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A short review of information and communication technologies and basic education in LDCs—what is useful, what is sustainable?☆

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Abstract

Information and communication technologies such as radio and television have long been used in education. The advent of the technology of the Internet has created pressure for Internet access in primary and secondary schools across the world. This paper reviews some of the available evidence on the impact and cost of such technologies in developing countries. It concludes that while there is strong evidence for the efficacy and efficiency of interactive radio instruction, the evidence on the impact of computer-supported education remains mixed, and costs are prohibitive for many LDCs (less developed countries).

Keywords: International education; Information technology

1. Introduction

Information and Communication Technologies (ICTs) have long been an integral part of education systems. Radio in particular has had an important role to play in LDCs. New ICTs also have a place in the learning process, offering tools for expanding educational access and improving skills and knowledge. The ability to connect PCs to local area networks (LANs) and the Internet makes remote information access and knowledge sharing possible. Some hope that these new technologies might transform the nature and reach of education in LDCs. Nicholas Negroponte, founder of the MIT media lab, for example, suggests leaders in developing countries "adopt an education strategy that focuses digital technology on primary education, particularly in the poorest and most rural areas" (Negroponte, 1998).[1]

This paper briefly discusses the role of ICTs in basic (primary and secondary) education, with a focus on radio, computers and the Internet. Evi-

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☆ The views expressed in this paper are the authors' own, and do not necessarily represent those of the World Bank, its Executive Directors or the countries that they represent. The paper is based in part on material from Grace et al. (2001).

[1] See also Seymour Papert (2001) and Mark Malloch Brown (2001).

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dence is presented on the efficacy of the radio, computers and the Internet as pedagogical tools. The cost effectiveness and sustainability of each technology in an LDC context is discussed before the paper concludes.

2. The role of ICTs in basic education

The advent of radio and television courses in the 1970s, along with early studies suggesting the efficacy of such programs (Schramm, 1973), substantially broadened the role of ICTs in education systems. For example, Nwaerondu and Thompson (1987) reported in a partial list that looks at the impact of educational radio that the technology has been utilized in:

- Mexico and Mali, for literacy training;
- Thailand, to teach mathematics to school children, and for teacher training and other curricula; and
- The Dominican Republic and Paraguay, in support of primary education.

Interactive radio instruction (IRI) programs, in which radio content is integrated with classroom activities, are also growing in number in the developing world—Dock and Helwig (1999) list 33 projects in 20 developing countries.

Radio instruction has a range of features that supports its use in LDC contexts. Programs can be broadcast in a number of local languages, techniques can include educational soap operas, call-in or write-in shows, and interview techniques. Interactive radio instruction can play a particularly significant role in reducing rural–urban imbalances in the quality of education by providing access to quality education to previously unserved groups. For example, since 1983, the Dominican Republic's RADECO project has helped isolated rural children with no access to formal schools achieve scores in mathematics and language tests that are equal to or greater than those of children in government schools (Leigh and Cash, 1999). Because of its proven advantages, radio is by far the most widely used electronic media in developing world distance learning programs. Tony Dodds' (1996) 50-country survey and 1999 update found that 55% of distance education programs surveyed used radio compared to 37% using audiocassette, 15% video, 7% TV and under 3% using computers.

Turning to television, in Mexico, for example, over 700,000 secondary-school students in remote villages now have access to the *Telesecundaria* program, which provides televised classes and a comprehensive curriculum through closed-circuit television, satellite transmissions, and teleconferencing between students and teachers. While rural students enter the program with substantially lower mathematics and language test scores than their counterparts at traditional urban schools, by graduation, they have equaled their math scores and cut the language-score deficit by half (de Moura Castro et al., 1999).

The stand-alone PC has also played a role in changing pedagogic methods worldwide. The essential difference between traditional and computer-based education results from the interactive nature of the technology. Computers can be used to provide students with tools that augment the problem-solving process and with connections to people and information that can support the development of a collaborative learning community (Kozma et al., 1999, p. 12). The claims for effectiveness of such "Virtual Classrooms" and the benefits of Internet access on educational achievement are many:

- *Equalizing Access to Education*: The Internet, as with other ICTs, can alleviate urban–rural educational discrepancies, providing all students with access to modern pedagogic methods and knowledge. In Chile, The Enlaces Project (http://www.redenlaces.cl/ visited 03/11/03), has linked almost all secondary schools and more than half of all primary schools to the Internet. Schools are provided with computers and technical support, as well as extensive technical training in order to make the program equipment self-sustaining (Crede and Mansell, 1998). Especially for students distant from other information sources, the PC can function as a mini reference unit in which large databases can be accessed in response to the needs and interests of the student. The information from the

Encyclopedia Britannica, for example, can now be stored on two CD-ROMs.

- *Individualized Interactivity*: Due to the interactive nature of the Internet, it is well suited for a creative learning approach in which experimentation and critical thinking skills are emphasized. In Chile, the Genesis program in the municipality of Nunoa has trained staff and equipped 13 schools with PCs to use the LOGO programming language with students to improve problem-solving skills (Potashnik and Adkins, 1996, p. 4). Computer testing and assessment of performance can also fine tune the nature and order of questions presented to the test-taker to automatically focus on the weaknesses and strengths that traditional testing may not capture. By combining the 'broadcast' features of the radio with the personalized features of computer interaction, the Internet can achieve economies of scale in the use of pedagogical tools whilst preserving an individualized learning experience.
- *Acquiring the skills needed to succeed in the digital age*: Finally, the emergence of the digital age requires a technologically competent work force. Educational systems that ignore ICTs might fail to produce a technically literate population and hinder a country's ability to compete in the global economy. Access to ICTs from the earliest grade levels might enhance these skills, and ensure that populations are able to adapt to new technologies and remain competitive.[2]

However, while the benefits of interactive radio instruction has been comparatively well documented by statistical and case studies, we shall see that the benefits of the Internet on educational outcomes in LDCs, beyond the type of anecdotal study noted above, remain little-evaluated.

3. Cost effectiveness

As UNESCO notes, "assessing the cost-effectiveness of ICT in education is difficult, if not impossible, for at least four reasons—lack of meaningful data, variability in the implementation of ICTs, difficulty in generalizing from specific programs, and difficulty in assessing the value of qualitative educational differences" (UNESCO, 1996). Studies from around the world also suggest that the impact of programs is highly dependent on a range of exogenous factors—such as teacher interest and commitment, student capacities and the environment for learning.

Nonetheless, the effectiveness of well-designed traditional distance education programs using interactive technologies has been demonstrated in many different environments (Potashnik and Capper, 1998). Adkins' (1999) survey of seven educational intervention cost effectiveness studies suggest that, in terms of incremental improvement, the impact of a dollar spent on IRI is nearly 70% higher than a dollar spent on purchasing textbooks and over 11 times higher than a dollar spent on teacher training.[3] Studies of Mexico's television- and radio-based *Telesecundaria* program have also found

[2] It should be noted that parents of children and children themselves strongly support the idea that the Internet is a powerful tool for learning. A Pew Research Study (Lenhart et al., 2001) found that 78% of US children and 87% of their parents believe that the Internet helps them with their studies. Sugata Mitra, architect of the 'Hole in the Wall' experiment that put a computer next to a slum area in India to see how quickly children learned to use it, says he was motivated by the fact that proud computer-owning parents kept on telling him that their children were geniuses based on their performance in learning how to use the device (see http://www.globalideasbank.org/inspir/INS-31.HTML visited 03/11/03).

[3] Adkins' study looks at 11 interventions in seven countries spanning IRI, textbook purchase and teacher education. This is a small sample, with data that is not completely comparable across countries in terms of what was included as a cost (see Rumble, 1997, on this problem more broadly). Because of this and (more significantly) the highly varied results in terms of effect on students, the 'effect size per dollar' that Adkins reports varies dramatically across interventions. For IRI, it varies by a factor of over 3 between studies, for textbooks by nearly a factor of 7 and for teacher education (where there were only two studies used as a basis) by 50%. Further, the most effective textbook purchasing project studied was more effective than any of the IRI programs. This suggests the need for further work on the relative cost effectiveness of interventions, and what factors determine this relative performance. See also Nwaerondu and Thompson (1987) and Dodds (1999) on the effectiveness of radio-supported education.

that the program is only 16% more expensive per pupil served than normal urban secondary schools while students benefit from much smaller student/teacher ratios and catch up significantly with their urban counterparts (de Moura Castro et al., 1999).

In contrast, it is, as of yet, hard to move beyond anecdotal evidence on the impact of the Internet on education in LDCs. Many pilot projects involving the Internet in education typically incorporate some form of review and feedback. However, frequently these are limited to questionnaires asking project beneficiaries to describe their experience with the new technologies. For example, in the case of the World Links for Development (WorLD) program, which supports the use of the Internet in LDC classrooms, the monitoring and evaluation report for 1999 notes that its measurements are based on subjective interpretations of the impact of the program derived from questionnaires distributed directly to teachers, students, and administrators (Kozma et al., 1999). While obtaining first-hand feedback is critical in ensuring that projects meet local needs, non-subjective criteria are also needed to measure the degree to which perceptions adequately capture real improvements in learning.

To date, most of this type of research has been concentrated in industrialized countries.[4] In the United States, there have been a range of studies over the last 20 years (already, by the middle of last decade, McKenzie (1995) had found 321 studies, of which he estimated about 32 cited actual student performance data). One more recent example, and one of the few to look specifically at the Internet, is by the Center for Applied Special Technology (CAST). It used a double blind trial to measure the impacts of Internet access on performance among elementary school students. Based on large urban school districts, the study divided 28 schools into two control groups, one with Internet access as a major component of learning, and one without. Each group carried out a common learning module based on the school's curriculum and student performance was measured through a blind evaluation of student journals, written reports, and tests. The study found that "overall, students with access to ... the Internet produced better projects than students without online access. They received higher marks in all nine learning measures. The higher scores were statistically significant for five out of nine measures" (CAST, 1997, p. 4).

Even in the US, however, the evidence remains mixed, and the impact of new technologies is still much debated (see Ruth and Shi, 2001). For example, two recent studies looked at data on the relationship between student scores and computer use more broadly in the National Assessment of Educational Progress mathematics and reading tests. While there was a positive and significant link between math scores and computer use for higher-order thinking skills, there was a negative relationship between math scores and computer use for drill and practice. Computer use was also negatively associated with reading scores (Johnson, 2000). Kirkpatrick and Cuban's (1998) survey of studies and meta-surveys of computer efficacy in schools finds some evidence that computers improve standardized test scores, perhaps by 2–16% (see also Schachter, 1999), but they also find a number of studies with contradictory results, and a number of critical reviews of the positive studies (see also McKenzie, 1995).[5] Looking specifically at the Internet, Goolsbee and Guryan's (2002) study of the impact of the e-rate subsidy program in California from 1996 to 2000 found that although there were about 66% more Internet classrooms than there would have been without the program, "[t]he increase in Internet connections has had no measurable impact on any measure of student achievement". Overall, results appear to

[4] Two papers regarding Israel are rare examples of such studies. Osin (1998) found that students in Israel which used computer-assisted learning for practice and testing in mathematics improved their progress by 121%. However, a more broad-based study using a range of statistical analyses by Angrist and Lavy (2002) found that the 'Tomorrow-98' program, which placed 35,000 computers in schools across Israel between 1994 and 1996, had no impact on maths and Hebrew scores at the fourth or eighth grade level.

[5] Overall, in American schools (K-12), the number of computers increased 11-fold to more than 8 million between 1984 and 1997. This development has certainly not dampened a widespread feeling of 'crisis' in the education systems.

depend greatly on the broader environment for student learning—factors such as the quality of the teacher, and whether the teacher actively incorporates computer use in their lessons.[6]

Few studies of computer instruction note cost effectiveness compared to other interventions. One early exception (Fletcher et al., 1990) found that approximately 1h a week of computer aided instruction cost between one-third and one-quarter of the cost of reducing class sizes, an eighth the cost of increased instructional time and only a little more than peer tutoring in terms of raising mathematics test scores. A 1990 study reported by Capper (2001) suggested similar results.

These are but two, early studies, however, and relate to only a few types of intervention in US classrooms—their wider applicability has to be questionable, especially in the light of more recent skepticism regarding the impact of computers in schools,[7] and the differences between educational environments in LDCs and developed countries.

For networked technologies in LDC schools, the current low access to equipment itself suggests problems for the attractiveness of the technology for school use. A high part of the costs of providing Internet content or radio material for educational purposes is the fixed costs of web site or radio broadcasting and content creation. In an environment where few schools have computers, while many have radios, the returns to fixed investment in Internet educational content creation will be far lower than that to radio content creation.

Further, in an environment where human resources for education are relatively cheap (teachers in LDCs are paid very little compared to their counterparts in developed countries) while IT capital is more expensive (computers (unlike radios) tend to cost more in LDCs than in the US), the cost-effectiveness of placing IT capital in schools (as compared to decreasing class sizes, or using funds for IRI) is likely to be lower than in the US.

Turning to the impact of learning computer skills on future earnings potential, there is evidence from LDCs that computer users receive a wage premium over non-computer users (see Patrinos, 2001 for a review). This might imply that market measures suggest the benefit of computer-aided education. Again, however, the evidence on the wage premium for computer users is mixed—many studies conclude that more highly paid workers use computers rather than that computer use leads to higher pay. Borghans and ter Weel (2000) also report that while computer usage and the sophistication of that usage is correlated with increased income, measures of computer skills are not.

Further, even if a limited number of computer users in developing countries see a premium in wages, that the premium is already declining over time (see Patrinos, 2001). Expanding computer access in basic education might speed that decline, to the point that it is probable that supply of computer-aware workers will outstrip demand. The great majority of people in LDCs have no access to the Internet, as is clear from Table 1. This is likely to remain the case for a number of reasons apart from the lack of computer skills: Internet access is difficult and expensive, especially for the majority of those in LDCs who live far from the nearest telephone line or electricity connection—capital costs for working systems are as much as $20,000 per computer in unconnected rural areas, with recurrent costs of $5000 a year. One must compare these costs to an average GNP per capita in LDCs of approximately $1240. Even those fortunate enough to have access face the barriers of literacy (25% of adults in LDCs cannot read), language (72% of web-sites are in English) and usable content. The majority of people in LDCs perform jobs where the Internet might at best be a useful adjunct, with services accounting for but 20% of employment in low-income economies (data from Kenny, 2002 and World Bank, 2001). The low user base caused by all these factors itself deters content and application creations relevant to people in LDCs, creating a vicious circle of low use leading

[6] One reason Goolsbee and Guryan posit for their negative results is that surveys suggest only one-third of US teachers surveyed considered themselves prepared to use computers and the Internet in classrooms.

[7] The Fletcher et al. study was of US military personnel, its applicability to children in LDC contexts is thus questionable. There was also no attempt to compare computer use to other interventions including IRI, video-based systems, books or teacher training.

Table 1
Access to ICTs by level of development

Income group	Access to ICTs		
	Radios/1000 people	PCs/1000 people	Internet hosts/1000 people
Low	157	4.4	0.48
Middle	360	27.1	13.2
High	1289	345.9	981.74

Source: World Bank, 2001.

to low value added leading to low use. Under such circumstances, computer training will be of limited value to the majority of LDC citizens.

Overall, the burden of evidence appears to be mounting in favor of some impact of computer aided instruction in schools, if the social context is favorable (Coley et al., 2000, Woolf and Regain, 2000). However, as we shall see, introducing computers and the Internet in schools is very expensive, suggesting that its impact, if it were to be a cost effective intervention, should be very large. To date, it is perhaps fair to say that the evidence has not been accumulated to demonstrate such a large impact in developed countries, let alone LDCs.

4. Sustainability

Table 2 displays the average annual expenditure per student at the primary and secondary level for a number of low-income countries with available data.[8] 'Discretionary' expenditure here is calculated as that left over after paying teachers' salaries. This sum therefore has to cover supplies, teaching equipment, utility bills, building maintenance—in other words, all school costs apart from salaries.

In some low-income countries, this 'discretionary' budget is about $5 per year per primary student. Adkins (1999) also provides primary teaching material expenditures for a number of other low-income countries. These range from three cents per student per year in Swaziland, to $1.6 in Mauritania, $3.6 in Suriname, $16 in Korea, $25.4 in Malaysia and $290 in the Czech Republic. More broadly, Adkins estimates that discretionary expenditure in primary education systems in developing

[8] Table calculated from data in World Bank, 2001.

Table 2
Education expenditures in LDCs

	Annual expenditure per student ($US)				Secondary enrollment (%)
	Total		Discretionary		
	Primary	Secondary	Primary	Secondary	
Chad	15	50	5	18	10
Lao	15	38	5	12	29
Lesotho	77	297	32	125	31
Togo	31	84	8	22	27
Zimbabwe	106	186	10	17	50

countries overall (estimated as 20% of total per-student expenditure) averages $12 in lower income, $54 in lower middle and $174 in upper middle income countries. The position is slightly better in secondary schools, with discretionary expenditures perhaps 2–3 times larger. But this still suggests average expenditures of perhaps $20–30 per secondary student per year in low income and $100–150 in lower middle income countries.

At such low expenditures, the low price of educational interventions is vital for their practicality and sustainability. In this regard, the radio is a particularly powerful tool. Investment costs for interactive radio instruction tend to be of the order of $1–5 per student, depending on the scale of the program (including teacher training, printed materials, program production). Recurrent costs (including radio purchase and replacement, batteries, printed materials, distribution and administration) are of the order of $3 per student. First-year costs for a large-scale IRI program, for 1 million students, would equal perhaps 23% of discretionary primary education expenditures in lower income developing countries, 9% in lower middle and only 2% of discretionary expenditures in upper–middle income countries (Adkins, 1999). There are a number of issues that need to be addressed to ensure quality interventions—such as access to and freedom of use of broadcasting facilities, program design and integration into the curriculum—but it appears that there is the potential for IRI to be a cost effective system throughout the Third World.

The cost of providing Internet access will be far higher. The cost of providing one networked computer lab per school in the United States has been estimated at $225 per student one-time costs and recurrent costs of $80 per student per year (Consortium for School Networking, 1999). While labor costs might be cheaper in LDCs, the cost of Internet access, equipment and maintenance tends to be higher.

Looking at total cost estimates from LDCs reported by Potashnik and Adkins (1996), three computer-assisted instruction projects that provided computer laboratories in schools at the level of one computer per 20 students carried an annualized cost of $78–104 per student.[9] It should be noted that the schools connected in these studies were from wealthier LDCs—they did not face the problems of lack of electricity or phone service, and faced less significant bottlenecks in terms of skilled technicians and physical access to schools. Further, these costs did not include Internet access itself.[10]

One must compare these figures to the budget available for funding Internet classrooms. Computer labs cost between 2.4 and 21 times the discretionary budget per primary student figures reported in Table 2. Looking at the figures another way, even an optimistic estimate would suggest that network computer access costs at least $0.15/h.[11] If all of Zimbabwe's discretionary spending at the secondary level was used to provide students with computer access, this would buy 113 h a year per student in front of the computer. The remaining (approximately) 1240 h per year would go unfunded. It is likely that widespread access for all students to the Internet will thus remain the preserve of OECD and upper middle income countries such as Chile and Turkey.

[9] With lower computer to student ratios, these numbers obviously fall. For example, Cawthera (2001) provides estimates from Turkey where there are 40 students per computer which suggests costs of $32 per student per year.

[10] Estimates from a recent World Bank project in Turkey provide another measure of the costs of a program of Internet rollout in an LDC setting. The project has supported the equipping of 2828 schools with IT classrooms. The cost of hardware and software alone was $137 million. Project documents suggest that eight classes of 43 students each are expected to benefit from access over the life of the equipment. This suggests that the fixed cost per student for the IT classrooms, excluding training, housing and recurrent costs, is $141 (data from World Bank, 1998).

[11] This is based on the assumption that total costs over 5 years for computer purchase, use, Internet access, housing and training of support staff is $1000, and that it is used 6 h a day, 5 days a week, 45 weeks a year. This is very optimistic given that Bakia (2002) suggests *annual* costs per computer based on studies in Barbados, Turkey and Egypt of between $1280 and $2048 and Osin (1998) gives figures for Israel suggesting costs of US $3.15 per h.

5. Conclusion

Since Thomas Edison predicted in 1922 that motion pictures would supplant textbooks in schools, new technologies have been held out as the salve to educational problems. Perhaps too far on the other extreme, Steve Jobs of Apple Computer (a company with a strong commitment to computers in education) has concluded that “What’s wrong with education cannot be fixed with technology, no amount of technology will make a dent…” (quoted in Oppenheimer, 1997). ICTs (should) have a growing role in LDC education systems, and proven, cost effective technologies such as the radio should be utilized more widely. The Internet has a *potentially* huge role, but one that has so far been little-evaluated and that will be very expensive. Poorer LDCs, with extremely small education budgets and significant barriers to the widespread rollout of the Internet including large populations attending rural schools that remain unconnected to telephone and electricity, and a lack of skilled staff, should (can) probably not engage in a widespread experiment in putting this relatively untested, comparatively expensive, technology in all of their schools.

Nonetheless, there is a role for the Internet in some parts of LDC education systems. First, it is possible that further and continuing education can be provided over the Internet at costs that are competitive to existing methods in LDCs. Certainly, this is true of more traditional ICTs. In Taiwan, for example, one study found that the distance-based National Open University was able to reach 30% more students than the National Taiwan University while spending less than 1/3 of the National Open University’s budget (UNESCO, 1996).[12]

Second, and despite the mixed evidence on returns on Internet training to individuals, it is clear that LDCs will need to build up a body of trained Internet technicians both in order to be able to participate in global exchanges that will be increasingly carried out (or at least facilitated) over the Internet and to operate e-enabled activities within countries that are more demonstrably cost effective. These individuals should probably be trained outside the basic education system however—in tertiary education and/or private facilities, perhaps supported by government subsidy programs.

Some of the cost-effective and sustainable activities on which a new generation of LDC Internet technicians will work will involve the education sector itself—in areas such as budget management and tertiary education. Further, the Internet can act as a distribution network among educational broadcasters. Two projects provide radio content accessible by community stations worldwide for broadcast, for example.[13] Nonetheless, it is likely that widespread direct access to Internet-enabled computers over the short term in the least developed nations is an unrealizable, undesirable goal.

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[12] A number of efforts to provide cost-effective distance education at higher levels over the Internet have begun in LDCs. In Africa, 22 sub-Saharan countries are currently linked to the African Virtual University (http://www.avu.org, visited 03/11/03). Through Internet connections, satellite uplinks, and audio-visual media, the program provides original courses that link students to professors in Africa, North America, and Europe. To date, courses have been offered on computer technology, economics, language, and remedial coursework (Diagne, 2000). Similarly, since 1989, the Virtual University of the Technological Institute of Monterrey in Mexico has offered 15 distance-degree programs (mostly at the Masters level) in administration, education and engineering as well as a variety of technical training and skills development programs. By 1998, the Virtual University had an enrollment of 52,000 students across Latin America pursuing a wide variety of education and training programs (Wolff, 1999) (see also Capper, 2001). There might also be a role for the Internet in teacher training. A recent evaluation of the WorLD program found that as a result of access to new ICTs, 80% of participating school administrators reported that the program had “greatly affected teachers’ computer skills, their attitudes about technology, and their attitudes about their own teaching” (Kozma et al., 1999).

[13] The Panos Institute’s Banque de Programmes On Line, located in Mali, has correspondents in 20 francophone African countries, and Latin America’s Agencia Informativa Pulsar is a similar initiative for Spanish-language programming (see http://www.oneworld.org/panos—audio/, http://commons.somewhere.com/rre/2000/RRE.Radio.and.the.Intern.html, and http://www.pulsar.org.ec, all visited 03/11/03).

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