

A System Dynamics Approach to Educational Technology Introduction in Developing Countries

by

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Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

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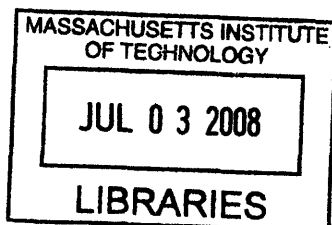
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Submitted to the System Design and Management Program and the Engineering Systems Division on May 9th, 2008 in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

Developing nations around the globe are focused on ways to use Information and Computing Technologies (ICTs) as springboards to advance their national development in all areas, including education. There are multiple ways in which various organizations are tackling the unique challenges these nations face in equipping their schools with modern educational technologies. This study evaluates two examples of computing technology intended for wide-scale deployment in developing nations. It aims to test the hypothesis that in order to be successful, ICT implementations require adequate funding, available electrical and telecommunication infrastructure, the presence of strong local champions and a local support ecosystem.

Interviews were conducted with stakeholders involved in two pilot implementations in Nigeria. A system dynamics model was used to investigate into the relative effects of relevant factors on the speed of ICT deployment. The results from the modeling show the need for a significant increase in financial investment, in order to cover all costs associated with ICT deployments. The results also revealed the daunting task nations face in equipping all students with individual laptops and it presents some alternatives to a wide-scale deployment of one-to-one computing. Finally, the results highlight the necessity of providing economical means of completely powering ICTs in order to rapidly deploy these technologies to the nation's schools. A number of recommendations were made for the consideration of any developing nation undertaking ICT implementations in education.

Thesis Advisor: J. Bradley Morrison

Title: Senior Lecturer of the Engineering Systems Division

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Thank you Dad and Mum for always encouraging me to reach higher.

Thank you Lord for making this dream come true.

To the Nigerian Child

Fix these words of mine in your hearts and minds; tie them as symbols on your hands and bind them on your foreheads. Teach them to your children, talking about them when you sit at home and when you walk along the road, when you lie down and when you get up. - Deuteronomy 11: 18 – 19, New International Version

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1 Introduction

1.1 Motivation

“The world is undergoing dramatic and unprecedented changes in this age of increasing globalization...Today, a country’s competitiveness and development potential depend on several factors...Key among such factors is the creation of a high-skilled workforce with the ability to access, adapt, apply, and create new knowledge and technologies. Education at all levels thus plays a major role in increasing a country’s development and competitiveness.¹” – The World Bank

“Education is central to development and a key to attaining the Millennium Development Goals. It is one of the most powerful instruments for reducing poverty and inequality and lays a foundation for sustained economic growth.²” – The World Bank

In September 2000, 189 nations around the world endorsed the Millennium Declaration which included the Millennium Development Goals (MDGs) – eight broad goals to achieve significant advances in meeting the needs of the world’s poorest by 2015. One of these goals is to achieve universal primary education echoing a similar goal endorsed earlier in 1990, to achieve Education for All (EFA) by 2015. In order to meet these goals, nations everywhere have implemented educational reform policies aimed at increasing student enrollment, attendance and gender equity. These educational goals also tie-in the 8th Millennium Development Goal - to develop a global partnership for development and in

¹ The World Bank, Retrieved March 24, 2008 from <http://go.worldbank.org/QJ8706OX90>

² The World Bank, Retrieved April 30, 2008 from <http://go.worldbank.org/GMDMICVFF0>.

cooperation with the private sector improve access to new technologies, especially information and communication technology.³ As stated by the World Bank, education is seen as the basic building block to eradicating poverty and developing the human capital required to harness the economic growth possible from a knowledge-based economy.⁴ To this end there is growing interest in introducing technology, specifically Information and Communication Technologies (ICT), to all of the world's school children in order to prepare them for contributing to the economic growth of their respective nations.

As each nation struggles against a myriad of obstacles to improve the quality of education for their children, international donor agencies and organizations propose solutions in the form of recommended policies, practices and technologies; some identical to those used previously in developed nations and some customized for the developing world. Meanwhile, there is significant debate as to the efficacy of ICTs in encouraging deeper understanding in students in spite of its prevalence of developed nations. Still there is general consensus that the world economy is driven by information and nations with well-educated knowledge workers are able to foster economic growth in new ways.

The question pondered by developing nations remains that given the unique constraints in the developing world of limited financial and infrastructure resources, what is the best manner to introduce computing into educational systems to ensure that future graduates, the nations' human capital, are employable in an increasingly digital world? This thesis aims to provide some answers to that question within the context of two recent education ICT programs. In doing so, it considers the global challenge issued in the MDGs: to enroll in primary school the 72 million children worldwide who are out-of-school by 2015 – less than seven years away.⁵

³ The United Nations website, "UN Millennium Development Goals", Retrieved April 30, 2008 from <http://www.un.org/millenniumgoals/#>

⁴ The World Bank, "Education Policy Reform: Regional Responses to Global Challenges, ECA Region", Retrieved April 30, 2008 from <http://go.worldbank.org/QJ8706OX90>

⁵ "The Millennium Development Goals Report", The United Nations, 2007 <http://www.un.org/millenniumgoals/pdf/mdg2007.pdf>

1.2 Objectives and Hypothesis

This thesis aims to determine the factors that affect the implementation of technology on educational reform efforts in developing countries. This is done by investigating into two existing educational technology projects in Abuja, Nigeria. These projects are the pilot projects of the One Laptop Per Child® (OLPC) organization and the Intel® World Ahead Classmate initiative.

While there are a lot of factors to consider when introducing technology into the educational systems in developing nations, there are a few key factors that overwhelmingly determine the successful adoption of these technologies. It is hypothesized that in addition to the well-known factors of available funding and teacher buy-in, there are three other key factors that should always be actively managed when introducing technologies. They are:

- The need to encourage the growth of a local ecosystem with skilled personnel able to perform all implementation, repair and content creation tasks related to the Educational ICTs.
- The need for a strong presence of local champions who are able to influence the financial investments in the technologies.
- The need for available affordable electrical and telecommunication infrastructure.
- And finally, the need to manage expectations of any wide-scale ICT implementations.

1.3 Approach

The research approach involves reviewing the existing literature on the effects of technology on educational objectives. The review focuses on these areas: the historical background of computer technology in education, its challenges and best practices. Following the literature review, interviews were conducted with key players in both pilot projects operating in Abuja, Nigeria. These pilots were chosen due the unique opportunity

to evaluate similar projects side-by-side within the same city. These interviews were conducted with the IT director of the Universal Basic Education commission (UBE), the CEO and the Director of Alteq.ict – a local consulting firm, the principal of the LEA Galadima Primary school (OLPC pilot) and the Computer Science teacher of the Jabi Junior Secondary School (Intel® pilot).

With the information gathered from the interviews and extensive data collection via the internet, a system dynamics model was created to explore the two cases and represent the mental models of the key stakeholders in implementing ICT in the education system – government, local companies, teachers, students and parents. First, a causal loop diagram was created to summarize the key causal relationships within the system of implementing ICTs. With this summary, each causal loop variable was initially considered as a stock (a level) in order to model the system. Some stocks were eliminated and summarized as variables based on their overall importance to the model. With this concise system dynamics model, sensitivity analyses and what-if scenarios were performed to test the relative effects of the various ICT implementation factors and develop a recommendation for introducing technology into education in developing nations.

1.4 Thesis organization

Chapter 1 presents the introduction to the thesis outlining the approach and assumptions. Chapter 2 reviews a selection of literature on the history of computers in education and research findings regarding the impact of technology on student learning and the costs associated with this technology. With this background Chapter 3 will present the developing nation, Nigeria, which is the location of the case studies and will review the history and state of education in that nation. In this context the two ICT in education programs are introduced. Chapter 4 presents the findings of the interviews performed with key stakeholders in the recent pilot projects and Chapter 5 steps through the formation of the system dynamics models for these pilots. The interpretation and sensitivity analysis follow in Chapter 6 while Chapter 7 presents the recommendations for future implementations of educational technology projects in developing countries and the conclusion of the thesis.

2 Literature review

I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks...The education of the future, as I see it, will be conducted through the medium of the motion picture...where it should be possible to obtain one hundred percent efficiency. - Thomas Edison, 1922⁶

2.1 Historical background of computer use in education

Thomas Edison's hopes and declaration that a particular technology would dramatically improve education was not a new one at the time, having being preceded by similar hopes for instruction via radio, and it has been echoed many times since for a variety of technologies like television, video disc and, in the last five or more decades, computers.

A review of literature reveals the various phases of the use of computers in education. Van Melle et al.⁷ compiled the use of information and computing technology in education in developed nations, showing the progression from teaching machines in the 1950's through Computer Assisted Instruction, Multimedia (CD ROMs), Hypermedia and on to the present age of computer networks, the internet and the World Wide Web. With this progression in technology has been a shift in focus from drills with computers to the promotion of higher order thinking skills. Throughout this shift, there has been a corresponding adoption of

⁶ Edison, T. quoted by Cuban, L. in *Teachers and Machines: The Classroom Use of Technology Since 1920*. New York: Teachers College Press, 1986.

⁷ Van Melle, E. Cimellaro L. and Shulha, L., "A Dynamic Framework to Guide the Implementation and Evaluation of Educational Technologies", *Education and Information Technologies*. Vol. 8 No. 3. 2003

various theories of learning – Behaviorism, Cognitivism and Constructivism which reflect societies changing views of the goals of education. The most recent view held widely by all nations, including developing nations is that education, especially ICT-assisted education, is a key element in building a knowledge-based economy. According to Van Melle et al., the skills that society believes are required for this kind of economy are summarized within the 7C's:

- Critical thinking and doing
- Creativity
- Collaboration
- Cross-cultural understanding
- Communication
- Computing
- Career and learning self reliance

Warschauer likewise in his book 'Laptops and Literacy'⁸, agrees with Van Melle et al. on society's changing views of computers in education, choosing to divide the stages into two waves – the first wave of computers as teaching machines and the second wave of computers used as tools. In the latter wave, educational theorists like Seymour Papert are well known for their views on using computers to encourage in children higher-order thinking skills, creativity and a desire to explore the world of knowledge. Papert based his theories on the work of his mentor Jean Piaget, the well-known constructivist and in his book 'Mind--Storms. Children, Computers and Powerful Ideas'⁹ Papert states, "I believe that the computer presence will enable us to so modify the learning environment outside the classrooms that much, if not all, the knowledge schools presently try to teach with such pain and expense and such limited success will be learned, as the child learns to talk, painlessly, successfully, and without organized instruction."

This is a bold claim and one that is still quite controversial more than 25 years later. Nonetheless, the Logo programming language designed by Papert is based on this goal – to

⁸ Warschauer, M. "Laptops and Literacy: learning in the wireless classroom", Teachers College Press, 2006

⁹ Papert Seymour, "Mind-Storms. Children, Computers and Powerful Ideas", Basic Books, Inc. 1980

present an intuitive method of interacting with a computer in order to “learn learning”. This is achieved by the student interacting with a computer ‘Turtle’ in ways that teach concepts of geometry and physics, amongst other subjects. The key benefit Papert identifies with this approach is the habit of exploration. This habit is one that ICT initiatives generally wish to foster when proposing that each student have their own computer; the idea being that sole ownership will provide them with enough time to explore and create knowledge. Watson in articulating the problems with the widely-used configuration of computer laboratories in schools states, “It is ironic that limited time may be available for the very open-ended exploratory work which the technology can facilitate, but which demands flexibility. It is not the resource itself, but the restricted access to it, that causes the problem.”¹⁰

2.2 Impact of computer technology on education

It is in this context that nations throughout the world continue to debate and implement varying configurations of computers in schools – from one-to-one computing, where every student has a computing device, to moveable carts which transport the computers between classrooms at appointed times, and then to computers available in special laboratories or libraries and even to configurations where students use multiple inputs to control one computer.¹¹ Each configuration is not without its advantages and disadvantages, yet overshadowing this ongoing debate of computer configuration are the larger unanswered debates of whether computer-aided instruction leads to an improvement in student skills at all, and if it does, how best to integrate it into the school curriculum in order to realize that improvement.

Van Melle et al.¹² present findings based on industry research into the best practices of implementing technology in education. Some of the findings show little to no

¹⁰ Watson, D. M., “Pedagogy before Technology: Re-thinking the Relationship between ICT and Teaching”, *Education and Information Technologies*, Vol. 6:4, 251–266, 2001

¹¹ Pal, J. Pawar, U., Brewer, E., Toyama, K. “The case for multi-user design for computer aided learning in developing regions.” 15th International WWW Conference, Edinburgh, May 2006.

¹² Van Melle, E. Cimellaro L. and Shulha, L., “A Dynamic Framework to Guide the Implementation and Evaluation of Educational Technologies”, *Education and Information Technologies*. Vol. 8 No. 3. 2003

improvements on student learning by introducing technology into the classroom. For example, in a separate study, Russell¹³ investigated into the impact of using technology for distance education and found no significant impact on student learning. Likewise in a study of Missouri schools, Alspaugh¹⁴ found 'no relationship between the availability of computers and traditional measures of education outcomes'. Another study by Christmann et al.¹⁵ of the academic achievement level of science students exposed to Computer Assisted Instruction found it had the strongest positive effect on science students from urban settings. Finally, in a study of whether increased access to computers increased their use when teaching, Cuban et al.¹⁶, found that it did not cause increased use. Rather, computers only helped to maintain the current teaching practices. InfoDev, a partnership of international development agencies, published 'Knowledge Maps: ICT in Education'¹⁷ in which it summarized the lack of empirical evidence on the impact of ICTs on education. It concedes that only Computer Aided Instruction has been seen to slightly improve test scores of students but that the impact on student learning is still open to question. InfoDev also summarizes the counter arguments that claim that the lack of positive results is due to the measurements of traditional education outcomes rather than new outcomes only possible with ICT. In line with this, there is a commonly held view that since computers are in common use in business today, there are long-term benefits to teaching their use as a tool in schools.¹⁸

¹³ Russell, T. R., "The no Significant Difference Phenomenon.", North Carolina State University, 1999

¹⁴ Alspaugh, J.W., "The relationship between the number of students per computer and educational outcomes." *Journal of Educational Computing Research*, 21, 141–150, 1999

¹⁵ Christmann, E. and Badgett, J., "A comparative analysis of the effects of computer-assisted instruction on student achievement in differing science and demographical areas." *Journal of Computers in Mathematics and Science Teaching*, 18, 135–143., 1999

¹⁶ Cuban, L., Kirkpatrick, H., Peck, C., "High access and low use of technologies in high school classrooms: Explaining an apparent paradox.", *American Educational Research Journal*; Vol. 38, No. 4; pg. 813, Winter 2001

¹⁷ Trucano, M., "Knowledge Maps: ICT in Education." Washington, DC: infoDev / World Bank, 2005. <http://www.infodev.org/en/Publication.8.html>

¹⁸ Warschauer, M. "Laptops and Literacy: learning in the wireless classroom", Teachers College Press, 2006

2.3 The realities of ICT in education

Several works cite various reasons for the apparent disconnect between intentions and realities. Watson¹⁹ in reviewing pedagogy in relation to ICT in schools states that the reason ICT has had marginal impact on the teaching practices of all school disciplines is because teachers are the recipients of two confusing, and potentially resource conflicting, goals – to use ICT as a teaching tool for all subjects and to teach the use of ICT in preparation for use in the business world. Watson states that the innovation diffusion model which relies on a few early adopters to spread the innovation does not necessarily apply within schools and so the early adopter model was not used in this thesis. Watson in an earlier work, attributes this to the fact that the small percentage of teachers willing to overcome the obstacles to incorporate ICT into the classrooms are viewed as unique, and therefore, are not imitated by the larger teacher body.²⁰ Watson further argues that the best way to change this situation is to introduce education reforms by considering educational philosophies and introducing ICT as a tool to further those goals rather than set technology up as a catalyst for needed curriculum and pedagogical reform. This Watson believes would reduce the occurrence of teaching lower-order skills and retrieval of information rather than critical accumulation of knowledge.

Overall, this assessment of the lack of concrete direction in the use of ICT is echoed in several texts, and as stated by InfoDev²¹, it is certainly evidenced by a number of vague national policies that generally herald in the funding of ICT projects in schools. It would appear that in the rush to provide short-term tangible evidence of progress, most educational systems appear loathe to entangle their push for modern skills into bigger less tangible educational reform projects. Some reluctance is understandable in systems where lengthy projects receive less attention and funding over time. Nonetheless, ICT in education is largely reported by users to make a positive difference in their learning, with

¹⁹ Watson, D. M., "Pedagogy before Technology: Re-thinking the Relationship between ICT and Teaching", *Education and Information Technologies* 6:4, 251–266, 2001.

²⁰ Watson, D. M., "Do enthusiastic users inhibit change?", *Informatics and Changes in Learning*, Amsterdam, pp. 269–276, 1993

²¹ Trucano, M., "Knowledge Maps: ICT in Education." Washington, DC: infoDev / World Bank, 2005. <http://www.infodev.org/en/Publication.8.html>

increased access time cited as being directly correlated to user confidence in using the technology. It is also presumed that this user confidence will translate directly into the business world. As such, improved ICT use is an important goal of most education policies in the developing world today, with a wide variety of ICT projects in process – from supplying computers and connectivity to schools, creating electronically formatted curricula, to distance learning for remote students. Electronic content and distance learning in particular, are expected to provide students with access to high quality learning content and overcome the deficiencies in teacher attention & expertise where the teacher-to-student ratio is high. It also presents an enticing way for schools that do not currently have sufficient updated textbooks to overcome this issue once and for all, by substituting print for the growing number of locally adapted materials. In addition, for nations with geographically dispersed populations, the elimination of transportation costs for students and printed material may be significant.

Finally, there are those who believe that the 'soft' benefits to ICT use are also significant – instilling a feeling of connectedness between students and the world outside their village/town/city has the potential for knowledge transfer and innovation possibilities as students have the opportunity to learn in a manner that is different from the traditional rote repetition model often used in a lot of developing countries. Ultimately, the initial primary impact evidenced in the case studies in this thesis is increased student attendance & enrollment. In developing countries with little new resources allocated to the majority of schools, ICT implementations catch the interests of the students, teachers, parents and their communities-at-large and bring to the forefront each community's aspirations for their children.

2.4 A proposed framework for implementing ICTs in schools

For projects that target increased student learning there are a number of conditions that enhance the likelihood of ICT being incorporated into school pedagogy and resulting in real knowledge gains in students. Below are some examples of practices found in existing literature that may be incorporated into a framework for implementing ICTs in schools:

- Establish clear goals for the ICT project.^{22, 23}
- Incorporate ICT into teaching practice.²⁴
- Professional support (i.e. teacher training) needs to be continuous.²⁵
- Use evaluation methods that are aligned to learning goals.^{26, 27}
- Planning and budgeting need to incorporate the Total Cost of Ownership (TCO) calculations.²⁸

2.5 Total Cost of Ownership (TCO)

Few ICT projects accurately calculate the total cost of ownership of ICT investments and as more developing countries with few resources to spare consider and implement ICTs in the educational sector, this area is beginning to receive more attention. ICTs in general are expensive, even for developed countries, however developing countries often face costs that are up to double the costs faced by developed countries.²⁹ Even donated or refurbished computers are found to be costly when repairs and maintenance are taken into account. Typical projects cite only the hardware costs, neglecting that hardware has been evaluated to account for only 17 – 49% of the total cost, depending on the configuration, with software, maintenance, repair, connectivity and facilities absorbing the rest of the costs.³⁰ In addition, it is typical for estimates to ignore recurring costs and leave the sustainability of the project in question.³¹ According to InfoDev there are few rigorous studies in the

²² Trucano, M., “Knowledge Maps: ICT in Education.” Washington, DC: infoDev / World Bank, 2005. <http://www.infodev.org/en/Publication.8.html>

²³ Van Melle, E. Cimellaro L. and Shulha, L., “A Dynamic Framework to Guide the Implementation and Evaluation of Educational Technologies”, Education and Information Technolgies. Vol. 8 No. 3. 2003

²⁴ Ibid

²⁵ Ibid

²⁶ Ibid

²⁷ Trucano, M., “Knowledge Maps: ICT in Education.” Washington, DC: infoDev / World Bank, 2005. <http://www.infodev.org/en/Publication.8.html>

²⁸ Ibid

²⁹ “Paying the price? A Total Cost of Ownership comparison between new and refurbished PCs in the small business, NGO and school in Africa”, Open Research, 2004

³⁰ Bakia, M., “The costs of computers in Classrooms:Data from Developing Countries”, TechKnowLogia, January – March 2002

³¹ Perraton, H., Creed, C., “Applying New Technologies and Cost-Effective Delivery Systems in Basic Education”, International Research Foundation for Open Learning, 2000

Least Developed Countries (LDCs) of the cost-effectiveness and opportunity costs of the investments related to ICTs. This leads organizations like UNESCO, (United Nations Educational, Scientific and Cultural Organization) to conclude based on cost data alone that many countries should realistically only consider implementing ICTs in secondary, tertiary and higher levels of education.³² The lack of proven returns on investments leaves the door open for significant disagreements on whether any widespread ICT projects should be undertaken given the resource constraints that developing nations face. Yet that argument is countered by those who feel that ICTs are the only way developing nations can bridge the huge divide that exists today between the schools in developing nations and those in developed nations. This thesis presents two education ICT projects and considers aspects of their TCOs in order to make recommendations on implementation strategies to nations considering ICTs in education.

³² Trucano, M., "Knowledge Maps: ICT in Education." Washington, DC: InfoDev / World Bank, 2005. <http://www.infodev.org/en/Publication.8.html>

3 Case Study Background: Nigeria

3.1 Nigeria Facts

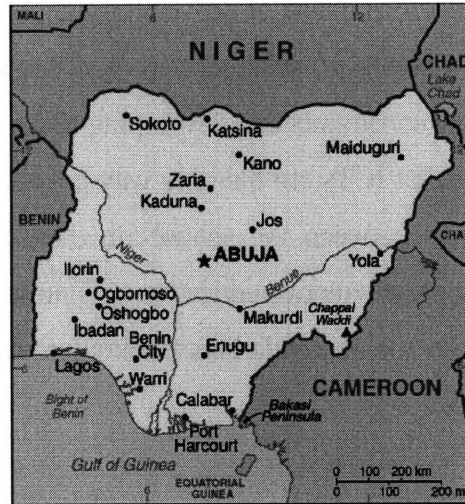


Figure 1: Map of Nigeria
(Source: CIA World FactBook)³³

	Nigeria Facts ³⁴	USA Facts
GDP (purchasing power parity):\$	294.8 billion (2007 est.)	\$13.86 trillion (2007 est.)
Population:	135,031,164	301,139,947 (July 2007 est.)
Age Structure:	0-14 years: 42.2% 15-64 years: 54.7% 65 years and over: 3.1%	0-14 years: 20.2% 15-64 years: 67.2% 65 years and over: 12.6%
Population growth rate:	2.379% (2007 est.)	0.894% (2007 est.)
Labor force - by occupation:	agriculture: 70% industry: 10% services: 20% (1999 est.)	farming, forestry, and fishing: 0.6%, manufacturing, extraction, transportation, and crafts: 22.6%, managerial, professional, and technical: 35.5%, sales and office: 24.8%, Other services: 16.5% <i>note: figures exclude the unemployed (2007)</i>
Unemployment rate:	5.8% (2006 est.)	4.6% (2007 est.)

³³ CIA Fact Book Online, Accessed March 28, 2008 <https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html>

³⁴ Ibid

	Nigeria Facts (contd.)	USA Facts (contd.)
Population below poverty line:	70% (2007 est.)	12% (2004 est.)
Population without electricity	71.1 million ³⁵	0

Table 1: Country facts - Nigeria and USA
 (Source: CIA World FactBook³⁶ and International Energy Agency³⁷)

3.2 Nigerian Education Policies

The goal of mass education for all has been a long-term Nigerian goal since colonial times and how to achieve it has been the subject of many papers and conferences over the years. During the Second World War, Vischer³⁸ commented on the report ‘Mass Education in African Society’ written by a sub-committee to the Advisory Committee on Education in the Colonies. Vischer’s comments echoed the hope expressed in the report that the Africans who were engaged in the war effort would be the greatest forces in creating a movement towards mass education from within. Yet even while there was a hope that techniques such as “literature, libraries, the press, broadcasting, cinema and other visual aids”³⁹ would be used to reach the goals of literacy for all, there was a recognition that social forces, not techniques, would be required to begin and sustain that movement. Here we see even, the beginnings of the still echoed goals of ICT in education – leverage knowledge from outside your community and use aids to educate widely.

In the past, the colonial government operated with a “policy of co-operation with voluntary agencies” according to Oldham,⁴⁰ where the government allowed voluntary agencies, such as missionary societies, to set up schools as long as they were in accordance with the

³⁵ World Energy Outlook 2006. Paris, International Energy Agency (IEA). 2006. Retrieved from UNDP website <http://hdrstats.undp.org/indicators/211.html>

³⁶ CIA Fact Book Online, Accessed March 28, 2008 <https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html>

³⁷ World Energy Outlook 2006. Paris, IEA (International Energy Agency). 2006. Retrieved from UNDP website <http://hdrstats.undp.org/indicators/211.html>

³⁸ Vischer, H. “Report of the Advisory Committee on Education in the Colonies. Mass Education in African Society”, Africa: Journal of the International African Institute, Vol. 14, No. 6. (Apr., 1944), pp. 336-339.

³⁹ Ibid

⁴⁰ Oldham J. H., “The Educational Work of Missionary Societies”, Africa: Journal of the International African Institute, Vol. 7, No. 1. (Jan., 1934), pp. 47-59.

policies of government. The missionary societies were therefore instrumental in setting up schools with a largely British curriculum and in areas like northern Nigeria, where missionaries were largely unwelcome, the Quranic schools and indigenous schools were prevalent.⁴¹ From these beginnings of co-operative policies with agencies such as missionary societies, the Nigerian education system evolved into what it is today – A system of government at the national, state and local level with advisory boards, including the National Union of Teachers (NUT) to influence policies. From 1947 when Nigerians took on governance of their educational policies through 1975 the number of pupils enrolled grew dramatically due to continued grants, establishments of government, local, community and private schools and the expansions of fields of studies in higher educational institutions.⁴² The increase in the number of institutions produced a structural change in the educational system. In 1976, the Universal Primary Education Board was created to provide free primary education and was later disbanded after its failure to provide free quality education in all parts of the country. According to Ajetomobi et al, in 1994, the funding of education was modified to allocate responsibility for funding between government, state, [local government], pupil enrollment and state taxes.⁴³ Yet the rate of increase in enrollment did not match increases in funding and schools have fallen into disrepair, unrest has arisen repeatedly amongst teachers who are frequently unpaid and left to teach without basic teaching tools like textbooks and governments frequently use capital expenditure funds for teacher salaries⁴⁴.

In 1999, the Nigerian government implemented a broad reform program, National Economic Empowerment and Development Strategy (NEEDS), which outlined several strategies to “lay a solid foundation for sustainable poverty reduction, employment generation, wealth creation, and value reorientation”.⁴⁵ With an urban unemployment rate

⁴¹ “Education in Nigeria”, OnlineNigeria, Accessed March 26, 2008, <http://www.onlinenigeria.com/education/index.asp>

⁴² Ajetomobi, J.O and Ayanwale, A.B, “Education Allocation, Unemployment and Economy Growth In Nigeria: 1970 – 2004”, Ladoke Akintola University of Technology, 2005

⁴³ Ibid

⁴⁴ Hinchliffe, K., “Public Expenditures on Education in Nigeria: Issues, Estimates and Some Implications”, The World Bank, 2002

⁴⁵ Nigerian National Planning Commission, “Meeting Everyone’s Needs” National Economic Empowerment and Development Strategy”, The Nigeria Direct, Accessed April 2, 2008 <http://www.nigeria.gov.ng/NR/rdonlyres/93D67FD4-FDDF-4641-BOA7-360BEE82FB46/1184/NEEDSpart1.pdf>, pg iii, 2004

of 10.8 percent, one of the targets for employment generation was improving the skills of the citizens by improving the educational system. This led to the reformation of the Universal Primary Education Board as the Universal Basic Education (UBE) commission. The UBE set funding priorities on building vocational and technical schools and “Improving training and exposure to information and communication technology at all levels.”⁴⁶ Percentage targets for achieving information and communication technology literacy skills were set for various levels of education while at the same time tackling other educational issues like adult illiteracy (57 percent as of 2004) and a lack of qualified teachers (49 percent of the teaching force at the time was unqualified).⁴⁷ In 2007, the National Information Technology Development Agency (NITDA) was established by the Federal government to create and implement a strategic plan to incorporate Information Technology into the ‘Vision 20-20-20’ goal of placing Nigeria amongst the 20 leading economies in the world by year 2020 and the ICT4D (ICT for Development) plan developed targets for ICT in education as one of eleven key goals.⁴⁸

3.3 Nigerian Educational System Statistics

The Nigerian educational system is composed of 6 years of primary education, 3 years of lower secondary (Junior Secondary School), 3 years of upper secondary (Senior Secondary School) and at least 4 years of tertiary school education. According to UNESCO, the duration of compulsory education is 9 years.⁴⁹ Also according to The World Bank, in 2005, Nigeria had 26 Federal Universities, 21 Polytechnics, 32 Monotechnics and 22 Colleges of Education. In addition, there were about 59,800 Primary Schools and 27,549 Secondary Schools (102 of which were Federal secondary schools).⁵⁰ Enrolment figures and the

⁴⁶ Nigerian National Planning Commission, “Meeting Everyone’s Needs” National Economic Empowerment and Development Strategy”, The Nigeria Direct, Accessed April 2, 2008 <http://www.nigeria.gov.ng/NR/rdonlyres/93D67FD4-FDDF-4641-B0A7-360BEE82FB46/1184/NEEDSpart1.pdf> , pg xvi, 2004

⁴⁷ Nigerian National Planning Commission, “Meeting Everyone’s Needs” National Economic Empowerment and Development Strategy”, The Nigeria Direct, Accessed April 2, 2008 <http://www.nigeria.gov.ng/NR/rdonlyres/93D67FD4-FDDF-4641-B0A7-360BEE82FB46/1185/NEEDSpart2.pdf> , pg 34, 2004

⁴⁸“Nigeria’s ICT Infrastructure Plan validated by Stakeholders”, United Nations Economic Commission for Africa (UNECA), Accessed April 27, 2008 <http://www.uneca.org/istd/news/istd-dna-20080123-en.asp>

⁴⁹ Beyond 20/20 WDS – Report, UNESCO Institute for Statistics. Accessed April 9, 2008, <http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx>

⁵⁰ The World Bank website, Accessed March 26, 2008 <http://go.worldbank.org/T41RGRDEL0>

number of teachers are summarized in the charts below as comparisons between Nigeria and the USA.

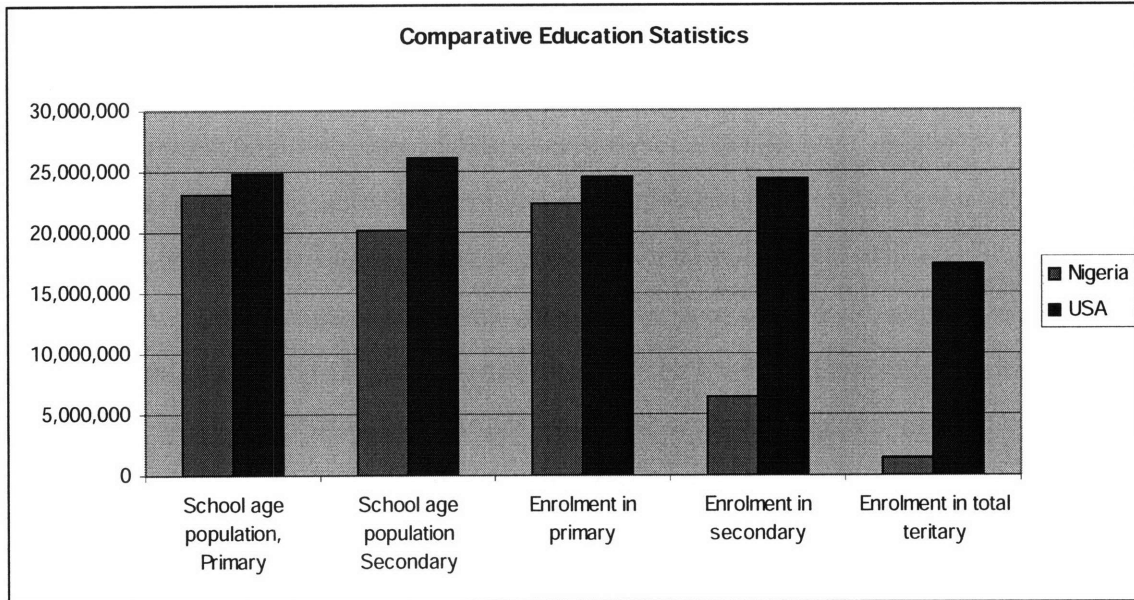


Figure 2: Graph of Comparative Education Enrolment Statistics - Nigeria and USA
(Source: UNESCO Institute for Statistics, 2005)⁵¹

⁵¹ Beyond 20/20 WDS – Report, UNESCO Institute for Statistics. Accessed April 9, 2008, <http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx>

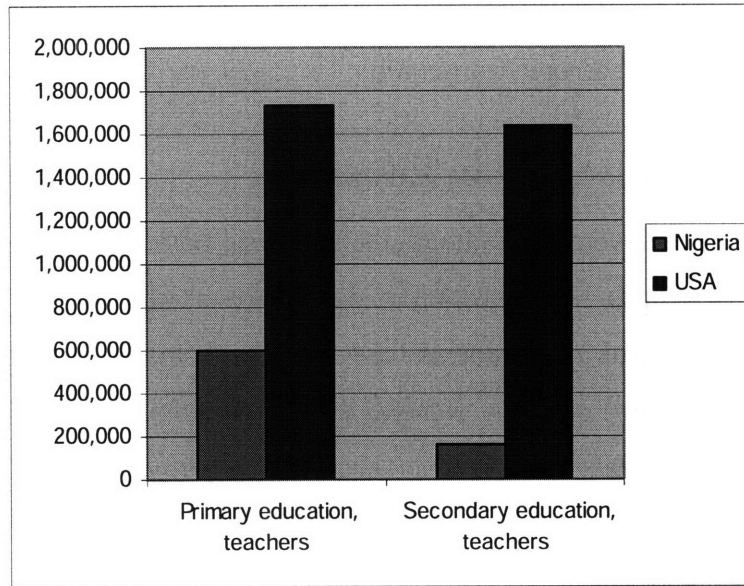


Figure 3: Comparison of number of teachers - Nigeria and USA
(Source: The World Bank, 2007)⁵²

There are inadequate numbers of teachers in the Nigerian educational system producing high teacher-to-student ratios of 1:37 when compared to the US teacher –to-student ratio of 1:14.

3.4 Current ICT in Education initiatives

With low ICT penetration in the population (145 fixed and mobile phone subscribers⁵³ and 38 Internet users per 1000 inhabitants⁵⁴), only a few private primary schools and a handful of secondary schools have computer laboratories. Some tertiary-level schools have made bigger strides into providing campus-wide wireless networks for a number of computer laboratories. These initiatives are typically undertaken as public-private-partnerships (PPP)

⁵² EdStats, The World Bank. Accessed March 26, 2008 <http://www.worldbank.org/education/edstats>

⁵³ Agyeman, O., T., "Survey of ICT in Education in Nigeria". Survey of ICT and Education in Africa (Volume 2): 53 Country Reports. infoDev / World Bank., 2007. Available at <http://www.infodev.org/en/Publication.354.html>

⁵⁴ EdStats, The World Bank. Accessed March 26, 2008 <http://www.worldbank.org/education/edstats>

with local banks and telecommunication providers, in addition to international corporations like Microsoft, Cisco and Carnegie Corporation.⁵⁵

3.5 National Investment in Education

In Nigeria, the Federal Government through the Universal Basic Education board, state and local governments assigns the education budget and sets the policies for technology spending. State and local governments match Federal funds with their percentage contribution to education. Local governments are almost wholly responsible for funding primary schools while state governments bear the majority of the responsibility for secondary schools. The Federal government is directly responsible for funding federal secondary schools and public universities. Local private institutions like banks, oil companies and telecommunication companies are involved typically for additional local funding or donations. In existence today, is a 2% Education tax levied against all commercial entities in order to raise funds for education projects like ICT implementations.

The 2008 Federal budget allocated 210.4 billion Naira which amounts to 1.2% of the GDP. This amount is equivalent to US\$1.75 billion using the currency conversion of 120 Naira to US\$1. (This currency conversion rate is used throughout this thesis) Also some of the government's efforts in providing educational access are allocated to meeting the Millennium Development Goals (N110 billion, US\$917 million) amounting to 0.6% of the GDP⁵⁶. As a benchmark, countries belonging to the OECD (Organisation for Economic Co-operation and Development) spend an average of 6.2% of their respective GDP on educational institutions.⁵⁷ While a country like India currently spends 0.8% of its GDP with plans to increase it to 6%.⁵⁸

⁵⁵ Agyeman, O., T., "Survey of ICT in Education in Nigeria". Survey of ICT and Education in Africa (Volume 2): 53 Country Reports. infoDev / World Bank., 2007. Available at <http://www.infodev.org/en/Publication.354.html>

⁵⁶ Nigeria's 2008 Appropriation Bill, LeadCapital, Nigeria <http://www.leadcapitalng.com/resources/Nationalbudget2008.pdf>, 2007

⁵⁷ OECD StatLink data, Accessed May 6th, 2008 from <http://dx.doi.org/10.1787/068186423156>

⁵⁸ "India's ICT spending still behind", digitalLearning News online, 26 March 2008 <http://www.digitalllearning.in/news/news-details.asp?Title=India%E2%80%99s-ICT-spending-still-behind&catid=&newsid=14084>

3.6 Introduction to One Laptop Per Child Foundation

"The mission of the One Laptop per Child association is to develop a low-cost laptop—the "XO Laptop"—to revolutionize how we educate the world's children. Our goal is to provide children around the world with new opportunities to explore, experiment, and express themselves. Why do children in developing nations need laptops? Laptops are a window and a tool: a window into the world and a tool with which to think. They are a wonderful way for all children to learn learning through independent interaction and exploration. - The OLPC wiki⁵⁹

The One Laptop Per Child (OLPC) Foundation is a not-for-profit organization located in Cambridge, Massachusetts. It was birthed in its present form at the MIT Media Lab in 2005 under the directorship of Nicholas Negroponte who chairs the OLPC foundation. It is funded by a number of sponsor organizations who have representatives on the Board of Directors. These include AMD, Brightstar Corporation, eBay, Google, Marvell, News Corporation, SES Astra, Nortel Networks, and Red Hat.⁶⁰

3.6.1 Philosophy

OLPC's origins are rooted in the earlier project of Seymour Papert in the 1980's where children were provided with computers in order to gain better education through self-directed learning, encouraging children to learn in a manner that is different from traditional schooling – one in which children are allowed to view incorrect solutions as the impetus to debug their answers and discover correct solutions. Key to the OLPC philosophy is open collaboration between all stakeholders and local self-sufficiency. For example, OLPC is staffed mainly by volunteers and the OLPC wiki promotes sharing of ideas with educators, interested parties and the general public while providing a forum for

⁵⁹ The One Laptop Per Child Wiki, Accessed March 26, 2008 <http://wiki.laptop.org/go/Home>

⁶⁰ The One Laptop Per Child website, Accessed March 26, 2008 <http://www.laptop.org/en/vision/people/index.shtml>

receiving ideas from the same. In addition, the open source platform of the laptops encourages contributors to modify the interface and keyboards to match local needs, e.g. language localization. Local self-sufficiency for hardware and software development is also encouraged within recipient nations to keep the costs of the laptop low. Its strategy is to avoid overhead costs like external support centers.⁶¹

OLPC espouses five core principles of child ownership, low ages (The hardware and software are designed for elementary school children aged 6-12), saturation in a given community, connection between laptops and free and open source software and content.⁶²

3.6.2 Technology

The main product of OLPC is the XO laptop – a redesigned laptop designed to be low-cost, low power and rugged with features tailored to the unique environments of developing nations e.g., it contains a flash drive instead of an expensive and damage-prone hard drive. The laptop was intended to be manufactured and sold in large quantities to governments of developing nations. The XO is designed for children in developing nations and it is intended that each child will own one and use it for learning activities and ultimately begin to break the cycle of poor education, which leads to continued poverty.

The XO laptop is built on an Advanced Micro Devices, Inc. (AMD) processor with a free, open-source Linux-based operating system. It has a unique user interface named ‘SUGAR’ which promotes collaboration on activities by displaying the current network of students and teachers. Its revolutionary high-contrast low-power display enables the laptop to use very little power and still be visible in the glare of direct sunlight for use outdoors by schools that have few or no buildings. It comes equipped with a video camera, wireless network and has a rugged design. The mesh network is designed to automatically build connections to any other XO laptops within a wide area and use the internet connection of any laptop within the network or through a school server.

⁶¹ The OLPC Wiki Accessed March 27, 2008, http://wiki.laptop.org/go/Deployment_Guide/Service_Repairs

⁶² The OLPC Wiki. Accessed April 9, 2008, http://wiki.laptop.org/go/Core_principles

3.6.3 Challenges

The laptop was built and demonstrated as a prototype to the world in November 2005 by Kofi Annan, former UN Secretary General, at the World Summit on the Information Society at Tunis.⁶³ Its distinctive design and goals quickly gained it favorable responses from a number of developing nations. However, the project has encountered a number of challenges since that promising demonstration. For instance, the minimum orders of 1 million laptops per nation required to keep the unit price of the laptops at \$100 have not materialized. Instead smaller batches of tens of thousands are being ordered which has kept the laptop prices relatively high compared to the goal – from \$199 for 10, 000+ laptops up to \$299 for 100 laptops.⁶⁴

Some of the many concerns and criticisms of the OLPC project are related to the lack of technical support, uncertainty of sustainability as new waves of school children get enrolled, physical security for the laptops, undesirable internet use and laptop recycling. The main criticism of cost and comparisons against similar projects is reported to have been answered by Nicholas Negroponte saying: "It's an education project, not a laptop project."⁶⁵ However to date nations like Brazil still attempt to compare the OLPC offering with other competing projects on the basis of price.⁶⁶ A small selection of the other projects that have been competing against the XO laptop are: the Asus Eee PC, Comes Aristo Pico, Everex Cloudbook, Packard Bell EasyNote XS and the Intel ® Classmate PC.⁶⁷ In addition, recent news highlights various challenges and new directions which have occurred. A sample of these are: OLPC America is set to launch in 2008 to provide XO laptops to American children; Intel ® has stepped down from the board due to differences of opinions; and a patent lawsuit is pending from Nigerian Lancor for keyboard design infringements. Also, CTO Mary Lou Jepsen recently stepped down and Nicolas

⁶³ The OLPC Website, Accessed March 26, 2008 <http://www.laptop.org/en/laptop/design/>

⁶⁴ The OLPC Website, Accessed March 26, 2008 <http://www.laptopfoundation.org/en/participate/givemany.shtml>

⁶⁵ The OLPC Wiki website, Accessed April 30, 2008 http://wiki.laptop.org/go/Nicholas_Negroponte

⁶⁶ Van de Sande, A., "UCA Brazil Auction for Classmate PC - Canceled!", OLPC News website, Accessed March 29, 2008 <http://www.olpcnews.com/countries/brazil/>

⁶⁷ Stern, J., "Low-Cost Laptop Cheat Sheet", Laptop, Accessed April 30, 2008 <http://blog.laptopmag.com/low-cost-laptop-cheat-sheet>

Negroponte announced his intention to step down as CEO of OLPC pending a replacement. He intends to continue as the foundation's chairman.

Given all these challenges the XO laptop has gained slow acceptance from nations with only a handful to date committing to purchase volumes far lower than the 1 million laptops each anticipated by OLPC. As part of an attempt to lower the cost of the machines for children in developing nations, OLPC recently concluded a promotion Get One Give One (G1G1) where customers in the developed nations could order a laptop for twice the price in order to donate the extra laptop to children in developing nations – Mongolian children have been the first recipients of this scheme. However, this promotion did not avoid some supply chain challenges. Afghanistan, Cambodia, Haiti, Rwanda and Mongolia are amongst the G1G1 recipients with Peru, Uruguay⁶⁸ and the USA⁶⁹ ordering small quantities of laptops. Pilots are underway in a number of countries including India⁷⁰ and Nigeria.

3.7 Introduction to Intel's® World Ahead program

Under the banner of the Intel® World Ahead program, Intel ® is targeting the ICT needs of developing countries from high-speed connections via Wi-Fi (Wireless-Fidelity) and WiMax (World Interoperability for Microwave Access) to healthcare technologies and education. As part of its education offering, Intel ® produces a laptop similar to the XO, the Classmate PC (CMPC). In addition, Intel's® Teach program trains teachers on pedagogical changes to school curriculum (Intel ® claims 4 million teachers have been trained in 40 countries)⁷¹ and the skool™ Learning and Teaching Technology provides free online

⁶⁸ “Plan Ceibal se extenderá a los maestros y profesores”, El País Uruguay. Accessed April 30, 2008
http://www.elpais.com.uy/Registro/Login.asp?refacc=0&vurl=%2F08%2F03%2F18%2Fpnacio%5F336123%2Easp&erra cc=99&url_qs

⁶⁹ Leech, M. “Birmingham Board of Education votes to accept 1,000 low-cost laptops for pilot program”, The Birmingham News, <http://www.al.com/birminghamnews/stories/index.ssf?/base/news/1207296912202190.xml&coll=2>, April 2008

⁷⁰ “One-laptop project to debut in Maharashtra”, digitalLearning, Vol IV Issue 2, February 2008 pg.14

⁷¹ “Bridging the digital divide in Nigeria”, Intel ® website, 2007. Accessed April 30, 2008.
http://download.intel.com/intel/worldahead/pdf/casestudy_nigeria.pdf?iid=worldahead_home+body_nigeria,

education content and collaboration forums. These are programs that Intel ® has been developing over the years with some financial funding from corporations like Microsoft.⁷²

3.7.1 Technology

The Classmate PC runs on the Microsoft ® Windows/Intel ® platform with the option of running Linux. It is also ruggedly built for children in developing nations and comes with a flash drive, an optional wireless digital pen and a wireless connection. Its design is fairly similar to a regular sub-notebook with a carrying cover. Intel ® sells the laptop for between \$250 and \$300.⁷³ The teacher typically has a similar laptop with customized software capable of taking control of the student's laptop.

3.7.2 Challenges

In 2007, Intel® attempted a failed partnership with the OLPC program⁷⁴ and has since been criticized for marketing the Classmate PC to the same countries OLPC has approached. In an interview, Intel's ® chief executive Paul Otellini responded to this criticism by highlighting what he views as the key differentiators in the products; “Ours is focused on working with teachers, OLPC is focused on 'Give the kids a laptop, turn them onto the internet and just let them go’”.⁷⁵ Intel® plans to train 1,600 teachers in Nigeria in the use of technology by 2011.⁷⁶

3.8 A Comparison of the two projects

3.8.1 Strategy

On the surface the difference between the OLPC and Intel ® programs appears to be in their philosophical approach to ICT education – OLPC appears geared towards using the

⁷² Caterinicchia, D., “Microsoft, Intel donation to help train 400,000 teachers”, CNN news Online, 2000. Accessed April 30, 2008 <http://archives.cnn.com/2000/TECH/computing/01/25/ms.intel.help.teachers.idg/index.html>

⁷³ Lemon, S. “Intel offers Classmate PC to vendors in developed countries”, The Washington Post, 2008 Accessed April 30, 2008 <http://www.washingtonpost.com/wp-dyn/content/article/2008/03/20/AR2008032001577.html>

⁷⁴ Fildes, J., “Intel and \$100 laptop join forces”, BBC News Online, 2007. Accessed April 30, 2008 <http://news.bbc.co.uk/2/hi/technology/6897950.stm>

⁷⁵ Cellan-Jones, R., “Intel 'will survive US recession’”, BBC News Online, 2008. Accessed April 30, 2008 <http://news.bbc.co.uk/2/hi/technology/7334518.stm>

⁷⁶ “Bridging the digital divide in Nigeria”, Intel ® website, 2007. Accessed April 30, 2008. http://download.intel.com/intel/worldahead/pdf/casestudy_nigeria.pdf?iid=worldahead_home+body_nigeria,

computer to foster general creativity, whilst Intel ® follows the more traditional approach of teaching children programs similar to those used in the business world. OLPC's focus is also in the lower ages whilst Intel® is targeting both primary and secondary schools. There are however differences in the approaches of both organizations to implementation - Profit vs. non-profit, student vs. teacher-initiated learning. And there is a different approach to working with the local ecosystem – OLPC encourages any and all local individuals/companies to contribute to developing additional software, providing feedback and product ideas using their wiki forum to freely share ideas. In comparison, Intel's ® strategy is to follow the business world's partnering model, e.g., partnering with a Nigerian educational software company, Cinfores, to develop local curriculum.⁷⁷

3.8.2 Progress

To date, Intel® has secured contracts in countries like Nigeria where the XO implementation has run into issues with the patent infringement lawsuit. Countries like Brazil are evaluating both schemes based on the large upfront capital and operating costs.

3.8.3 Costs

Several attempts have been made by various people to compare the total cost of ownership of the OLPC and Intel® offerings. Most comparisons focus on the extremely low power requirements of the XO laptop over the CMPC – almost one-tenth of CMPC by OLPC's calculation⁷⁸. This would affect the long-term operating costs of the laptops as each developing country has varying costs of electricity. Nigeria's cost of electricity is subsidized at 0.065US cents⁷⁹ per KiloWatt Hour while a country like India in 2000 had an estimated average cost of 0.05 US cents (208 paise)⁸⁰ per KiloWatt Hour (US costs vary but the average is 10.4 cents per kWh⁸¹) . However, in Nigeria, the ideal of operating

⁷⁷ "Bridging the digital divide in Nigeria", Intel ® website, 2007. Accessed April 30, 2008. http://download.intel.com/intel/worldahead/pdf/casestudy_nigeria.pdf?iid=worldahead_home+body_nigeria

⁷⁸ Daly, S., "Interview with Mary Lou Jepsen", Groklaw, 2008 <http://www.groklaw.net/article.php?story=20080107182525297>

⁷⁹ Tyler, G., "Public and Private Electricity Provision as a Barrier to Manufacturing Competitiveness", The World Bank, 2002.

⁸⁰ Audinet, P., "Electricity Prices In India", International Energy Agency, Energy Prices And Taxes, 2nd Quarter 2002

⁸¹ "Residential Electricity Prices: A Consumer's Guide", Energy Information Administration, 2006 <http://www.eia.doe.gov/bookshelf/brochures/rep/>

entirely on the publicly available power is rarely possible as intermittent power outages are routinely experienced. As such, most organizations and individuals rely on privately generated power, typically from diesel generators. A World Bank study estimated that the cost of privately generated power is between 2.42 and 3.9 times the cost of public power.⁸² The XO laptop is said to run on so little power that solar panels can generate enough electricity to power them.⁸³ There is however ancillary equipment like the school server (if one exists) and the wireless equipment that are not configured to run on minimal power.

In analyzing the XO and CMPC implementations we focus on the key cost differences which are the cost of the laptops, cost of electricity used and cost of wireless communication (XOs are currently deployed with VSAT (Very Small Aperture Terminal) dishes and the CMPC is deployed with WiMax). We also test the scenario were both laptops cost exactly the same, allowing for future market competition to drive prices down. If this is assumed, then the only cost difference would be with the fact that the XO is meant to be owned by each student while CMPC's model does not at this time promote ownership, instead the laptop is an assigned resource which can be reassigned the following school year to another student. The replacements of CMPC laptops would therefore occur at the end of the assumed 5-year useful life, while XOs would require some new laptops to be purchased annually with newly enrolled children.

3.8.4 Technology

In such a competitive environment it can be expected that existing differences in technology today will be rapidly overcome based on user needs e.g. the second version of the Classmate now includes mesh networking technology. This leaves the XO's outdoor screen readable display and its extremely low power consumption as an advantage today over other competitors.

⁸² Tyler, G., "Public and Private Electricity Provision as a Barrier to Manufacturing Competitiveness", The World Bank, 2002.

⁸³ Daly, S., "Interview with Mary Lou Jepsen", Groklaw, 2008 <http://www.groklaw.net/article.php?story=20080107182525297>

4 Case Studies

In order to gather information for use in creating the system dynamics model, a series of interviews were conducted in Abuja, Nigeria in February, 2008. This section summarizes the One Laptop Per Child and Intel ® projects based on interviews with:

- Mr. Leda – IT director of the Universal Basic Education commission (UBE)
- Dr. Onamusi - the CEO of Alteq.ict – a local consulting firm
- Dr. Armstrong - the Director of Alteq.ict
- Mrs. Okonkwo - the principal of the LEA Galadima Primary school (OLPC pilot)
- Mr. Edegbe – a teacher of the Jabi Junior Secondary School (Intel® pilot).

4.1 Galadima Primary school – One Laptop Per Child pilot

LEA Galadima Primary school is a school located in a model housing town on the outskirts of Abuja, the capital city of Nigeria. It is the school selected by Alteq.ict and the Universal Basic Education program (UBE) as the Nigerian pilot school for the One Laptop Per Child project. The school has roughly 450 students who come from areas outside of the city. It is a modest cement block school with an additional block of classrooms under construction.

In March 2007, Alteq.ict and the UBE chose this school based on proximity to the city and the fact that the number of students at that time (approx. 250) closely matched the number of anticipated laptops, according to Mr. L. of the UBE. A survey was performed, and the Galadima students from Primary 4 to 6 (Grades 4 to 6) were chosen. In addition, 13 teachers were selected to receive training from Alteq.ict. In total, over 351 laptops were distributed over the period from March to November 2007. Over that period, there was about a 30% equipment failure rate (102 out of 351 laptops). Replacement laptops were shipped and provided for any faulty ones. In addition to laptop distribution, a school server was installed.

Prior to equipment arrival however, the school needed to be connected to the electric grid and to compensate for irregular power, solar panels were initially installed. This source of power was soon replaced by a small diesel powered generator. In addition, a satellite antenna was installed for providing a wireless VSAT connection to the Internet. Following the initial test with the primary 4 to 6 students, primary 1-3 were added to the pilot program.

Both sets of students took to the computers enthusiastically, quickly learning the nuts and bolts, literally, of the laptops in order to perform minor repairs on faulty laptops. In addition, students found it easy to share digital files and pictures with one another via the mesh network. Items like pictures, drawings and documents were eagerly created and shared. Attendance improved and enrolment almost doubled (increase of between 150 and 200 students). Some of the dramatic results could be attributed to the fact that parents heard by word of mouth or the press of the pilot and enrolled their children to take advantage of this free 'good thing', as Mrs. O., the principal of the school relayed. This increase necessitated the commissioning of a new classroom wing to accommodate the extra children – a capital project undertaken by the UBE during this pilot.

Other improvements were observed in the student's English grammar, writing and communication skills with some of these attributed to the frequency with which the children were interviewed by numerous visitors. Additionally, the teachers and principal noted an increase in student motivation to learn. This led to greater teacher motivation to modify curricula to include the laptops and the distinct usage differences observed between the girls and boys – the girls typically focused on mastering one computer application at a time, while the boys tried to learn a few things about all the applications.

Some hardware problems were encountered during the pilot (e.g. damaged keyboards, dead batteries etc.) but these were promptly evaluated and replaced by OLPC as part of the pilot's lessons learned. It was also observed that the need to provide electricity for the school, sometimes using the small diesel generator, was an additional necessary cost since children typically lived in homes where there was no electricity and as such needed to recharge the laptops at school. In addition, internet content filters were added to the laptops

to prevent students from viewing inappropriate websites. To ensure the physical security of the laptops, server and communication equipment, Mr. L of the UBE proposed the hiring of a security guard for the school premises.

Overall, the pilot was perceived in a very positive light by the UBE and school authorities. It was seen as a step towards connecting the students to the world outside their community and an enhancement to the student experience in school. Unfortunately, prior to the date of the interviews the XO laptops had been retrieved from the school students pending the resolution of a keyboard patent infringement lawsuit filed in Nigeria. Mrs. O. stated that due to fact that the pilot did not last a full year, there were no quantitative results available on student performance with the laptops.

4.2 Jabi Junior Secondary School – Intel® Classmate pilot

Jabi Junior Secondary school was also located on the outskirts of Abuja. A large sign welcomes a visitor on arrival to the location of the Intel® Classmate PC pilot site. The classrooms house 600 – 700 students and Intel® provided between 200 – 300 Classmate PC laptops for a portion of the students. The laptops are setup in a lab classroom during certain classes. They are interactively incorporated into the classes on mathematics and integrated science while they are only used for web searches during other classes. Though the laptops are used in a lab environment, each student in the selected classes ‘owns’ one i.e. they are assigned to one laptop to use for the duration of their time in that class and so students can store their documents and files on the built-in flash drive. Each laptop is labeled with a letter and series of numbers for the students to identify their laptops and also for each teacher to identify which students within the school network belong to their class.

Prior to the pilot start the teachers in the school received some basic computer training and Mr. E. became the lead teacher in the use of the CMPC laptops during the pilot. In addition, Mr. E. trains teachers in other schools where the CMPC laptops are installed and with this he is able to share his experience with other teachers both in person and via an email forum. Some of the topics he covers with the other teachers are: Changes to behavior management with the laptops in the classroom to minimize the distraction of the students; the change in

the teacher's role from provider of knowledge to facilitator; increased class preparation time to create meaningful sessions. He found the younger teachers more open to adopting the technology, as expected, but found overall that a key challenge was with getting enough laptops for the teachers in order for teachers to practice and create new curricula.

The school obtained electrical power from the power grid. Frequent power outages however, required the school to run a diesel generator during school hours. As noted by Mr. E., it takes understanding principals to accept that without constantly available power for the school laptops, the teachers (and students) would be unable to consistently complete classes as needed. It would, Mr. E. noted, only take a few interrupted class sessions to discourage teachers from working with the technology.

Overall, Mr. E. perceived one of the major benefits of the laptop program was to train students in computer use in order to qualify for the majority of office jobs that require such skills, adding that prior to this program the biggest disappointment for teachers was to hear that their students were unemployable.

4.3 The local consulting firm – Alteq.ict

Alteq.ict, a consulting firm focused on public sector initiatives, was selected by both OLPC and Intel® as the liaison between these organizations and the Nigerian government and schools. The firm was instrumental in locating the schools, performing some of the training of teachers and students and evaluating the progress of each pilot. In addition, during the duration of the pilot the firm's engineers were able to work with external experts on troubleshooting and configuring the systems, thereby gaining local expertise with the products. Alteq.ict is also the creator of a software educational portal which is hardware agnostic and provides access to educational materials.

From the pilots the Alteq.ict team was able to report that the computers had indeed been beneficial in the schools in a number of ways:

- The computers proved that children in underserved areas would take easily to the technology
- The children benefited from using the technology in their academic performance, confidence level, ability to understand general concepts and their level of exposure to the world.
- The pilots proved that when teachers are presented with obvious advantages of using the computers, they are willing to adapt their teaching methods.
- The pilots also proved that local proof-of-concepts are successful in convincing government authorities of the benefits of the program. In the case of the One Laptop Per Child it encountered a change in government and would need to re-pitch the advantages to the new government.

5 Case study analysis

Based on the information obtained from the conducted interviews and extensive research via the internet, a causal loop diagram was synthesized to show a summary of the key variables affecting the implementation of these two ICT projects.

5.1 Education Technology Introduction Model Summary

Each of the following variables was considered in turn when creating the summary cause-and-effect model for the implementation process.

5.1.1 Local ICT Champions

At the beginning of any policy change there exist one or more champions for the change in question. In the case of educational changes within developing countries this champion(s) is typically within the government having been influenced by a variety of local and international contacts e.g., the Millennium Development Goals mentioned earlier. In environments of information and democratic openness, local champions are able to exert considerable political pressure on the government in cases where the budget allocated to the implementations is below what is required to sustain and expand the technology program. In these cases, the local champions exert pressure in order raise the budget allocated to the ICT implementations. This pressure, however, can be weakened in countries of low democratic openness.

ICT champions that are local to the developing country are typically acquired in a manner similar to the adoption of any new technology through a population – through direct or indirect contact with the technology. In this case, teachers and parents alike are the most likely potential adopters along with the immediate communities around the schools.

In modeling the adoption by local champions, the One Laptop Per Child XO champions have a slightly faster population adoption rate due to the fact that students own the laptops and have the opportunity to use them anywhere within the community, whereas, at present, students with the CMPC project use laptops that stay in the schools and are available for a limited period of time during the day. For both implementations it takes a number of years

for the local innovation champions to gain significant numbers and place considerable amount of pressure on government to increase budget spending.

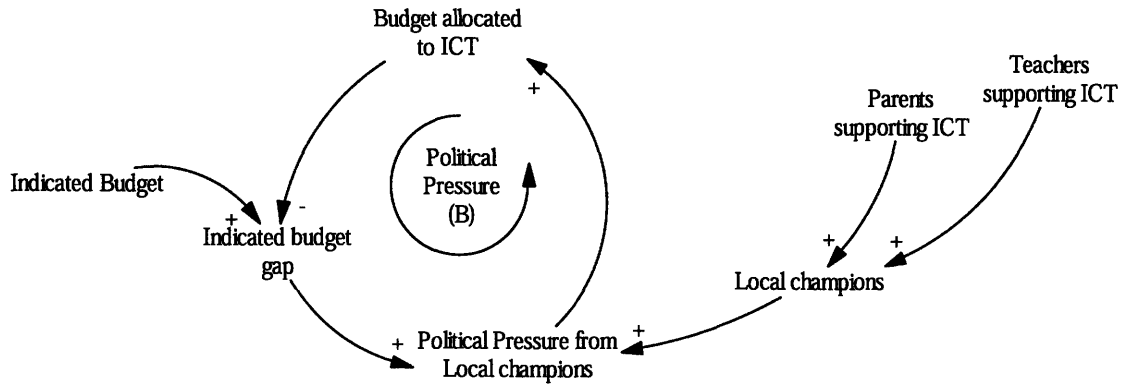


Figure 4: Local champions exert political pressure to adjust ICT budget

5.1.2 Local Skilled Implementers

This government’s commitment in the form of a budget for the ICT project is typically carved out of the total education budget and it drives forward the implementation process. In order to implement the ICT system however, the government will need to rely on local companies with skilled implementers who are able to perform all the tasks required for a sustainable implementation. Examples of these implementers are providers of the wireless communication system (WiMax or VSAT), the installation, repair and service personnel for the computer equipment and the creators of local educational content and educational programs. A part of the ICT budget is used through contract commissions to recruiting and training these implementers and the availability of these commissions creates incentives for local companies to recruit the required technical personnel. In developing countries, Nigeria in particular, government contracts are still seen by private companies as lucrative ways to generate company profits and so increases in the allocated government budget would stimulate the growth of the skilled ecosystem. In order to grow optimally however, the ecosystem will also require moderate to high levels of information from the innovation suppliers in order to provide quality service. This availability of a local ecosystem is a limiting factor to the number of implementations that can be completed, especially in the

early years of the implementations when local knowledge of the deployed technology is low.

The XO implementations will likely experience quicker growth due to the OLPC philosophy of open and distributed collaboration through their wiki and Internet Relay Chat rooms and the use of open source free software.

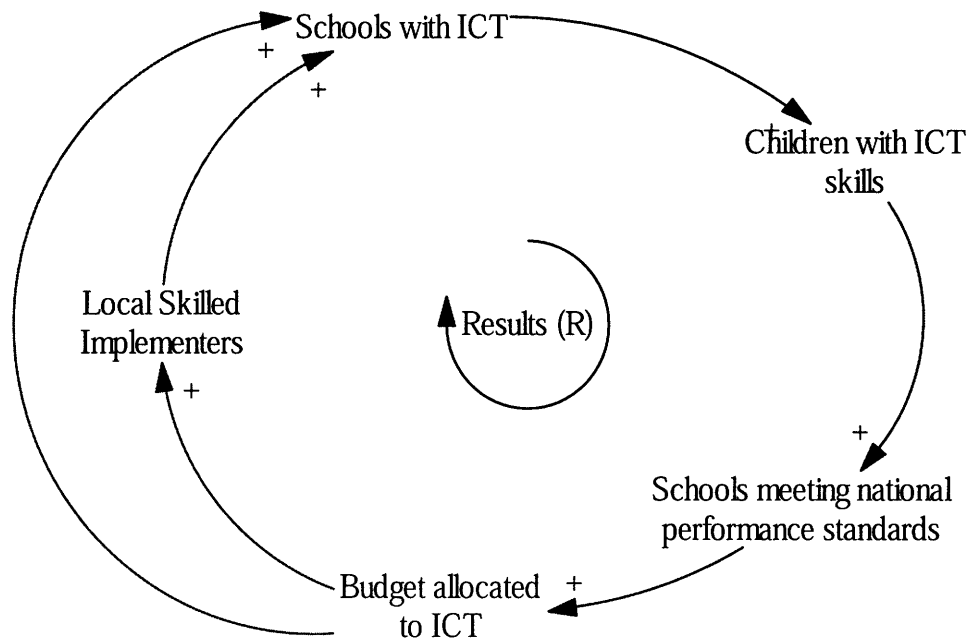


Figure 5: ICT Budget drives implementation of schools and growth of implementers

5.1.3 Schools with ICT

The number of ICT implementations completed is influenced by the presence and reliability of electrification, the local ecosystem capacity to provide skilled implementers and the number of implementations the budget can pay for. Initial years show a modest number of implementations and over subsequent years the number of schools with electricity which are awaiting implementation dwindles unless the nation's electrification pace is faster than the maximum pace at which the implementations can be completed. Based on government announced electrification plans to increase rural electrification by

40% in the next 13 years, the project to implement ICTs in all the nations schools will take at least that long, if there are no alternative power generation sources for the laptops, servers and communication equipment. Due to the fact that the electrification project is an exogenous one, it is recognized as a limiting factor but not explicitly modeled.

5.1.4 Teachers and Students with ICT skills

Following the ICT implementation the local implementers would perform technology and pedagogy training for teachers, showing them how to best incorporate the technology into their curriculum. In the case of CMPC, there is use of teachers from prior installations to help in providing personal perspective and helpful tips through the Intel ® Teach Program. Teachers who find the technology useful will typically adopt the technology and join existing teacher forums online as formal or informal champions.

Students are also taught ways of using the laptops to collaborate with each other, to create individual pieces of work and to research for additional educational materials. In the XO case, students are also taught how to dismantle the laptops and encouraged to develop basic repair skills. Several accounts during interviews performed relayed the ease with which students understood the mechanics of using the laptops, however, as evidenced in the literature reviewed earlier, there is additional in-class exploration that may be necessary for students to use the technology to improve their educational performance.

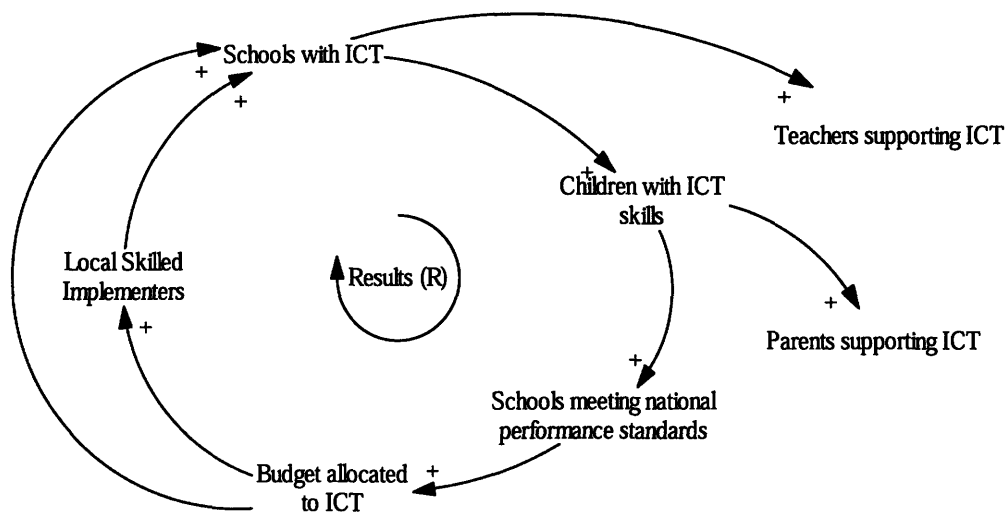


Figure 6: Teachers and Students with ICT skills

5.1.5 Schools meeting national performance standards

In general, there is little consensus on the best way to measure mastery of the skills students gain from using ICTs. This is made especially difficult when the knowledge and skills measured are not specific ICT skills e.g. literacy, and in some cases, the gains are ‘soft skills’ like increased creativity. In the case of the CMPC pilot, measures of improvements in subject test scores were used to determine student improvements.

In the absence of a standard measure, it is likely that each nation will develop some metrics with which to determine the efficacy of the ICT program. Throughout the program, there would be a certain percentage of schools that would meet the selected metrics and would influence the allocation of the following year’s budget for ICT. In the early years, if only a modest number of schools are observed to meet this standard, the impact on the ICT budget may be such that the financial investment is only maintained, if not reduced. This is largely due the popular view of ICT in education being a ‘quick win’ with immediate expected gains. Over time however, as the number of schools meeting the expected knowledge and skills grows, the ICT budget is likely to grow.

5.1.7 Model Summary

When all the causal effects are mapped, the resulting model shows that there are a number of causal loops that influence the implementation of ICTs. Two of these loops – the ‘Results’ and the ‘Local Champions’ loops are reinforcing loops that tend to grow the number of schools that ICT is deployed to. On the other hand, two other loops – the ‘Cost Increase’ and the ‘Political Pressure’ loops are balancing loops that tend to change the direction of increase or decrease of the ICT budget. These are represented in the complete model below.

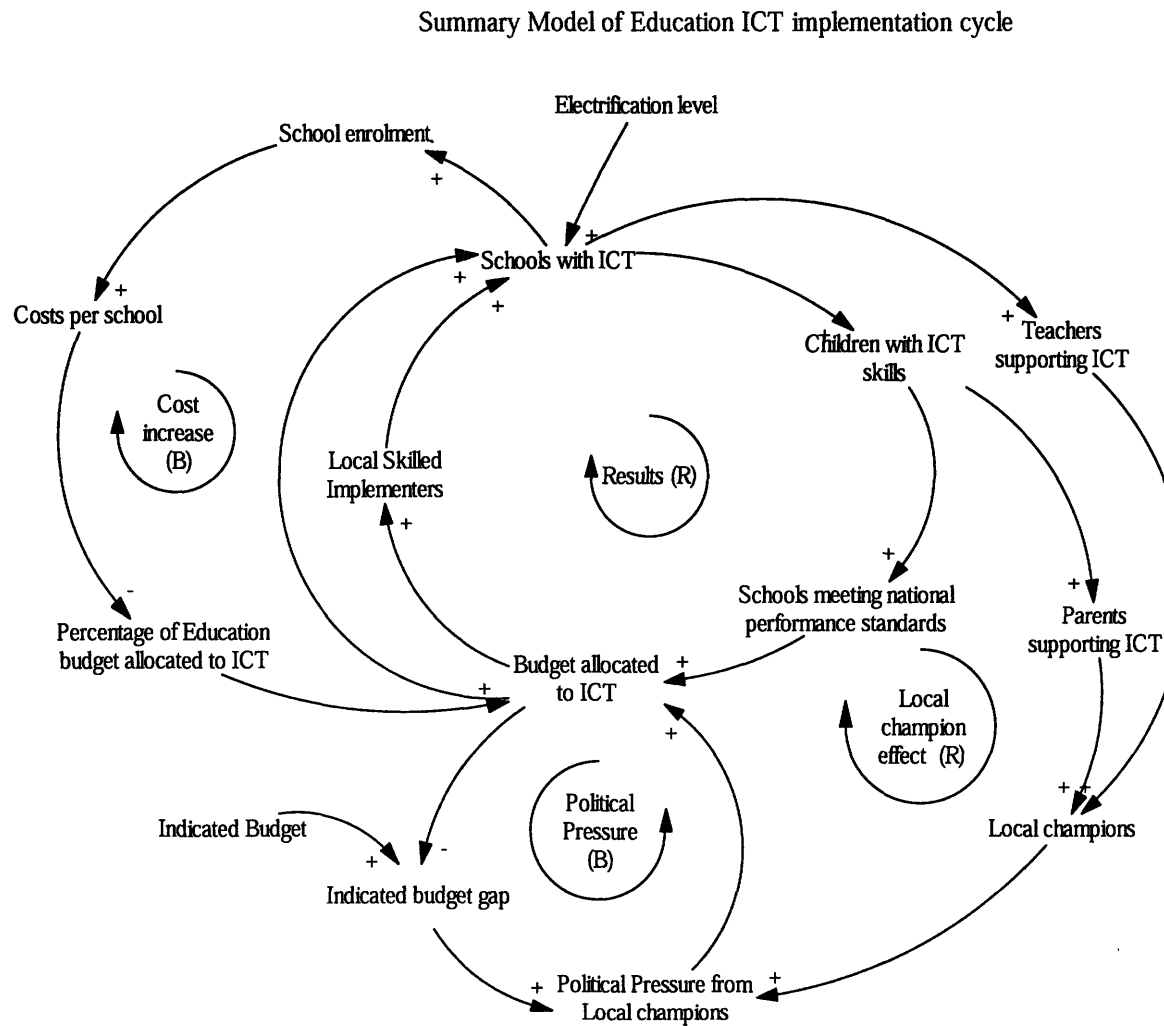


Figure 8: General Model for educational technology introduction in developing countries

5.2 Model analysis details

In creating the detailed model from the causal loop diagram, each variable was considered as a stock or level variable where appropriate. In addition, every effort was made to obtain factual values for key variables, in the absence of which, reasonable estimates were made and subjected in the next section to a series of sensitivity analyses.

5.2.1 Budget allocated to Education ICT

In 2008, Education received US\$1.75 billion from the federal budget and MDG initiatives received US\$917 million.⁸⁴ Reasonable assumptions of about 5% of the education budget (US\$75 Million /year) were estimated as the initial government financial investment into ICT for education. The model however can be easily extended to include funding from other non-governmental sources.

When an ICT implementation budget is created it is common to focus on only the costs related to the initial implementation. This typically means that implementation contract assignments are based on the cost of equipment alone. In addition, roll-out implementation plans consider mainly the number of schools that can be equipped based on the available funding. A base system dynamics model was created using only implementation costs and each additional 'hidden' cost was layered on top of the base model to view the effects on implementation.

5.2.2 Base Model – Implementation costs only

In order to calculate the implementation schedules for the XO and CMPC implementations reasonable estimations were made based on current advertised costs and prices. In particular, actual costs spent on the pilot equipment were hard to determine since, as is typical of pilots, the equipment (laptops, servers, computers, communication and electricity generation equipment) were donated. Some estimates were performed based on publicly available information and summarized in Appendix 4. It is also worthy of note that true costs may vary based on the volume of systems ordered. The comparative implementation

⁸⁴ Nigeria's 2008 Appropriation Bill, LeadCapital, Nigeria <http://www.leadcapitalng.com/resources/Nationalbudget2008.pdf>, 2007

schedule based on the installation costs alone were generated by simulating the XO and CMPC model shown in Appendix 2. The results for the implementation schedule are displayed in Figure 9 below:

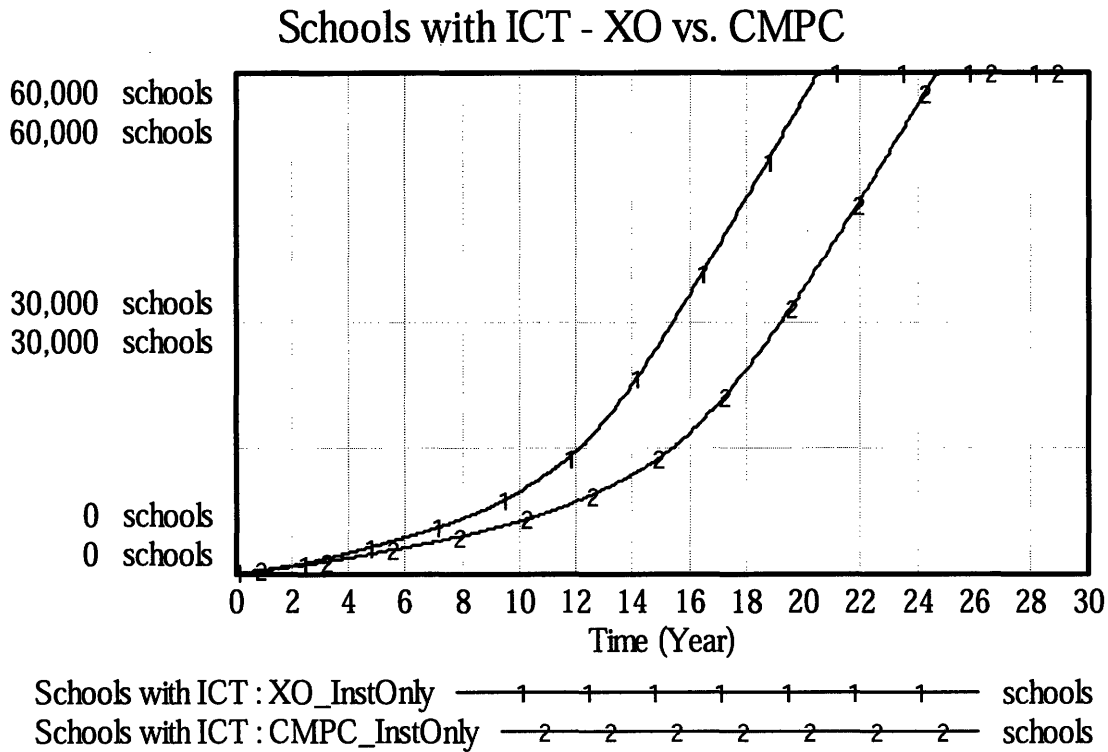


Figure 9: XO vs. CMPC Implementation - Installation costs only

The comparatively higher initial cost of CMPC slows the progress of the implementations and the end of the CMPC implementations lag the XO's by approximately 4 years.

5.2.3 Model with additional Operating and Installation costs

In addition to the installation costs however, governing bodies will need to consider the cost of operating the ICTs in schools after installation and also the cost of labor for the installation. Operating costs typically comprise of the ongoing costs of electricity for the ICTs – laptops, servers and communication routers/dishes. Local skilled implementers are generally in short supply and each company in the local ecosystem is responsible for training skilled technicians to perform the tasks of installation and training at the onset of the project. As time progresses these skilled implementers also need to be trained to repair

and contribute to the creation of educational content and programs. In order to perform wide-scale deployments in nations who typically do not have skilled local labor, a portion of the proceeds to the installation company would need to be allocated to training of this labor. The model takes this into account and presents a modified implementation schedule for the XO using the same ICT budget as previously.

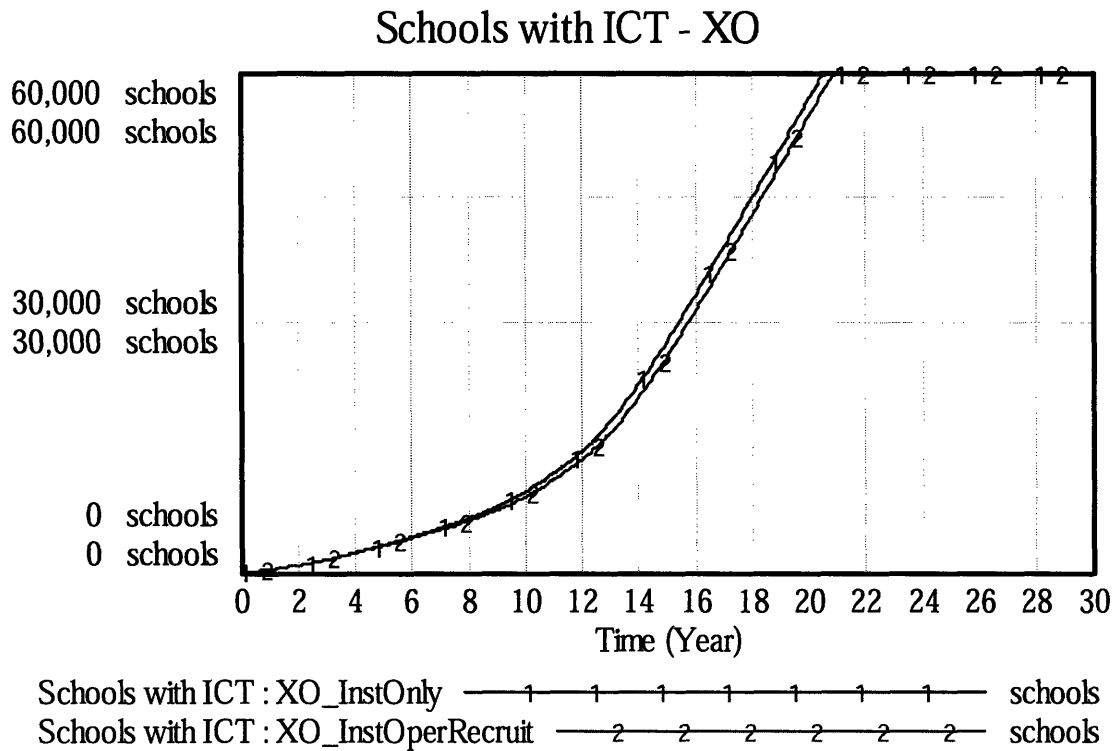


Figure 10: Implementation of XOs - Operating and Implementers' Recruiting costs

Over time, this additional cost of providing funds for labor to install ICTs and for operating schools already installed with ICTs delays the proposed implementation plan by about 0.5 years.

5.2.4 Model with additional costs of new student enrolment

When ICTs are deployed to developing nation schools it is hoped that the increased value of the education would be appreciated by students and parents alike and translate into increased student enrolments and improved student attendance. As evidenced in the

Galadima school, the advent of ICT prompted parents from around the school to enroll their children in school. Galadima experienced an almost twofold increase in students. This ties in with desired Millennium Development and Education for All goals to increase school enrollment and is a desired effect of implementing ICTs.

These newly enrolled students typically require additional resources – classrooms, teachers, books. Each of these resources costs an incremental amount estimated by the cost of a new student/year (1400 Naira/approx. \$12 USD⁸⁵). Assuming that the same fixed educational budget amount will be used to cover the additional costs per newly enrolled child whilst simultaneously reducing the amount of money allocated to educational ICT project, the implementation schedule for the XO is as shown:

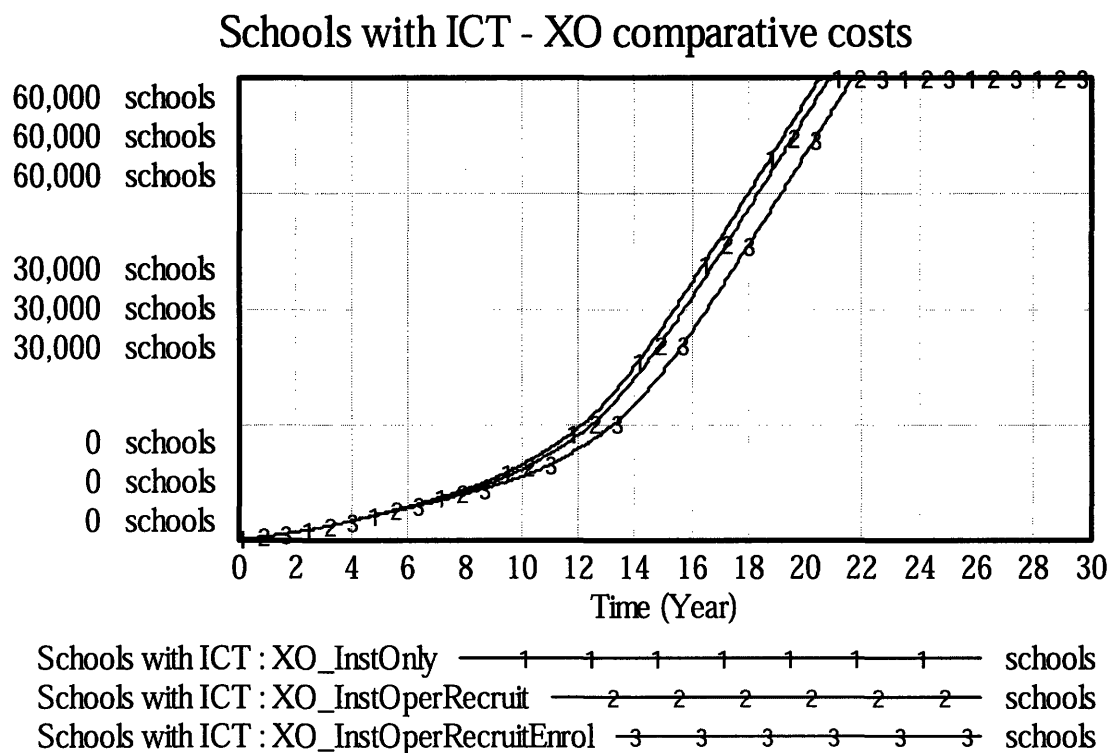


Figure 11: Implementation of XOs - Increased Enrolment impact

⁸⁵ Hincliffe, K. "Public Expenditures on Education in Nigeria: Issues, Estimates and Some Implications", The World Bank, 2002

It can be seen that by accounting for the additional funds needed for the newly enrolled students, the implementation schedule slips a further one year from the schedule when considering only installation and operating costs.

5.2.5 Overall implementation progress – all costs considered

Overall, the XO and CMPC implementation schedules perform similarly producing extended implementation schedules of over 20 years to implement the full complement of 59,800 primary schools and over 17 years to achieve implementations in all 27,849 secondary schools. This schedule is projected independent of the electrification progress which would potentially lengthen the projections further.

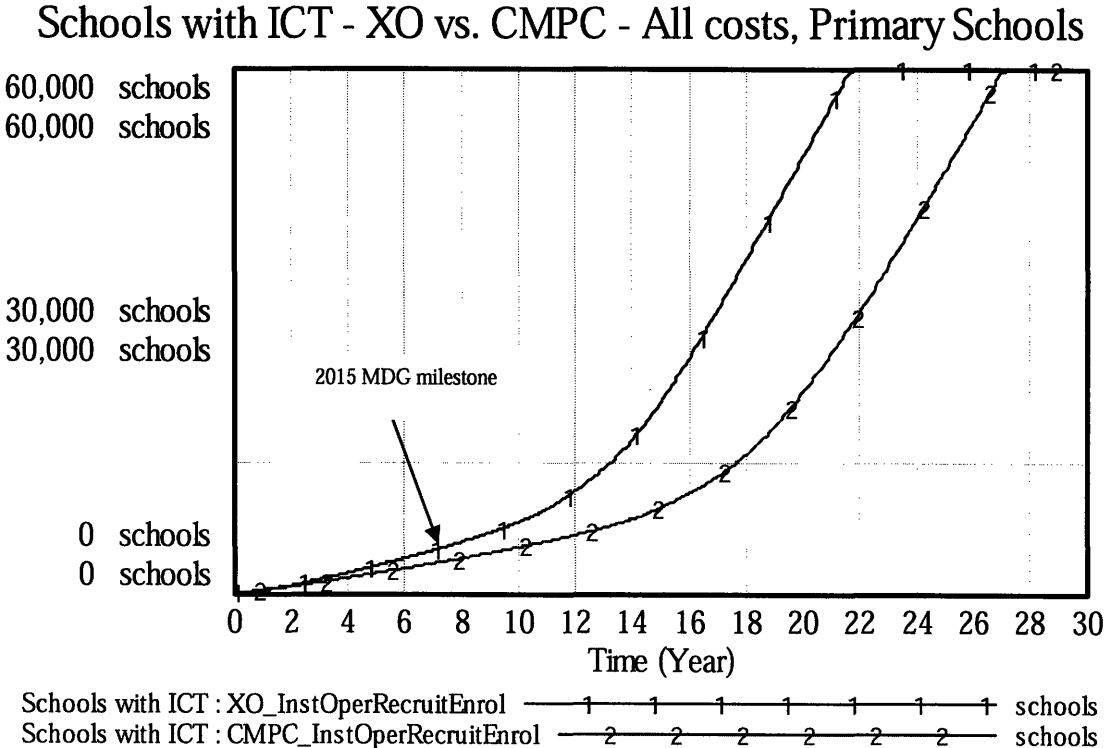


Figure 12: XO vs. CMPC Implementations - All costs considered (Primary schools)

Schools with ICT - XO vs. CMPC - All costs, Secondary Schools

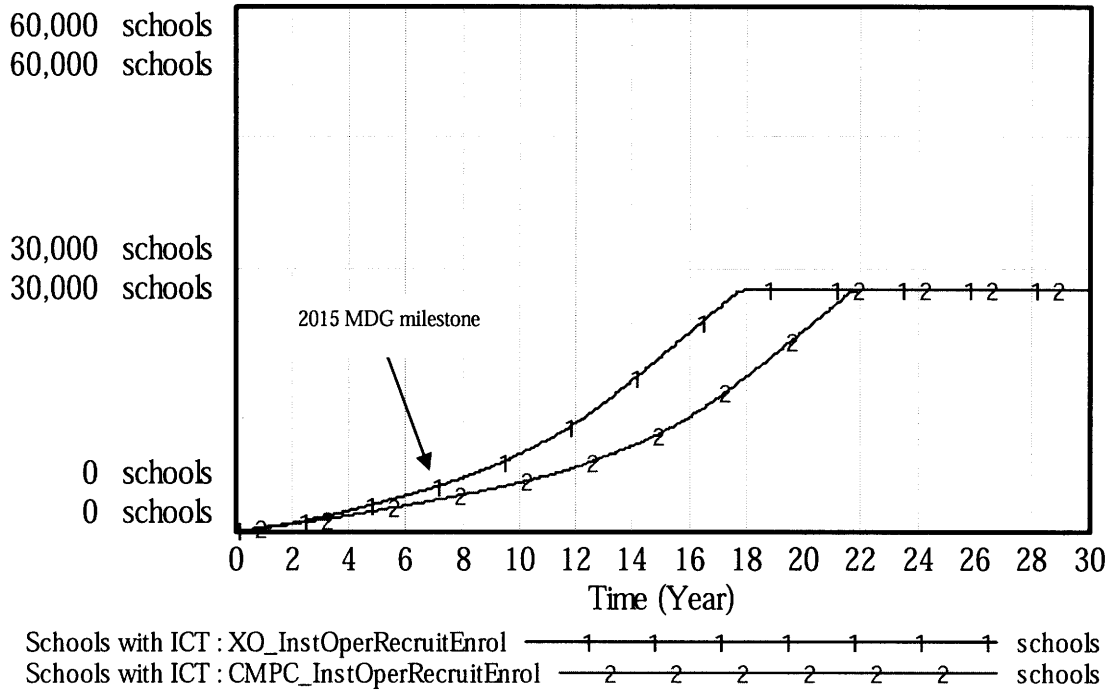


Figure 13: XO vs. CMPC Implementations - All costs considered (Secondary schools)

In general, based on the model cases, the CMPC implementations lag those of the XO by a widening amount as the implementations grow, ending with a lag of about 4 years at the end of the implementation cycle.

Overall, the calculated implementation schedules are excessively long when considered against the stated government goal of using ICT to achieve the 2015 Millennium goal of providing basic education for all students. Based on the results of the base model, less than 5,000 students would have received an ICT tool by 2015.

In addition, the ICT technology has an average useful life of five years. An implementation schedule of over 20 years would need to expand its budget and implementation plans to include replacing obsolete equipment multiple times. All efforts must therefore be made to reduce the implementation times from the times calculated in the base model. Sensitivity analyses will assist in determining which implementation factors would produce the most dramatic changes.

5.2.6 Electrification Infrastructure

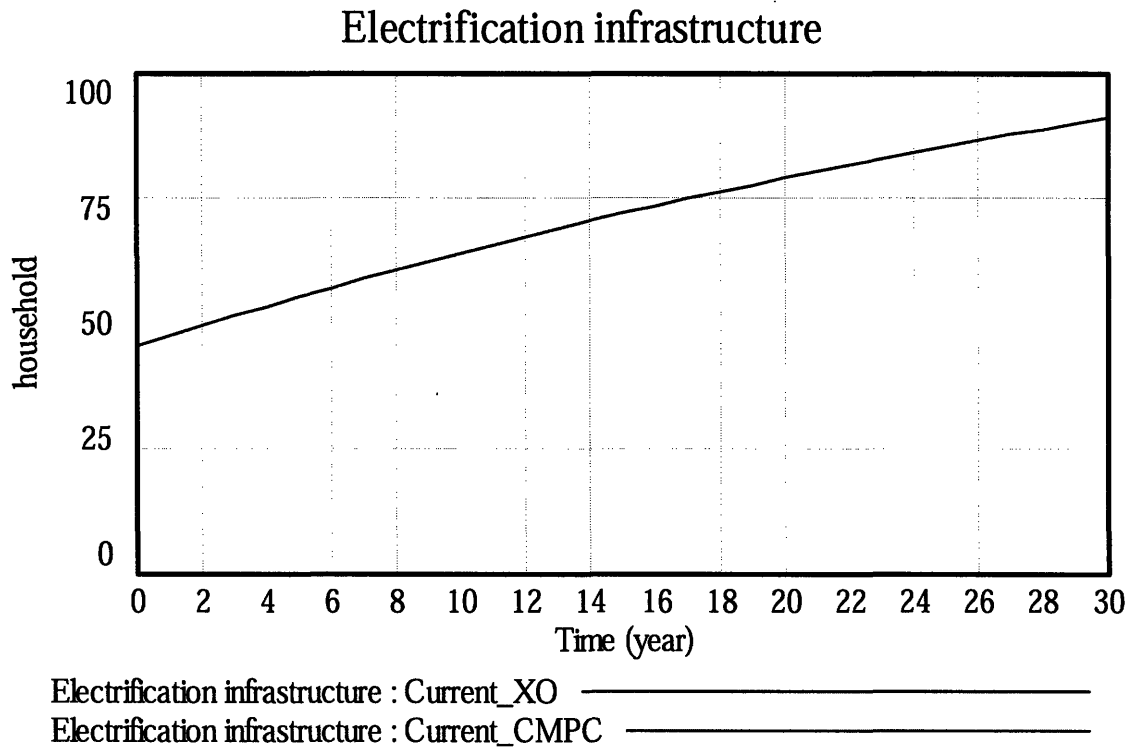


Figure 14: Electrification Infrastructure Projected Growth

Access to electricity within the developing country is seen as a key requirement for cost-effective rollout of the innovation and yet this is a limiting factor on the speed with which ICTs can be implemented. In order to demonstrate the impact of electrical infrastructure progress on the implementation schedule, a separate model was used to project the proposed growth of electrical infrastructure over the next 30 years and is included in Appendix 3. Nigeria has a current electrification rate of about 45% of the country⁸⁶. Based on stated goals by REA, the Rural Electrification Agency, of the electrification of rural areas from 35% to 75% by 2020⁸⁷, the rate of electrification was set at 3.1%. It can be seen that by the 30th year, electrification is high but still remains below the 100% electrification necessary to implement all the nation's schools. If, however, schools choose to bypass the

⁸⁶ "Nigeria Living Standards Survey (NLSS)", Nigeria Bureau of Statistics, <http://www.nigerianstat.gov.ng/nlss/2006/index.html>, Accessed April 23, 2008

⁸⁷ Taiwo, J, "Nigeria: FG to Achieve 75 Percent Rural Electrification By 2020", This Day, 3 July 2007. <http://allafrica.com/stories/200707030314.html>

national electric grid, the only option is to purchase a means of generating enough power for the school and the setup and maintenance costs will replace those of purchasing power from the national grid in the model.

5.3 Summary of XO and CMPC model differences

Variable	XO model	CMPC model
First time implementation cost per school	\$94,782	\$138,449 ^{88, 89}
Maintenance cost per school	\$1,432	\$2,564 ⁹⁰
Time to close Implementer gap	5 years	7 years
Adoption Fraction	0.3	0.1
Total number of schools	59,800	59,800

Table 2: Summary of XO and CMPC Model differences

⁸⁸ Fildes, J. "Africa's digital poster child.", BBC News online, <http://news.bbc.co.uk/2/hi/technology/7115218.stm>, November, 2007

⁸⁹ (Refer to Appendix 4 for calculations)

⁹⁰ Meira Rocha, J. A., "TCO for laptops UCA: TCO compared", translation by Google, <http://translate.google.com/translate?u=http%3A%2F%2Fspreadsheets.google.com%2Fpub%3Fkey%3DpH0vKjlkMrh25j-5b-iyRMg&langpair=pt%7Cen&hl=en&ie=UTF8>, Accessed April 19, 2008

6 Discussion and interpretation

6.1 Sensitivity analysis

The system dynamics model was tested for sensitivity to the values of certain variables. For simplicity the sensitivity analysis were run on the XO case of the model and are presented here. (Note: all tests exclude the effects of electrification)

- Annual initial budget for education ICT – by increasing significantly the initial budget allocated to educational ICT we can advance the climb to the limit imposed by electrification. Extreme initial values of US\$5 billion (24.5% of the entire 2008 Federal budget), will accelerate the XO implementations to complete secondary schools within 6 years and primary schools within 11 years. Smaller and more realistic initial investments of US\$1.5 billion and US\$750 million would extend the primary schools implementation completion up time from just under 12 years to 13 years. The marginal difference in time scale compared to the investment can be attributed to operating costs that absorb more and more of the budget with each successful implementation. These are however, in sharp contrast to the original 22 years required by the originally modeled investment of US\$75 Million.

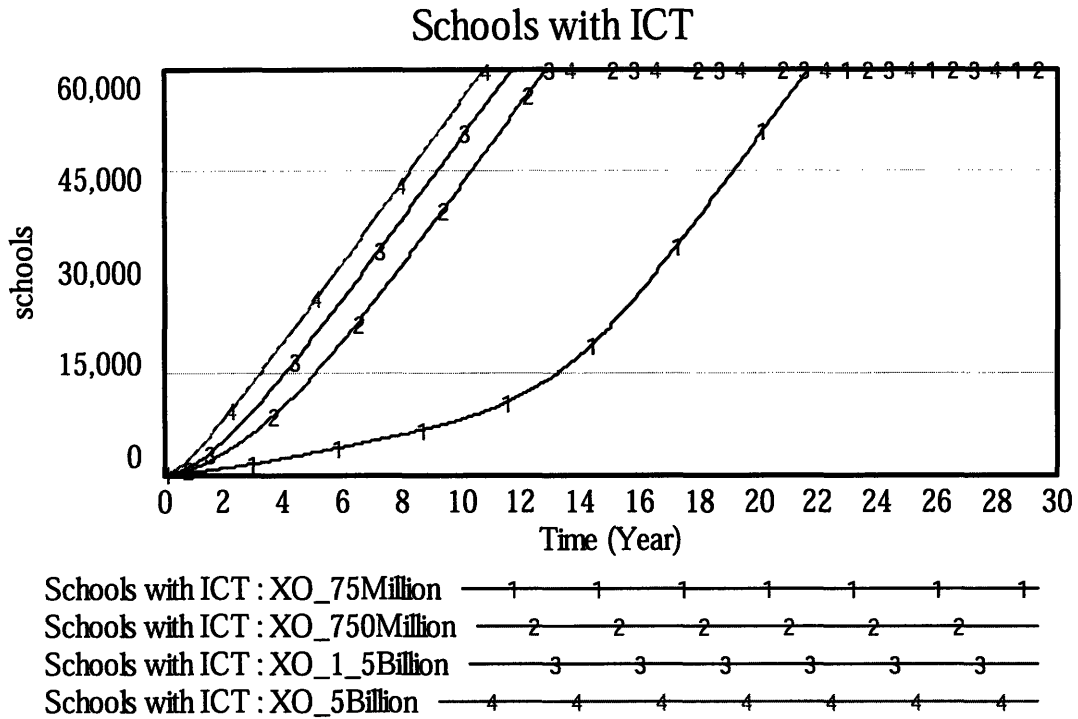


Figure 15: Sensitivity Analysis - Varying Initial Budget

- Costs of laptops and other equipment – by assuming that competition could possibly drive the cost of the laptops downwards even further in coming years, we can modify the model to show the effect of setting the cost of the XO from USD\$176 each, down to the original goal of USD\$100 and then down even further to USD\$50 each. Based on the analysis USD\$100 laptop would take 19 years to deploy to all primary school students while a USD\$50 laptop would take 17 years. Again, only marginal improvements are obtained due to the fact that the operating costs have remained the same

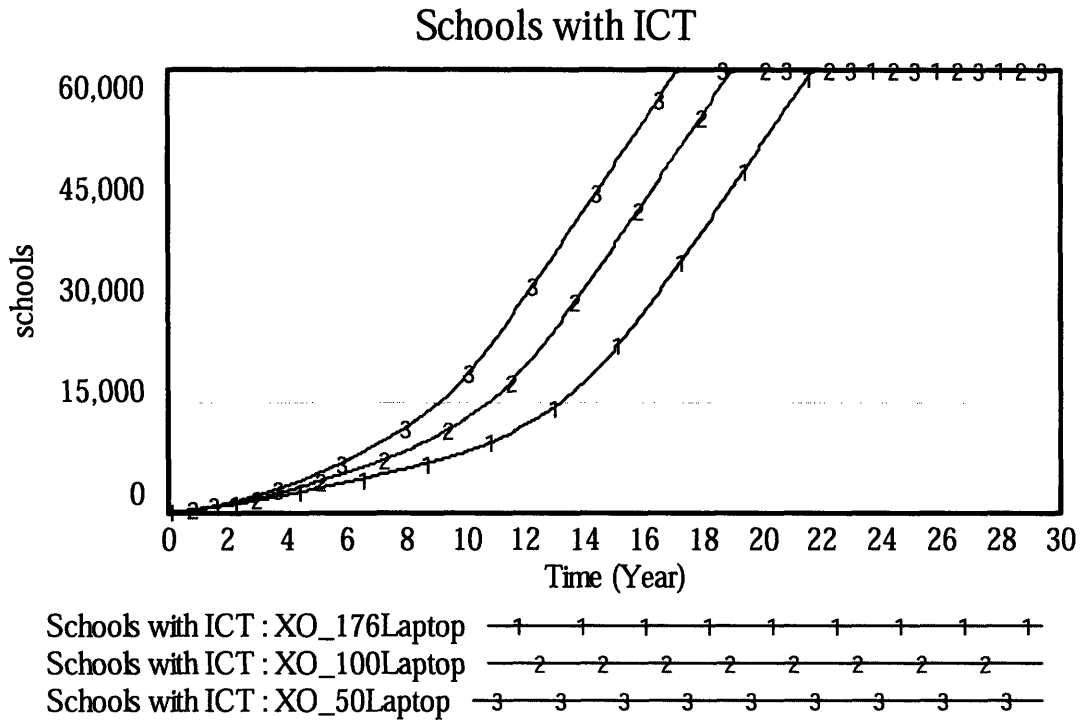


Figure 16: Sensitivity analysis: Varying XO laptop costs

Assuming a corresponding drop in connectivity costs of \$100 with each drop in price, the implementation schedule IS shown below to be almost identical to keeping the operating costs constant:

considering that the laptop cost is only a portion of the setup and operating costs.

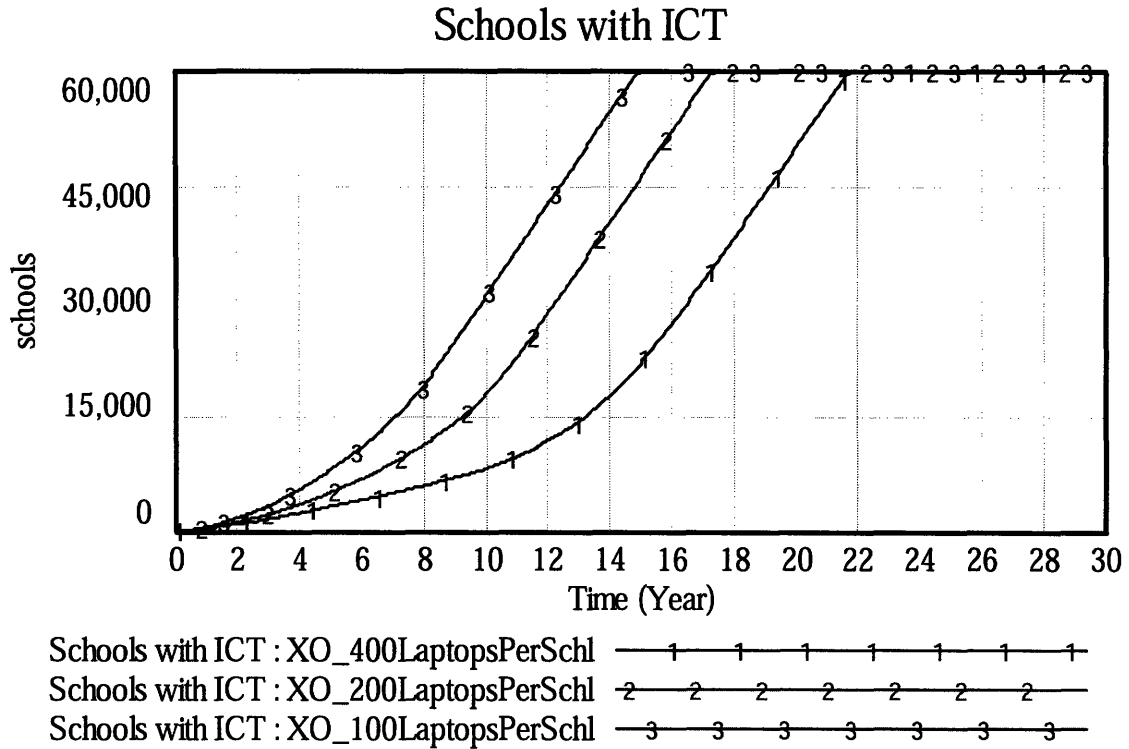


Figure 18: Sensitivity Analysis - Varying Number of Laptops Per School

- Local ecosystem growth – initial conditions for the growth of the skilled implementers who make up the local ecosystem was assumed to start with a pool of 200 skilled implementers. This value was deliberately chosen as a low value since the use of laptops in schools is an entire new market for most computing firms in the nation. If this number of implementers is adjusted upwards there is a marginal improvement of implementation speed by less than 2 years.

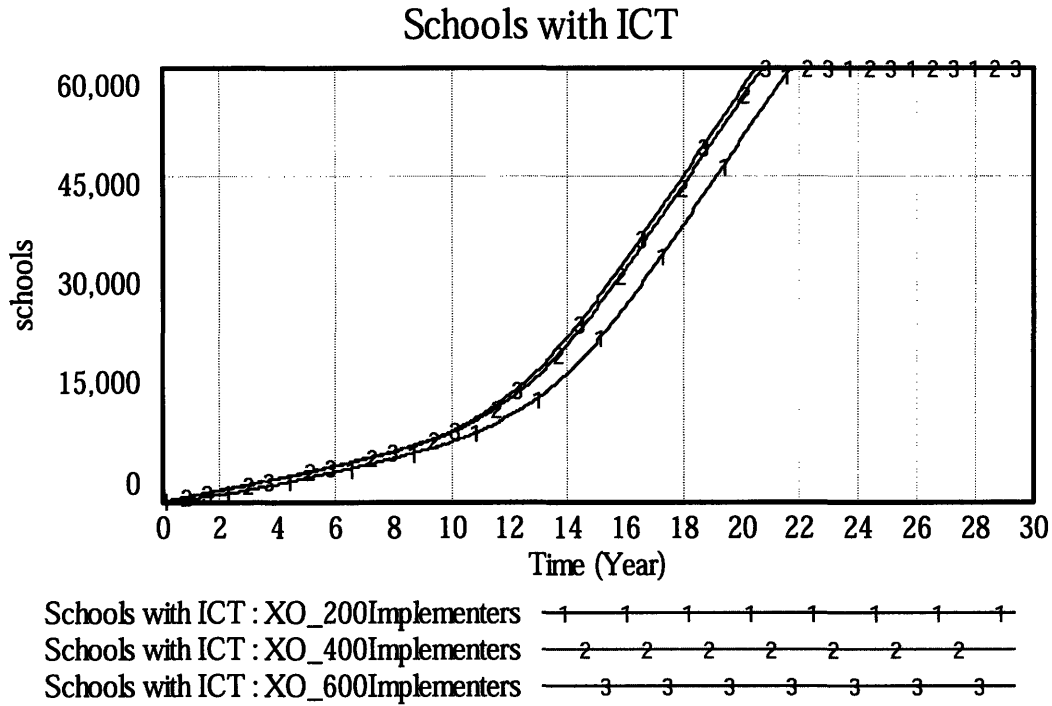


Figure 19: Sensitivity Analysis - Varying Number of Initial Local Skilled Implementers

Likewise, if the number of initial skilled implementers is kept at 200 implementers and concerted efforts are made by government and private enterprises to grow the pool at a faster rate by reducing the allowable time to build up the required implementer pool down from 5 years and increasing the amount spent in doing so – up from 1% of the implementation cost, the following results are obtained:- The implementations can be sped up by only approx. 2 years.

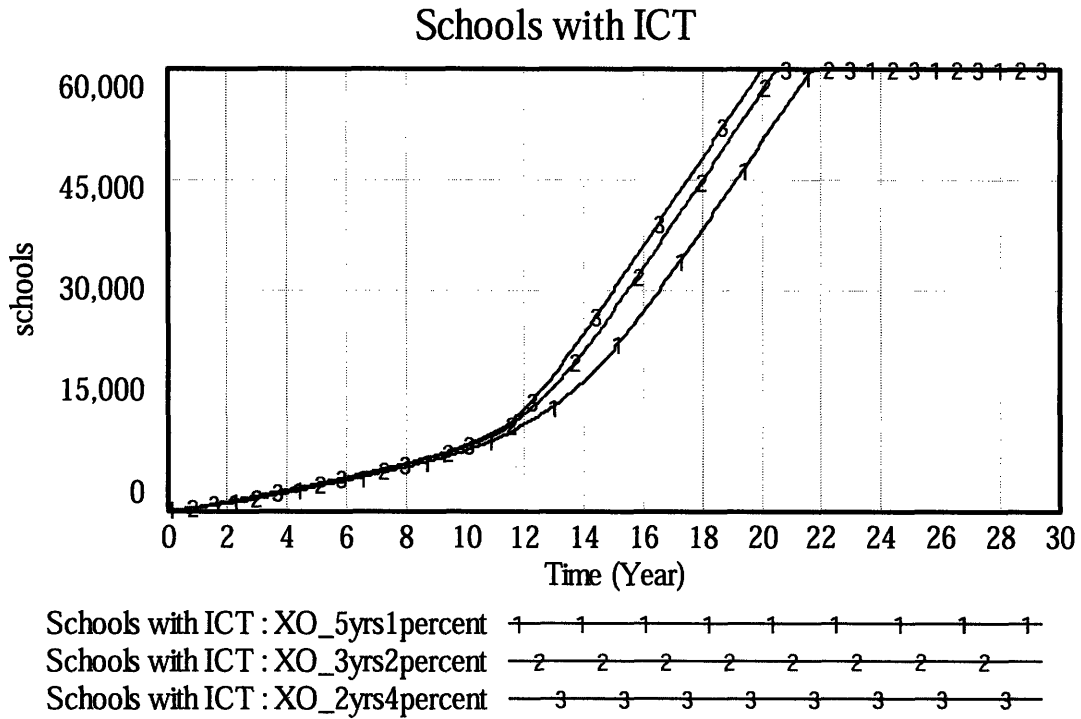


Figure 20: Sensitivity Analysis - Varying Recruiting Investments in Skilled Implementers

- More Local Champions per School – In making the base model it was assumed that each school contained on average 10 teachers and approx. 100 parents given Nigeria’s high fertility rate. Of these, 110 adults a certain percentage would adopt the ICT to the degree where they would be willing to place pressure on government to increase the ICT spend budget. If however this number were increased to 300, and then to 600 adults, the implementation schedule speeds up by 4 and 6 years respectively.

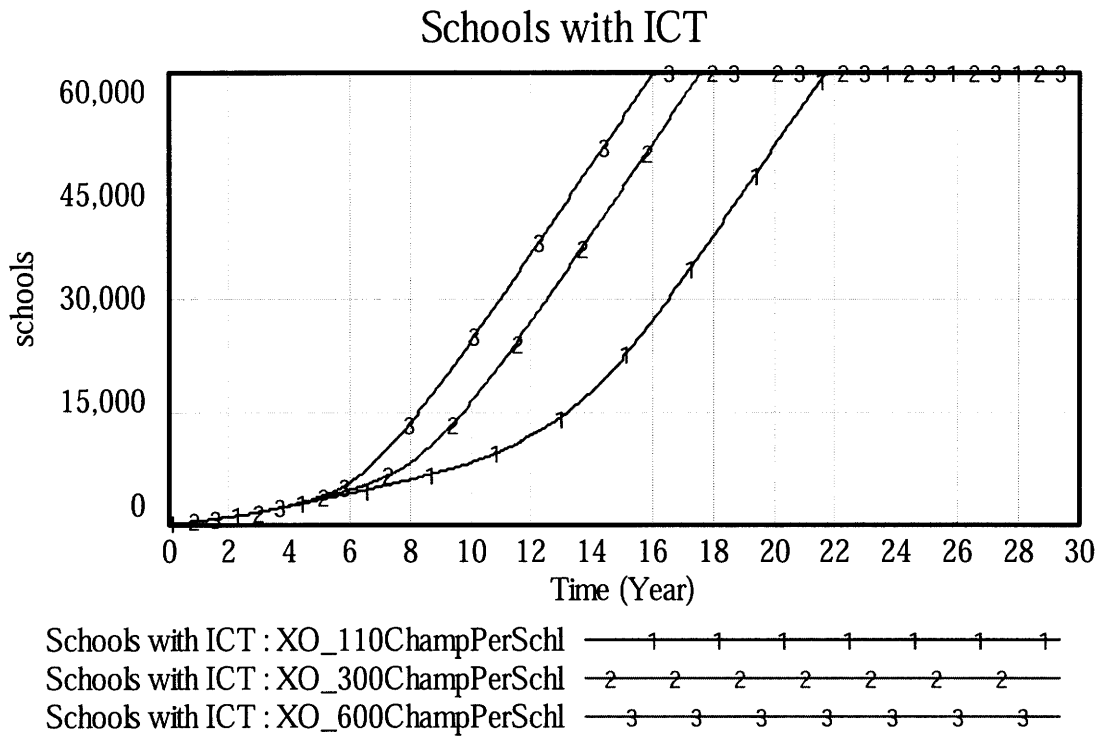


Figure 21: Sensitivity Analysis - Varying Number of ICT Champions Per School

- Faster Electrification & Alternate power sources – The preceding analyses have assumed that during implementations electrified schools would obtain power from the electric grid whilst non-electrified schools would generate power by other means at the same cost. It should be noted that this is typically not the case as a majority of communities (including the two schools visited) choose diesel generators for power generation. These are typically more expensive to purchase and operate than the subsidized cost of electricity. This implies therefore, that implementation schedules would still be lengthened when alternate power sources like diesel generators are used due to the increased cost. If however, a cheaper energy source is available and reliable, e.g. solar, the costs could be reduced slightly, shortening the implementation schedule. At present, in the pilots visited, it should be said that neither OLPC nor Intel® was able to power an entire school (laptops, server and modem) off alternative power sources like solar panels, though the XO laptop is low-power consuming in order to facilitate the use of alternate

power sources. It is anticipated though, that technological advances would continue to be made in this area.

6.2 What-If Scenarios

If it is assumed that due to market forces the XO and CMPC laptops could end up costing the same to implement, we can create what-if scenarios to assist in planning future implementations which is technology agnostic.

6.2.1 Scenario 1 – Increased funding and faster ecosystem growth

What if the government rallied private and external donors to co-fund both the laptop implementations and increase funding by factor of 10 to US\$750 million, and simultaneously the timeframe for the ecosystem growth is shortened whilst increasing the percentage of the costs that are allocated to training skilled implementers? The secondary schools can be implemented within 6 years while primary schools would take almost 12 years to achieve.

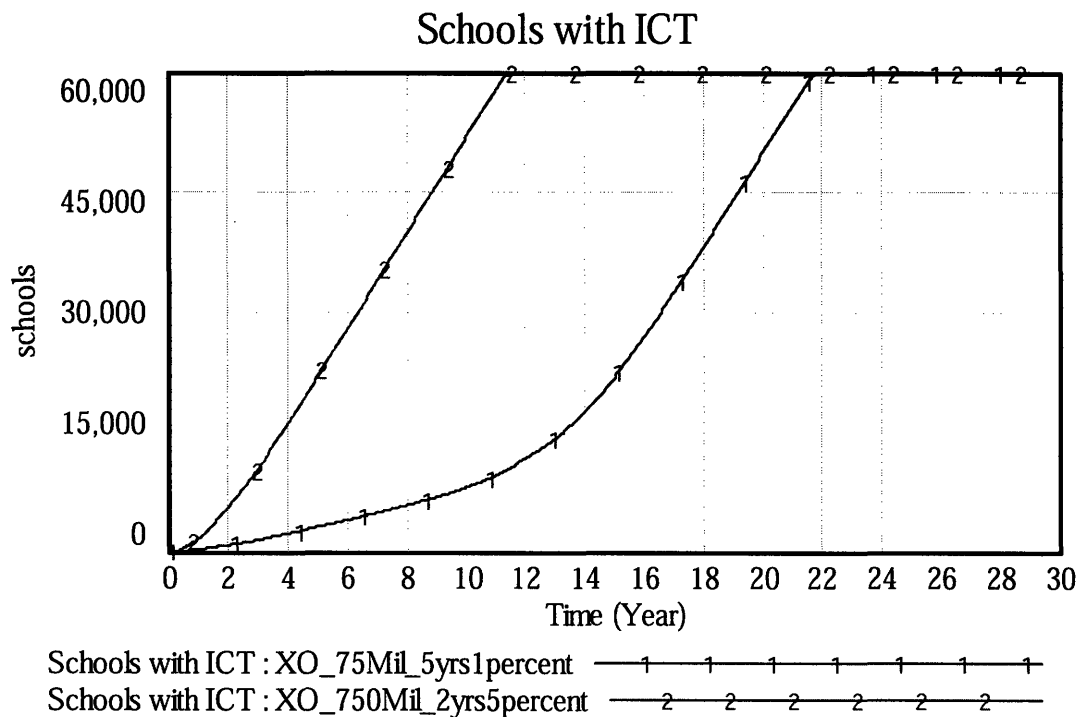


Figure 22: Scenario 1 - Increased Funding and Faster Ecosystem Growth

6.2.2 Scenario 2 – Increased funding and less laptops

What if there was a 10-fold increase in financial investment and a decrease in number of laptops to a student-to-laptop ratio of 4:1? All the secondary schools would possibly receive their ICT system within 6 years and primary implementations within 11 years also.

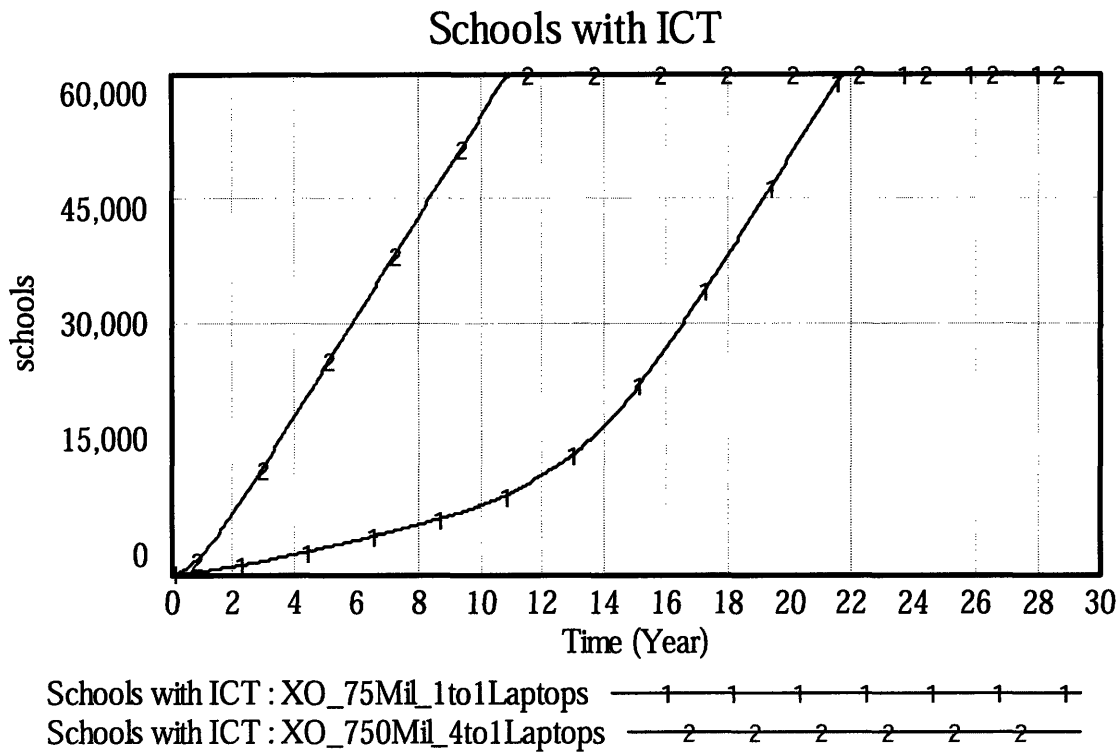


Figure 23: Scenario 2 - Increased funding and Less Laptops

6.2.3 Scenario 3 – Increased funding, less laptops and faster ecosystem growth

What if there was a 10-fold increase in financial investment, a corresponding decrease in number of laptops to one student and measures to ensure faster ecosystem growth? The rate of implementation is found to be identical to scenario 2 due to a portion of the implementation budget being used to fund the faster ecosystem growth.

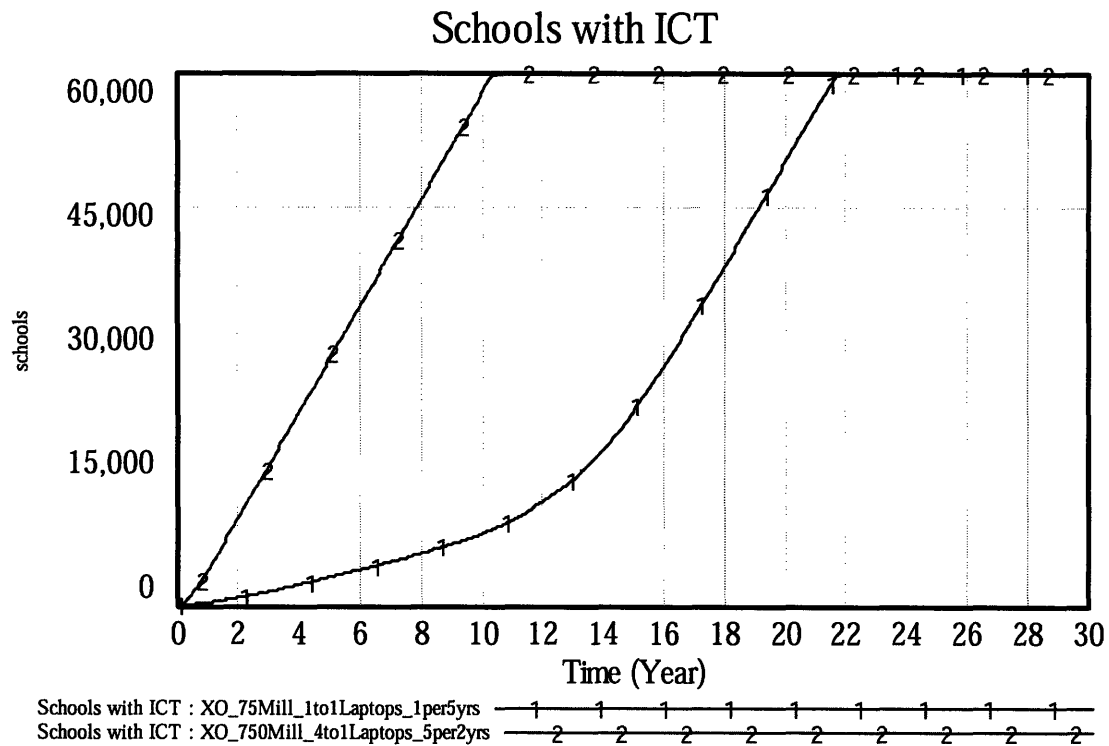


Figure 24: Scenario 3 - Increased Funding, Less Laptops and Faster Ecosystem Growth

6.2.4 Scenario 4 – Increased funding, less laptops, more local champions per school

What if there was a 10-fold increase in financial investment, a corresponding decrease in number of laptops to one student whilst still being able to increase the number of ICT champions per school? The rate of implementation is found to be identical to scenario 2 – Secondary schools implemented with 6 years and primary schools within 11 years.

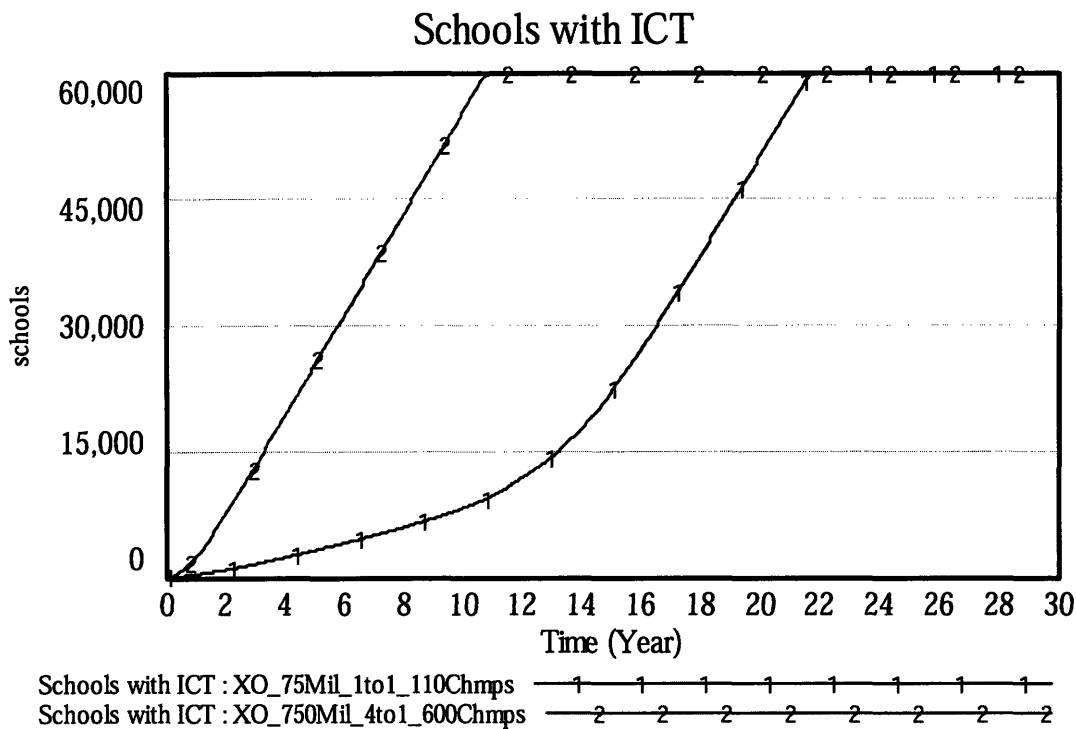


Figure 25: Scenario 4 - Increased Funding, Less Laptops and More Champions Per School

6.3 Assumptions made in what-if scenarios

- Independence from Electrification progress – as mentioned, if the ICTs are not powered by alternate power sources, the rate of the nation’s electrification would further limit the implementation progress.
- Replacement of obsolete ICT equipment - with the extended implementation timeframes, the implementation progress would be further slowed by the need to return to schools that have already been implemented to replace aging equipment. With the average ICT technology useful lifespan of 5 years, even the best scenario would involve several replacements before the end of the first wave of implementations.
- Abandonment – The track record for lengthy ICT projects the world over is less than encouraging. With such a lengthy implementation schedule, there is a high probability that the government will abandon the project before roll-out is

complete. It can also be expected that the political pressure exerted by the ICT champions would decrease over the course of a lengthy roll-out.

6.3.1 Summary of Scenario Findings

Scenarios	Primary schools time to full implementation (years)	Secondary schools time to full implementation (years)
Scenario 1 – Increased funding and faster ecosystem growth	11.8	6
Scenario 2 – Increased funding and less laptops	11.4	5.5
Scenario 3 – Increased funding, less laptops and faster ecosystem growth	10.8	5
Scenario 4 – Increased funding, less laptops, more local champions per school	11.3	5.5

The four different scenarios combining key factors within the implementation of ICTs in the schools of Nigeria, the best case scenario was achieved where secondary schools are implemented in 5 years and primary schools within 10.8 years i.e., Scenario 3.

7 Recommendations and Conclusion

7.1 Radical Changes to implementations

If any government requires laptop implementations to occur within the first 6-8 years for about 28,000 schools, it is recommended that the following be considered in drawing up implementation plans:

1. Higher Financial Investment: Invest heavily from the start – 750 million US dollars or more in the implementations would be required. For a country like Nigeria that represents almost half of the Federal Government’s education budget. However, as stated in section 3, Nigeria on the whole is currently under-spending on its education based on the percentage of GDP allocated to it.
2. Purchase less Laptops: In addition, it would be necessary to reduce the ratio of students-to-laptops from 1:1 down to about 4:1 based on current laptop prices in order to gain some ICT exposure to all students nationwide. Alternately, each student can have access to a laptop for only a portion of their primary and secondary education lifespan.
3. Ensure adequate electric power: Finally, the system providers will need to ensure that the laptop systems can be run completely independent of the national electric grid through the use of alternate power sources like solar, wind, biomass power or even car batteries. Diesel generators are not cost-effective alternatives based on the numbers of schools being considered. It should be noted however that even if these laptop platforms are setup independent of the electric grid, long-term electric power sources are a key requirement for sustainable ICT growth.

7.2 Incremental Changes to Implementations

Incremental gains in implementation time and expense may be gained by implementing any one of the following changes in isolation:

7.2.1 Adjust budget expectations

To implement even a modest starting goal like providing ICT in education to 1 million children (approx. 2500 schools) in Nigeria requires significant financial investment in the order of US\$750 Million in order to achieve this portion of the goal within 2 years. It therefore stands to reason that, providing ICT to every school student would require significantly more financial investment than just increasing the education ICT budget by a few million dollars. With the assumption that the ideal implementation plan should be to finish the roll-out before equipment begins to become obsolete (ideally within 5 to 6 years), there is a need for a large effort to be made to fund the initiative – private public partnerships should be forged with local donors and international donors like the World Bank, UNESCO and USAID (United States Agency for International Development).

7.2.2 Adjust implementation expectations

From the results shown, it is critical that governments approach all wide-scale ICT projects with the realistic expectations of the length of time it would take to achieve full coverage. Our results show that even with extremely high financial investments in ICT, a long-range view should be taken when planning project roll-outs. This long-range view is typically very difficult to achieve when government is the project driver due to the high probability that the project will be abandoned when the government administration changes every 4 to 8 years. As such, wide-scale ICT projects should be structured to provide tangible and publicized achievements at various milestones of the project.

7.2.3 Reduce Student-to-Laptop ratio

It would be worthwhile for nations to perform further investigations into the degree to which learning is hampered when students share the laptops up to a ratio of 4:1.. In order to expose the maximum number of students to the technology, it may be necessary to start with a high ratio of students to laptops at the beginning of the implementations, deploy to schools quicker and then, as a long-term strategy, invest in further laptops to bring the ratio back down to the promised ideal of one-to-one computing. A similar benefit may be obtained by selecting only a few grades within a school as recipients of the laptops instead of equipping all grades of a school at once. Further studies could also indicate a reasonable

age after which students must have a computer in order to perform adequately. This alternative of reducing the years for which a student uses a laptop appears from research to be more advantageous than placing a small number of laptops in a lab and providing access for limited periods during the school week. The concept of a phased approach is currently being used by India, for example, which has as the first stage of India's 11th Five Year plan for education the creation of high-quality content, followed by providing connectivity to the content and then providing access to it using desktops.⁹¹

7.2.4 Reduce Implementation costs

- Reduce the high operating costs either by negotiating lower costs or modifying equipment to use even lower amounts of power.
- Reduce the relatively high shipping and distribution cost through improvements to the supply chain process and perhaps, by performing local manufacturing of the equipment.
- Minimize any hidden costs like the costs of repair, disposal and software upgrades by purchasing easy-to-repair laptops with cheap replacements parts. Interestingly, the XO laptop addresses this recommendation in its focus on teaching students to repair/replace laptop parts and providing cheap components for the laptops.

7.2.5 Invest in local ecosystem growth

For any wide-scale sustainable implementation, there is the need for a well-trained and active cadre of local technicians and content creators as part of the ecosystem. All efforts should be made to train and provide this local ecosystem with the knowledge and tools needed to be locally self-sufficient. The faster the local ecosystem grows, the more capable the local personnel will be with implementing and supporting the innovation. The speed of implementations depends on this ecosystem capacity growth. Also, future sustainability in terms of lower costs of maintenance, updated equipment and learning materials require investments in this area.

⁹¹ "Internet In All Secondary Schools By 2012", Digital Learning, Vol 4, Issue 1, January 2008

7.2.6 Increase electrification progress

Increasing the electrification infrastructure construction rate is required in order to reach those schools that are off the electric grid if, as was mentioned above, there are no significant strides in providing alternate power sources for the ICT systems. It should be noted that at present, even schools that are electrified require increased electric power reliability as teachers and students are highly likely to experience frequent black outs that result in damaged ICT equipment and reduced use of the equipment. It cannot therefore be overemphasized that there is an urgent need to increase the rate of building and upgrading the electrical infrastructure. All efforts on ICT without this as a parallel effort will reduce the ultimate effect of purchasing these technologies. Even after implementation graduate students with ICT skills would need to find means of utilizing their ICT knowledge in their communities. As evidenced by the graph below, near the top of the concerns of the general public in a country like Nigeria is the need for electricity.

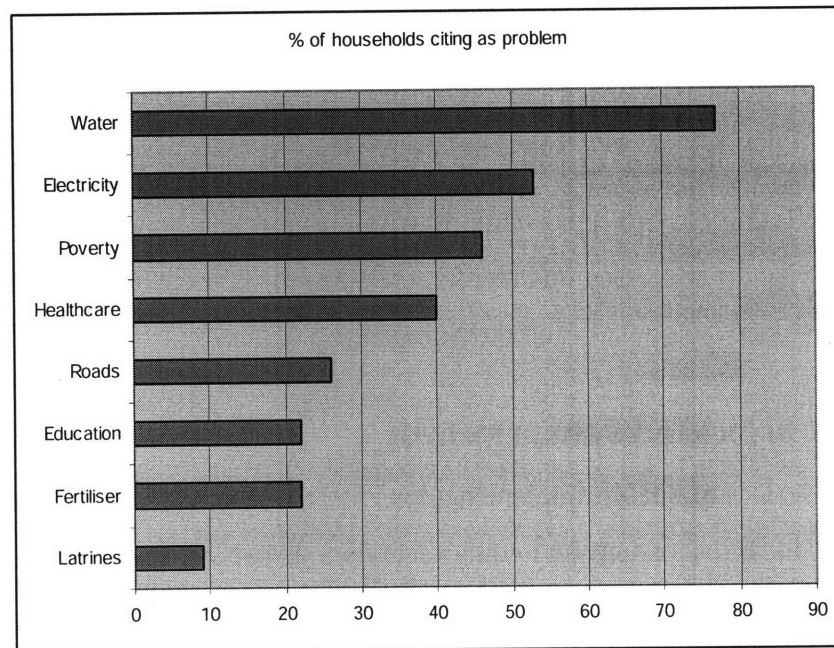


Figure 26: Problems Identified by Rural Nigerian Households
(Source: National Rural Water Supply and Sanitation Program)⁹²

7.2.7 Minimal effect – Size of the local champion network

The presence of a local champion network was found to have minimal effects on the speed with which the implementations could be rolled out. This is likely due to the fact that each

⁹² "Nigeria: Expanding Access to Rural Infrastructure Issues and Options for Rural Electrification, Water Supply and Telecommunications", Energy Sector Management Assistance Program, The World Bank, 2005

individual champion does not purchase their own ICT equipment but relies on influence on funding sources to get the equipment rolled out. In nations where private enterprise is able to capitalize on the levels of adoption of the general populace it is possible that this effect would be more pronounced.

7.3 Conclusion

The study of two ICT in education projects in Nigeria using system dynamics model enabled a step-by-step review of the process of implementing a nation-wide information and communication technologies system such as the One Laptop per Child (XO) and the Intel ® Classmate PC. By separating each factor affecting these implementations, it was possible to evaluate the relative effects and present recommendations on the areas of focus for such endeavors. Our study presented some of the unique challenges that developing nations face as they seek to accelerate the speed with which their future generations become knowledge workers, able to compete equally with other developed nations. The XO and CMPC programs, along with other similar programs, have brought to the forefront of the global consciousness the possibility of using ICTs to overcome the myriad of difficulties developing nations face in providing education to their children. With the technical strides made thus far, it is possible to see, as this study has proven, how immediate increases in financial investments in educational technologies like ICTs, and renewed advances in providing electric power to all citizens can quickly place in the hands of children worldwide a tool that has reshaped the nature of human communication and the knowledge sharing. Developing nations must move towards this goal with realistic and long-range plans if they are to bridge the education divide that separates billions of children from a quality education. No single tool can fix this divide, however a tool, such as a laptop, can start the revolution of educational change that is long overdue.

Appendices

Appendix 1 – Education Statistics

Education statistics from UNESCO

	Nigeria	USA
School age population, Primary	23,157,824	24,766,683
School age population Secondary	20,203,991	26,148,736
Enrolment in primary (public and private.)	22,267,407	24,454,602
Enrolment in lower secondary (public and private)	3,624,163	13,166,222
Enrolment in upper secondary (public and private)	2,773,418	11,265,712

Table 3: Comparison of education statistics of Nigeria and USA
(Source: UNESCO Institute for Statistics, 2005)⁹³

Educational statistics from The World Bank, 2005

	Nigeria	USA
Out-of-school children, (primary)	6,583,599	1,557,785
Pupil-teacher ratio, primary	37	14
Primary education, teachers	598,981	1,730,721
Secondary education, teachers	159,283	1,634,890
Population growth (annual %)	2	1
Internet users (per 1000 people)	38	630 ⁹⁴

Table 4: Educational statistics comparing Nigeria with the USA
(Source: The World Bank, 2007)⁹⁵

⁹³ Beyond 20/20 WDS – Report, UNESCO Institute for Statistics. Accessed April 9, 2008, <http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx>

⁹⁴ “World Development Indicators 2007. CD-ROM”, The World Bank; 2007. Data refers to 2004.

Nigerian 2008 Budget

(Currency conversion rate used: 120 Naira to US\$1)

	2007	2008	% Change	% of Overall Budget	% of GDP
	(N'bn)	(N'bn)			
Security	213	444.6	108.7	18.1	2.4
Education	188	210.4	11.9	8.6	1.2
Energy	118	139.8	18.5	5.7	0.8
Health	120.8	138.2	14.4	5.6	0.8
MDG	110	110	0	4.5	0.6
Pensions	148	99.7	-32.6	4.1	0.5
Transportation	13	94.4	625.8	3.9	0.5
Agriculture	38	90	136.7	3.7	0.5
Public Service Reforms	50	22.5	-55	0.9	0.1
Others	1301.2	1100.5			
Total Budget	2300	2450	6.5		13.4

Table 5: Summary of Nigerian 2008 Federal budget
(Source: Lead Capital, Nigeria)⁹⁶

⁹⁵ EdStats, The World Bank. Accessed March 26, 2008 <http://ddp-ext.worldbank.org/ext/DDPQO/member.do?method=getMembers>

⁹⁶ Nigeria's 2008 Appropriation Bill, LeadCapital, Nigeria <http://www.leadcapitalng.com/resources/Nationalbudget2008.pdf>, 2007

Appendix 2 – Estimated XO and CMPC Implementation Costs

Estimated Costs of an XO implementation

"Estimated XO Costs"		
Primary Schools Goal	59,800	
Students per School	400	
New Students per School per Year	67	
Students Exiting School per Year	67	
Schools per Community	10	
Unit Life	6 Years	
Annual Budget		
Government	\$ 7,500,000	
Other	\$ -	
Total Budget	\$ 7,500,000	
Annual Cost (per School)		
	Year 1	Assumptions
Unit Cost	\$ 70,400	\$176 per unit
Connectivity	\$ 600	\$600 per School/year (VSAT)
Alternate Power Source	\$ 0	\$850 per School
Generator	\$ -	\$5,000 per School
VSAT Dish	\$ 2,500	\$2,500 per School
Electrical Wiring	\$ 100	\$100 per School
Shipping	\$ 20,000	\$50 per Unit
School Server	\$ 200	\$200 per School
Community Awareness	\$ 150	\$1,500 per Community
Cost of Electricity	\$ 832	\$10.40 per Unit Life [160kWh per unit useful life(5years) @ 6.5 US cents/KWH]
Total Annual Cost (per School)	\$ 94,782	
First time installation cost/per school	\$ 94,782	
Maintenance cost per school	\$ 1,432	=Connectivity + Cost of electricity
Renewal product cost/per school	\$ 15,142	=Unit cost + Shipping

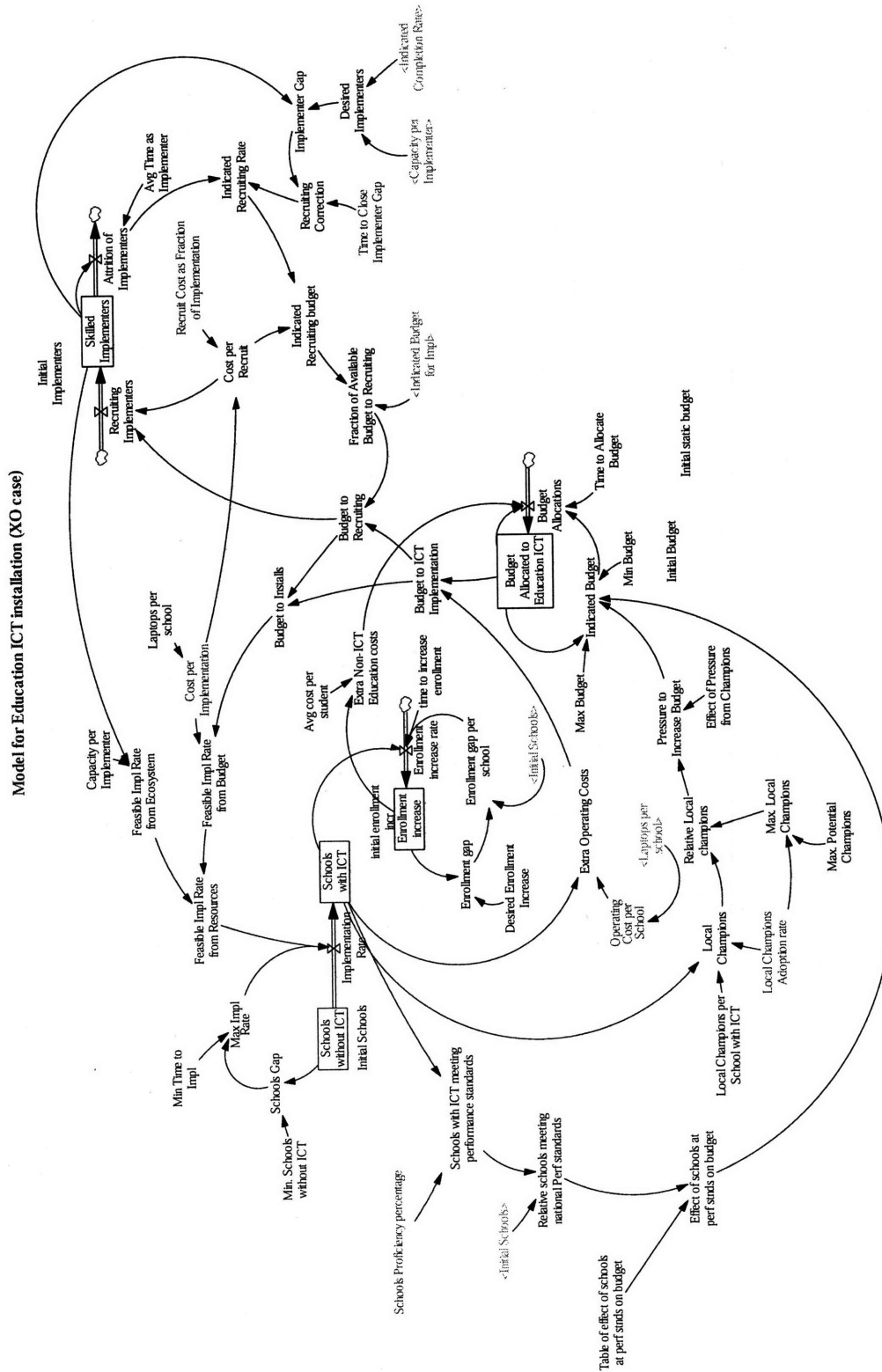
Table 6: Estimated Costs of an XO Implementation

Estimated Costs of a CMPC Implementation

"CMPC"		
Secondary Schools Goal	27,549	
Students per School	400	
New Students per School per Year	67	
Students Exiting School per Year	67	
Schools per Community	10	
Unit Life	5 Years	
Annual Budget		
Government	\$ 7,500,000	
Other	\$ -	
Total Budget	\$ 7,500,000	
Annual Cost (per School)		
	Year 1	Assumptions
Unit Cost	\$ 114,000	\$285 per unit
Connectivity	\$ 900	\$50 per unit/year (WiMax)
Alternate Power Source	\$ 0	\$850 per School
Generator	\$ -	\$5,000 per School
WiMax Receiver	\$ 1,500	\$1,500 per School
Electrical Wiring	\$ 100	\$100 per School
Shipping	\$ 20,000	\$50 per Unit
School Server	\$ 285	\$285 per School*
Community Awareness	\$ -	\$0 per Community
Cost of Electricity	\$ 1,664	\$20.80 per Unit Life [320kWh per unit useful life(5years) @ 6.5 US cents/KWH]
Total Annual Cost (per School)	\$ 138,449	
First time installation cost/per school	\$ 138,449	
Maintenance cost per school	\$ 2,564	
Renewal product cost/per school	\$ 134,000	

Table 7: Estimated Costs of a CMPC Implementation

Appendix 3 - The XO and Classmate PC System Dynamics model



XO and CMPC Model Details (VenSim)

- (01) Attrition of Implementers= Skilled Implementers/Avg Time as Implementer
Units: people/Year
- (02) Avg cost per student= 1400/120
Units: dollar/person/Year
Naira 1400 divided by 120 for dollars. (Hincliffe, K. "Public Expenditures on Education in Nigeria: Issues, Estimates and Some Implications", The World Bank, 2002
- (03) Avg Time as Implementer=1e+006
Units: Year
- (04) Budget Allocated to Education ICT= INTEG (Budget Allocations,Initial Budget)
Units: dollars/Year
- (05) Budget Allocations=(Indicated Budget-Budget Allocated to Education ICT-"Extra Non-ICT Education costs")/Time to Allocate Budget
Units: dollars/Year/Year
- (06) Budget to ICT Implementation= max(0,Budget Allocated to Education ICT-Extra Operating Costs)
Units: dollars/Year
- (07) Budget to Installs=Budget to ICT Implementation-Budget to Recruiting
Units: dollars/Year
- (08) Budget to Recruiting=Fraction of Available Budget to Recruiting*Budget to ICT Implementation
Units: dollars/Year
- (09) Capacity per Implementer=1.6
Units: schools/Year/person
4 people per school - comms (1), server & laptops(2), training, electrical (1). Each school takes 1.5months therefore each implementer can install 1.6 schools (by themself)
- (10) Cost per Implementation=237*Laptops per school
Units: dollars/school
XO = \$94,782 (\$237 per laptop) CMPC = \$138,449 (\$346 per laptop)
- (11) Cost per Recruit=Cost per Implementation*Recruit Cost as Fraction of Implementation
Units: dollars/person
- (12) Desired Completion Time=10
Units: Year
- (13) Desired Enrollment Increase=890417
Units: people
- (14) Desired Implementers=Indicated Completion Rate/Capacity per Implementer
Units: people

- (15) Effect of Pressure from Champions $[(0,0), (1,4)], (0,1), (0.110092, 1.08772), (0.183486, 1.42105), (0.238532, 2), (0.29052, 2.49123), (0.348624, 2.96491), (0.394495, 3.29825), (0.452599, 3.54386), (0.525994, 3.77193), (0.614679, 3.78947), (0.703364, 3.84211), (1,4)$
Units: Dmnl
- (16) Effect of schools at perf stnds on budget=Table of effect of schools at perf stnds on budget(Relative schools meeting national Perf standards)
Units: Dmnl
- (17) Enrollment gap= $\max(0, \text{Desired Enrollment Increase} - \text{Enrollment increase})$
Units: people
- (18) Enrollment gap per school= $\text{Enrollment gap} / \text{Initial Schools}$
Units: people/school
- (19) Enrollment increase= INTEG (Enrollment increase rate, initial enrollment incr)
Units: person
- (20) Enrollment increase rate= Enrollment gap per school*Schools with ICT/time to increase enrollment
Units: person/Year
- (21) "Extra Non-ICT Education costs"= $\text{Avg cost per student} * \text{Enrollment increase}$
Units: dollars/Year
- (22) Extra Operating Costs= Schools with ICT*Operating Cost per School
Units: dollars/Year
- (23) Feasible Impl Rate from Budget= $\text{Budget to Installs} / \text{Cost per Implementation}$
Units: schools/Year
- (24) Feasible Impl Rate from Ecosystem= $\text{Skilled Implementers} * \text{Capacity per Implementer}$
Units: schools/Year
- (25) Feasible Impl Rate from Resources= $\min(\text{Feasible Impl Rate from Budget}, \text{Feasible Impl Rate from Ecosystem})$
Units: schools/Year
- (26) FINAL TIME = 30
Units: Year
The final time for the simulation.
- (27) Fraction of Available Budget to Recruiting= $\text{Indicated Recruiting budget} / (\text{Indicated Budget for Impl} + \text{Indicated Recruiting budget})$
Units: Dmnl
- (28) Fraction of Operating Budget Recognized=1
Units: Dmnl
- (29) Fractional Initial Budget=0.5

- Units: Dmnl
- (30) $\text{Implementation Rate} = \min(\text{Max Impl Rate}, \text{Feasible Impl Rate from Resources})$
Units: schools/Year
- (31) $\text{Implementer Gap} = \text{Desired Implementers} - \text{Skilled Implementers}$
Units: people
- (32) $\text{Indicated Budget} = \min(\text{Max Budget}, \max(\text{Budget Allocated to Education ICT} * \text{Pressure to Increase Budget} * \text{Effect of schools at perf stnds on budget}, \text{Min Budget}))$
Units: dollars/Year
- (33) $\text{Indicated Budget for Impl} = \text{Indicated Completion Rate} * \text{Cost per Implementation}$
Units: dollars/Year
- (34) $\text{Indicated Budget for Operating} = \text{Extra Operating Costs}$
Units: dollars/Year
- (35) $\text{Indicated Completion Rate} = \text{INITIAL}(\text{Schools without ICT} / \text{Desired Completion Time})$
Units: schools/Year
- (36) $\text{Indicated Recruiting budget} = \text{Indicated Recruiting Rate} * \text{Cost per Recruit}$
Units: dollars/Year
- (37) $\text{Indicated Recruiting Rate} = \max(0, \text{Attrition of Implementers} + \text{Recruiting Correction})$
Units: people/Year
- (38) $\text{Indicated Total ICT Budget} = \text{Indicated Budget for Impl} + \text{Fraction of Operating Budget Recognized} * \text{Indicated Budget for Operating}$
Units: dollars/Year
- (39) $\text{Initial Budget} = \text{INITIAL}(\text{Initial static budget})$
Units: dollars/Year
- (40) $\text{initial enrollment incr} = \text{INITIAL}(0)$
Units: person
Enrolment in primary (public and private. All programmes) 22,267,407
Enrolment in lower secondary (public and private. All programmes) 3,624,163
Enrolment in upper secondary (public and private. All programmes) 2,773,418 (DATA: UNESCO, 2006)
- (41) $\text{Initial Implementers} = 200$
Units: people
Assume the nation initially has 200 skilled technicians for the install jobs
- (42) $\text{Initial Schools} = 59800$
Units: schools
59,800 Primary Schools and 27,549 Secondary Schools
- (43) $\text{Initial static budget} = 7.5e+007$

Units: dollars/Year

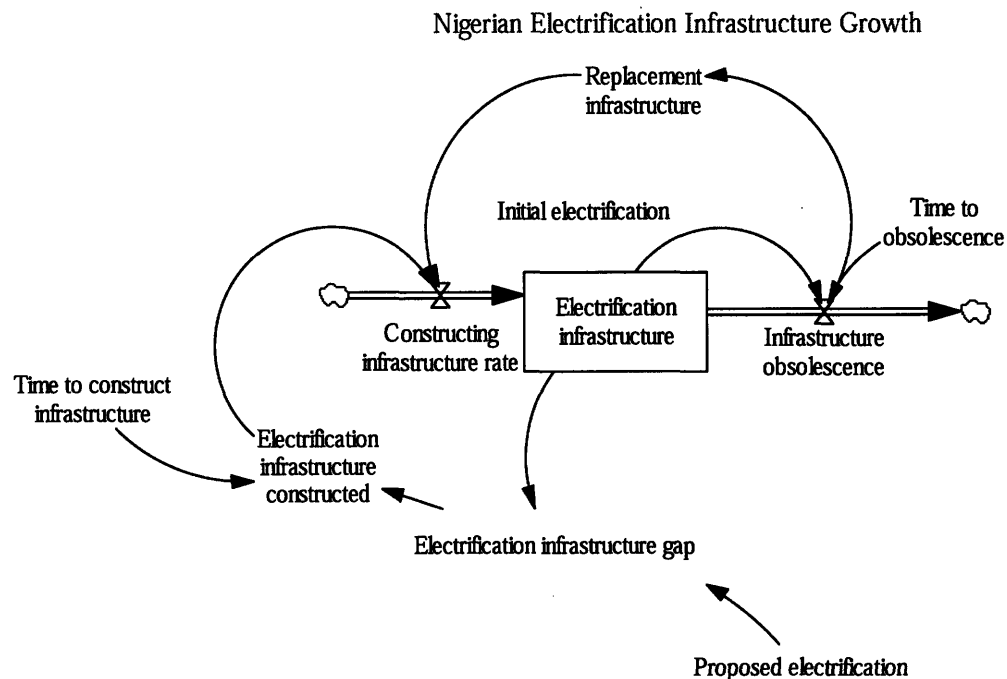
- (44) INITIAL TIME = 0
Units: Year
The initial time for the simulation.
- (45) Laptops per school=400
Units: Dmnl
- (46) Local Champions=Schools with ICT*Local Champions per School with ICT*Local Champions Adoption rate
Units: people
- (47) Local Champions Adoption rate= 0.3
Units: Dmnl
XO - 30% adoption rate, CMPC - 10%
- (48) Local Champions per School with ICT= 110
Units: people/school
10 teachers per school with ICT + 400/4 mothers who have a 10% (Intel) or 30% (XO) adoption rate = 20 champions (Intel) or 40 champions (XO) per school [Fact: number of children per woman is higher - 5.4. 4 is a high value for school age children/mother]
- (49) Max Budget=1.8e+009
Units: dollars/Year
Max budget = 1.8 bi dollars (entire Federal Education budget in dollars)
- (50) Max Impl Rate= Schools Gap/Min Time to Impl
Units: schools/Year
- (51) "Max. Local Champions"=Local Champions Adoption rate*"Max. Potential Champions"
Units: people
Max. Local champions = 10 teachers + 100 parents * number of schools (59,800 primary and 27, 549 Secondary) = 6.6 mil (pry) or 3.03 mil (sec)
- (52) "Max. Potential Champions"=6.6e+006
Units: people
Max. Local champions = 10 teachers + 100 parents * number of schools (59,800 primary and 27, 549 Secondary) = 6.6 mil (pry) or 3.03 mil (sec)
- (53) Min Budget=500000
Units: dollars/Year
- (54) Min Time to Impl=0.125
Units: Year
- (55) "Min. Schools without ICT"=0
Units: schools
- (56) Operating Cost per School=3.58*Laptops per school
Units: dollars/school/Year

no cost = \$1432 (\$3.58 per laptop), CMPC = \$2564 (\$6.41 per laptop)

- (57) Pressure to Increase Budget=Effect of Pressure from Champions(Relative Local champions)
Units: Dmnl
- (58) Recruit Cost as Fraction of Implementation=0.01
Units: school/person
5% of the implementation budget to the implementers (5 implementers per install =1% each)
- (59) Recruiting Correction= Implementer Gap/Time to Close Implementer Gap
Units: people/Year
- (60) Recruiting Implementers=Budget to Recruiting/Cost per Recruit
Units: people/Year
- (61) Relative Local champions=Local Champions/"Max. Local Champions"
Units: Dmnl
- (62) Relative schools meeting national Perf standards=Schools with ICT meeting performance standards/Initial Schools
Units: Dmnl
- (63) SAVEPER = TIME STEP
Units: Year [0,?]
The frequency with which output is stored.
- (64) Schools Gap=max("Min. Schools without ICT", Schools without ICT-"Min. Schools without ICT")
Units: schools
- (65) Schools Proficiency percentage=0.5
Units: Dmnl
- (66) Schools with ICT= INTEG (Implementation Rate,1)
Units: schools
- (67) Schools with ICT meeting performance standards=Schools with ICT*Schools Proficiency percentage
Units: schools
- (68) Schools without ICT= INTEG (-Implementation Rate,Initial Schools)
Units: schools
- (69) Skilled Implementers= INTEG (+Recruiting Implementers-Attrition of Implementers, Initial Implementers)
Units: people

- (70) Table of effect of schools at perf stnds on budget([(0,0)-(1,4)],(0,1),(0.088685,1.09649),
(0.16208,1.21053),(0.238532,1.33333),(0.311927,1.63158),(0.342508,1.92982),(0.38532
1,2.45614),(0.437309,2.92982),(0.495413,3.4386),(0.571865,3.7193),(0.669725,3.87719)
,(1,4))
Units: Dmnl
- (71) TIME STEP = 0.0625
Units: Year [0,?]
The time step for the simulation.
- (72) Time to Allocate Budget=1
Units: Year
- (73) Time to Close Implementer Gap=5
Units: Year
- (74) time to increase enrollment=200/365
Units: Year
ASSUME based on 200 new students enrolled within a 1 year period

Appendix 4 – Electrification Infrastructure Growth



Electrification Model Details

- (01) $\text{Constructing infrastructure rate} = \text{MAX}(0, \text{Electrification infrastructure constructed} + \text{Replacement infrastructure})$
Units: household/Year
- (02) $\text{Electrification infrastructure} = \text{INTEG}(\text{Constructing infrastructure rate} - \text{Infrastructure obsolescence}, \text{Initial electrification})$
Units: household
- (03) $\text{Electrification infrastructure constructed} = \text{Electrification infrastructure gap} / \text{Time to construct infrastructure}$
Units: household/Year
Increase in electrification of households.
- (04) $\text{Electrification infrastructure gap} = \text{Proposed electrification} - \text{Electrification infrastructure}$
Units: household
- (05) $\text{FINAL TIME} = 30$
Units: Year
The final time for the simulation.
- (06) $\text{Infrastructure obsolescence} = \text{Electrification infrastructure} / \text{Time to obsolescence}$
Units: household/Year

- (07) Initial electrification=45.39
 Units: household
 45.39% of households use public electricity (Stat: Poverty Profile for Nigeria, Nigerian Bureau of Statistics, 2004)
- (08) INITIAL TIME = 0
 Units: Year
 The initial time for the simulation.
- (09) Proposed electrification=85
 Units: household [0,100]
 DATA: Goal of rural electrification of 40% in 13 years
- (10) Replacement infrastructure=Infrastructure obsolescence
 Units: household/Year
- (11) SAVEPER = TIME STEP
 Units: Year [0,?]
 The frequency with which output is stored.
- (12) Table of effect of electrification on implementation(
 [(0,0),(10,1)],(0,0),(1,1),(10,1))
 Units: Dmnl
 Assume a linear relationship between electrification and innovation implementations
- (13) TIME STEP = 0.0625
 Units: Year [0,?]
 The time step for the simulation.
- (14) Time to construct infrastructure=13
 Units: Year
 Time to construct electrification infrastructure after approval. Data: 13 years
- (15) Time to obsolescence=45
 Units: Year
 Assume very large time to obsolescence