Usage Models of Classroom Computing in Developing Regions

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***Abstract*— This paper examines low-cost computing projects for education in developing regions, and presents some of the common entrepreneurial and technical problems faced by past and current initiatives. In particular, we look at various models of computer usage, and evaluate their appropriateness according to their effectiveness in education, their socio-cultural suitability, and economic feasibility. Based on detailed field studies and interviews conducted in rural Indian classrooms and economic analysis, we show that shared rather than single-user devices constitute a more realistic and sustainable approach for low-cost computing projects targeting children's education.[1]**

***Index Terms*—** computers for education, ICTD, developing regions.

I. Introduction

There are numerous projects that target human development in emerging regions by introducing computers into schools. We find that many struggle because they do not adequately take into account the significance of the social aspects of computer-aided learning and the content available for it. In our research we found organized projects run by governments and state education departments as well as quality content that effectively introduces children to computers and enhances their curricular learning. Even in remote villages we found knowledgeable teachers with systematic ideas on how computer deployments should be conducted, and how children can be introduced to the use of computers. Initiatives for classroom computing in developing regions that ignore these resources in favor of new paradigms of learning do so at their own risk. In the following sections we delineate the focus of this study and present a case for shared user models of computing in classrooms in developing regions.

We begin in Section II by tracing the historical path of major initiatives in this domain and look specifically at how the evolution of the *"Computers for the Poor"* paradigm has moved towards children as its target users. We discuss how the direction of research in single-user devices has taken a techno-centric orientation towards technical research and engineering which has produced well-designed gadgets but in the process has been distracted away from the practical goals of computer use in extremely resource strapped scenarios.

We present three categories of computer usage models in the context of children's education in primary schools: personal single-user devices, single-user computers in shared computer labs at school, and multiple-user computers shared by tens of children at school. We then evaluate each of these usage models from three different perspectives: cost and economic feasibility, socio-cultural suitability, and educational effectiveness.

We conclude that for primary school education the shared model of computing is comparable to the single user model of computing in improving quality of education, while being more economically viable and better suited to the realities in developing regions.

II. Background

This section summarizes research on IT and technology focusing on initiatives that target human development with the development of inexpensive computers for the masses, or with computers as learning aids in children's education.

A. IT and Development

The relationship between technology and development has been a consistent theme in social sciences. At a macro-economic level, the high-tech industry has been cast as an important engine for regional growth, while, at a micro-economic level, computers have been linked with human development. The academic community became interested in the macro-economic aspect of this relationship since the 1960s, with a large body of literature exploring the knowledge economy [1]. By the 1980s, this interest had taken the color of Information Society theory [2]. As major social theorists [3, 4]

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Initiative	Usage Model	Envisioned Cost (US $)	Actual Cost (US $)	User	Buyer	Status in 2007	Strategy
Simputer	Single user, shareable	$100	$200	Low income users	Institutions, Individuals	Discontinued	Complete redesign
OLPC	Single user	$100	$135 ($208)[2]	Low income children	Government	In production	Complete redesign
Classmate	Single user	$400	$200+	Children	Individuals	In production	Complete redesign
Computador Popular	Shared	$300	-	Kiosks	Individuals, subsidized	Conceptualized, never produced	Stripped-down desktop PC
NComputing	Shared – Thin Client	$11/access terminal (excl. monitor)	$66/access terminal (excl. monitor)	Classrooms Kiosks	Individuals	In production	Server w/ multiple thin clients
HP 441	Shared	$250	$250	Classrooms Kiosks	Institutions	Discontinued	Server w/ multiple dumb terminals

Table 1: Some representative low-cost computing initiatives. Comparison of costs and the current status of implementation.

joined the bandwagon in the 1990s, industry interest in the field grew. By mid 1990s, the subject captured the interest of many international agencies [5][6][7][8][9], international funders like the IDRC and USAID, national governments in Latin America, West Africa, and South Asia, non-profit implementation agencies from all over the world, as well as corporations [10]. This wave of interest quickly transferred to the micro-economic realm, and the first projects exploring the relationship between computers and human development were born. Two of the main focuses for these projects were the creation of inexpensive computers for the underserved masses, such as the Computador Popular (Brazil) and the Simputer (India) initiatives [11], and the use of computers in children's education.

B. Inexpensive Computing Devices

Historically, there have been numerous initiatives targeting the creation of "computers for the poor", but the quest for such devices has been an elusive one (see Table 1 for a selection).

Computing-for-the-Poor Initiatives: Arguably the original "low-cost PC" was IBM's PCJr. in 1984 which was launched with much fanfare, including a magazine devoted to it even before its actual release. The product led to a wave of clones, some fairly successful, including the Tandy 1000, though did not itself succeed in the market due to design issues. This first low-cost computer was not intended as a "computer for the poor", but it was an attempt to extend the range of people having access to computers (in this case from businesses to home users), by drastically reducing device costs.

The second wave of low-cost PCs came in the early days of the World Wide Web. Products such as the Net PC were conceptualized, but never made it to production, because the 90's were a period of such rapid decline in PC prices, that a low-enough threshold for a "computer for the poor" as then imagined, would be attained by the market without any need to innovate.

The market then was middle- and low-income households in developed countries. Initiatives targeting special computer needs for the developing world took off only after the normalization of demand in developed countries in the late 1990's. This new wave aimed to concurrently deal with three problems. The first, and most emphasized one, was the reduction of the device cost. Second was the creation of form factors and functionalities specific usage in developing countries, accounting for the lack of urbanization and infrastructure. This second factor was frequently equated with building robust machines that withstood harsh weather, dust and poor quality power. The third factor was that of "usage appropriateness", including issues related to literacy, cultural appropriateness and social norms of resource sharing.

The pioneer in this most recent wave was the Simputer project that originated in 1998. The Simputer (Simple Inexpensive Multilingual Computer) aimed to address all these three sets of issues. The device was sold at a significantly lower price point of US $200 compared to the average computer cost of US $1000 on the market, even though it was originally envisioned to cost as little as US $100. Second, the Simputer came in a strong casing and a plastic cover for dusty and hot weather, and large sturdy buttons for rough use. Finally, there was a lot of investment in making the UI easy-to-use by first-time computer users, with speech synthesis to accommodate illiteracy. The device was easily shareable, allowing each user to utilize their individual flash memory.

Around the same time, the Computador Popular (CP) was conceptualized in Brazil. As opposed to the Simputer, they

[2] While the estimated price for future sales is around $135, the actual cost of ownership (including maintenance) agreed upon in the MoU between OLPC and Libya was of $208 per unit.

only innovated on trying to minimize the cost of the device. In fact, the CP was nothing more than a plain, stripped-down version of a PC running Linux, but the project was more important for a different reason: it was the first project to actively seek state intervention to subsidize cost of computers by reduced taxes and loans. This device was to be priced at US $300.

By the turn of the century, there were numerous projects in this space, and a number of major technology players created “computers for the poor” products or initiated research in this direction. Almost all of these players departed significantly from their core businesses and competencies to try a hand at selling new devices to a market that had not been sold on the idea. Oracle had a brief brush with the ‘New Internet Computer’, which was priced roughly at US $199, started around 2000, and was abandoned around 2003. Chip manufacturer Via Technologies designed a low-cost box-PC similar to the AMD PIC at a price point of approximately US $250. In developing countries, smaller manufacturers ventured into the design space with ruggedized products such as the SuperGenius Bharat PC and the Beijing Rural PC (with Intel). HP experimented with the 441 device, with a changed Linux kernel to support 4 keyboards and screens from a single processor and priced at approximately US $1200 for the entire unit. This attempt was abandoned along with its parent e-inclusion program in 2005, although their technology has lived on in products such as the ‘Useful Desktop Multiplier’. Recently, NComputing has released the X300 that uses low cost access terminals connected over ethernet to share a single PC with up to 7 users. The current cost is US $200 for three users excluding monitors and peripherals.

But probably the most discussed project, and arguably the one with the largest expectations, is the One Laptop Per-Child (OLPC) initiative. Also originally known as the $100 laptop, or more recently the XO-1, the current price of the device is about US $208, but is expected to decrease with volume. This device, the brainchild of some of the leading scientists of the MIT Media Labs, is an inexpensive, low-power laptop designed for harsh conditions in developing countries, intended to be distributed to children around the developing world. Intel also started selling its own laptop branded ‘Classmate’ for children in schools at a starting price point of US $400. Recently Intel and the OLPC decided to join hands and collaborate on technology and educational content development.

Experience on the Market: While the fate of the latest computing-for-the-poor projects like OLPC remains to be seen, valuable lessons can be learned from the market experience of the other similar projects in the past, which unfortunately were either entirely ineffective or enjoyed very limited success. The reasons for these outcomes were related to both the *supply* and the *demand* side of the market.

On the supply side, the companies producing these low cost devices were either not typical computer companies (e.g. the Simputer), or they were outside of their core competencies (e.g. Intel, HP, AMD) in terms of *production*, *marketing* and *distribution*. In terms of production, these new devices did not enjoy large enough volumes to decrease their cost significantly. Cost considerations also prevented device customization, and constrained manufacturers to build a single version of a device, rather than a suite of products. For example, there is only one version of the OLPC, two versions of the Simputer, one of the Classmate and so on. Such products are difficult to sell to institutional buyers such as schools, who are less inclined towards experimentation with untested products. On the marketing side, a unique and almost universal marketing approach taken by producers in the ICTD space has been engaging governments in a range of ways – from tax concessions to direct purchases. This has been a risky strategy that has rarely worked well due to a range of factors: state priorities in more basic spending, equity (thus the problem of selecting the location for the pilot group of free computers), government stability, and procurement process. Finally, on the distribution side, working through the government plays a detrimental role by separating producers from the micro-environment within which technology sales and maintenance take place, such as training of local suppliers and support staff.

On the demand side of the market, the problems were even more challenging. A major concern is planning for the creation of appropriate content and applications. The Simputer, a device different from a typical standalone computer was especially affected by this – as getting a critical mass of developers working on creating applications for it depended on its widespread usage – a chicken and egg conundrum. The same kind of problem is seen with community kiosks [21] which have failed to attract users despite low prices due to a lack of “things to do” using computers. Designing applications for adults that do not have a conscious need for computers in their daily lives is non-trivial, as it is difficult to convince these adults to incorporate technology in possibly disruptive ways into their livelihoods [23].

From the free market perspective, the “computer for the poor” faced its strongest challenge from standard low end desktop computers. Beyond the US $250 mark, there is a whole range of Linux-based desktop products available both in the US (e.g. Lindows Family PC) as well as several developing countries (e.g. PC for India, ApnaPC). The typical cost of an assembled unbranded machine is also around US $250 though these often come with pirated OS copies. These generic computers enjoyed the advantage of being independent on any specific user segment’s adoption, offering comparable computing power to the typical branded PC. This is an important factor, with research showing that the association of ICTD products with low-income groups or low-attainment populations has a damaging brand impact because the target market perceives purchasing “computer for the poor” as a climb-down of status. Similar effects have been observed both with subsidized community kiosks [26] and with refurbished computers [27].

Figure 1: Single ownership model. Each child owns a laptop.

C. Computers and Children's Education

Children's use of computers has became a growing area of interest, both as customers of low-cost computing initiatives, and also more generally as classroom technology. This became especially important for developing regions, where the shortcomings in primary school education and the shortage of adequately trained teachers led to the projection of computers and computer-aided education as tool for overcoming these teaching gaps [12].

These beliefs resulted in a sizeable expansion of computing facilities in schools, with states deploying programs to build computer labs in poor rural schools. Projects like HP 441 saw their use in school computer labs; NComputing's X300 is projected as a low cost solution for building school computer labs, the Simputer was designed as a PDA to be shared among multiple children; the AMD and VIA devices were used in classrooms and community kiosks, while the Classmate and OLPC were marketed as take-home laptops for kids. OLPC already holds the (unbinding) commitment of more than 15 countries, including Argentina and Pakistan - even though countries like India have rejected the initiative, arguing that "it would be impossible to justify an expenditure of this scale on a debatable scheme when public funds continue to be in inadequate supply for well-established needs" [43].

These programs operate primarily on the assumption that computers can complement teachers, or make learning more valuable in general, but there is little evidence to suggest that such assumptions can be taken for granted. The issue of whether or not computers have an overall positive impact on children's learning is not a subject on which there is widespread agreement. There is even less consensus on the larger issue of schools choosing to invest in computers over other types of potential investments.

While studies show that children's access to computers yields clear gains in certain types of skill building [29], especially when these are home computers, there is a plethora of material to suggest that the context within which the computers are used is especially important in ensuring both education efficiency and equity in education opportunity. There is strong evidence that investment in computers can be highly inefficient [31] and driven by an enthusiasm for technology instead of the needs of the children. There is also evidence that the positive impact of access to and use of computing facilities can be highly biased [30] due to cultural and cognitive factors.

Figure 2: Elementary school computer lab in Washington, US. Showing the usage model of single user computers in community owned labs.

III. Focus of this Paper

Low-cost computing initiatives often target children in the classroom as a means of improving and equalizing quality of education. The successes and failures of these initiatives is determined by how well they are accepted in a particular socio-economic context, and by the influence of various market and political forces. In the end, these factors are potentially more decisive than the impact on the resulting quality of education. Each initiative's design is motivated by its intended goals, which may have grown from current uses of technology in education or dreamed up in a lab far from ground realities. The focus of this paper is to evaluate past and present initiatives along their model of usage, according to their criteria of economic suitability, education effectiveness and socio-cultural suitability.

A. Usage Models

We distinguish between three models of computer usage for child education: (a) Single ownership (Figure 1), (b) Single user per classroom computer/terminal (Figure 2), (c) Multiple users per shared classroom computer (Figure 3). More models are possible, and indeed, as we will mention, some initiatives share properties with each model. We find these categories useful, however, for understanding the design decisions between specific initiatives and for demonstrating in later sections how the choice of usage model must match existing contexts and practices in order to have a long term impact on establishing more equitable education.

Figure 3: Multi-mouse software grew from existing classroom models of shared computers. Shows the usage model of multiple users for each shared computer.

1. Single ownership: OLPC and Classmate: In the case of the deployment model for OLPC, laptop computers are intended to be purchased by governments in large quantities (no less than 1 million units) and issued to children at schools. The Intel Classmate is a similar small laptop, designed specifically for classrooms and is intended for sale to individual families. The recommended usage is individual child learning, parent-child collaboration, or teacher-child collaboration. The Simputer, a hand held device with a durable casing and buttons designed for dust and head was also trying to target the same application domain. This device was also intended for individual use, but it was easily shareable, with pluggable flash memory cards for each user. Given these features, the Simputer could be passed from child to child, or from home to home with each child or home responsible for their individual flash memory. This, as well as other design characteristics of the design (such as speech synthesis for illiterate users), point to some level of consideration for existing cultural practices and economic realities of the targeted user base.

All these devices targeting single users are complete redesigns from the standard PC's physical properties and user interface. Also, they all have fairly small screens, most suitable for a single user at a time.

2. Single user per community-owned computer/terminal: Computer labs in the US and India: A second usage model, which has been the standard in US primary schools as well as some developing country schools, is the computer lab, a classroom dedicated to computer usage where each child has access to their own computer in the classroom environment. In this model, the responsibility of purchasing and paying for computer maintenance is shared by the community. The teacher plays a primary role in educational settings that adopt this model, guiding and supervising child-computer interactions.

One attempt to bring cost effectiveness to this standard scenario was the HP 441. The goal of the HP 441 was to support multiple screens and keyboards connected to a single computer. This design features some shared structure, however, this is not visible to the user and is still suited to individual interaction with computers from within a group setting. HP 441 was sold to institutions and schools. NComputing's X300 on the other hand connects up to 6 separate access terminals to a single PC. Each of these access terminals is equipped with its own monitor, keyboard and mouse thus making it fully shareable. Its intended use is to build classroom computer labs at much lower cost by reducing the total number of PCs.

Schools and low-income families were also the intended buyers for the Computador Popular (CP). The design for the CP was geared simply to minimize the costs of the standard personal computer to suit the economic needs of intended buyers.

Devices that target the usage model in which single users operate computers that are shared by the community tend to feature low-cost versions of standard PCs. The ownership by the community allows for higher prices per unit, but in practice, the cost is comparable to devices that target a single ownership model. Community-owned computers operate in a group setting, where group interactions external to the child-computer interaction play a central role in their overall use.

3. Multiple-users per shared computer: Multi-mouse in rural Indian schools: In rural India and many other developing regions or impoverished communities, computers donated to a school may be available, but they are shared by 5 students at once, on average. The multi-mouse [37,38] initiative (now termed MultiPoint) is designed to leverage existing infrastructure and practices into a flexible platform for computer-aided learning with the minimal cost of peripherals (mouse and mouse splitter). Not only can PCs with multiple mice be used to run learning applications for curricular material, the keyboards can be used for textual entry also when required and thus behave like a standard desktop PC. Unlike the two previous usage models, a wide variety of child-child interaction styles are available, including competition, parallel user interactions, and collaborative interactions to achieve group goals. As in the case of the Simputer or the community-owned computers, each child may have individual memory devices to work on the shared infrastructure.

The canonical multi-user usage models are video game consoles (Nintendo, Playstation, etc.) which allow for the same variety of interaction modes (parallel, competitive, and collaborative). To support multiple users, the output is generally a split-screen display and the inputs are controllers for each individual. Currently, these consoles support a few educational game titles (e.g. Big Brain Academy), however the cost per console is much higher than other initiatives discussed in this paper, local language content is mostly unavailable, and the platform does not transition well to standard PC functions such as document and spreadsheet editing.

Cost of desktop PC that is shared	Rs 25000 or US $530
Cost of maintenance paid by Govt. for each PC (per year)	Rs 1800 or US $38
Cost of teacher (per year)	Rs 24000 or US $510
Cost of laptop (e.g XO-1)	Rs 9770 or US $208

Table 2: Parameters for cost comparison. They are taken from Government aided deployment of school computers in India.

In the following section, we present observations from field studies in rural India in which children play educational games with shared input using the multi-mouse, as well as evidence that children's learning is improved in the multiple-user usage model in typical learning scenarios.

B. *Evaluation Methodology*

Design considerations of low-cost computing initiatives for education depend on the envisioned usage model. In the previous section, we showed how previous initiatives have varied in their strategies of cost-minimization and marketing (depending on intended buyers and users). The resulting initiatives support certain types of learning interaction, depending on the number of users and the overall context of use. Single user models seek to redesign existing teaching practices and infrastructure. The multiple-user models seek to support a variety of interactions that build on existing teaching practices and existing infrastructure.

In the following sections, we will show that factors beyond the cost per unit of each device can predict which models are more or less effective in facilitating more equitable education.

1. Cost: For each of the usage models, we will examine the costs of production, maintenance and training. In addition we analyze economic projections for governments or other buyers to achieve intended goals.
2. Education effectiveness: Based on the additional field work in primary schools of rural India, we analyze the effectiveness of learning with different usage models. We use statistical findings on test results taken by children before and after computer use. We also examine how children use computers in their educational context in rural schools.
3. Socio-cultural Suitability: Qualitative results from detailed field work in government primary schools in rural India inform the appropriateness of a usage model in the social context of the children using computers. In particular, we present the opinions of 165 parents of various education levels from a wide range of districts in India who were interviewed about the use of computers in child education and how they perceived the relative roles of teachers and computers. Many socio-cultural factors we present are unique to rural India. However, in many ways, the contextual factors we discuss are representative of other developing regions.

IV. Economic Feasibility

In this section, we evaluate the economic feasibility of various computing initiatives for schools, and their associated usage models. Given the harsh financial constraints, cost is one of the most important considerations for any of these initiatives. We consider both initial capital costs and running costs, including replacement, maintenance and additional expenditures for developing appropriate content and training of teachers.

An economic analysis of the "computers for the poor" projects is necessary because these projects have typically targeted government buyers, projecting the provision of computers to children as a state responsibility. The most important criticism of such projects, and often one very difficult to address, is the argument that money would be better spent on school buildings, safe drinking water and toilets in these schools, books, additional teachers and so on, which are all basic needs and with immediate returns on investment. In contrast, computers in education address less stringent needs, and only have a long-term return on investment. It is not our goal to claim here that the hierarchy of needs argument applies in absolution, and that investment in computers should be preceded by the solving of all other world problems. Governments all around the world are introducing computers in schools, in moderation, attempting to balance these expenditures with more basic ones. However, it is essential to ensure that the already scarce resources are utilized in the most effective way. It is notable that the two countries farthest ahead in adopting OLPC-type schemes are Libya and Nigeria, both nations that have limited political opposition in getting these schemes accepted at the highest levels.

A. *Reduction of computing cost*

Most low-cost computing initiatives are reducing the capital cost of hardware by riding on the computer industry's exponential trends of increasing integration and performance. They also downgrade or remove certain components from the final device. Such initiatives often use low-end processors (OLPC uses the AMD Geode, Classmate uses low power Intel processors), replace hard disk with flash memory, and remove other capabilities like high-end graphics, optical drives, and peripheral connectors.

The cost of ownership can be reduced by lowering the running cost of power. Power consumption can be reduced by using lower power displays and smarter sleeping techniques. Interestingly, refurbished computers have performed poorly, due both to maintenance and to disenchantment with "second rate" computers [10].

Though the overall cost of computing has gone down, none of the low-cost devices have broken the off-the-shelf US $200 mark, not including the cost of maintenance. OLPC's XO-1

Metric	Scenario 1	Scenario 2	Scenario 3
No. of computers (million)	149.4	15.19	4.0
Total initial cost ($billion/year)	31.06	8.08	2.15
Cost of replacement ($billion/year)	6.21	1.62	0.43
Cost of maintenance ($billion/year)	5.72	0.58	0.153
Cost of teachers ($billion/year)	0.483	0.483	0.483
Total cost ($billion/year)	**12.42**	**2.68**	**1.06**

Table 3: Comparison of costs for various scenarios for deployment of computers in all rural schools of India (total of 165 million students in 1.04 million schools)

laptop expects to achieve this by selling the hardware in batches of at least 1 million. However, according to the contract between OLPC and Libya, the cost per device, including maintenance, is US $208. Interestingly, Intel's Classmate PCs were initially sold at a price of US $400, but their price is expected to fall to around US $200 as well. The cost of NComputing's X300 is also expected to fall to US $11 per access terminal in large production volumes [47].

B. *Cost Comparison*

To compare the economic viability of various deployment models, we consider the capital and operational cost of providing computers in the whole of India. As discussed earlier in Section III, we consider three scenarios:

1. *Single ownership model.*
2. *Single user per community-owned computer/terminal:* We assume a ratio of 1 computer per 10 children in the school. During classes, each child gets his or her own computer.
3. *Multiple-users:* We assume a ratio of 1 computer per 40 children. During computer classes, 3-5 children share a computer. This can be done with or without multiple input devices.

We use data about schools children distribution in India from [46]. Approximately 1.04 million schools in India serve about 165 million children between the ages of 6 and 13. The schools vary in size, serving less than 30 students to more than 300 students. Approximately 91% of all schools in India, and overwhelmingly so in rural India, are government-aided and/or managed schools [35]. Infrastructure resources in these schools are very scarce - 59% of all Indian schools have no safe drinking water, 26% have no blackboards, 89% have no toilets, and less than a quarter of the schools have functional access to electricity [36].

Table 2 summarizes the cost parameters involved in our comparison, based on latest figures from OLPC and the Indian government. For the scenarios where desktop computers are used in classroom (scenarios 2 and 3), we use cost figures reported from current deployments of computers in Indian schools (expenditures for teacher salaries and maintenance of equipment that the Government provides) and recent market prices (for the price of desktops). We assume a gradual deployment model where computers are introduced over five years. Assuming that the lifetime of the computers is also about five years, the replacement capital cost for the hardware every year is one fifth of the total capital cost. We also assume that each school has only one computer teacher.

The cost comparison, showing the total cost per year for all the three scenarios is presented in Table 3. As can be seen from the table, the annual cost of providing shared computers (1 per 40 children) to all of 149 million Indian students is only about US $1.06 billion a year. In contrast, the annual expenditure of providing laptops to every child is about 12 times higher at US $12.42 billion. These are conservative estimates that ignore the additional costs of running such a large program such as the recurring cost of power and other infrastructure in schools, the cost of developing educational content in local languages, and the cost of providing Internet connectivity to schools.

The total public expenditure for India on education was about US $22.9 billion (3.3% of GDP) in 2004 [11] of which 30% or US $6.8 billion was allocated for primary schooling [37]. In these conditions it is unrealistic to expect the Indian government to spend more than half of the education budget on buying computers, especially without having any guarantees on the educational benefits of such a program.

V. EDUCATION EFFECTIVENESS

An important comparison across usage models is done by looking at the educational value provided by those models. Education scientists would have an open debate on the question of how to best define value. However, it is possible to compare across usage models, relying on studies with easily quantifiable metrics based on objectively assessable learning outcomes.

Few studies focus on learning outcomes in the single computer per computer model. The OLPC project is starting field studies with the XO-1 project in a few countries. The Maine Laptop per Child project [44] conducted some studies but results did not find that a separate computer per child leads to strong and measurable changes in learning outcome metrics. However, for scenarios with computers inside the classroom, we present preliminary results from India for various single and multi-user scenarios, using single or multiple input devices.

Our study in India shows that learning effectiveness with collaborative learning on multiple input computers can be as good as learning with single user computers in classrooms, for some types of learning outcomes. A key reason for this seems to be the inherent social nature of learning provided in shared computing scenarios which is absent from single PC scenarios.

A. Study methodology in India

We conducted observations and qualitative interviews during May 2005 and August 2006 of 22 schools in India, all catering to children from disadvantaged backgrounds. The schools were selected based on regional profile and longevity of computer-aided learning programs running in them. These programs were state-supported and contracted to Azim Premji Foundation, an NGO that sets up computer aided learning centers for children. A total of 179 interviews were conducted with parents, teachers, a variety of stakeholders in local education, and policy-makers on their views about computers in schools, and the short- and long-term goals of their programs. Observations were conducted of 5th and 6th grade children in the schools visited, as they sat in front of computers and used the applications provided to them by the schools.

We tried two approaches to work towards the goal of providing equity to all users around the shared resource (the PC with the learning application) – first, enforced resource-sharing, and second, multiple-input. Results published elsewhere [45] showed that in the former case, there was often some degree of collaboration between children, especially as the 'alpha children' – i.e. the typical mouse controllers (usually the scholastic achievers within groups) tended to discuss learning material with others in a group, thereby leading to some impact on learning. However, in practice, this was a difficult goal to realize as the alpha children grew impatient with their role as surrogate teachers, and wanted complete control for themselves.

Due to teacher shortages, children are often required to learn and manage how to use computers themselves and with limited teacher intervention, thus making supervision-intensive tasks difficult. As a result, children who established dominance among their own small groups of colleagues tended to repeatedly be 'mouse-controllers' who dictated the pace of computer-aided learning sessions. Observations of eye-contact with screens showed that mouse-controllers were predominantly in command of the entire interaction, and learning trickled down from them to other children. In short, our key finding was that with regard to computers in schools even where equitable access was available, the dynamics of sharing between children often created new forms of power structures, generally to the detriment of the children who are most in need.

B. Experiments with Multiple Input Devices in India

Following our initial findings on device-sharing, we tried using a single computer with multiple mice on test applications to see if there was any difference in children's learning in the new modality. Looking at the educational applications being used in the schools, we tested a word learning application in Sep 2006 with 238 children (11-12 year olds) in various single and multi-user scenarios, using single or multiple input devices. The children were shown a number of words that were new to them, and then they were asked to identify the words from multiple choice options. The application was built like a game and tested in real classroom settings in rural India, in two schools selected from among recently instituted computer aided learning programs.

Mode	Word Gain	Engage -ment	Response Error	Decision making	Dominate by 1 child
1	4.11	High, tails off	Low	Indiv.	n/a
2	3.77	Low	Very Low	Collab.	Varied
3	3.6	Very high	High	Indiv.	None
4	4.3	High	Very Low	Collab.	Varied

Table 4: Words learned during tests across single and multiple-user shared-input modes (N=238 α=0.5)

Children were tested for a list of English words before and immediately after the test – words which were included in the test application. Children were asked to play in 4 modes – (1) single-user, single input mode; (2) multi-user single input mode; (3) multi-user, multi-input competitive mode; (4) multi-user, multi-input collaborative mode. All multi-user modes had 5 users. Of these, mode 1 was a simple single-user single-child mode, which is the model for which most applications are designed. Mode 2 was the closest to what is the typical usage scenario observed in India (and elsewhere) with many children at one computer, but only one controlling the mouse. In Mode 3, each child had their own mouse, and the child who clicked the right answer first got points. In Mode 4, each child had a mouse, but the application moved to the next stage only if the children had all clicked on the correct response.

During two rounds of experiments [45] with a total of 238 children, we found that for the specific application of word learning, children were able to consistently retain the most in mode 4 (results shown in Table 4). The stark differences in results came when we looked at results separately by gender, and this emphasizes the social nature of learning, as gender influences social behavior and engagement which in turn affects learning. Overall, a key observation was that for this learning task, multiple mice could offer the same benefits. In the competitive mode however, learning was hampered, as the competition lead to a decrease in collaboration.

We hence found that increasing access to input was not enough to make the learning more effective, collaboration was an essential part to improve the quality of learning. More detailed results from these tests are included in a greater exploration case elsewhere [45]. The tests were used only to establish short-term retention (a knowledge retention task, which is similar to a lot of educational tasks in these communities – be it computer applications, or state conducted

Reasoning	Preference for location of computer	Fraction of parents (%)
Cannot learn at home	School	31
Only teachers can teach	School	32
Children will learn better in collaboration	School	24
Don’t want responsibility	School	8
Lack of power etc at home	School	4
Ease of access, device safety	Home	3

Table 5: Parents beliefs about computer usage models

board exams), they were useful in creating an overall case for collaborative learning over single display groupware (SDG) for learning, a case that has in the past also been made of mathematics [40, 41] and visual learning [42].

VI. Socio-Cultural Suitability

A common criticism of the “computers for the poor” devices has been that these have not been grounded in good design principles that look at devices contextually, and are designed in a lab-centric rather than need-oriented paradigm [11].

Two important factors that need to be evaluated are whether the computer usage model under consideration is suitable in the actual social context and whether it would fit well with existing teaching methods in developing countries. Our goal is to work within the limitations of the current deployments that are already happening and work incrementally to increase access for all children.

Parent's Beliefs about Computers and Education: Our own primary research showed that both parents and teachers controlled the amount of time that children were allowed to work on computers in India, often very restrictively since the computer was the most expensive, or the only electronic gadget at home. As many as three years into having access to computers, teachers in some schools still let children use the computers only under their supervision. Likewise, many parents did not allow their children to use the television sets at home. The idea that parents, especially those in very poor families with no household assets will allow and encourage use of computers in the same way as parents in developed countries may be a gross overestimation.

To dig deeper, we conducted interviews with 165 parents across 4 districts to determine parents' feelings about the use of computers in schools and homes. The interviews sampled a wide range of parents whose ages ranged from 24 to 70 and who had completed between 0 and 12 years of education. The interviews revealed an extremely important role played by parents in decisions around children’s use of computers in schools. When asked whether parents thought that computers should be in schools, in the home, or both, parents overwhelmingly chose schools (Table 5). In other words, they disfavored the single ownership model adopted by OLPC and Intel Classmate, most of them citing the primary role of teachers as their reason for preferring computers in schools.

Due to a system of education very centered on structured learning coming from the teachers to the students, parents were not convinced of games as having a positive role to play in children’s learning, and were more concerned with ensuring children’s progression through curriculum. Computers are generally seen in a positive light and beneficial to children, but mostly so long as the work on them leads towards better learning immediately. For example, when asked if the same amount of money should be spent on teacher salaries or a new computer, 60% of parents felt that additional teachers would be a better investment for learning, whereas 40% thought that the one-time purchase of a computer would positively impact student learning.

Compatibility with existing teaching methods: We also found that early exposure to computers in developing countries comes through curricular content based on the dominant teaching methodologies which tend to be highly structured and instructive rather than constructive. We found almost universally that computer-based learning material for children’s reflected the classroom: created in a ‘narrative-interactive’ loop fashion, with the application feeding some content first, and following it up with multiple-choice type questions testing a child’s understanding of the material. We found to be highly compatible with content on multi-input single-screen computers.

The central role played by teachers in making such programs effective has been much discussed [32], as has the idea that class and cognitive issues impact the level and complexity of access that is available to children. Social class can also have an impact on computer learning: There is evidence that children from marginalized and underserved groups tend to do more drill-type activity, whereas children from affluent backgrounds tend to get greater access to higher level activities and creative resources on computers [33].

VII. Conclusion

Low cost computing initiatives that target child education in developing regions adopt a particular usage model which informs the design and market strategy of each device. Single ownership models, where each child owns a laptop for use at school or at home may have slight advantages in promoting effective learning. The shared usage models, however, are more suited to developing regions for several reasons. Sharing computers in a classroom is more economically viable, allows for collaboration among children, a primary role for teachers, and other interactions that stimulate learning and match current teaching practices. Furthermore, the shared model of classroom computing is already in effect in most developing regions, out of the need to use scarce resources wisely. If the goal of a low cost computing initiative is indeed to extend quality education to those children most in need, then replacing existing methods and infrastructure with new paradigms of learning and entirely new devices might lead to failure.

VIII. References

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