, where they ferret out information themselves and then use the computers to write reports and develop presentations (Education Week 1998). However, the full realization of the potential of technology for learning is a complex, large-scale implementation process that involves professional development, administrator commitment, changes in pedagogy, curriculum and assessment as well system-wide strategies for equity and partnerships among education stakeholders (Dede, 1998).

Considerably less empirical research has been published on the effectiveness of constructivist computer applications than on traditional CAI, although a few studies have shown positive, significant results. In the projects in both Chile and Costa Rica, "teachers and principals report that computer use in the schools has had a positive impact on several aspects of student attitudes and behavior. Anecdotal data show that students were more motivated to come to school, more excited about learning and better behaved after the introduction of technology" (Alvarez et al 1998). One longitudinal study of computer's effects on classroom practice "observed profound changes in the nature of instruction, learning, assessment and the school culture itself" (Dwyer 1994). In a school that focused on computer-use specifically to improve test scores, test scores in vocabulary, reading comprehension, language mechanics, math computation, and math concept/application did rise among computer-using students (Memphis Public Schools 1987). Additional evidence suggests that computer applications may hold particular promise for improving math and science instruction.

Computers have been used to center the curriculum on 'authentic' problems that mimic those faced by adults in real-world settings. For example, in one middle school in the United States, teachers use a near-by polluted river to get their students to apply what they are learning in class to real problems in their community. Students document their observations, collect samples and hunt for other specimens.

While none of the students have learned how to solve the differential calculus equations that real scientists would use, by using a software-application called Model-It, "students can circumvent their cognitive limitations and get to the concepts behind the formulas" (Education Week 1998). Other tools for scientific inquiry include "microcomputer-based labs, which consist of probes attached to a computer. The benefits include easier, more accurate measurement, direct linkages between cause and effect, and greater reflection since students have archival records of the measurement for later review.

A growing body of research supports the use of spreadsheets and graphing tools as well as data analysis and statistical tools for educational purposes. Shaughnessy (1992) among others suggests that probability and statistics education ought to rely more heavily on computer simulations, spreadsheets, and use of computers for exploratory analysis. "'The computer's most powerful uses are for making things visual,' says James Kaput a math professor. 'It can make visual abstract processes that are otherwise ineffable'" (Archer 1998). Spreadsheets and graphing tools support student work on realistic applications and can reinforce abstract concepts with visual representations. Students using these applications to study functions, for example, often understand functions better than traditionally instructed students (Fyfe 1995).

In one of a handful of studies that looks at computer use on a national scale, type of computer use in mathematics instruction was correlated with level of mathematical achievement.

There are many anecdotes that suggest computer use can be a highly effective tool for math and science instruction, inquiry based learning, and developing research and writing skills, but the literature is still inconclusive. In the face of this uncertainty, political incentives to be modern and hi-tech have often provided additional impetus, and countries have moved forward on technology initiatives.

The effects of computer use were greater for older children.¹⁰ The study found that eighth graders who used computers mostly for simulations and applications performed better on a standardized math test, while those whose teachers used computers primarily for drill and practice performed worse on average on the test. Moreover, students whose teachers had professional development in computers outperformed students whose teachers did not.

¹⁰ The size of the relationship between professional development and using the computer for higher order thinking skills was larger for eighth-graders (more than a one-third of a grade level increase) than for fourth graders, who only benefited by the equivalent of a few weeks of instruction (ETS 1997).

Appendix 2: Costing Terms and Methodology

Cost analysis is an important tool in identifying opportunities for increasing institutional or systemic efficiency¹¹. There is now an accepted literature detailing standardized cost analysis practices (Jamison, et al 1978; UNESCO 1980; Rumble 1997). Cost analysis relies on the compilation of various types of program variables and related costs. Number of courses, number of students a year, and life of course are essential details. Total cost, average cost and marginal cost are typically reported. These costs are treated as functions, where Total Cost = $TC = TC(N)$ where N = number of students. The Average Cost Function can be represented by: $Average\ Cost = AC(N) = TC(N)/N$. Marginal cost functions indicate the cost of adding an additional student as a function of number of students already participating and can be represented by the function: $Marginal\ Cost = MC(N) = dTC(N)/dN$ (Jamison et al 1978: 28).

Costs are usually categorized as either capital or recurrent and fixed or variable. Capital costs are goods with an expected life of more than one year. Capital costs are “annualized” to determine the cost per year (Jamison et al 1978: 32). Capital cost, C , is multiplied by an annualization factor determined by the following function:

$$a(r,n) = [r(1+r)^n]/[1+r)^n - 1]$$

where $a(r,n)$ is the annualization factor
 r is the social discount rate
 n is the lifetime of capital.

Recurrent costs refer to goods and services consumed immediately (labor, electricity, etc). Fixed costs are not dependent on the scale of the program, and variable costs are directly related to the number of students served. Television production costs are largely fixed, for instance, because they are irrelevant to the number of students that might eventually watch. The structure of costs have important implications for program planners and managers as well as donors. Hypothetically speaking, a program with high capital costs and low recurrent costs is likely to represent an opportunity for donors as well as offer a promising sign for sustainability. Costs can also be identified based on the source of finance and by the nature of inputs (Orivel 1987).

Cost analysis has some practical difficulties. Information on the full range of costs for a program is rarely available. While some data about prices can be found in budgets and expense documents, planning, administrative, and capital costs are frequently overlooked or difficult to determine. Goods and services that are donated by sectors of government or the private sector may also be difficult to determine. The method of incorporating capital and investment costs is not always well understood, creating errors in the analysis. Finally, comparisons of projects across countries carry all of the inherent difficulties of currency conversion and generalizability. Nevertheless, better empirical information on the costs of educational technology projects, particularly those in developing countries, is essential.

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Appendix 3:

Cost Model of Computer/Internet Instruction in 67 Primary Schools in Barbados, 1998* (US\$)

Cost Model of Computer/Internet Instruction in 67 Primary Schools in Barbados, 1998* (US\$)								
Cost Category	Item	Life (Years)	Unit Description	No. of Units	Average Unit Cost	Investment Cost	Annualized or Annual Cost**	%
INVESTMENT**					US\$	US\$	US\$	
Central Management	Project planning	5	Central Ministry	1	11,379,204	11,379,204	3,001,805	10
	Ministry Hardware	(a) 5	Central Ministry	1	729,798	729,798	192,519	1
School Facilities	Civil Works	40	Ave. per school	67	527,300	35,329,102	3,612,733	12
	Air Conditioning	(b) 10	Ave. per school	67	163,800	10,974,611	1,786,067	6
	Uninterrupted Power Supply	10	Ave. per school	67	19,280	1,291,751	210,227	1
	computer furniture	15	Ave. per school	67	7,708	516,443	67,899	0
<i>Subtotal Facilities</i>							5,676,926	19
School Equipment	Server, Hubs, Telecom	5	Project Aggregat	1	8,797,979	8,797,979	2,320,885	8
	Computers	© 5	Total Units	17,874	2,000	35,748,000	9,430,232	31
	Peripherals	5	Per school	67	1,000	67,000	17,674	0
	Contingency	5	5% of Equip.			2,230,649	588,440	2
Software	Network, Server and other	5	Project Aggregat	1	4,154,918	4,154,918	1,096,057	4
	Instructional courseware, database, reference	5	Per school		150,000			
<i>Subtotal Equipment and Software</i>				67		10,050,000	2,651,165	9
						61,048,546	16,104,453	53
Technical Assistance		5	Per Teacher	2,000	1,250	2,500,000	659,494	2
Total Investment						\$ 110,256,852	\$ 23,378,485	77
CURRENT								
Personnel	Technology Coordinator	(d)	Per school	67	1,515		\$ 101,515	0
Maintenance/Upgrade	Hardware, Software, Routine		5% Equip Cost	1	2,230,649		2,230,649	7
Support and Train.	On-going support and trai	(e)	Per School	67	18,428		1,234,644	4
Insurance	All school hardware		Per School	67	32,078		2,149,195	7
Utilities	Annual charge		Per School	67	240		16,080	0
Telecommunication	Telephone Line Charges		Project total	1	545,455		545,455	2
Computer Supplies			Per School	67	4,300		288,100	1
Monit. & Eval.	Regular budget for on-going act.		Per school	67	5,000		335,000	1
Total Current							\$ 6,900,637	23
Total							\$ 30,279,122	100
COST PER STUDENT						Current Cost	Total Annual Cost	
<i>Average school size is 700 students</i>						\$ 147	\$ 646	

Source: Cobbe and Klees 1998.

* Exchange rate used is B\$1.98 = US\$1.00. Estimates do not include costs of a wireless pilot included as project component. Space not costed in this analysis.

Computer renovations estimates include furniture, network cabling, and electrical wiring. It does not include any security measures or air conditioning.

** 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.

(a) Includes purchase and maintenance of internet hardware and for some professional support.

(b) Includes recurrent costs for cooling, which should not be amortized. However, sufficient information to disaggregate this number was not available.

(c) Student per instructional computer is approximately 3 to 1.

(d) A total of \$13,640,000 was budgeted for the 10 year life of the project. This will presumably be a combination of "up front" and "on-going" training and support, although no details were provided in the document. Therefore the sum is divided by 10 and allocated per school as a recurrent expenditure to emphasize the need for on-going support.

¹¹ While important, cost modeling is one of several tools. Cost analysis must go hand in hand with several other analysis as well, such as evaluation of student needs, institutional capacity, and pedagogies.

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Appendix 4:

Cost Model of Computer/Internet Instruction in 2,452 Primary Schools in Turkey, 1999* (US\$)								
Cost Category	Item	Life (Years)	Unit Description	No. of Units	Average Unit Cost	Investment Cost	Annualized or Annual Cost**	%
INVESTMENT**					US\$	US\$	US\$	
Central Management	Project planning and support	5	Central Ministry	1	20,000,000	20,000,000	5,275,950	5
School Facilities	Computer Room Renovation #	15	School	2,452	10,000	24,520,000	3,223,737	3
School Equipment	Server and Hubs	5	Per Lab	2,837	3,700	10,496,900	2,769,056	3
	Student Computers	5	Total Units	42,205	1,100	46,425,500	12,246,930	12
	Instructor/Admin Computer	5	Total Units	5,023	1,100	5,525,300	1,457,560	1
	Peripherals	5	Per school	2,452	1,500	3,678,000	970,247	1
	Telecom Equipment	5	Per school	2,452	1,800	4,413,600	1,164,297	1
	Contingency	5	5% of Equip.			3,526,965	930,404	1
	<i>Subtotal Equipment</i>					<i>74,066,265</i>	<i>19,538,494</i>	<i>19</i>
Software	Authorware, reference, and othe	5	Per Staff Compute	5,023	200	1,004,600	265,011	0
	<i>Subtotal Equipment and Software</i>					<i>149,137,130</i>	<i>39,341,999</i>	<i>38</i>
Training (Upfront)	Series 1 Formator Training	5	Per Teacher	2,000	1250	2,500,000	659,494	1
	Materials Development	5	Program	1	250,000	250,000	65,949	0
	Promoter Training	5	Per Teacher	250	400	100,000	26,380	0
	Series 2 Training	5	Per Teacher	2,500	100	250,000	65,949	0
	<i>Subtotal Training</i>					<i>3,100,000</i>	<i>817,772</i>	<i>1</i>
Total Investment						\$ 196,757,130	\$ 48,659,458	47
CURRENT								
Personnel	Promotor salaries		3 per region	240	\$ 5,600		\$ 1,344,000	1
	Formator salaries		Per Lab	2,452	\$ 5,600		\$ 13,731,200	13
Maintenance/Upgrade	Hardware, Software, Routine		5% Equip Cost	1	3,526,965		3,526,965	3
Support and Train.	On-going support and upgrade		Per Lab	2,452	200		490,400	0
Utilities	Annual charge		Per Lab	2,452	240		588,480	1
Telecommunication	Telephone Line Charges		10 comps per lab	28,370	960		27,235,200	26
	Internet Service Provider		10 comps per lab	28,370	240		6,808,800	7
Computer Supplies			Computer	47,228	10		472,280	0
Monitoring and Eval.	Regular budget for on-going act.		Per school	2,452	\$ 500		1,226,000	1
Total Current							\$ 55,423,325	1
Total							\$ 104,082,783	100
COST PER STUDENT						Current	Total Annual	
<i>(School with 1704525 Students - Averaging 1.5 Hours Computer Contact Per Week</i>						Cost	Cost	
<i>With 2 Students Per Computer. Lab assumed to be used 30 hours per week.)</i>						\$ 33	\$ 61	

* Estimates are for configuration listed. Space not costed in this analysis.
 # Computer renovations estimates include furniture, network cabling, and electrical wiring. It does not include any security measures or air conditioning.
 ** 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.

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Appendix 5:

TABLE 4-5. Cost Model of Computer/Internet Instruction in a Large Secondary School in Egypt, 1998* (US\$)

Cost Category	Item	Life (Years)	Unit Description	No. of Units	Average Unit Cost	Investment Cost	Annualized or Annual Cost**	%
INVESTMENT**					US\$	US\$	US\$	
Facilities	Space#							
	Computer Room Renovation	15	Job	1	3,000	3,000	394	1
	Furniture	10	Set	22	150	3,300	537	1
	Elec., Network, Telecom Wiring	10	Job	1	2,500	2,500	407	1
	Contingency & Other	10	2% of Facil.	1		126	21	0
	Subtotal Facilities					8,926	1,359	3
Equipment	Server, Hub, Network Cards	5	Unit	1	3,500	3,500	923	2
	Student Computers	5	Unit	20	1,600	32,000	8,442	19
	Instructor Computer	5	Unit	1	2,800	2,800	739	2
	Peripherals	5	Set	1	2,000	2,000	528	1
	Air Conditioning	5	Unit	1	500	500	132	0
	Telecom Equipment	5	Computer	22	50	1,100	290	1
	Power Equipment	5	Set	22	300	6,600	1,741	4
	Security (Locks, etc.), Other	10	Computer	22	50	1,100	179	0
	Contingency	5	5% of Equip.	1		2,425	640	1
	Subtotal Equipment					52,025	13,613	30
Softw. Site Licenses	Windows NT Network Softw.	4	Set	1	700	700	221	0
	Educational (unbundled)	5	Set	1	1,000	1,000	264	1
	Other (unbundled)	5	Set	1	1,000	1,000	264	1
Training (Upfront)	Lab Pers., Teachers, Others	7	Person-hours	1,500	9	13,500	2,773	6
	Subtotal Software and Training					16,200	3,521	8
Total Investment						\$ 77,151	\$ 18,493	41
CURRENT								
Personnel	Prorated Technical Support		Share	1	\$ 2,000		\$ 2,000	4
	Lab Teacher Salary		Annual Salary	1	4,200		4,200	9
	Lab Asst + Prorated Managmt		Annual Average	1	3,500		3,500	8
Maintenance	Equipment		Computer	22	75		1,650	4
	Software		Computer	22	30		660	1
	Routine		Year	1	250		250	1
Loss & Theft	Facilities and Equipment		1% Cost	1	610		610	1
Training	Lab Pers., Teachers, Others		Person-hours	1,500	7		10,500	23
Utilities			Computer	22	20		440	1
Telecommunication	Telephone		Year	1	1,100		1,100	2
	Internet Service Provider		Year	1	1,000		1,000	2
Computer Supplies			Computer	22	120		2,640	6
Total Current							\$ 26,550	59
Total							\$ 45,043	100
COST PER STUDENT						Current	Total Annual	
<i>(School with 600 Students - Averaging 2 Hours Computer Contact Per Week</i>						Cost	Cost	
<i>With 2 Students Per Computer. Lab assumed to be used 30 hours per week.)</i>						\$ 44	\$ 75	
			Computer Contact		Number of			
			Hours Per Student		Students			
le	Discount Rate	No. Students in School	Per Week		Per	Lab Hours of		
					Computer	Instruction		
						Per Week		
4-5	10%	600	2.00		2	30		

* Estimates are for configuration listed.

Space not costed in this analysis.

** Long-lived training, facilities and equipment costs are annualized, i.e., presented as average annual costs, using a 0% discount rate and with varying useful lives. Depreciation is included.

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