Affordable Computing for Schools in Developing Countries

A Total Cost of Ownership (TCO) Model for Education Officials

Executive Summary

Education decision-makers face the challenge of equipping young people with the skills necessary to compete in the global economy and need information and tools for formulating effective policy. This white paper discusses key issues related to technology in education and presents several major findings, including:

- Academic research and private-sector investment decisions indicate that computers in schools contribute to improved academic outcomes, boost a nation's economic competitiveness, and attract job-creating economic investments.
- Governments need to consider the entire cost of school computing solutions, rather than merely the initial expenses. A total cost of ownership model takes into account recurrent and hidden costs such as teacher training, support and maintenance, and the cost of replacing hardware over a five-year period.
- Support and training are recurrent costs that constitute two of the three largest costs in the total cost of ownership model. They are greater than hardware costs and much higher than software fees.
- Ultra-low cost computers and Linux-based solutions are relatively equal in cost to traditional hardware and proprietary software solutions because they require higher labor and replacement costs over a five-year period.
- The total cost of ownership for different computer types and software platforms is relatively consistent. Critical success factors, such as IT ecosystems and platform stability and longevity therefore need to be considered in affordable computing decisions.

Introduction

Developing-country education budgets are increasingly strained by greater numbers of young people and rising expectations among students and global markets. Governments face difficult choices on how to allocate scarce resources to advance national goals for social and economic development. Education decision-makers need information and tools that allow them to provide the growing youth population with the skills required to excel in the knowledge economy.

> One of the Millennium Development Goals is achievement of universal primary education by 2015. We must ensure that information and communication technologies are used to help unlock the door to education. **Kofi Annan**, 2005

Computer technology is a common element of most developing-country education plans. The intended outcome of computer integration in schools is typically to improve students' ability to learn and work, support equal access to quality education, and contribute to the nation's economic competitiveness.

Success in realizing these outcomes depends largely on adequate funding and skillful implementation. To effectively allocate resources for computer initiatives, education officials must base their decisions on the total cost of ownership (TCO) of the full range of computing solutions. The TCO model created by Vital Wave Consulting with support from Microsoft Corporation, includes the **initial** cost of acquiring and deploying computer hardware and software, as well as the **recurrent** and **hidden** expenses required to effectively support and utilize the technology over a five-year period.[1]

This white paper is designed to assist education officials in developing countries with planning and executing effective affordable computing initiatives in primary and secondary schools. It reviews the immediate and future benefits of integrating computing solutions into educational institutions and presents a model for assessing the TCO of computers for public schools in developing countries.

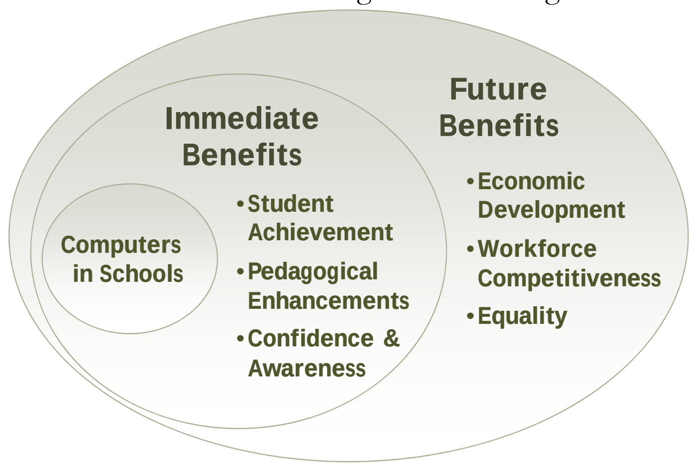
Immediate Benefits of Affordable Computing in Developing Countries

Student Achievement

Students report increased motivation and superior academic achievement as a result of school computing initiatives

World Links, a World Bank-supported program, works with 21 developing countries to promote communication and collaboration between underprivileged schools and helps ministries of education prepare and execute effective information technology (IT) programs. Third-party studies performed on the outcomes of these projects have found that students report higher motivation, attendance and academic achievement as a result of the programs.[2] Student collaboration and global knowledge were also shown to have increased.

A World Bank-sponsored study of computers-in-education programs in Chile and Costa Rica also found enhancements in student learning, technology skills, and self-esteem, as well as benefits for students with special needs. In Egypt, 92% of students who participated in an iEARN Internet-based learning program reported improved English-language skills.[3]



Math and language scores have increased among students with access to computers

In studies of affordable computing initiatives in Mexico and India, investigators compared the performance of students with and without computers on math test scores. In the Mexican case, students with technology tools outscored their counterparts without such access.[4] In the Indian example, pre- and post-test comparisons of a computer-assisted math learning program implemented in 100 municipal primary schools found that the program was correlated with significant increases in math achievement.[5] Another study conducted in low-income and rural areas of India found that students who had free computer access at public kiosks performed better on science and math tests than students without such access.[6]

Pedagogical Enhancements

Teachers report being more motivated, interactive with other teachers and their students

World Links studies also provide evidence that effective computing initiatives lead to improvements in teaching. For example, studies have suggested that effective technology initiatives promote:[7]

- Increased motivation for teachers
- Enhanced teacher-student interactions and adoption of more student-centered approach
- An expanded sense of community among and more opportunities for peer-to-peer training

Harvard University and the World Bank Institute surveyed 126 primarily public secondary schools in eleven developing countries around the world and found that the use of computers is associated with improvements in teacher learning.[8] Teachers and administrators alike reported very positive attitudes toward technology, with 74% of teachers and 95% of administrators noting that the overall impact of computers in their school has been somewhat or extremely positive. The iEARN-Egypt study, in addition to reporting higher student learning outcomes, also found that 88% of teachers felt they had become more effective teachers as a result of participation in the study.

Future Benefits of Affordable Computing in Developing Countries

Economic Development

A tech-literate population is crucial to economic development

The acceleration of globalization in the past decade has given new impetus to national drives to develop the brightest and best-educated workforce possible. As nations endeavor to improve their economies and create high-paying jobs for millions of new labor force entrants, a tech-savvy and well-educated workforce has become a prerequisite for meeting these goals.

Technology education has played an important role in the development of nations such as South Korea, Taiwan, and Israel and aided their emergence as manufacturers and creators of high-tech products and services. The benefits of a large pool of highly-skilled workers can also be seen in China and India. These countries are luring major multinational investments and creating robust local companies such as Huawei and Wipro that generate thousands of jobs. These jobs in turn nurture a growing middle class, produce tax revenues, and deepen the local IT ecosystem. If computer education is not available in schools, many students in developing countries would have no access to technology and weaker employment prospects. Nearly two-thirds of teachers surveyed in a Harvard / World Bank Institute study reported that computer use in schools had positively impacted their students' job opportunities after graduation.[9]

Workforce Competitiveness

Education plays a central role in nations' competitiveness

Affordable computing in schools has the real (and perceived) power to foster the essential skills required to compete in the "knowledge economy" – a frequently stated goal of education administrators. International competition to lure lucrative, multi-billion dollar investments is intense, and a country's educational development plays a prominent role in its efforts to win such prizes. National levels of investment in technology and education figure prominently in indices such as the the *World Knowledge Competitiveness Index* and the *Global Competitiveness Index*.[10] Similarly, the World Bank's *Knowledge Economy Index* uses school Internet access and national information and communication technology (ICT) expenditure as two variables in ranking over 130 nations. Increasing investment in school IT resources can boost a country's standing in these indices, which are widely used by multinational companies to guide investments in manufacturing and market expansion.

IT Education Attracts Investment

In 2006, Intel decided to locate a massive new semiconductor factory (projected to employ 4,000 people by 2012) in Vietnam. Intel chose Vietnam over other Asian countries partly due to the strength of its education curricula and policies. According to Intel Vice President Brian Krzanich, "Once we decided to expand our capacity, [the choice of Vietnam] was driven by a vibrant and well-educated workforce, an improving education infrastructure and a government that is forward-looking." The company even evaluated Vietnam's educational curriculum during its assessment, illustrating the importance of a national educational technology policy to private-sector decision-makers.

Equality

Computers in education may reduce inequalities

High levels of **inequality** are common in developing countries. There are large material discrepancies between schools in well-developed, usually urban areas, and poorer, rural schools which often serve minority populations. Frequently, there is also gender inequity, though many countries have made strides in addressing this issue, particularly in primary education. Several studies support the notion that IT furthers the goal of achieving **Education for All (EFA)**. A broad 2004 study of 385 schools participating in Chile's Enlaces IT initiative showed that, while far more private schools children than public school children have computers at home, 85% of all students, regardless of socioeconomic level or school type, cited school as the most common place to access technology. The report concluded that "the public policy on access to ICTs by integrating them into schools is the mechanism that has permitted equalization [among] Chilean families."[11] Some qualitative studies have concluded that distance education is also a useful, cost-effective means of delivering educational materials and training to rural, underserved areas.

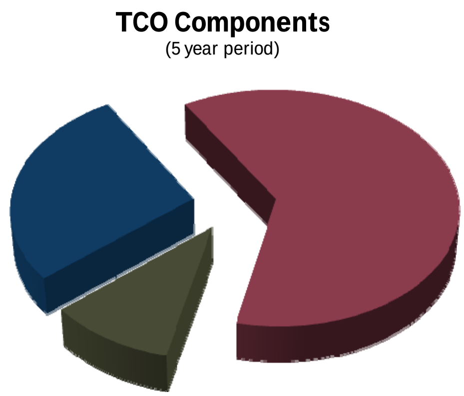
A Total Cost of Ownership Model for Affordable Computing in Education

The quest for a $100 laptop and the subsequent development of low-cost and ultra low-cost computer categories have focused the discussion about computers in the education environment on the initial hardware cost. This focus is misplaced, as the initial hardware investment represents less than 28% of the total cost of ownership over a five-year period. In the case of ultra low-cost computers, the initial hardware investment is only 13% of the five-year TCO.

Figure 1 shows the wide-range of costs and their respective contribution to the total cost of ownership for effective educational computing. These costs are categorized as:

- **Initial costs** – capital costs for acquisition and installation
- **Recurrent costs** – ongoing costs incurred over the lifetime of the equipment
- **Hidden costs** – unanticipated or underestimated one-time charges after the initial purchase

Figure 1 - TCO Components over a 5-year Period



Initial Costs (26%)	Recurrent Costs (61%)	Hidden Costs (13%)
Retrofitting	Support	Replacement hardware
Cabling & wiring	Training	Damage or theft
Software	Connectivity	Planning costs
Hardware	Electricity	End-of-life costs
Deployment	Consumables	
	Subscriptions	

The World Bank notes that there is very little data on the costs of deploying computers in developing-country school contexts.[12] To enable government leaders to make accurate and reliable investment decisions, Vital Wave Consulting has created a five-year **TCO model** that illustrates the true relative costs of hardware, software, teacher training, connectivity, infrastructure, support and maintenance for computers installed in developing-country schools. This model covers multiple:

- *Access scenarios* – shared (Computer Lab) and 1:1 access ("Smart" Classroom)[13]
- *Computer types* – mainstream, low-cost and secondhand desktop computers and ultra low-cost laptops
- *Operating platforms* – Microsoft and Linux

This TCO model was created based on data inputs from developing-country technology and education experts specializing in (or from) countries from a mixture of income levels and geographic regions including: Chile, China, Dominican Republic, Georgia, Ghana, India, Pakistan and South Africa. In addition, numerous third-party studies of developing- and developed-country educational technology implementations were reviewed.[14]

It is important to note that the model only covered the costs of technology and not performance or usability issues.

Reasonable Costs

The TCO Model is based on reasonable costs or the sufficient level of investment required to ensure the operation and effective use of the computer equipment during a five-year period. The costs will therefore include items such as Tier 2 & 3 support and extensive teacher training that may not be commonly seen in the field but were deemed necessary to fully realize the educational outcomes desired from the technology investment.

Initial Costs vs. Recurrent and Hidden Costs

One of the most striking results of this and most other TCO analyses is the extent to which the initial costs associated with a school computer installation represent only about a third of all the costs that will be incurred over a five-year period. While the initial hardware purchase is a very significant cost, teacher training and support are higher, relatively fixed, and recur throughout the five year period. Furthermore, in no instance did the Microsoft software costs exceed 2% of the TCO.[15] This observation holds true across access scenarios, computer types, and operating platforms. Put simply, the total investment required to realize affordable computing and its benefits is substantially higher than the price of acquisition, and **labor-related costs are higher than hardware and software costs**. Moreover, these labor-related costs are tied to the choice of computer type and operating platform in such a way that they may cancel out savings realized in the purchase of low-cost hardware and software.

Support Cost Calculations

Support costs are based on several models observed in developing-country school contexts. For example, Indian government schools typically receive bids for support from local IT firms and public schools in Chile often form support agreements with both IT firms and local universities. In Africa, a contractor or recent computer graduate may provide support on a for-fee or voluntary basis. Informal, student-provided support, which is used in some developed country contexts, was considered but not used due to lower levels of student home computer usage and proficiency, the difficulty of measuring the cost of student time and different cultural norms.

<u>Tier 1 support:</u>

Assume the computer lab or Smart Classroom is supported by a part-time contract lab technician, by the computer teacher, or a local university. If it is a Linux installation, assume that these individuals would be supported by a centralized pool of experts on the specific Linux platform.

<u>Tier 2 & 3 support:</u>

Assume a comprehensive service contract with an IT company that provides on-site maintenance and parts covering everything except natural disasters, intentional misuse and theft.

Training is key

"Teacher training and continued, on-going relevant professional development are essential if benefits from investments in ICTs are to be maximized"[14A]

Teacher training was consistently emphasized as an area in which under-investment was common and had negative impacts on the effectiveness of the technology investments. Training costs are based on the training requirements set out in **UNESCO's ICT Competency Standards for Teachers** (part of the Technology Literacy Approach Curriculum).

Costa Rica's teacher training program is used as a proxy for the Technology Literacy Approach and is used as the basis for the teacher training levels in the TCO model. Under the Costa Rican model, the core team receives three weeks of initial face-to-face training with approximately 120 additional hours of online training. Costa Rica provides approximately 15-40 hours of training per year for non-core team teachers.

Computer type

A variety of computer types were analyzed to create the TCO model. The price of these computers ranges from under US$300 per unit for ultra low-cost laptops and secondhand desktops to US$500 and above for mainstream and low-cost desktop computers. Despite the range of acquisition costs, the TCO per seat is comparable for each computer type. Also, two of the three largest costs – training and support – are remarkably consistent. The TCO for low-cost desktop PCs is lower than secondhand PCs, and only slightly higher than that of ultra-low cost computers, despite a per-unit price that is almost twice as high. This is due to the hidden cost of replacement for secondhand and ultra-low cost computers, which have a shorter lifecycle than mainstream or low-cost desktop computers. Teacher training and Tier 1 support are among the top three costs for all computers, reinforcing the importance of labor-related costs in a TCO analysis. Table A compares the key components of the TCOs for the four computer types analyzed in this study.

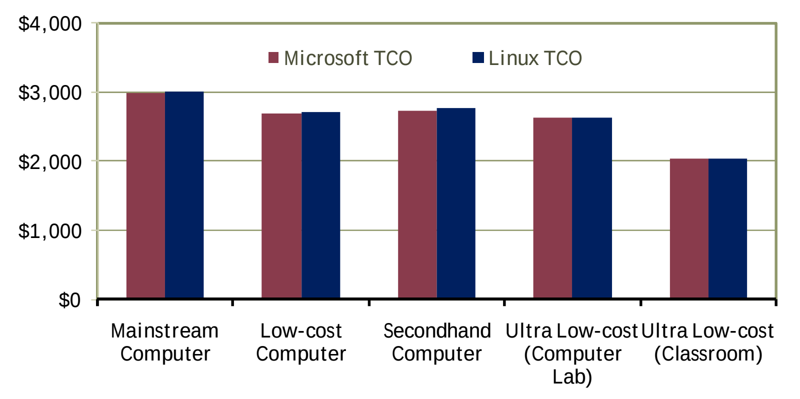
Table A - TCO Comparison for Various Computer Types

Environment	Computer Lab (16 computers) Secondary School -Urban Area - Microsoft Platform				
Device Type	Mainstream Computer	Low-cost Computer	Secondhand Computer	Ultra Low-cost	
Price per computer	$750	$500	$254	$285	
Lifespan of the computers	5 years	5 years	3 years	3 years	
Total TCO	$47,885	$43,053	$43,721	$41,992	
TCO per seat	$2,993	$2,691	$2,733	$2,625	Relatively Equal
Initial costs					
Computers (16)	$12,000	$8,000	$4,064	$4,560	
Other hardware, software, wiring and retrofitting costs	$5,351	$5,351	$5,031	$4,028	
Recurrent costs					
Teacher training	$10,620	$10,620	$10,620	$10,620	Major costs constant across computer types
Support (Tier 1)	$10,920	$10,920	$10,920	$10,920	
Support (Tier 2 & 3)	$3,024	$2,432	$1,904	$1,904	
Connectivity, electricity, subscriptions and consumables	$3,281	$5,351	$5,031	$4,028	
Hidden costs					
Computer Repurchase	$0	$0	$4,276	$4,688	Initial cost advantage negated
Damage/Theft, planning, downtime and end-of life costs	2,690	$2,640	$2,794	$2,256	
Differentiators	Higher initial costs partially counteracted by five year lifespan and lower hidden costs	Five year lifespan results in lower hidden costs	Increased support costs due to older equipment, replacement hardware in year four	Increased support costs due to integrated laptop computer, replacement hardware in year four	

Operating Platform

While the idea of avoiding software licensing fees appeals to policy-makers, this TCO model reveals that, in developing-country public schools, the TCO is relatively equal regardless of whether a Linux or Microsoft platform is chosen (see Figure 2). Here again, the importance of labor-related costs becomes apparent. The cost of retaining Linux-trained professionals exceeds that of hiring people with Microsoft skills (see box below). Since support and training costs are such a large percentage of overall TCO, these higher costs, along with higher planning and deployment expenses, cancel out the savings realized by avoiding licensing fees. It is important to note that even though several of the most common distributions of Linux such as Red Hat, charge subscription fees, these were not assumed in the model.

Figure 2 - Microsoft TCO Compared to Linux TCO (per seat)



The Linux Premium: Skills Shortage Raises Operating Costs

Trained IT professionals are scarce in many developing countries. This is especially true for IT professionals trained on the Linux operating system. This scarcity often translates into higher salaries. Data on the costs of hiring Linux- and Microsoft-trained professionals indicate that in both developed country and developing-country contexts, Linux-trained professionals command higher salaries. Salary surveys conducted in the U.S., Britain, and Australia by payscale.com and IT Jobs Watch show that Linux-certified professionals earn 10-20% more than their Microsoft counterparts. The Red Hat India website even promotes the fact that Red Hat-certified professionals earn up to 30% more than their Microsoft certified professional peers.[16]

The International Telecommunications Union and UNESCO note that the shortage of Linux-trained professionals and/or familiarity with Linux tools and developing environments is inhibiting or delaying the productive use of Linux in these countries.[17] Although evidence is more anecdotal, the salary gap in developing countries appears to be similar, if not higher, that that in developed countries.

Examples: according to a headhunter at a leading Chinese recruitment firm, a senior developer at a major foreign software firm, and the head of a medium-sized Chinese software firm (approximately 50 staff), salaries for Linux IT professionals are from 30% (systems administrators) to 43% (software developers) higher than salaries for Microsoft IT professionals in the same categories. Linux-experts in South Africa estimate that the differential between Linux and Microsoft IT professionals is closer to 10-20%, with Linux professionals earning the premium salaries. A global staffing firm and a high-tech company with affiliates in India as well as a local IT firm that provides maintenance for school labs estimate that Linux IT professionals in India earn up to double their Microsoft Certified Engineer peers. A major staffing firm in Pakistan provided survey data that found that Linux IT professionals with three years of experience earn 12.5% more than Microsoft professionals with the same number of years of experience.

Access Scenarios (Shared and 1:1 Access)

Some countries have begun to experiment with "smart" classrooms, in which each student uses a computer (likely an ultra-low-cost laptop for cost and mobility considerations) for learning subject-specific material or for general IT education. Data from this TCO analysis indicate that while the one-to-one smart classroom scenario does allow decision-makers to reap some economies of scale on fixed costs due to the higher number of units purchased (resulting in a lower TCO *per seat*), the overall TCO is higher than that of a computer lab with the same type of computer (ultra low-cost laptops) given the increase in variable costs. The low purchase price of the computers in the one-to-one scenario is countered by the hidden cost of replacing ultra-low cost computers with a shorter lifecycle (Figures 3 and Table B).

Figure 3 - Cost Components for the Computer Lab and Smart Classroom

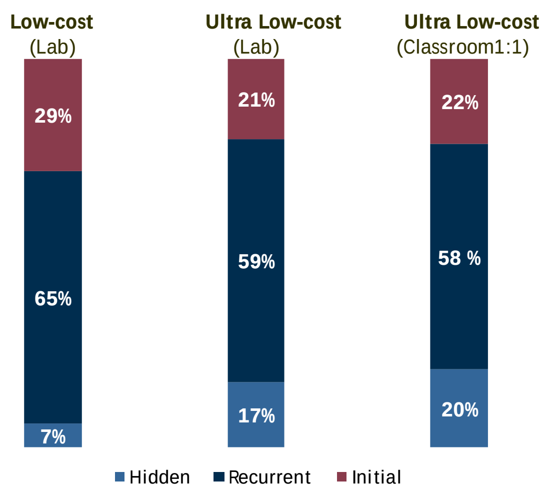


Table B - Five-year TCO Computer Lab and Smart Classroom

5 year TCO	Low-cost Computer (Lab)	Ultra Low-cost Computer (Lab)	Ultra low-cost Computer (Classroom)
TCO – Total	$43,053	$41,992	$41,992
# of seats	16	16	32
TCO per seat	$2,691	$2,625	$2,048

TCO Variation by Context and Geography

The cost inputs in this TCO model are based on values from urban areas of selected developing countries. However, context and geography can cause the TCO to change drastically. Moving to a rural environment, for example, increases transport expenses for support staff and teachers who travel to training centers, and may require back-up or alternative power sources.

Cost differentials between rural and urban areas are highly dependent on a country's infrastructure and geography. Small countries with good roads and many urban centers will see a smaller premium associated with rural installations than countries with few cities, difficult terrain, and poor infrastructure. Table C (based on computer labs with mainstream desktops) shows how rural and urban areas have different costs for school computers.

Table C - Rural versus Urban Costs

5 year TCO	Rural environment	Urban environment
Back-up power supply	$2,600	$1,262
Transportation	$739	0
Connectivity	$3,600	$2,100
Support	$3,326	$3,024
Downtime	$420	$245

Electricity and connectivity are two other areas where dramatically higher local costs could have a large impact on TCO. While electricity usage is a relatively small portion of the 5-year TCO for the conditions assumed in this study, power considerations can be critical in developing-country scenarios where electricity prices and availability are volatile. A school with electricity costs of US$0.80 per kilowatt hour, which is ten times higher[18] than this study's assumed price of US$0.08 per kilowatt hour, would have electricity costs of nearly US$4,000 over a five-year period. This would put electricity costs into the top cost categories, being nearly equal to the initial purchase price of the 16 ultra low-cost computers (US$ 4,560). Similarly, in areas that rely on satellites to provide Internet connectivity, Internet access costs can total up to US$60,000 over five years, more than doubling the TCO in all scenarios.

Where to Invest

Governments tend to concentrate their technology investments in universities, vocational and secondary schools. This is a logical and sound approach as these institutions serve the students closest to the job market where basic computer literacy is increasingly a pre-requisite for employment. UNESCO even notes that it may be unrealistic to deploy computers in primary schools, purely from a cost perspective.[18A]

Cost differentials for primary schools (secondary schools were the baseline used in the study) were relatively minor. A greater amount of training may be required for primary school teachers that could raise costs in that area (although since a relatively robust level of training was assumed in the secondary school model, the amount of training was not increased for primary schools), but this would be offset by lower salaries for these teachers. With costs differentials fairly small, the discussion around education level centers around the return on investment. Governments wanting to maximize the impact of computing initiatives should consider that investments in secondary schools are likely to have a more immediate impact on a country's workforce than investments in primary school students.

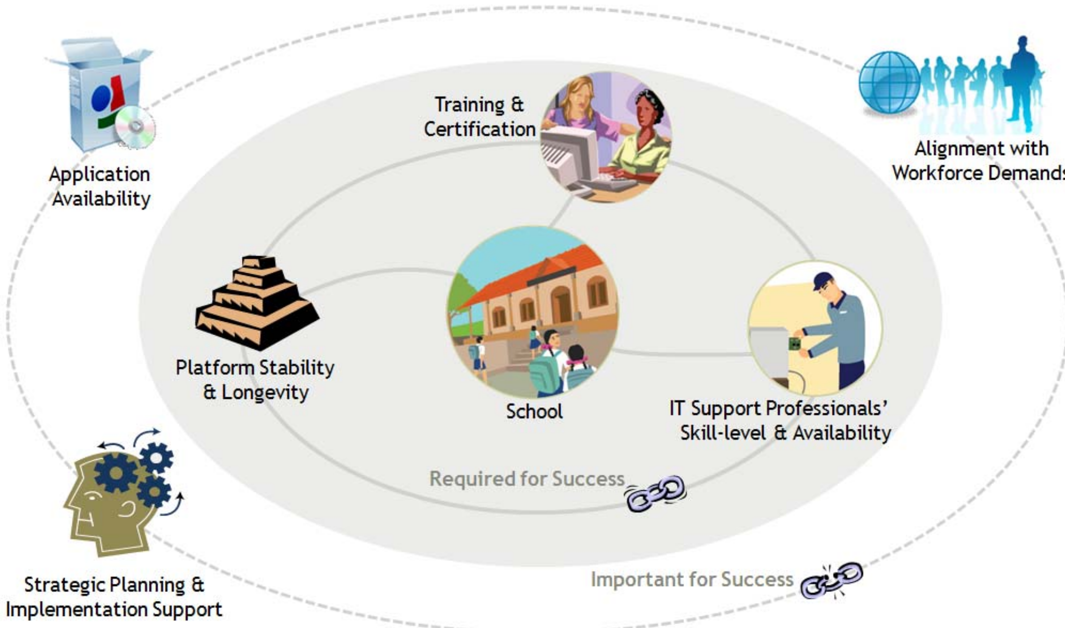
Critical Success Factors

Because the TCO across computer types and software platforms is relatively similar, decision-makers should also take into account critical success factors that could potentially affect the costs and effectiveness of their affordable computing initiatives. School computing programs are part of a larger IT ecosystem, therefore adequate human and technological resources to support the program are critical. When choosing an operating platform, the state of the IT ecosystem in which installations will occur is a consideration of great importance.

Factors Required for Success

Several factors are essential to a successful affordable computing solution. The existence of a sufficient pool of skilled IT professionals, adequate training and certification resources, and a stable and durable platform are elements without which any installation risks failure. Skilled professionals are an especially crucial area. Decision-makers must consider whether they will be able to find local individuals to service and support the platform they choose. School installations have failed or been forced to migrate to more widely-used platforms due to an inability to find and retain such people. Training and certification resources are another vital ingredient for success. Since training is such a major part of the planning and implementation of successful school computing programs, leveraging established, large-scale training programs with a long track record of success in preparing teachers to integrate technology in teaching is key to ensuring long-term success. Finally, choosing an operating platform assured of being supported and maintained for the life of an installation provides peace of mind and security for long-term technology in education planning. Figure 4 outlines the essential ecosystem components that will impact the success and sustainability of affordable computing initiatives in schools in developing countries.

Figure 4: The Ecosystem Impact in Affordable Computing



Factors Important for Success

Other aspects of the IT ecosystem in a particular country have a less obvious but still important impact on the success of affordable computing programs. The presence of a large network of **software application providers** creating content compatible with a school's operating platform allows teachers to engage and stimulate children and build support among families and communities for further initiatives. **Community and societal support** is further strengthened by programs that produce graduates with the skills needed to find high-paying jobs, a goal that may be advanced by choosing platforms and computers that align with the demands of the global marketplace. Lastly, choosing technology partners with **experience in large-scale school computing implementations** is likely to minimize the risk of disruptions or failures that might weaken efforts to expand computing initiatives. This experience can also translate into more efficient and cost-effective support, training, and technical assistance.

Content

Teachers in many developing countries note that the "lack of relevant content in my language" is a major challenge to using computers for teaching.[18B] Education officials recognize the importance of relevant educational content, but there is no standard educational software used by schools globally and investments range dramatically. The cost of purchasing or creating content is therefore not reflected in the TCO model. Education officials that intend to develop customized materials or purchase special software should do a careful cost analysis to determine the budgetary impact of these activities.

Conclusion

Around the world, education policy-makers are confronted with difficult choices on how to allocate resources, maximize their returns on investment, and meet long-term social and economic goals. When making the decision to invest in technology in schools, they need information and tools that will give them a clear picture of the true costs involved. The TCO model presented in this report shows that, in developing-country schools, the TCO remains fairly consistent across computer types and operating platforms. This key finding demonstrates the need for decision-makers to look beyond costs to the ecosystem factors that will be critical to the success or failure of school computing initiatives.

This TCO model is a tool to assist with resource allocation and facilitate informed decision-making. The TCO for a particular country, school district or academic institution can be gained by determining the actual direct and indirect costs in that environment. With a true calculation of the TCO for computers and a clearer perspective on the other factors that impact computing initiatives, education officials can better allocate resources to fit their nations' economic and social development goals.

Appendix A – TCO Model Calculations

This table provides the total five-year TCO calculations for mainstream computers in a computer lab in an urban and rural secondary school for both Microsoft and Linux platforms. All costs in US$.

Total Cost of Ownership Model, 5 year period, Computer Lab: 16 computers, Smart Classroom: 32 computers	Computer Lab - Secondary School				Computer Lab - Secondary School			
	Rural Area				Urban Area			
	Mainstream Computer				Mainstream Computer			
	Microsoft OS		Linux OS		Microsoft OS		Linux OS	
	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO
Form factor	Desktop Computer				Desktop Computer			
Initial Costs								
Total Retrofitting, Wiring and Infrastructure Costs	$2,100	4.10%	$2,100	4.07%	$2,100	4.39%	$2,100	4.36%
Total Hardware Costs	$14,775	28.84%	$14,775	28.63%	$13,562	28.32%	$13,562	28.13%
Total Transportation costs	$739	1.44%	$739	1.43%	$0	0.00%	$0	0.00%
Total Network Cabling Costs	$865	1.69%	$865	1.68%	$865	1.81%	$865	1.79%
Total Deployment Costs	$141	0.27%	$153	0.30%	$128	0.27%	$139	0.29%
Total Software - OS and Productivity Suite Costs	$600	1.17%	$0	0.00%	$600	1.25%	$0	0.00%
Total Software - Anti-virus Costs	$96	0.19%	$0	0.00%	$96	0.20%	$0	0.00%
TOTAL INITIAL COSTS	$19,316	37.70%	$18,632	36.11%	$17,351	36.23%	$16,666	34.56%
Recurrent costs								
Total Training Costs	$9,880	19.28%	$10,035	19.45%	$10,620	22.18%	$10,775	22.35%
Total Internet Costs	$3,600	7.03%	$3,600	6.98%	$2,100	4.39%	$2,100	4.36%
Total Electricity Costs	$392	0.76%	$392	0.76%	$392	0.82%	$392	0.81%
Total Subscriptions Costs	$384	0.75%	$0	0.00%	$384	0.80%	$0	0.00%
Total Service (Tier 2 and 3 support) Costs	$3,326	6.49%	$3,617	7.01%	$3,024	6.32%	$3,281	6.80%
Total Tier 1 Support Costs	$10,920	21.31%	$11,848	22.96%	$10,920	22.80%	$11,848	24.57%
Total Consumables Costs	$405	0.79%	$405	0.78%	$405	0.85%	$405	0.84%
TOTAL RECURRENT COSTS	$28,907	56.42%	$29,897	57.94%	$27,845	58.15%	$28,801	59.73%
Hidden								
Total Keyboard/Mouse Replacement Costs	$400	0.78%	$400	0.78%	$400	0.84%	$400	0.83%
Total Replacement Computers Repurchase & Deployment Costs	$0	0.00%	$0	0.00%	$0	0.00%	$0	0.00%
Total Informal Support & Downtime Costs	$1,245	2.43%	$1,245	2.41%	$1,120	2.34%	$1,120	2.32%
Total Theft or Damage Losses Costs	$750	1.46%	$750	1.45%	$750	1.57%	$750	1.56%
Total UPS replacement battery pack Costs	$600	1.17%	$600	1.16%	$400	0.84%	$400	0.83%
Total End-of-Life Costs	-$459	-0.90%	-$447	-0.87%	-$459	-0.96%	-$447	-0.93%
Total Plannning Costs	$479	0.93%	$527	1.02%	$479	1.00%	$527	1.09%
TOTAL HIDDEN COSTS	$3,015	5.88%	$3,075	5.96%	$2,690	5.62%	$2,750	5.70%
Total TCO	**$51,237**	100.00%	**$51,603**	100.00%	**$47,885**	100.00%	**$48,216**	100.00%
TCO per seat	**$3,202**		**$3,225**		**$2,993**		**$3,014**	

This table provides the total five-year TCO calculations for low-cost and secondhand computers in a computer lab in an urban secondary school for both Microsoft and Linux platforms. All costs in US$.

Total Cost of Ownership Model, 5 year period, Computer Lab: 16 computers, Smart Classroom: 32 computers	Computer Lab - Secondary School				Computer Lab - Secondary School			
	Urban Area				Urban Area			
	Low-cost Computer				Secondhand Computer			
	Microsoft OS		Linux OS		Microsoft OS		Linux OS	
	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO
Form factor	Desktop Computer				Desktop Computer			
Initial Costs								
Total Retrofitting, Wiring and Infrastructure Costs	*$2,100*	4.88%	*$2,100*	4.85%	*$2,100*	4.80%	*$2,100*	4.75%
Total Hardware Costs	*$9,562*	22.21%	*$9,562*	22.07%	*$5,630*	12.88%	*$5,630*	12.73%
Total Transportation costs	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%
Total Network Cabling Costs	*$865*	2.01%	*$865*	2.00%	*$865*	1.98%	*$865*	1.96%
Total Deployment Costs	*$128*	0.30%	*$139*	0.32%	*$128*	0.29%	*$139*	0.31%
Total Software - OS and Productivity Suite Costs	*$600*	*1.39%*	*$0*	*0.00%*	*$280*	*0.64%*	*$0*	*0.00%*
Total Software - Anti-virus Costs	*$96*	*0.22%*	*$0*	*0.00%*	*$96*	*0.22%*	*$0*	*0.00%*
TOTAL INITIAL COSTS	*$13,351*	*31.01%*	*$12,666*	*29.23%*	*$9,099*	*20.81%*	*$8,734*	*19.75%*
Recurrent costs								
Total Training Costs	*$10,620*	24.67%	*$10,775*	24.87%	*$10,620*	24.29%	*$10,775*	24.36%
Total Internet Costs	*$2,100*	4.88%	*$2,100*	4.85%	*$2,100*	4.80%	*$2,100*	4.75%
Total Electricity Costs	*$202*	0.47%	*$202*	0.47%	*$1,219*	2.79%	*$1,219*	2.76%
Total Subscriptions Costs	*$384*	0.89%	*$0*	0.00%	*$384*	0.88%	*$0*	0.00%
Total Service (Tier 2 and 3 support) Costs	*$2,432*	5.65%	*$2,639*	6.09%	*$1,904*	4.35%	*$2,066*	4.67%
Total Tier 1 Support Costs	*$10,920*	25.36%	*$11,848*	27.34%	*$10,920*	24.98%	*$11,848*	26.79%
Total Consumables Costs	*$405*	0.94%	*$405*	0.93%	*$405*	0.93%	*$405*	0.92%
TOTAL RECURRENT COSTS	*$27,063*	62.86%	*$27,969*	64.54%	*$27,552*	63.02%	*$28,413*	64.24%
Hidden								
Total Keyboard/Mouse Replacement Costs	*$400*	0.93%	*$400*	0.92%	*$164*	0.38%	*$164*	0.37%
Total Replacement Computers Repurchase & Deployment Costs	*$0*	0.00%	*$0*	0.00%	*$4,276*	9.78%	*$4,207*	9.51%
Total Informal Support & Downtime Costs	*$1,120*	2.60%	*$1,120*	2.58%	*$1,120*	2.56%	*$1,120*	2.53%
Total Theft or Damage Losses Costs	*$500*	1.16%	*$500*	1.15%	*$254*	0.58%	*$254*	0.57%
Total UPS replacement battery pack Costs	*$400*	0.93%	*$400*	0.92%	*$400*	0.91%	*$400*	0.90%
Total End-of-Life Costs	*-$259*	-0.60%	*-$247*	-0.57%	*$282*	0.64%	*$306*	0.69%
Total Plannning Costs	$479	1.11%	$527	1.22%	$575	1.31%	$632	1.43%
TOTAL HIDDEN COSTS	*$2,640*	6.13%	*$2,700*	6.23%	*$7,070*	16.17%	*$7,083*	16.01%
Total TCO	**$43,053**	100.00%	**$43,334**	100.00%	**$43,721**	100.00%	**$44,229**	100.00%
TCO per seat	**$2,691**		**$2,708**		**$2,733**		**$2,764**	

This table provides the total five-year TCO calculations for ultra low-cost computers in a computer lab and smart classroom in an urban secondary school for both Microsoft and Linux platforms. All costs in US$.

Total Cost of Ownership Model, 5 year period, Computer Lab: 16 computers, Smart Classroom: 32 computers	Computer Lab - Secondary School				Smart Classrooom 1:1 Scenario, Secondary			
	Urban Area				Urban Area			
	Ultra Low-cost Computer				Ultra Low-cost Computer			
	Microsoft OS		Linux OS		Microsoft OS		Linux OS	
	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO
Form factor	Subnotebook Computer				Subnotebook Computer			
Initial Costs								
Total Retrofitting, Wiring and Infrastructure Costs	*$2,100*	5.00%	*$2,100*	4.97%	*$1,398*	2.13%	*$1,398*	2.14%
Total Hardware Costs	*$5,491*	13.08%	*$5,491*	12.99%	*$11,397*	17.39%	*$11,397*	17.46%
Total Transportation costs	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%
Total Network Cabling Costs	*$173*	0.41%	*$173*	0.41%	*$173*	0.26%	*$173*	0.26%
Total Deployment Costs	*$128*	0.30%	*$139*	0.33%	*$192*	0.29%	*$208*	0.32%
Total Software - OS and Productivity Suite Costs	*$600*	*1.43%*	*$0*	*0.00%*	*$1,200*	*1.83%*	*$0*	*0.00%*
Total Software - Anti-virus Costs	*$96*	*0.23%*	*$0*	*0.00%*	*$192*	*0.29%*	*$0*	*0.00%*
TOTAL INITIAL COSTS	*$8,588*	*20.45%*	*$7,903*	*18.70%*	*$14,552*	*22.21%*	*$13,176*	*20.18%*
Recurrent costs								
Total Training Costs	*$10,620*	25.29%	*$10,775*	25.49%	*$15,850*	24.19%	*$16,000*	24.51%
Total Internet Costs	*$2,100*	5.00%	*$2,100*	4.97%	*$2,100*	3.20%	*$2,100*	3.22%
Total Electricity Costs	*$127*	0.30%	*$127*	0.30%	*$231*	0.35%	*$231*	0.35%
Total Subscriptions Costs	*$384*	0.91%	*$0*	0.00%	*$768*	1.17%	*$0*	0.00%
Total Service (Tier 2 and 3 support) Costs	*$1,904*	4.53%	*$2,066*	4.89%	*$2,792*	4.26%	*$3,029*	4.64%
Total Tier 1 Support Costs	*$10,920*	26.00%	*$11,848*	28.03%	*$16,380*	25.00%	*$17,772*	27.22%
Total Consumables Costs	*$405*	0.96%	*$405*	0.96%	*$405*	0.62%	*$405*	0.62%
TOTAL RECURRENT COSTS	*$26,460*	63.01%	*$27,321*	64.64%	*$38,526*	58.80%	*$39,537*	60.56%
Hidden								
Total Keyboard/Mouse Replacement Costs	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%	*$0*	0.00%
Total Replacement Computers Repurchase & Deployment Costs	*$4,688*	11.16%	*$4,699*	11.12%	*$10,027*	15.30%	*$10,043*	15.38%
Total Informal Support & Downtime Costs	*$1,120*	2.67%	*$1,120*	2.65%	*$1,120*	1.71%	*$1,120*	1.72%
Total Theft or Damage Losses Costs	*$570*	1.36%	*$570*	1.35%	*$855*	1.30%	*$855*	1.31%
Total UPS replacement battery pack Costs	*$200*	0.48%	*$200*	0.47%	*$400*	0.61%	*$400*	0.61%
Total End-of-Life Costs	*-$266*	-0.63%	*-$242*	-0.57%	*-$617*	-0.94%	*-$569*	-0.87%
Total Plannning Costs	$632	1.51%	$695	1.65%	$661	1.01%	$727	1.11%
TOTAL HIDDEN COSTS	*$6,944*	16.54%	*$7,043*	16.66%	*$12,446*	18.99%	*$12,576*	19.26%
Total TCO	**$41,992**	100.00%	**$42,266**	100.00%	**$65,523**	100.00%	**$65,290**	100.00%
TCO per seat	**$2,625**		**$2,642**		*$2,048*		*$2,040*	

This table provides the total five-year TCO calculations for mainstream computers in a computer lab in an urban primary school for both Microsoft and Linux platforms. The main distinction between the TCO for primary and secondary schools are teacher's salaries, which are assumed to be US$7 per hour in secondary schools and US$6 per hour in primary schools. All costs in US$.

Total Cost of Ownership Model, 5 year period, Computer Lab: 16 computers, Smart Classroom: 32 computers	Computer Lab - Primary School			
	Urban Area			
	Mainstreatm Computer			
	Microsoft OS		Linux OS	
	5 Yr TCO	% cost to TCO	5 Yr TCO	% cost to TCO
Form factor	Desktop Computer			
Initial Costs				
Total Retrofitting, Wiring and Infrastructure Costs	*$2,100*	4.41%	*$2,100*	4.38%
Total Hardware Costs	*$13,562*	28.48%	*$13,562*	28.28%
Total Transportation costs	*$0*	0.00%	*$0*	0.00%
Total Network Cabling Costs	*$865*	1.82%	*$865*	1.80%
Total Deployment Costs	*$128*	0.27%	*$139*	0.29%
Total Software - OS and Productivity Suite Costs	*$600*	*1.26%*	*$0*	*0.00%*
Total Software - Anti-virus Costs	*$96*	*0.20%*	*$0*	*0.00%*
TOTAL INITIAL COSTS	*$17,351*	*36.44%*	*$16,666*	*34.76%*
Recurrent costs				
Total Training Costs	*$10,480*	22.01%	*$10,635*	22.18%
Total Internet Costs	*$2,100*	4.41%	*$2,100*	4.38%
Total Electricity Costs	*$392*	0.82%	*$392*	0.82%
Total Subscriptions Costs	*$384*	0.81%	*$0*	0.00%
Total Service (Tier 2 and 3 support) Costs	*$3,024*	6.35%	*$3,281*	6.84%
Total Tier 1 Support Costs	*$10,920*	22.93%	*$11,848*	24.71%
Total Consumables Costs	*$405*	0.85%	*$405*	0.84%
TOTAL RECURRENT COSTS	*$27,705*	58.18%	*$28,661*	59.77%
Hidden				
Total Keyboard/Mouse Replacement Costs	*$400*	0.84%	*$400*	0.83%
Total Replacement Computers Repurchase & Deployment Costs	*$0*	0.00%	*$0*	0.00%
Total Informal Support & Downtime Costs	*$995*	2.09%	*$995*	2.08%
Total Theft or Damage Losses Costs	*$750*	1.57%	*$750*	1.56%
Total UPS replacement battery pack Costs	*$400*	0.84%	*$400*	0.83%
Total End-of-Life Costs	*-$459*	-0.96%	*-$447*	-0.93%
Total Plannning Costs	$479	1.01%	$527	1.10%
TOTAL HIDDEN COSTS	*$2,565*	5.39%	*$2,625*	5.47%
Total TCO	**$47,620**	100.00%	**$47,951**	100.00%
TCO per seat	**$2,976**		**$2,997**	

Appendix B – TCO Computer Hardware Configurations Used in the Model

This table outlines the computer hardware configurations used in the TCO model as well as the sources for these configurations.

Usage Scenario	COMPUTER LAB SCENARIO				Smart Classroom, 1:1 Scenario	
Computing Device	Mainstream Computer	Secondhand (used) Computer	Low-cost Computer	Ultra low-cost Computer	Ultra low-cost Computer	
	Client & PC Server	Client	Client & PC Server	Client and Laptop Server	Client	Server (and student/teacher's
Price per seat*	750	254.25	500	285	285	1000
Form Factor	desktop	desktop	desktop	mini laptop	mini laptop	full-sized laptop
Performance						
Processor Type	Intel Pentium Dual Core E2XXX	Pentium 4	Intel Pentium Dual Core E2xxx	x86 <1G	x86 <1G	Intel Pentium Dual Core E2xxx
RAM	2 GB	512 MB	1GB	512 MB	512 MB	2 GB
Capacity						
Primary Storage	320 GB HDD	40-80 GB HDD	320 GB HDD	2G flash	2G flash	64 GB HDD
Flexibility						
Peripheral Ports	6	5	6	2	2	3-5
Video Ports	1	1	1	0	1	2
Card Slots	3	0	3	0	0	1
Multimedia						
Display	19"	17" VGA (refurbished)	19"	7" LCD	7" LCD	13.3" LCD
Camera	none	no	none	low resolution	low resolution	low resolution
DVD/CD-RW	yes	y	yes	no	no	yes
Networking						
Networking	Ethernet	Ethernet	Ethernet	Wireless Mesh networking enabled	Wireless Mesh networking enabled	Ethernet
Input Devices						
keyboard	full keyboard	full keyboard (refurbished)	full keyboard	typical ultra-portable laptop keyboard	typical ultra-portable laptop keyboard	typical laptop keyboard
touchpad/mouse	optical mouse	standard PS/2 (refurbished)	optical mouse	Touchpad and cursor control keys	Touchpad and cursor control keys	not included
Misc.						
Weight	20 lbs	» 20 lbs	20 lbs	3 lbs	3 lbs	3.97 lbs
Number of seats	16	16	16	16	32	32
data source	Derived from an analysis of recent government tenders for computers for primary and secondary schools from countries in Eastern Europe, Asia, Latin America	Based on input from refurbished computer configurations from South Africa and Latin America	Vital Wave Consulting Global Low-cost Computing Scan, January 2008	Vital Wave Consulting Global Low-cost Computing Scan, January 2008	Vital Wave Consulting Global Low-cost Computing Scan, January 2008	
Note: Price per seat includes the hardware (CPU, monitor, keyboard and mouse) and any required control software. The price does not include any additional software (i.e., operating system, productivity suite or anti-virus software) as these are separate line items in the model.						

Appendix C – TCO Model Assumptions, Methods and Sources

This section of the white paper outlines the key assumptions, methods of calculating the data and sources used. The sources fall into three broad categories:

- Input from emerging market technology and education experts from countries of various economic levels (low, middle and upper-middle incomes) and geographic regions[19]:
  - Countries by economic levels: Low income: Ghana, India and Pakistan; Lower-middle income: China, Georgia, and the Dominican Republic and Upper-middle Income: Chile, South Africa and Turkey.
  - Countries by geographic region: Europe/Central Asia: Georgia and Turkey; Sub-Saharan Africa: Ghana and South Africa; Latin America & the Caribbean: Chile and the Dominican Republic; South Asia: India and Pakistan and East Asia & Pacific: China.
- Third party studies with cost data from developing countries (see complete list in Third Party Reports and Case Studies – Developing & Developed Countries – Appendix D)
- Third party studies with cost data from developed countries (see complete list in Third Party Reports and Case Studies – Developing & Developed Countries – Appendix D).

Overarching Assumptions		
Cost Item	**Assumptions and Calculations**	**Source(s)**
School environment, school hours, teacher salaries	Assume the school year lasts 39 weeks and classes in both the computer lab and classroom environment are held 7 hours a day, 5 days a week each week of the school year. Students are not allowed in the computer lab without a teacher present. According to a UNESCO study of 19 developing countries, teachers with 15 years experience earn a median salary of US$14 per hour in secondary and US$11 per hour in primary schools. The same study notes that many developing country teachers are young (less experienced), therefore, assume a mixture of experienced and relatively new teachers for an average salary of US$7 per hour in secondary and US$6 per hour in primary and rural secondary schools.	Teacher salary data is based on: UNESCO (20707) Education Counts: Benchmarking Progress in 19 WEI Countries, World Education Indicators – 2007. UNESCO. Retrieved on 8 March 2008 from http://www.uis.unesco.org/template/pdf/wei/2007/WEI2007report.pdf
Computer lab	Assume 16 computers are connected to each other in a local area network in a computer lab largely dedicated to teaching students computer skills.	The average number of 16 computers in a computer lab was based on a scan of computer in school programs in Southeast Asia, Africa and Latin America, (range of computers in computer labs was from 10-21).
Smart Classroom	Assume 32 computers - laptops - are connected to each other in a local area mesh network in a dedicated technology-ready classroom in which all subjects are taught. The computers are used for mainstream curriculum such as reading, math, science, languages and not specifically for computer training.	The mean class size, according to a UNESCO study of 19 developing countries (UNESCO, Education Counts), is 28 students, but there is wide variation. This study assumes 32 students to facilitate comparisons between the Smart Classroom and the Computer Lab environment.
Taxes	Value Added Taxes (VAT) and other taxes are not included in the TCO, many public sector	Scan of VAT, import and other taxes from a

	entities are exempt from these taxes and they vary widely country to country.	sampling of developing countries
Insurance	Assume insurance is cost prohibitive in most countries and hence theft/damage costs are incurred during the 5 year TCO.	Input from emerging market technology and education experts
Amortization	Costs are included when incurred and are not amortized over several years.	
Currency	All prices are in US$.	
IT Technician Daily Rates	Assume a daily rate for IT technicians of US$64 ($8 per hour) for Microsoft-trained IT professionals and an 8.5% higher rate, US$69.44 (US$8.68 per hour) for Linux-trained IT professionals. Assume that the daily rate for rural areas is 10% higher. Data on the costs of hiring Linux- and Microsoft-trained professionals indicate that in both developed country and developing-country contexts, Linux-trained professionals command higher salaries and are thus more expensive to retain. Salary surveys conducted in the U.S., Britain, and Australia by payscale.com consistently show that Linux-certified professionals earn 10-20% more than their Microsoft counterparts. The Red Hat India website claims that Red Hat-certified professionals earn up to 30% more than Microsoft-certified professionals (RHCE: What does it mean? on Red Hat website, http://www.redhat.in/training/rhce_meaning.php). Although evidence is more anecdotal, the salary gap in countries such as China, India, Pakistan and South Africa appears to be similar, if not higher, that that in developed countries. According to a headhunter at a leading Chinese recruitment firm, a senior developer at a major foreign software firm, and the head of a medium-sized Chinese software firm (approximately 50 staff), salaries for Linux IT professionals are from 30% (systems administrators) to 43% (software developers) higher than salaries for Microsoft IT professionals in the same categories. Linux-experts in South Africa estimate that the differential between Linux and Microsoft IT professionals is closer to 10-20%, with Linux professionals earning the premium salaries. A global staffing firm and a high-tech company with affiliates in India as well as a local IT services firm estimate that Linux IT professionals in India earn up to double their Microsoft Certified Engineer peers. A major staffing firm in Pakistan provided survey data that found that Linux IT professionals with three years of experience earn 12.5% more than Microsoft professionals with the same number of years experience.	IT technician salaries were calculated based on an analysis of salary surveys (IT salary benchmarks from 2006 in Asia, http://www.zdnetasia.com/techjobs/salary-benchmarks/), IT technician jobs posted on career websites in Latin America and data from IT experts in China, India, Pakistan and South Africa.
Cost Categories	Initial costs: out-of-pocket costs for initial acquisition of the solution, Recurrent costs: ongoing costs incurred during the lifetime of the equipment, Hidden Costs: Often unanticipated or under-estimated post-purchase, one-time charges	
Computer life-cycles	Assume that both the mainstream and the low-cost computers have a 5 year lifecycle and hence no repurchase during the five-year TCO. Assume that ultra-low cost laptops and secondhand computers have 3 year lifecycles and require one repurchase during the five-year TCO period.	Computer lifecycles are based on assumptions laid out by GeSCI, the global e-schools and communities initiative, an NGO supported by Ireland, Sweden, Switzerland, Finland, and Canada. Available from: http://www.gesci.org/files/GeSCI%20TCO%20Tool.xls

Rural area	Population under 5,000 and infrastructure poor (i.e., lack of broadband Internet, unstable electricity)	
Urban Area	Population greater than 5,000 with adequate infrastructure (i.e, broadband Internet, stable electricity)	
Primary School	Grades one through five or the first five years of formal education. This definition is consistent with the one used by the United Nations Millennium Development Project.	UN Millennium Project, "Background Paper of the Task Force on Education and Gender Equality" http://www.unmillenniumproject.org/documents/tf03edapr18.pdf
Secondary School	Grades nine through 12. Many countries, as well as UNESCO, separate secondary school into segments such as lower secondary or upper secondary school ("middle" or "junior high school", and "high school" in the U.S.).	UNESCO
TCO Philosophy: Reasonable costs	TCO assumes reasonable costs or sufficient enough investment in order to ensure the operation and use of the computer equipment during the five-year TCO period. Under this philosophy, items such as corruption, mismanagement and illegally acquired software are excluded from the TCO.	

Cost-specific Assumptions		
Cost Item	**Assumptions and Calculations**	**Source(s)**
Initial Costs		
Total Retrofitting, Wiring and Infrastructure Costs		
Total Retrofitting, Wiring and Infrastructure Costs	For the computer lab environment, assume a school will use an existing room to house the computer lab and will conduct two or three of the following activities prior to installing the computers: installing and purchasing an air conditioning unit capable of cooling a 300 square foot classroom, light construction (including flooring, adding security features such as bars on windows or extra locks), furniture (i.e., computer tables, locked cabinets and chairs) and electrical wiring and/or electrical infrastructure upgrades. The total assumed cost for these facility and technology infrastructure improvements is US$3,497, the estimated cost of two or three of these enhancements is $2,100. Actual costs will greatly depend upon local conditions. Assume any price differentials for rural areas will not impact overall costs. For the classroom environment, assume a school will only need to conduct only one or two of these upgrades, for a total investment of US$1,398.	Third party studies - developing countries** and Input from emerging market technology and education experts*
Total Hardware Costs		
Computer Hardware: Student computer,	Mainstream Computer: Assume a price of US$750 for the mainstream computer, which is a desktop computer with a monitor, keyboard and mouse. Assume that the computer lab is equipped with 16	The price was calculated based on the creation of a typical

PC and Laptop Servers, and control software	mainstream computers, one of which is a "PC Server" and functions as the server as well as a student or teacher-used computer. Assume a one-year, comprehensive, on-site warranty for each computer.	configuration derived from a scan of recent government tenders found on dgMarket and government procurement websites for computers for primary and secondary schools from developing countries in Eastern Europe, the Middle East, Asia and Latin America.
Computer Hardware: Student computer, PC and Laptop Servers, and control software	Low-cost Computer: Assume a price of US$500 for the low-cost computer, which is a desktop computer with a monitor, keyboard and mouse. Assume that the computer lab is equipped with 16 low-cost computers, one of which is a "PC Server" and functions as the server as well as a student or teacher-used computer. Assume a one-year, comprehensive, on-site warranty for each computer.	This price was calculated based on the creation of a typical configuration derived from a global scan of low-cost computing solutions targeted to developing countries conducted by Vital Wave Consulting in the winter of 2007. Vital Wave Consulting Global Low-cost Computing Scan, January 2008

Computer Hardware: Student computer, PC and Laptop Servers, and control software	Ultra Low-cost Computer: Assume a price of US$285 for the ultra low-cost computer, which is a mini-laptop computer. Assume that the computer lab is equipped with 16 ultra low-cost computers, one of which is a "PC Server" and functions as the server as well as a student or teacher-used computer. In the case of the Classroom access scenario, assume the classroom is equipped with 31 ultra low-cost computers (which come bundled with the required control software) and that the server (a US$1,000 mainstream, full-featured laptop computer) is also the teacher's computer. Assume that the ultra low-cost computer has an operational life of three years; hence the server as well as each of the ultra low-cost computers will need to be replaced one time during the 5 year TCO. Assume a one-year, comprehensive, on-site warranty for each computer upon purchase. Note: a mini-laptop computer is a clamshell-style portable computer that can run on batteries and is smaller than a standard laptop.	This price was calculated based on the Classmate PC, which is the sub-laptop with the most traction in the education field in developing countries (note: the Classmate PC list prices are not publically available, the US$285 price is derived from a scan of the prices of recently announced sales). Vital Wave Consulting Global Low-cost Computing Scan, January 2008
Computer Hardware: Student computer, PC and Laptop Servers, and control software	Secondhand Computer: Assume a refurbished computer and associated components are purchased in the formal channel and are priced at US$254.25 (US$198 for the CPU, with a refurbished monitor US$46, a refurbished keyboard for US$6.75 and refurbished mouse for 3.50).Assume a one-year, comprehensive, on-site warranty for each computer. Assume that the computer lab is equipped with 16 secondhand computers, one of which is a "PC Server" and functions as the server as well as a student or teacher-used computer. Assume that the secondhand computer has an operational life of three years and hence a second group of 16 refurbished computers and associated components priced at US$254.25 will be purchased in year 4 and will have a one-year, comprehensive, on-site warranty for each computer. Assume a one-year, comprehensive, on-site warranty for each computer for each of the purchases (total of two one-year warranty periods).	The computer configuration was derived from installations in Africa and Latin America as described and configured by emerging market technology and education experts in South Africa and the Latin America.
Unlimited Power Supply (UPS) or Inverter and Batteries	Assume the purchase of 2 UPS systems and associated battery packs that will provide 1-2 hours of back-up for the 16 desktop computers in the computer lab environment and the 31 sub-laptop and one full-featured laptop computers in the classroom environment for a total cost of US$1,262 and a set of two replacement batteries (either 2 large batteries or 2 banks of smaller batteries) that are purchased subsequently during the 5 year TCO period at a total cost of US$400. Assume the purchase of 1 UPS system and associated battery pack that will provide 1-2 hours of back-up for the 16 sub-laptop computers for a total of US$631 and a set of replacement batteries (either 1 large battery or a bank of smaller batteries) at a total price of US$200 during the 5 year period. For rural areas, assume the purchase of two Inverters (2.0 KVA with a back-up time of 180 minutes, minimum VAH 8640) priced at US$1,000 each with an associated battery pack priced at US$300 each for the mainstream computers for a total cost of US$2,600. Assume the repurchase of battery packs US$300 each, one time during the 5 year TCO for a total cost of US$600.	Input from emerging market technology and education experts*

Printers	Assume the purchase of one mid-range DeskJet printer priced at US$100 and with a one-year warranty.	Input from emerging market technology and education experts*
Router or Switch	Assume a local area network (LAN) connects the computers in both the computer lab and classroom environments. Assume that the PC / Laptop Server or host is connected to the Internet (via dial-up in rural areas and broadband, DSL, in urban areas) and the PC/Laptop Server or host shares the Internet connection with the other computers through the LAN, either wirelessly in the case of the ultra low-cost laptop computers or via Ethernet connections in the case of the mainstream computers, low-cost computers, and secondhand computer solutions. In the rural dial-up scenario, the PC / Laptop Server is connected to the phone line and the ethernet port is connected to a to the input of a 16 port switch which in turn connects to the other PC's. In the broadband scenario the PC/Laptop Server, as well as the other computers/laptops are connected to the DSL line through a 16 port router. Assume the single port DSL modem/router costs US$75, the 16 port router costs US$200 and the 16 port, 100 MBPS switch costs US$75. Assume a one-year warranty on the routers and switches.	Input from emerging market technology and education experts*
Total Transportation Fees		
Transportation fee	Assume a transportation cost equivalent to 5% of the value of the total initial hardware investment for delivery of the technology to rural areas. The value of the total initial hardware investment includes the price of the hardware: cost of computers, PC / Laptop server(s), monitors, keyboards, mouses, printer, UPS system and the router or switch and network cabling for the computer lab).	Input from emerging market technology and education experts*
Total Network Cabling		
Network cabling	Assume cabling costs US$865 for the mainstream, low-cost, and secondhand installations in the computer lab. Assume cabling costs 80% less, or US$173, for the ultra low-cost computers solutions in both the classroom and computer lab environments because they are configured with wireless, and not ethernet, networks (80% less is assumed as some cabling needs to be done to connect the laptop server to the Internet connection and a technician may charge a minimum rate for making a site visit to conduct this work).	Third party studies - developing countries** and Input from emerging market technology and education experts*
Total Deployment Costs		
Deployment	Assume that the installation, deployment and acceptance of the hardware, software and the network is conducted by a certified technician. In the computer lab, the deployment costs are equivalent to two days of service fees and for the classroom environment they are equivalent to three days of service fees (for the Microsoft-based solutions it is based on the Microsoft-trained technician daily rate and for the Linux-based solutions it based on the Linux-trained technician daily rate). Assume an additional two days for the installation, deployment and acceptance of the replacement ultra low-cost computers in the computer lab (three days for those in the classroom) as well as the replacement secondhand computers in the computer lab in year 4 at the Microsoft and Linux rates. Assume all software is pre-installed and software deployment consists of configuring the network. Assume that the daily rate is 10% higher in rural areas.	Input from emerging market technology and education experts*

Total Operating System and Productivity Software		
Operating System software (OS)	Microsoft Operating System: For the classroom scenario and the mainstream, low-cost and ultra low-cost computers, assume a $25 licensing fee for a perpetual license [covering the 5-year TCO period] for Microsoft Starter Edition, which allows for the complimentary Windows Upgrade via the Partners in Learning Program. For the secondhand computers, assume that they are covered under the Microsoft Authorized Refurbisher program, with Windows XP at $5 per computer.	Microsoft Partners in Learning
	Linux Operating System: Assume a non-subscription-based distribution of Linux. (Note - there is evidence in the field of the usage of subscription-based distributions of Linux in public sector organizations including primary and secondary schools, however this TCO conservatively assumes a non-subscription based distribution of Linux.)	Input from emerging market technology and education experts*
Productivity software	Microsoft Productivity Suite: Assume Microsoft Partner in Learning licensing fees which consist of a pre-established licensing fee of US$2.50 per computer, including servers and hosts, charged every year for the five-year license period for Microsoft Office Enterprise.	Microsoft Partners in Learning
	Linux Productivity Software: Assume OpenOffice is bundled with the Linux operating system distribution.	Input from emerging market technology and education experts*
Total Anti-virus Software		
Anti-virus software	For Microsoft Operating System configurations, assume a very steep educational discount (up to 80-90%) on the list price of leading anti-virus software packages, or a slightly discounted price for local anti-virus programs, for a total initial purchase fee of US$6 per computer plus a subsequent, annual subscription fee of US$6 per computer. For Linux-based operating systems, assume no anti-virus or a non-subscription based anti-virus software program is used.	Input from emerging market technology and education experts*

Recurrent Costs		
Total Training Costs		
Basic computer skills training	For the computer lab scenarios, assume that a group of teachers, and the school principal, receive a subset of Technology Literacy Approach Curriculum in UNESCO's ICT Competency Standards for Teachers, specifically related to the eleven basic computer literacy skills that are specified in the Technology Literacy Approach Curriculum point I.D. ICT. Costa Rica's teacher training program is again used as a proxy for the Technology Literacy Approach. Costa Rica provides approximately 15-40 hours of training per year per teacher. This study assumes 100 teaching training hours every year for a total of 500 hours, which could cover approximately 40 hours of training for 12 teachers or 15 hours of training for 33 teachers during the five-year TCO. Assume training is provided at the school and training costs include teacher salaries (US$7 per hour for secondary and US$6 per hour for primary and rural secondary school teachers), trainer costs (assume the secondary teacher salary rate of US$7 per hour - including materials -for Microsoft-based installations and the rate is US$7.25 per hour assuming increased development time required for Linux, especially customized-Linux, installations) and online materials (assume materials are shared and total US$50 per year for each of the 5 years of the TCO). Assume basic computer training is not provided in the classroom environment, only the enhanced specialized training.	ICT Competency Standards for Teachers - Implementation Guidelines Version 1.0 (2008) UNESCO, Retrieved on 1 May 2008 from http://cst.unesco-ci.org/sites/projects/cst/The%20Standards/ICT-CST-Implementation%20Guidelines.pdf and Verdisco, Aimee and Juan Carlos Navarro (1999) Costa Rica: Teacher Training for Education Technology, Inter-America Development Bank website, Retrieved on 4 April 2008 from: www.iadb.org/sds/doc/Edu&Tech24.pdf
Specialized Computer Skills and Pedagogical Training	For the computer lab scenarios, assume that one individual (likely the computer teachers) receives training similar to that laid out in the Technology Literacy Approach Curriculum in UNESCO's ICT Competency Standards for Teachers, which includes basic computer skills, incorporation of technology into curriculum and pedagogy and the use of technology for professional development and administrative tasks. Costa Rica's teacher training program is used as a proxy for the Technology Literacy Approach. Under the Costa Rican model, the core team receives three weeks (120 hours) of initial face-to-face training with approximately 120 additional hours of online training provided during the course of the academic year. Assume the costs include the teacher's salary, travel and living expenses (assume the initial training lasts 15 days, estimate travel costs at a total of US$40 per day, per person for a total of US$1,500) and cost of the course (US$7 per hour for the Microsoft trainer and US$7.25 for the Linux trainer, both including materials) and US$50 per year total to cover the costs of the development and distribution of all online training provided to the school). For the classroom environment, assume that a total of 5 teachers will require the 240 hours of specialized computer skills training during the five-year TCO at the same costs as those outlined above.	ICT Competency Standards for Teachers - Implementation Guidelines Version 1.0 (2008) and Aimee Verdisco Costa Rica: Teacher Training.
Total Connectivity Costs		
Internet Connectivity	Connectivity fees vary dramatically depending on bandwidth, existence of metered phone service and the maturity of communications networks. In urban areas, assume a broadband DSL Internet connection with a monthly price of US$35 for unlimited usage. These prices factor in the often significant "e-rate" discounts, which are often, but not always, provided to educational institutions. In rural areas, assume a dial-up Internet connection with a monthly price of US$60 for 20 hours of usage. Assume connectivity is paid for 12 months of the year although classes are only offered 10 months of the year.	Data from the International Telecommunications Industry cross-validated and updated with data and Input from emerging market technology and education experts*

Total Electricity Costs		
Electricity - computers	In the computer lab environment, assume 3.5 active use hours per day and 3.5 idle hours per day for each day of the 39 school weeks each of the five years and in the classroom environment assume 3.0 active use hours per day and 4.0 idle hours per day for each day of the 39 school weeks each of the five years. Assume power usage is for both the computer and the monitor (if applicable). The secondhand computer power usage rates were calculated based on a weighted average of Pentium III and IV computers. Assume power during active (W) of 46.4 W for the mainstream computer, 20.97 W for the low-cost computer, 12.52 W for the ultra low-cost computer, 15 W for the mainstream laptop (server in the classroom environment), and 153 W for the secondhand computer. Assume power during idle (W) of 38.4 W for the mainstream computer, 20.23 W for the low-cost computer, 11.42 W for the ultra low-cost computer, 14.5 W for the mainstream laptop (server in the classroom environment), and 121 W for the secondhand computer. Assume US$0.08 cost per kilowatt hour.	Median electricity prices for emerging markets were estimated based on data from IEA Publications (International Energy Agency, 2007, "Key World Energy Statistics", IEA Publications, Page 43. Retrieved on date March 21, 2008 from http://www.iea.org/textbase/nppdf/free/2007/key_stats_2007.pdf.), Kestrel Capital and input on current electricity rates in China, India and South Africa. Amount of kilowatt hours used by the various computers was based on: Refurbished calculations are based on CPU values provided at http://saf.bio.caltech.edu/saving_power.html#rawprint ; monitor values were provided at http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/monitors/draftmonitorspec.pdf and Pentium III vs. Pentium 4 ratios were provided at http://www.computeraid.org/index.htm. All other values are based on averages of measured values based on data from Low in Low-power computing: a special report (05 March 2008) ZDNet. Retrieved on 28 March 2008 from: http://www.zdnet.co.uk/misc/print/0,1000000169,39363065-30000001c,00.htm
Electricity - printer	Assume 0.35 active use hours per day and 6.25 idle hours per day for each day of the 39 school weeks each of the five years in the computer lab and classroom environments. Assume power during active of 400 W and power during idle of 22 W. Assume US$0.08 cost per kilowatt hour and a total cost of US$21.65 for the five years. (Used the deskjet HP2100M as a reference point for the power requirements)	Median electricity prices for emerging markets were estimated based on data from IEA Publications, Kestrel Capital and input on current electricity rates in China, India and South Africa. Amount of kilowatt hours used by the various computers was based on: Saving Power on idle PCs (8 August 2008) Analysis Facility (SAF), Biology Division, Caltech. Retrieved on 28 march 2008 from: http://saf.bio.caltech.edu/saving_power.html#rawprint
Total Subscription Costs		
Anti-virus software	For Microsoft Operating System configurations, assume a very steep educational discount (up to 80-90%) on the list price of leading anti-virus software packages, or a slightly discounted price for local anti-virus programs, for an annual subscription fee of US$6 per computer. For Linux-based operating systems, assume no anti-virus or a non-subscription based anti-virus software program is used.	Input from emerging market technology and education experts

Total Tier 1 Support		
Tier 1 Support (Lab technician)	Assume the computer lab or Smart Classroom is supported by a part-time contract lab technician, by the computer teacher, or a local university. If it is a Linux installation, assume that the computer teacher and local university would be supported by a centralized pool of experts on the specific Linux platform, especially if it is a customized version of Linux. Assume the computer lab is serviced up to 8 hours a week and at the urban, secondary teacher's salary rate of US$7 for a Microsoft-based installation or US$7.60 for a Linux-based installation. The Linux 8.5% premium is included as the IT technician would demand premium rates and the computer teacher and local university would likely be supported by a centralized pool of experts on the specific Linux platform, especially if it is a customized version of Linux. Assume the lab technician in the classroom environment can oversee fewer schools - three or four schools, for a total of 12 hours a week- as they will need to be able to assist with the support of more sophisticated programs and usage of the computers (integrated into the curriculum) as well as to maintain more computers. Assume that lab technicians, university partners and computer teachers are harder to find and retain in rural areas, hence they are paid equivalent to what the IT technicians earn in urban areas.	Tier 1 support costs are based on several models observed in developing-country contexts. For example, Indian government schools typically receive bids for support from local IT firms, which is complimented by centralized teams of experts, particularly for Linux software support and customization. The Director of an India technology in schools program noted that they have a group of Linux experts that provide software support to schools, in addition to the support provided for the hardware. Public schools in Chile often form support agreements with both IT firms and local universities. In Africa, a contractor or recent computer graduate may provide support on a for-fee or voluntary basis.
Total Tier 2 and 3 Support		
Service contracts	Assume a comprehensive service contract providing on-site maintenance and parts, which covers everything but losses due to Acts of God, intentional misuse and theft). The baseline service contract is priced at US$740 per year - for the mainstream computer in the computer lab - which is roughly equivalent to the cost of 1 service call per month for the ten-month school year and US$300 in parts and supplies per year (the actual percentage of service calls to parts/supplies will vary as the school becomes more familiar with the hardware and software services and the hardware ages). The Linux-based service contracts are priced 8.5% higher than the Microsoft baseline due to the increased daily rate for Linux IT professionals coupled with the decreased familiarity with the customized version of Linux. Assume service contracts are more expensive in rural areas (10% higher than the baseline service contract fee), that there is a discount for the low-cost computers in the computer lab (20% lower than the baseline service contract fee due to less complex hardware configurations and lower price point), for the ultra low-cost computer in the computer lab (20% lower than the baseline service contract fee due to more complex hardware - integrated, innovative and non-standard nature of this new category of laptops - and much lower price point) and for the secondhand computer in the computer lab (20% lower than the baseline service contract fee due to a combination of older, but less expensive, hardware). For the ultra low-cost computer in the classroom environment assume a premium rate (20% higher than the baseline service contract fee due to the larger number of computers, 32, complex configuration - server communicating via a mesh network with the and unfamiliarity and non-standard nature of this new category of laptops). Because of the repurchase of the ultra low-cost computers (computer lab and classroom) and the secondhand computers, there are only 3 years of service fees, there are four years for all other computers. Please see the IT Technician Daily rats for an explanation of the differences in pricing between Microsoft and Linux platforms.	Tier 2 and 3 support costs are generally provided by a combination of centralized resources (particularly for Linux installations) and local or multi-national IT vendors.

Out-of-warranty service calls	Assume that there is one out-of-warranty service call - priced at the Microsoft- or Linux-trained IT professional's daily rate - during the warranty period (year 1) for the mainstream and low-cost desktop computers) for problems that are outside of the coverage of the warranty contract. Assume that there are two out-of-warranty service call - priced at the Microsoft- or Linux-trained IT professional's daily rate - during the one-year warranty periods (years 1 and 4) for the secondhand and the ultra low-cost computers in the computer lab and the ultra low-cost computers in the classroom environment for problems that are outside of the coverage of the warranty contract. Assume that the daily rate for rural areas is 10% higher.	Input from emerging market technology and education experts
Total Consumables		
Consumables	Assume very limited usage of consumables including the purchase of one toner cartridge per year as well as several reams of paper and an assortment of storage supplies (i.e., CD ROMs) for an annual fee of US$81 per year for a total of US$405 for consumables in all environments. Any price differentials encountered in rural areas will be mitigated by decreased usage rates.	A very conservative number was used for consumables as the range in costs, and usage) is quite wide. In India several experts noted that peripherals such as printers were rarely if ever used, even in private schools whereas experts from South Africa noted that consumables can equal up to US$250 per year. Actual costs are based on expected usage rates and should be adjusted accordingly.

Hidden Costs		
Total Keyboard and Mouse Replacements		
Mouse	Assume either one US$12 replacement mouse or two less expensive (US$6) replacement mouses per computer during the 5 year TCO for the mainstream and low-cost hardware configurations in the computer lab. Assume just one US$3.50 replacement refurbished mouse per computer (in addition to the refurbished mouses purchased during the replacement cycle) during the 5 year TCO for the secondhand hardware configuration. Assume a computer mouse is not used for the ultra low-cost computers in the computer lab and classroom environments.	Input from emerging market technology and education experts*
Keyboard	Assume one US$13 replacement keyboard, or two US$6.50 keyboards, per computer during the 5 year TCO for the mainstream and low-cost hardware configurations in the computer lab. Assume just one US$6.75 replacement refurbished keyboard (in addition to the refurbished keyboards purchased during the replacement cycle) per computer during the 5 year TCO for the secondhand hardware configuration in the computer lab. A keyboard is not used for the ultra low-cost computers in the lab and classroom environments.	Input from emerging market technology and education experts*
Total Replacement Computers Repurchase & Deployment Costs		
	See Computer, software and deployment assumptions	
Total Informal Support & Downtime Costs		
Informal Support	Assume that teachers spend a certain amount of time per year on 'self-support', i.e. attempting to solve problems that arise with the computers in the computer lab or technology in the classroom. According to a comprehensive Becta study of 7 British schools, the amount of time per person spent on informal support is 38.2 minutes per week (25 hours per year). This study assumes the same amount of time per year spent on informal support and an employee (teacher) wage rate of US$7 per hour for secondary school teachers. Assume informal support is 10% higher in rural areas where teachers have less experience with technology and may be less able to help each other with troubleshooting and resolving minor problems.	British Educational Communications and Technology Agency, published on 12 May 2005, "Open source software in schools: A study of the spectrum of use and related ICT infrastructure costs", Becta, retrieved on March 12, 2008 from http://publications.becta.org.uk/display.cfm?resID=25907&page=1835.
Downtime	Assume that due to electricity shortages, Internet and telephony outages and travel time for service technicians that there is the equivalent of one day of downtime in both the classroom and computer lab per year in urban areas and two days per year in rural areas. Assume that downtime is lower in urban areas due to increased infrastructure and the increased availability of technical support). Assume that there is a set computer training curriculum and downtime in the computer lab will lead to an increase in the number of hours the teacher teaches the curriculum, to make up for the lost time, and is therefore priced equivalent to the teacher's salary. Schools could opt to not make-up for downtime and would therefore experience reduced educational attainment, which is not consistent with our model that assumes reasonable costs to achieve educational objectives. Downtime costs in urban areas total US$245 and in rural areas are US$420.	Several studies stress the importance of quantifying the impact of downtime on the TCO, but fail to do so as there is no standard method of calculation. Open Research provides some guidance in this area, they assume 2 days of downtime per PC failure, which is multiplied by average hourly staff wage or income for a cost figure. Because Open Research's study was only for Africa and this TCO model includes several other regions, the amount of downtime in urban areas was decreased to one day per year (2 for rural

		areas) and charged at teacher salaries. Open Research (December 2004) "Paying the price? A Total Cost of Ownership Comparison Between New and Refurbished PCs in the Small Business, NGO and School in Africa." Retrieved on 28 March 2008 from www.schoolnetafrica.net/fileadmin/resources/TCO_Report_Open_Research_FOR_PUBLICATION_01.doc.
Total Damage or Theft Losses Costs		
Theft/Damage	Assume the loss of the value of one of the desktop computers (mainstream, low-cost and secondhand) due to theft or damage during the five-year TCO. Assume the loss of the value of two laptops (ultra low-cost computer) in computer lab environment and three laptops (ultra low-cost) in the classroom environment during the five-year TCO. Costs vary depending on the cost of each computer type.	Input from emerging market technology and education experts*
Total UPS Replacement Battery Pack Costs		
	See UPS/Inverter assumptions in Initial Costs section	
Total End-of-Life Costs		
End of Life	Gartner has estimated the costs of alternative disposal options, several of which include the sale, auction or donation of the computer after it is prepared for disposal. This study assumes a cost of labor of US$8 per hour for a technical professional. Assume 0.5 hours of labor at US$8 per hour for administration, 0.25 hours of labor per computer for backing-up the hard drive, 0.25 hours per computer for media sanitization and .1 hours of labor for packing (total of 1.1 labor hours or US$8.80 in labor fees per computer) . Assume that the computer will either be auctioned or sold or the computers and/or parts will be used or harvested to equip other computers saving hardware replacement costs in the future, both scenarios would subtract 5% of the initial computer price from the TCO. Assume that the ultra low-cost computers in both the classroom and computer lab environments will have two end-of-life fees (given that replacement computers will be purchased in year 3 or 4) and that the residual value for the first group of ultra low-cost computers is 5% of the initial purchase price and the residual value for the second group is of 7% given that they still have at least one year of operational life. Assume that there is US$0 residual value for the secondhand computers.	Gartner TCO End of Life Tool, 2003 and Gartner (September 10, 2003) Management Update: Analyze TCO Issues When Planning PC Disposal, Retrieved on 4 April 2008 from: http://www-07.ibm.com/shared_downloads/financing/Gartner_0903_Analyze_TCO_issues.pdf and Open Research, which estimates that the residual value of a computer is approximately 5% of its initial purchase price - Open Research (December 2004) "Paying the price? A Total Cost of Ownership Comparison Between New and Refurbished PCs in the Small Business, NGO and School in Africa." Retrieved on 28 March 2008 from www.schoolnetafrica.net/fileadmin/resources/TCO_Report_Open_Research_FOR_PUBLICATION_01.doc.

Total Planning Costs		
Planning	Planning prices range significantly depending on the size, scope (i.e., national vs. regional vs. local) and nature (i.e., a typical Microsoft-based system or a Linux-based system). Assume a conservative baseline rate of 1% of the total TCO for the mainstream computer for planning as most planning fees are fixed expenses (salaries of government employees, contractors and school staff) and will not significantly increase or decrease due to lower priced technology. Evidence from discussions from experts from developing countries suggests that selecting an alternative hardware platform (i.e. ultra low-cost computer) or software technology platform (i.e., Linux - several countries conducted extensive cost-benefit and technology migration studies before selecting Linux-based operating systems for computer systems in educational environments and tested various distributions of Linux to determine which to use in their program) will increase planning costs and therefore increase the baseline planning costs by 10% in both of these cases in the computer lab environment. For the classroom scenario, significant increases in planning will be required to determine how the computers will be integrated into the curriculum and used, assume a 25% increase in planning. For the ultra low-cost computers and secondhand computers, which will require two planning periods, add an additional 20% to the baseline TCO (i.e., for the ultra low-cost computer in the classroom the planning fee will be 1% of the mainstream TCO * 10% for non-traditional platform * 20% for two purchase periods)	*info*Dev notes that there are "real costs associated with successful planning" IT in education programs, which are "often overlooked or underestimated, but are essential" (*info*Dev. "Knowledge Map: Costs." Knowledge Maps: ICTs in Education: What do we know about the effective uses of information and communication technologies in education in developing countries? November 2005, (Costs, p 2/5) Retrieved on 6 March 2008 from http://www.infodev.org/files/2907_file_Knowledge_Maps_ICTs_Education_infoDev.pdf). This TCO draws upon research done on TCOs in developing countries by M. Bakia (Bakia, Marianne (January - March 2002) "the Costs of Computers in Classrooms: Data from Developing Countries." TechKnowLogia.) and A. Paterson, (Paterson, Andrew (2007) "Costs of information and communication technology in developing country school systems: the experience of Botswana, Namibia and Seychelles." International Journal of Education and Development using ICT, Vol. 3, No. 4. Retrieved on 20 March 2008 from http://ijedict.dec.uwi.edu/viewarticle.php?id=416&layout=html), which were validated and updated with input from emerging market technology and education experts*

Appendix D – References

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Endnotes

[1] All calculations and assumptions for the TCO model are included in the Appendix A, B and C of this white paper.

[2] Kozma, R. (1999). World Links for Development: Accomplishments and Challenges. Monitoring and Evaluation Annual Report 1998–1999. SRI International; McGhee, R. and Kozma. R. (2000). World Links for Development: Accomplishments and Challenges. Monitoring and Evaluation Annual Report 1999–2000. SRI International; and Youth Impact Assessment (2006). World Links.

[3] Dewidar, and Khalil, D. (2004). iEARN Egypt Evaluation Study. Various documents can be accessed at http://www.iearnegypt.org/evaluation.php.

[4] The only instance in which students with computers did not outperform those without was in telesecundarias, a distance education program. Further research needs to be conducted to understand why this particular type of institution did not show improved math and language skills. See *Comparativo del promedio general de las escuelas que participan en Red Escolar y la prueba ENLACE*. (2008) Sondeos y Estadisticas – Red Escolar website. Retrieved on 4 April 2008 from: http://redescolar.ilce.edu.mx/redescolar2008/sondeos_estadisticas/enlace/index.htm.

[5] Linden, L., Banerjee, A., and Duflo, E. (2003). Computer-Assisted Learning: Evidence from a Randomized Experiment. Poverty Action Lab Working Paper.

[6] Inamdar and Kulkarni (2007) compared two schools (one kiosk school and one non-kiosk school) as well as frequent and infrequent kiosk users. Kiosk computers were determined to have a significant effect on mathematics achievement. In this study, the variable of interest was the school examination result (which included English, Science, and Mathematics components). A total of 161 students (aged 13-14 years) were studied during the 2004 academic year. Also investigated were variables for student intelligence, creative potential, leadership potential, and frequency of kiosk use. The schools were located in rural villages of Maharashtra State, India. The kiosks had been set up since early 2002. Initial examination scores were taken at that point, and final results were taken 2.5 years later. ANOVA results show significant differences between the groups of students on science scores in 2004. However, it is shown that these differences may result from pre-existing differences in intelligence. Math score differences, though, indicate that frequent use could be associated with increased math scores. See Inamdar, P, and Kulkarni, A. (2007). 'Hole-In-The-Wall' Computer Kiosks Foster Mathematics Achievement - A comparative study. Educational Technology & Society, 10 (2), pp. 170-179.

[7] Hawkins, R. (2001). Ten Lessons for ICT and Education in the Developing World. Center for International Development. Global Information Technology Report. Harvard University. Available at http://cyber.law.harvard.edu/itg/libpubs/gitrr2002_ch04.pdf.

[8] Harvard University's Berkman Center for Internet & Society and the World Bank Institute's *Global Networked Readiness for Education* website at http://cyber.law.harvard.edu/gnre/.

[9] Ibid.

[10] These indices are issued by the Center for International Competitiveness and the World Economic Forum, respectively.

[11] *Enlaces,* Centro *de Educación y Tecnología del Ministerio de Educación.* (2005). Encuesta "Educación en la Sociedad de la Información." Retrieved on 4 April 2008 from: http://www.economia.cl/aws00/Estatico/repositorio/N/j/h/NjhiY2VkOGIyOTlhYWIxNDAxYTdjMWVmOGU5YmZlNjJmMDMyZjE1Yg==.pdf.

[12] Trucano, M. (2005). Knowledge Maps: ICTs in Education. Washington, DC: *info*Dev/World Bank. Retrieved on 12 April 2008 from http://www.infodev.org/en/Publication.8.html.

[13] Computer lab consists of 16 computers are connected to each other in a local area network, which is largely dedicated to teaching students computer skills. The Smart Classroom has 32 laptop computers, which are connected to each other in a local area mesh network in a dedicated technology-ready classroom in which all subjects are taught. The computers are used for mainstream curriculum such as reading, math, science, languages and not specifically for computer training.

[14] Case studies typically contain little information on costs, and variable amounts of firm data. Therefore, studies from as early as 2001 were considered. A partial list of studies is available in the "For Further Reading" section and in the list of sources in Appendix B.

[15] *Microsoft Operating System & Productivity Suite*: For the classroom scenario and the mainstream, low-cost and ultra low-cost computers, assume Microsoft Partner in Learning licensing fee of $25 per computer which consist of a perpetual five-year license for Microsoft Starter Edition, which allows for a complimentary upgrade to Microsoft Windows XP Pro. For the secondhand computers, assume that they are covered under the Microsoft Authorized Refurbisher program, with Windows XP at $5 per computer. Assume Microsoft Partner in Learning licensing fees

which consist of a pre-established licensing fee of $2.50 per computer, including servers and hosts, charged every year for the five-year license period for Microsoft Office Enterprise. *Linux Operating System & Productivity Suite*: Assume a non-subscription-based distribution of Linux, which is bundled with OpenOffice.

[14A] Trucano, M. (2005). Knowledge Maps: ICTs in Education. Washington, DC: *info*Dev/World Bank. Retrieved on 12 April 2008 from http://www.infodev.org/en/Publication.8.html.

[16] *RHCE: What does it mean?* on the Red Hat website (http://www.redhat.in/training/rhce_meaning.php).

[17] For the ITU report on the lack of Linux-trained professionals see Rajani, N., Rekola, J. and Mielonen, T. (2003). Obstacles to the Extensive Use of FLOSS in the Developing World. Retrieved on 18 March 2008 from http://www.itu.int/wsis/docs/background/themes/access/free_as_in_education_niranjan.pdf., for the UNESCO report see: Nah Soo Hoe (2006) Breaking Barriers: The Potential of Free and Open Source Software for Sustainable Human Development, A Compilation of Case Studies from Across the World. UNDP-APDIP.

[18] This exaggerated rate for electricity was observed in remote areas of Africa.

[18A] Trucano, M. (2005). Knowledge Maps: ICTs in Education. Washington, DC: *info*Dev/World Bank. Retrieved on 12 April 2008 from http://www.infodev.org/en/Publication.8.html.

[18B] Harvard University's Berkman Center for Internet & Society and the World Bank Institute's *Global Networked Readiness for Education* website at http://cyber.law.harvard.edu/gnre/.

[19] Countries are classified according to the World Bank's List of Economies (July 2007) World Bank. Retrieved on 28 March 2008 from: siteresources.worldbank.org/DATASTATISTICS/Resources/CLASS.XLS.