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Closing the Digital Divide?
The $100 PC and Other Projects for Developing Countries

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INTRODUCTION

Bringing inexpensive computers to the developing world has been the focus of numerous government initiatives supported by technology proponents who feel that computers can bring social, economic, and educational benefits to countries where technology is considered a luxury. While private companies and governments have tried to deploy the necessary technology and support, myriad initiatives have ultimately failed or fallen short of their intended impacts. In most cases, the economic and infrastructure conditions necessary for success have been lacking.

An ambitious project in the United States, nicknamed the "$100 PC Project," now seeks to succeed with a plan for low-cost computing in the developing world. Nicholas Negroponte, co-founder of the MIT Media Lab, has formed a new organization called One Laptop Per Child (OLPC), with the intent to develop a $100 laptop for millions of children worldwide. With $20 million in start-up investment, agreements with major technology corporations and interest from at least seven countries worldwide, his goals have attracted interest, but challenges remain.

This paper looks at the idea and development of OLPC, the challenges facing the project as it goes to implementation, the experience with other similar projects in developing countries, and social obstacles to diffusion.

THE IDEA AND DEVELOPMENT OF ONE LAPTOP PER CHILD

Involvement in small-scale projects that brought computers to children in developing countries led Negroponte to consider the impact of such projects on a larger scale (Markoff, 2005; Stecklow, 2005). In January 2005, Negroponte announced plans to develop durable, robust laptops that children would own and use for their education. By producing the laptops in enormous quantities and choosing components wisely, Negroponte aimed for a cost of $100 per laptop, which governments could purchase in bulk.

Financial support and industry cooperation were crucial to securing funds for development and production. As co-founder and then-chairman of the MIT Media Lab, Negroponte was able to convince AMD, Brightstar, Google, News Corporation, and Red Hat to pledge $1.5 million each to the newly-established OLPC association, as well as an additional $500,000 to MIT Media Lab for project support (Young, 2005). The OLPC association holds the responsibility of developing the laptop and bringing the project to fruition. Research and development has been outsourced to the MIT Media Lab ("The Hundred Dollar Man," 2005).

Developing the system has required the consideration of both technical and social factors. The OLPC plans to encase the laptops in a bright, non-traditional color to discourage theft. When electricity sources are unavailable, a string-powered generator provides 10 minutes of power for every one minute that the user tugs a string. To counter the possibility of broken strings, ordinary strings like shoelaces can be used as replacements (Bullis, 2006). Instead of a hard drive, a flash drive will be used to store data. Unlike hard drives, a flash drive has no moving parts and is less likely to malfunction or be damaged by an accidental drop. Although specifications may still change, the laptop is anticipated to weigh under 1.5 kg (3.3 pounds) and

have dimensions of 193mm x 229mm x 64mm ("Specs: Discover the XO Laptop Specs," 2007). It is intended that the size of the laptop be comparable to a textbook and the weight comparable to a child's lunchbox to ensure small arms can easily carry the device ("Features: Discover the XO Laptop Features," 2007). The screen includes two modes: a black-and-white mode to save power and have greater sunlight readability, and a color mode for interactive software applications.

Beyond the hardware, finding an appropriate operating system was a key issue. Although Apple offered its OS X operating system to the project for free, the group wanted open access to the code for customization purposes, which Apple was not willing to provide. Microsoft also offered an operating system, but could not provide the open access sought by the OLPC association. Ultimately, a variant of Linux was chosen for its ability to be easily customized.

Using Linux and other open source software means that no software costs need to be factored into the $100 price. Below, Table 1 details the other components that comprise the laptop's cost.

TABLE 1: Original, Intended Cost Breakdown of the OLPC Laptop

Component	Details	Price (Approx.)
Display	7.5-inch color display with a black-and-white mode for easy readability and lower power consumption	$30
Processor	AMD Processor	$10
Storage	Flash drive	$10
Memory	Memory module	$10
Battery	Rechargeable battery for the laptop	$5
Keyboard	Laptop keyboard	$5
Miscellaneous Parts	Casing, plugs, USB ports, and other components	$20
Profit	Profit to suppliers	$10

Source: Jewell, 2005

In December 2005, the OLPC association and Quanta Corp. of Taiwan announced a deal in which Quanta would produce the laptops. Quanta is the world's largest manufacturer of laptops, supplying HP, Dell, Gateway and other major PC vendors. Since then, the OLPC laptop has undergone multiple revisions including color and design changes. Names for the machine have included the Children's Machine and 2B1, with XO ultimately selected as the final name. To provide power for the system, a crank-based generator was first chosen, but was replaced with a pull-string generator in which tugging on a string recharges the laptop's battery (Bullis, 2006).

Factors including the affordability of the laptops and a desire to enhance schools with technology have led a handful of countries to commit to purchasing the machines. The first countries began

to make preliminary agreements in August 2005, with Thailand leading the way and Nigeria, Brazil, and Argentina following soon afterward ("Progress: Discover the Origins of OLPC," 2007; "Four Countries Commit to Buy 4 Million Linux-Powered OLPC Laptops," 2006). In late 2006, Libya and Uruguay committed to orders for the laptop. In January 2007, Rwanda became the fifth country to announce participation in the OLPC project ("Progress: Discover the Origins of OLPC," 2007).

Not all agreements may be binding, however. Though Thailand was the first to commit to the project, it now seems likely that the government will not be purchasing laptops through the OLPC program. Following the recent coup in that country, Thailand officials now say there are no plans to purchase OLPC laptops ("OLPC Project is Scrapped Here," 2006).

Despite that setback, specifications for the laptop have fallen into place and progress toward deployment has intensified. In November 2006, a batch of 875 machines was produced for test purposes. After rigorous testing, production will begin on the first batch of laptops for use by children ("Progress: Discover the Origins of OLPC," 2007).

The various revisions of the OLPC machine, as well as the slow trek to mass production, reflect the complexity of designing a new laptop whose price point and design diverge from standard portable computers available in the marketplace. With the unconventional nature of the laptop and the plan, perhaps it is no surprise that the OLPC association has faced scrutiny.

FUTURE CHALLENGES FOR THE OLPC INITIATIVE

The OLPC project has seen success through funding, government interest, and impressive technical developments such as the $35 LCD. While other projects have focused on developing systems generally, the OLPC group has tailored their project through a smart physical design and appropriate software. Serious thought appears to have been invested with regard to how children will use the laptop. For instance, the laptop has similar dimensions and weight as a child's lunchbox, indicating the device should not be too much of a burden to carry. A pull-string generator has replaced an original plan for a hand crank, after concerns about the tedious nature of cranking, and a membrane keyboard is intended to ward off dust and spills (Bullis, 2006; "Features: Discover the XO Laptop Features," 2007).

Criticism for the project may be well-founded, however. The OLPC group has not yet detailed how the computers will receive software updates or maintenance. This is a colossal issue that needs to be addressed. It cannot be assumed that all children will be savvy enough to figure out when software needs to be updated, and further apply those updates themselves. Negroponte and the team have said that children will be given root access to the machines, so it is especially important to develop an infrastructure for updates to ensure the OLPC laptops remain stable. It is also unclear if and how data backups will occur, or whether children would simply have the misfortune of losing their work if the laptop is damaged or stolen. One solution may be the distribution of 1 gigabyte USB flash drives along with the laptop, but children would need to be taught how to back up their machine. This may be too much responsibility to expect from a child, so perhaps the parents or teachers would need to be involved as well. Further, solutions to

back up data are likely to require additional human and financial resources, which must be factored into the laptop's cost.

Criticism has also surfaced over the value of using technology to help educate children, when some countries lack basic educational resources and facilities. Proponents argue that the laptop has not been designed around traditional ideas of education. The display converts to a black-and-white mode for sunlight use, although modern laptops are generally not thought of as outdoor devices. The screen can be twisted and laid flat against the device as a tablet, a mode meant to enable reading electronic books. A pull-string generator makes traditional electric outlet access unnecessary. To address Internet connectivity costs, the laptops will use mesh networking so that many computers may share a single connection (Bullis, 2005). For all of these reasons, the OLPC laptop is not comparable to the modern business laptop; this is a device built around the assumption that there may be a lack of other educational resources like books and a lack of traditional facilities with electric outlets. Part of the OLPC intention is the development of future entrepreneurs, who will be better educated and capable of enhancing their communities.

Additional criticism has come from Negroponte's method of cost tallying, which skeptics say do not consider all expenses. In October 2006, the OLPC group signed a deal with Libya to provide 1.2 million laptops and infrastructure for the deployment, at a cost of $250 million (Markoff, 2006). At this rate, the actual cost per laptop becomes $208.33. The infrastructure included with the deal consists of one server per school, a team of technical advisers to set up the system, and satellite Internet access. In fact, all costs do not seem to be included in the $140-150 per device number, although OLPC claims that the $208.33 figure includes some up front, non-recurring costs ("Can a $100 Laptop Change the World?" 2007). Training costs and maintenance are noticeably absent from these numbers. The OLPC association has considered designing simple, user-replaceable parts so that the children can perform some repairs on the machines. But providing a distribution and warehousing system for replacement parts (and preventing loss, fraud or theft) will be costly.

One way to lower costs would be if officials required that children graduating from school return the laptops. Children just starting school would inherit the laptops, enabling the government to avoid purchasing a new set of laptops for incoming students. However, it remains to be seen what the life expectancy will be for these laptops in real world conditions, and whether graduating children would actually return their laptops.

With criticism to compound rampant challenges, creating a low-cost computing project for developing countries has typically been a monumental task with little payoff. As the OLPC situation illustrates, coordinating such projects involves examining hardware, software, design, costs, and manufacturing, as well as social factors. Despite the necessary effort, numerous government and private organizations over the years have attempted such projects, with mixed results.

Negroponte forecasts sales of 5 million units in 2007 and 50-100 million units in two years, although OLPC has not successfully sold the concept to large developing countries such as China and India.

LOW-COST COMPUTING PROJECTS WORLDWIDE

Brazil had one of the first government-run programs to bring inexpensive computers to its citizens. In 2001, Brazil sought manufacturers to develop a $250 computer dubbed the "Popular PC." To avoid high import taxes, the program would attempt to use as many domestic-made components as possible. In a further effort to keep costs low, designers pared specifications to the minimum: the computer would use a less expensive flash drive in lieu of a hard drive and would lack CD-ROM and floppy drives (Rebelo, 2005). The design was soon deemed too impractical for use, and a more conventional computer was developed. However, at a cost of $600 per box, the device was priced beyond what most consumers could afford, and far beyond the planned cost of $250. In late 2002, newly elected leaders chose not to continue the program (Rebelo, 2005). Although it seemed Brazil would end low-cost computing initiatives for the moment, the government announced a new plan in 2003 for the "Connected PC," later known as the "Computer for Everyone." The program encouraged domestic manufacturers to develop inexpensive consumer PCs. Participating manufacturers received an approximately 9.25% tax break, with the intention that the discount is passed along to consumers (Rebelo, 2005). The intended buyers are Brazilians with an income between 300 and 3,000 reals per month (approximately $140 to $1,400 USD) ("Five More Join PC Connected Program," 2005).

In Mexico, Intel Corporation's Classmate PC has been developed for the educational market. Unlike the OLPC laptop, cutting costs is not the primary goal. Intel CEO Paul Otellini has called the $100 laptop a "gadget," and has pledged to use technology comparable to modern laptops. Each Classmate PC is anticipated to cost $400, although the exact price may vary ("Intel to Launch Low Cost Laptop," 2006). Specifications for the device include a 7-inch color screen, a 1 gigabyte flash drive, 256MB memory, wired and wireless networking ability, and a battery that provides approximately 4 hours of use (Clendenning, 2006). Machines come equipped with either a Windows or Linux operating system ("Intel to Launch Low-Cost Laptop," 2006). In late 2006, Intel announced a plan to donate 700-800 of its Classmate PCs to Brazil for use in schools, although the country has already agreed to purchase OLPC laptops. The Brazilian government has said it will evaluate the two laptops and a third unspecified computer offered by an Indian company (Clendenning, 2006).

While it is unclear which Indian company has approached Brazil, multiple low-cost computing efforts within India have been underway. One device in particular, is a handheld Linux device known as the Simputer, or "simple, inexpensive, multilingual computer" ("Cyber's Poor Relations," 2005). First conceived in 1998, the Simputer was intended to be used within households for general computer use. Instead, the Simputer has mainly evolved as a tool for businesses. The low demand means that the product has not seen bulk production, which could have led to lower prices for the device. Pico Peta, one of the two companies selling the Simputer, sold less than 2,000 units between April 2004 and April 2005, with only 10% of the devices going to rural areas. Encore, the other company selling the Simputer, also sold less than 2,000 units during the same period ("Cyber's Poor Relations, 2005"). Prices for the Simputer start between $300-330. Although the device continues to sell in India, sales have not met expectations (Jewell, 2005).

A second system from Indian start-up Novatium has also gained attention. The Nova NetPC is intended to be a low-power, affordable computing solution for community use. The computer's cost breakdown is as follows: $25 for the monitor, $25 for chips, $20 for memory, $10 for the keyboard and mouse, $10 for miscellaneous parts, and $10 profit (Malik, 2005). Notably missing in the breakdown is a hard drive – this is because the NetPC uses a thin-client architecture, in which all data is stored on an external server and accessed through a network connection. Users may also save data through removable storage, such as USB flash drives.

Similar to the NetPC, the Ndiyo Project in Britain also uses a thin-client architecture called Nivo (network in-video out). Spearheaded by Open University professor and Ndiyo director John Naughton, the system incorporates desktop computers linked to a single server, in a set up similar to a computer lab. All software and data is stored on the server and accessed through an Ethernet connection ("FOCUS: Digital Deficit," 2005).

While there are advantages to the thin-client architecture designs under development by Novatium and the Ndiyo Project, these designs are not ideal for every computing project in developing countries. An obvious benefit is the ease of technical upgrades and handling maintenance issues, since one server provides all content. As long as a steady source of electricity is available for the server and machines, there is little worry of an outage affecting users' work. However, thin-client architectures require a robust network that can allow connections by multiple users at reasonable speeds. In the case of laptop-based projects like that proposed by the OLPC association, a network connection would need to be wireless. The association has said that the laptops will connect to each other to share a single wireless connection, in a design known as wireless mesh networking. Though this design may be suitable for sharing a wireless Internet connection, the impact of many children using a single connection for every activity would present significant strain to the network. Further, the continuous transmission of network packets mean a greater toll on battery life, which may not be acceptable for a laptop that must be manually powered in the absence of electricity.

Although the projects discussed herein have similar aims, costs and specifications vary widely. Table 2 illustrates the differences between three selected proposals.

TABLE 2. Comparison of the OLPC laptop, Intel Classmate PC, and Nivo

	OLPC Laptop	Intel Classmate PC	Nivo (Ndiyo Project)
Physical Design	Laptop with 7.5" color / black-and-white swivel display	Laptop with 7" color display	Desktop computer with stand alone monitor, keyboard, and mouse
Size	Laptop dimensions of 193mm x 229mm x 64mm	Exact dimensions unkown	CPU dimensions of 120mm x 80mm x 20mm, plus monitor
Developers	Spearheaded by a university professor	Spearheaded by a corporation	Spearheaded by a university professor
Intended Market	Children in developing countries	Children in developing countries	Children and adults in countries
Distribution Ratio	One computer for one child	One computer for one child or small group	One computer, shared by a small group (such as a cybercafe scenario)
Storage Capability	512 MB Flash Drive	1 Gigabyte Flash Drive	None; all data is stored on an external server
Included Memory	128 MB RAM	256 MB RAM	2 MB video RAM
Operating System	Linux	Linux or Windows	Linux-based
Software	Web browser, word processor, chat software, multimedia software	Said to be "education specific;" exact software unkown	Web browser, word processor, chat software
Power Consumption	2-3 Watts	Unknown	5 Watts (not including monitor)
Price Point	Currently around $150 USD	Currently around $400 USD	Approximately $30 USD for each Nivo unit, although servers are also required

Source: OLPC Laptop ("Specs: Discover the XO Laptop Specs," 2007); Classmate PC ("Classmate PC Product Brief," 2007); Nivo ("A Sustainable Architecture Networking," n.d.)

While there are myriad organized efforts seeking to bring computers to developing countries, few projects have examined the development of a communication backbone for such projects. Internet connectivity in developing countries may mean high costs and little reliability, particularly for rural areas. However, strides have been made to bring connectivity to isolated areas.

When fiber optic lines are within reasonable distance, Wireless Local Loop networks can be a favorable option. In the case of one type of Wireless Local Loop, corDECT, a primary base station connects to the lines in order to send data wirelessly to repeater base stations or other devices within 10 kilometers (6.2 miles). The repeater base stations have a span of 25 kilometers (15.5 miles) (Best & Maclay., 2002). A corDECT network can carry voice transmission at 70Kbps, and simultaneous voice and data transmission at 70Kbps (Prasad, 2003). The corDECT option becomes more economical with a greater user base. With 50 people using one corDECT network, the cost per line is approximately $650. When 500 people use the network, the cost per

line is in the low $400 range (Best & Maclay, 2002). By comparison, wireless VHF and UHF options connections run $800 per line and average speeds are lower (Best & Maclay, 2002). Thus, Wireless Local Loop networks such as corDECT are relatively inexpensive options for rural connectivity. In Uganda, a school using a corDECT-type system paid $1,500 in initial costs and $250 monthly to the Internet service provider, gaining reliable Internet connectivity 24 hours a day (Hawkins, 2002).

However, Wireless Local Loop networks are not feasible in rugged terrain or in areas where networks are not sufficiently near. In such situations, Very Small Aperture Terminal (VSAT) satellite may be used. Satellite connections are appealing in terms of reliability, though equipment costs of $4,000-$10,000 can be prohibitively high without outside funding (Best & Maclay, 2002).

SOCIAL OBSTACLES TO TECHNOLOGY DIFFUSION IN DEVELOPING COUNTRIES

Without consideration of social factors, projects that drive technology use and adoption within developing countries stand a high chance of failure. Therefore, aside from providing equipment, such projects must ensure that certain considerations are made.

One key step is to ensure that adequate content and software exist in the users' language. Even within the same country, content in a variety of languages may be necessary. This is particularly the case in India, where only 5% of the population is fluent in English. While many speak one of the country's 18 official languages, India has 850 local and regional dialects, which makes it difficult to provide sufficient content in a majority of languages spoken (Warschauer, 2004).

With computers robust enough to be tools for productivity, learning, and communication, educational facilities must decide how to develop lesson plans that utilize the most relevant functionality of the computer for the particular subject and age group. China has sought answers to this dilemma by developing a pilot program in which schools can develop plans to incorporate computing as they see fit. The aim of the program is to understand the most effective ways in which technology can impact learning at different levels (Warschauer, 2004).

Training teachers to learn and incorporate technology must also be considered when deploying computers in an education-based environment. Training could consist of Internet-based courses, occasional seminars, or ongoing courses. Issues of cost, time, and feasibility must be weighed in order to develop an effective program. When Brazil attempted to train teachers outside of major metropolitan areas, an Internet-based course was developed. However, the inaugural group had 46% of the teachers drop out prior to course completion. When program administrators incorporated occasional in-person meetings to the online program, the dropout rate sank to 8% (Warschauer, 2004).

Even adequate training cannot guarantee that citizens will take advantage of available technology. When people cannot understand what advantages a computer may provide, they will be unlikely to utilize the device without additional support and information. For business, educational, and

consumer purposes, the onus will be on governments and private organizations to provide the support and training necessary for successful deployment of technology. As previous efforts have shown, the complexity of these programs often results in limited success. However, the wave of recent computing projects for developing countries, along with the possibility of success from Nicholas Negroponte's OLPC idea, may spur new progress to bridge the digital divide.

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