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A NEW FACE OF EDUCATION

BRINGING TECHNOLOGY INTO THE CLASSROOM IN THE DEVELOPING WORLD

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BROOKE SHEARER WORKING PAPER SERIES

This working paper series is dedicated to the memory of Brooke Shearer (1950-2009), a loyal friend of the Brookings Institution and a respected journalist, government official and non-governmental leader. This series focuses on global poverty and development issues related to Brooke Shearer's work, including: women's empowerment, reconstruction in Afghanistan, HIV/AIDS education and health in developing countries. Global Economy and Development at Brookings is honored to carry this working paper series in her name.

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INTRODUCTION

In the small village of Hafizibad in Pakistan's Punjab province, a young girl is using her mobile phone to send an SMS message in Urdu to her teacher. After sending, she receives messages from her teacher in response, which she diligently copies by hand in her notebook to practice her writing skills. She does this from the safety of her home, and with her parents' permission, during the school break, which is significant due to the insecurity of the rural region in which she lives. The girl is part of a Mobilink-UNESCO program to increase literacy skills among girls in Pakistan. Initial outcomes look positive; after four months, the percentage of girls who achieved an A level on literacy examinations increased from 27 percent to 54 percent. Likewise, the percentage of girls who achieved a C level on examinations decreased from 52 percent to 15 percent.[1] The power of mobile phone technology, which is fairly widespread in Pakistan, appears in this case to help hurdle several education barriers by finding new ways to support learning for rural girls in insecure areas—girls who usually have limited opportunities to attend school and who frequently do not receive individual attention when they do. Often they live in households with very few books or other materials to help them retain over summer vacation what they learned during the school year.

On the other side of the world, in South America, the deployment of technology for education has not been so promising. In Peru, a number of colorful laptops sit in a corner of a classroom covered with dust. Given to the school through a One Laptop Per Child program arranged by the Ministry of Education, the laptops were intended to improve students' information communication technology (ICT) skills, as well as their content-related skills. Without the proper support for teacher training in how the laptops are used, with no follow-up or repair and maintenance contingencies, and with outdated and bug-infested software, the laptops are seen as unusable and serve little purpose.[2] In this case, technology has not helped improve the educational experience of learners.

Technology enthusiasts have long heralded the power of technology—from the printing press, to blackboards, to the laptop—to transform education. With the rapid expansion of information communication technologies around the globe, there is a high level of interest

in harnessing modern technology to help advance the education status of some of the world's poorest people. However, from Pakistan to Peru and beyond, experience shows that while there are numerous examples of how technology is used to the great benefit of teachers and learners alike, there are also many cases in which it does little to impact educational processes and outcomes. A better understanding of why and under what conditions these divergent outcomes emerge is the central aim of this study.

The potential of technology to help improve education has significance beyond teaching children reading and math. Quality education plays an important role in promoting economic development, improving health and nutrition and reducing maternal and infant mortality rates. Economic growth, for example, can be directly impacted by the quality of the education systems in developing countries. Studies by Hanushek and Woessman show a positive correlation over time between cognitive development, measured by student performance on international assessments, and individual earnings, income distribution and overall economic growth.[3] A study by the International Monetary Fund (IMF) found that Asia's increased economic performance over Africa and Latin America could be directly attributed to its higher investment in physical and human capital, such as education.[4] Quality education has also been a factor in reducing maternal and infant mortality rates. Over half of the reduction in child mortality worldwide since 1970 is linked to "increased educational attainment in women of reproductive age."[5] Educated women are also more likely to seek out healthcare for themselves and their families. Studies on maternal health show that 90 percent of women with a secondary education in South and West Asia seek neonatal care, compared with only 50 percent of women with no education.[6]

Our purpose is to provide guidance to non-specialists interested in pursuing technology for educational improvement in the developing world. Outside of a very small group of experts, educators working in and with developing countries rarely have an expertise or even a basic grounding in the wide range of technological innovations and their potential uses for education. Even the most seasoned education expert is likely to stare blankly if terms such as 'cloud computing', 'm-learning', or 'total cost of ownership' are introduced into the conversation. Questions about what technology is available to support education, what its possible benefits are, and how it can be used effectively, can be heard equally in the halls of the ministries of education in developing countries and in those of the headquarters and offices of international funders of education.

Our goal is to answer these questions by providing a broad overview of some of the common education challenges facing the developing world and the range of different technologies that are available to help address them. We look closely at the different enabling conditions that frequently shape the success or failure of technology interventions in education and derive a set of seven basic principles for effective technology use. These principles can provide guidance to decision-makers designing, implementing or investing in education initiatives. In doing so, we look both at the primary and secondary, as well as at the higher levels, of education systems. Using the World Bank classification of low-income and lower-

middle-income countries we focus our attention on the world's poorest countries from Sub-Saharan Africa to South and West Asia to the Caribbean.

We focus particularly on the possibilities of recent forms of technology, often known as Information Communication Technology (ICT). ICT refers to technologies that provide access to information through telecommunications. It is generally used to describe most technology uses and can cover anything from radios, to mobile phones, to laptops. Of course, education has used technology for centuries, from blackboards to textbooks, yet in recent history very little has changed in how education is delivered. Teachers in most schools stand at the front of a room, while students sit and listen, sometimes attentively. However, while for many years policymakers have been unconvinced about the usefulness of technology in education—citing multiple examples in which it adds little value—today there is a new focus on its possibilities.

We conclude ultimately that, if smartly and strategically deployed, modern information and communications technology holds great promise in helping bring quality learning to some of the world's poorest and hardest-to-reach communities. The strategy for doing so need not emulate the trajectory of educational technology use in wealthier developed nations. Indeed, in some of the most remote regions of the globe, mobile phones and other forms of technology are being used in ways barely envisioned in the United States or Europe. Necessity is truly the mother of invention in these contexts and often leads to creative and promising ends for teachers and learners.

BARRIERS TO QUALITY EDUCATION IN THE DEVELOPING WORLD

A quality education for every young person in the world's poorest countries remains elusive. Tremendous progress has been made over the past decade in enrolling children into primary school, thanks in large part to actions by developing country governments and to support from the international community for a shared policy framework articulated in the Millennium Development Goals (MDGs). Today there are 52 million more children enrolled in primary school than in 1999, and globally the education MDG focused on access to primary school is one of the goals most on-track.[7]

However, focusing on access to primary school is a poor global metric for understanding the real education needs of children in developing countries. While many enter school, few stay enrolled, and even fewer are mastering the basic skills needed to progress in their education. The national enrollment figures mask persistent disparities in educational opportunities within countries, with marginalized groups such as the poor, those living in rural areas, and girls continuing to be left behind. And there is an increasing need to pay attention to formal and non-formal secondary education opportunities, given the large and growing youth population in the developing world.

This has led to a call from multiple actors to shift the global education paradigm from a focus on access to a focus on learning for both those in and out of school.[8] A recent proposal for a *Global Compact on Learning* calls for renewed attention to the broader "Education for All" goals and focuses on the importance of early childhood development, literacy and numeracy at the lower

primary level, and the transition to relevant post-primary education. A "learning for all" lens highlights three common dimensions of primary and secondary educational shortfalls in the developing world: 1) access to learning opportunities; 2) mastery of foundational skills, including learning *how* to learn and analytic skills; and 3) the relevance of learning content to full participation in the economies and governing structures of today's world. If deployed effectively, technology has a role to play in helping to address all three of these dimensions.

Access to Learning

In low-income countries, 64 million primary school-age children and 72 million lower secondary school-age children are out of school.[9] There are large inequities among countries, but especially within countries, in terms of access to learning opportunities. The bulk of these out-of-school children live in Sub-Saharan Africa and South and West Asia. Four highly populous countries—the Democratic Republic of Congo, India, Nigeria, and Pakistan— top the list of countries with the most out-of-school children.[10] Collectively, low-income countries that have been affected by armed conflict, most of which are in Africa and Asia, house almost half of the children out of primary school.[11]

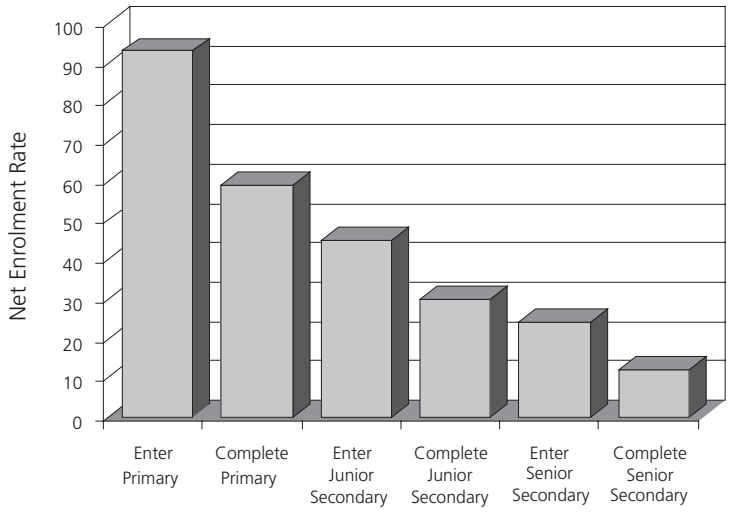
Many children enroll in school but drop out before completing a full cycle of primary education. In Sub-Saharan Africa, 10 million children drop out of primary school every year. In Malawi, for example, one-quarter of children drop out in the first year of school, as do 13 percent of children in South and West Asia.[12]

Children who drop out or never enter school are often poor, live in rural areas, are members of ethno-linguistic minorities, and are girls.[13] Finding creative ways to provide learning opportunities for these groups would go far in helping to address inequality and is certainly one possible challenge that technology could help address. Within countries, educational inequities are striking. In Pakistan, for example, the wealthiest 20 percent of the population experience near universal access to education and have on average nine years of schooling, whereas for the poorest 20 percent, the vast majority has had less than 2.4 years of school.[14] Across the developing world, gender compounds other forms of disadvantage with poor girls being less likely than poor boys to be in school. Inequity in access to primary and lower secondary school has resulted in 54 million "missing girls" in the education systems of sub-Saharan Africa and South and West Asia.[15] To date, post-primary education is mainly accessed by the well-to-do with only 36 percent of girls enrolling in lower secondary school in Sub-Saharan Africa.[16] Using the example of Sub-Saharan Africa, Figure 1 illustrates the large number of children lost at the various stages of a developing country's education system. While close to 90 percent of a given group enter into primary education, few complete it and even fewer enter and/or finish junior or senior secondary school.

Learning Foundational Skills

Equally worrisome as the inequities in access to learning opportunities, is the poor quality of education provided to many of the children who manage to go to school. While children of the elite are able to get a high-quality education in any low-income country, the majority of young people attending school learn relatively little.

Figure 1: Survival of a Cohort (%) of Students in Primary and Secondary Education in Sub-Saharan Africa



Source: Verspoor & Bregman, 2008.

Especially frightening are comparisons of learning levels between children in rich and poor countries, which show that the average child in a poor country performs worse than 95 percent of children in rich countries on international math and reading assessments.[17] In the past several years, data have emerged from Asia, Africa, and Latin America that highlight the difficulties students have in mastering foundational learning skills, such as reading. For example, in some Sub-Saharan African countries, children with five years of education had a 40 percent chance of being illiterate. In India, only half of grade 5 students in rural schools could read a grade 2 text, and in Peru, only one in five 15-year-olds was able to identify one piece of information in a text.[18]

In some countries, the quality of education in government schools is so poor that parents are opting to send their children to low-cost private schools. For example, in Pakistan, nearly one-third of all primary school students are educated in low-cost private schools, the majority of which are in local communities and financed by small parent contributions. At least one serious study found that students in these schools have higher learning achievement levels than do comparable students in government schools.[19] This phenomenon is also evident in a number of other countries across Sub-Saharan Africa and South and West Asia. Often a key factor in the provision of these schools is the presence of a literate and educated individual in the village or neighborhood who can serve as a teacher. Many times these teachers have little formal training; frequently they have not themselves completed their own education and, therefore, only possess subject-content familiarity through the upper primary grade levels. Certainly finding creative ways to support these teachers is a fruitful area for technological innovation.

Relevance of Learning

Often those students who are able to stay in school and master basic foundational skills are not progressing to learn additional skills or to develop the capacities that would best serve them in the world of work and adulthood. This starts in primary school, where an adequate ground-work for critical thinking and other forms of social and emotional learning is rarely laid.[20] But it is especially visible at secondary levels where curricula, pedagogical styles, and learning materials are often geared toward preparing students to become traditional government bureaucrats, a legacy of the colonial era.[21]

The demands for education to prepare young people to live and work in today's world are very different from those of a century ago. With education systems geared toward preparing students for the bureaucratic jobs available 50 years ago, employers regularly cannot find young people with the skills required to fill vacant posts. Many of the employment opportunities in the developing world are in the private sector, with jobs demanding a skill set quite different from that attained in a standard public secondary school. Between 2010 and 2015, an average of 1 million to 2.2 million young people is expected to enter the labor market every year in South Asia and Sub-Saharan Africa, respectively.[22] To ensure that this youth dividend is harnessed, education systems need to do a better job of developing students' transferable and adaptable skills, such as critical thinking, communication, teamwork, international language, and basic ICT familiarity.[23]

Barriers to Learning for All

The reasons why every child is not accessing quality and relevant learning opportunities are complex and differ across countries. However, there is a common set of persistent barriers that frequently hold back learning for all children and youth in a number of countries. To improve access to learning opportunities, it is imperative to address both the supply and demand sides. On the supply side, the provision of education opportunities—especially by governments—is generally much better at the primary than the secondary level. Yet even at the primary school level there are a number of barriers that reduce the odds of students attending school, such as distance and cost. At the secondary level, few governments are able to provide the number of secondary school seats for students and also provide the teachers needed for the increasingly larger cohorts of primary school graduates—which is another potential area for technology to help transform. The total cost of putting a child through a year of secondary school in Sub-Saharan Africa is three to twelve times that of a year of primary school, due to higher costs for teaching materials and classrooms.[24] The direct cost of secondary school for students makes it prohibitive for many of the poorest children. The ability of children to learn well once they are in school is often greatly affected by the teaching, materials, language of instruction, and management of the education system. Reducing these barriers would have a powerful effect on attendance in public schools, as evidenced by the startling growth of low-cost private schools, a growth fueled by the great demand for learning for all. Below is a short description of some of these common barriers.

Primary and Secondary Education

- **Distance and cost**. The limited availability of primary schools in remote, inaccessible, or particularly impoverished regions of developing countries often keeps marginalized children out of school. If schools are located too far from young children's homes, it is difficult and sometimes dangerous for them to make the journey each day. Countries differ on the distances children walk. In places like East Africa, young children frequently walk many miles to school. In Afghanistan, young girls in particular are being kept out of school if the school is too far away. A host of contextual reasons from culture to geography impact this issue in any given place. In Africa, only 56 percent of the total number of new schools needed to accommodate the projected increases in the enrollment rate among primary school-aged children have been constructed.[25] If the required number of new schools are not built, existing facilities will be taxed with accommodating larger numbers of students, thereby straining the ability of the schools to provide the students with high-quality education.

  The quality of school facilities can be important for ensuring that certain populations are able to enroll and complete schooling; the availability and quality of bathrooms in or near schools, for example, has been cited as an important factor in ensuring girls' access to education.[26] Where facilities are not available, or when quality is perceived as lacking, children may not be able to attend school at all. There are also conditions in which formal schooling structures may need to be adapted, such as in circumstances of poor security and armed conflict.

  Sometimes cost keeps the poorest children out of primary school, even when school fees have been abolished. Hidden costs, such as uniforms, exam fees, and other required contributions can be too large a barrier for poor families. The loss of potential income or help in the home from a child attending upper primary or secondary school, instead of working, additionally impacts the decision to continue the child's education. Direct and indirect costs are certainly one of the main reasons primary school students do not transition to secondary school. Often secondary school is not free and school fees become much more expensive, requiring substantial contributions from households. In Sub-Saharan Africa, household contributions cover 30 to 60 percent of the cost of secondary schooling.[27]

  Many countries, especially those with large youth populations, are struggling to provide sufficient secondary school options for eligible students. For example, Kenya, which recently adopted a policy of free secondary school, has had to devise a quota system for admitting students, because the government schools, especially the top-performing ones, simply do not have enough space to accommodate all those graduating from primary school.[28]

- **Teaching.** How much time teachers spend teaching and how they teach are important determinants of children's achievement. Teacher development programs that concentrate on preparing professionals in clinical settings and providing ongoing support, rather than in theoretical knowledge, are the most successful.[29] However, existing pre-service and, more importantly, in-service teacher education programs are not

sufficient to prepare teachers entering the profession or to support those teachers already in the classroom. UNESCO estimates that at least 10 million new primary teachers will be needed worldwide over and above the existing teacher stock in order to achieve universal primary education by 2015.[30] To keep pace with the growth of student populations, a number of countries will need to increase teacher recruitment by between 4 and 18 percent.[31] Many countries are struggling to keep up. For example, Ethiopia needs 141,000 additional teachers between 2008 and 2015 and only 10,000 graduated from teacher colleges in 2008. Malawi needs to increase trained teacher recruitment by more than 100 percent if it hopes to keep pace.[32] Many teachers labor under tough conditions with over 70 students in their class. In some remote regions the number of students per teacher rises to well over 100.[33]

The quality of teacher training that is available is also often quite weak, requiring improved learner-centered methodology as well as improved teaching skills in order to meet students' specific needs.[34] Many teacher training schools continue to develop teachers who use "robotic" teaching methods, where transmission of knowledge is primarily one-way. Research shows that high-performing education systems use training programs that prepare teachers in practical or hands-on settings and provide a great deal of in-service support.[35] Such training provides important experience in new pedagogies, including learner-centered and participatory teaching methods. Although teachers in the developing world are increasingly being asked to use similar learner-centered methods, they are provided little training or support to do so.[36] Formal teacher development programs are typically highly pre-service focused and are heavily theory-based. Although this is changing, particularly at the policy level, as more education professionals and politicians recognize the value of learner-centered teaching methods, high-quality teacher development programs that teach learner-centered instructional methods and appropriate classroom management skills are not yet widespread.[37]

For existing teachers, often too little time is spent teaching. For multiple reasons—from illness to child care to poor school management—teachers often spend only a small percentage of their time teaching in the classroom. For example, in lower primary school, after subtracting time lost, the remaining instructional time, as a share of the total days available, only amounted to 31 percent in Guatemala, 34 percent in Ethiopia, and 45 percent in Nepal.[38] Also, systems for adequately developing teachers' skills and providing them on-going support and motivation are often poor in developing countries. Many teachers need substantial support both in content knowledge and pedagogy. For example, "fewer than half of the grade 6 teachers in Mozambique, Uganda, Malawi and Lesotho were able to score at the top level of a reading test designed for their students."[39]

- **Materials and language.** Quality teaching and learning materials are essential ingredients for learning. In many developing countries there is a dearth of any materials, quality or otherwise. One study of southern African countries found that almost three-quarters of children in school did not have a basic textbook for mathematics or reading.[40] Often what learning mate-

rials are available are not of high quality. The content is either out of date, inappropriate for the learning or grade level at which it is being used, or not tied to the curriculum. Materials designed to assist students to learn to read are frequently found to be too advanced or not designed specifically for emergent readers. Rarely are there supplementary reading materials for students to practice reading with at home or in schools.[41]

Often, materials are not available in the children's mother tongue, reflecting a wider problem with local language instruction. "Fifty percent of the world's out-of-school children live in communities where the language of instruction in school is rarely, if ever, used at home."[42] Mother-tongue instruction in the early years of school, progressing methodically then to a bilingual or multi-lingual instruction has proven to be an important feature for successful learning achievement.[43] Inferior materials and inadequate and ineffective instruction are thus two of the main barriers to children beginning their educational career on a firm footing and in a language they understand.

- **Management.** Good education management is essential in providing and supporting well-functioning education systems for young people. Developing countries often face a myriad of management difficulties, from unwieldy teacher payment systems, to limited information collection and management capabilities, to poor learning assessment processes. In many places, teachers' pay is often late and, when it does arrive, is less than it should be due to leakages in the system. The phenomenon of "ghost teachers" is also widespread, where teachers who are on the payroll and collecting salaries are not present in the classroom. For example, in Pakistan an estimated 20 percent of officially registered teachers were not teaching in schools and the government recently took action to remove them from the payroll.[44] For those teachers in schools, there is often little support for formative learning assessments that provide on-going useful knowledge to teachers about how well their students are learning, especially for those teaching in overcrowded classrooms. An important complement to high-stakes testing, formative assessment has been shown to be valuable in improving student learning, yet very often teachers do not use it.[45] At the secondary level, there is often a lack of teachers to teach specialized and higher-level academic subjects, particularly in math and science. Due to an overall shortage of secondary teachers in Uganda for example, teachers are typically trained in two subject areas (i.e. math and science or geography and history). Once they begin teaching however, teachers are often required to teach additional subjects in which they are unqualified, due to the lack of qualified teachers in particular subjects.[46] Taken together these elements often lead to a lack of trust by parents in the public school system.

Higher Education

Due to the increased focus on primary and secondary education in the past several years, the needs and challenges of higher education in the developing world have been largely overlooked. There is now a greater focus on tertiary education systems in developing countries and recognition that higher education can be a key force for modernization, development and economic growth.[47] However, significant barriers associated with achieving

an effective tertiary education system remain. These barriers will be discussed more in depth below and include distance and cost, the quality of the faculty, access to materials and resources, and academically unprepared students—a range of issues that technology has a potentially important role to play in addressing.

- **Distance and cost.** Due to their highly decentralized management system, most higher education institutions in developing countries are located in urban centers. This makes it difficult for students in rural areas to participate in higher education programs, since relocation and/or travel is often quite expensive. Enrollment in tertiary institutions is very low; in Sri Lanka, enrollment stagnated at 2 percent of the school-age population due to a lack of government funding, among other things. Although tertiary education in the developing world costs much less than in the developed world—and is sometimes subsidized by the government through cost-sharing policies like in Tanzania—it is still substantially beyond the reach for many students.[48] Indirect costs contribute substantially to the expense of higher education: expensive textbooks and travel and the cost of using lab facilities or participating in extracurricular activities are often unexpected burdens. Lost income due to time spent outside the labor market is an additional indirect cost of higher education.

- **Quality of faculty.** Although the quality of a tertiary institution's faculty is integral to the overall quality of the institution itself, many faculty members in the developing world have little graduate or post-graduate level training.[49] This is compounded by the unavailability of graduate level education in general. In the Democratic Republic of the Congo most faculty members are trained at overseas institutions, which could create issues of sustainability and strategic planning for the future especially given the growing scarcity of international scholarships and decreasing government support to expand graduate programs.[50] Improving the quality of faculty is made difficult, in part, due to the low pay and lack of incentives offered by institutions for well-qualified candidates. Many faculty members teach several courses at multiple institutions in order to make a livable wage, which depletes the quality of their instruction since they must devote their time to several different places. Faculty and leadership are also appointed bureaucratically, which can mean that merit-based criteria are not paramount in appointment decisions.

- **Access to materials and resources.** In tertiary education budgets in developing countries, an estimated 80 percent is reserved for personnel and student maintenance expenditures.[51] This leaves little funding for libraries, research facilities, science labs, and other resources and supplies required for a functioning research institution. Expanding the knowledge economy through research is one of the hallmarks of a higher education institution, which is typically measured by the number of scientific publications that it produces. Universities in the developing world are clearly lagging behind the developed world in this area, accounting for only 5 percent of the total number of scientific publications.[52]

- **Students academically unprepared.** Most students are denied entry to tertiary institutions due to low academic performance on either secondary exit exams or tertiary entrance exams. In Ghana, 60 percent of

students who applied for university were rejected.[53] Even students who enter tertiary institutions are often unprepared for higher education, due to poor quality of education at the primary and secondary level, and a lack of choice at the higher level. Higher education institutions typically do not have the resources to support remedial programs, which leads to lower completion and higher drop-out rates among students who become frustrated with their academic performance and the cost of tuition. Graduation rates can suffer as a result.

Summary

Multiple and varied strategies are needed to address the complex issues affecting quality learning for all children and youth in the developing world. Technology—from distance learning, to digitized teaching and learning materials, to information management and teacher support—has the potential to help hurdle some of these existing barriers. Understanding the educational landscape can help identify the types of issues technology can or cannot help to address. But it is also necessary to understand the technological landscape in the developing world, the possibilities and limitations alike, in order to distinguish between smart and strategic uses of technology for improving education, and ineffective approaches that distract from the task at hand. A brief review of the technological landscape is where we turn next.

TECHNOLOGY IN THE DEVELOPING WORLD

Although the developing world still falls behind the developed world in terms of absolute access to basic technologies such as electricity, radio, wireless technology and computer access, the rapid growth in the basic technologies' suggests that this trend is changing dramatically. The developing world is also a source of some cutting-edge innovations that use technology to solve daily problems; for example, the use of mobile phones for personal banking, for paying government workers and for monitoring patients with HIV.

Overall, in the developing world, the cost of technology applications and of access to those applications has decreased over the past several years, especially in urban regions. Connectivity and the availability of reliable power sources have also expanded and as a result, access to technology is growing rapidly. An increasing number of people across a variety of sectors—from business to medicine and agriculture—are relying on technology to aid and expand their work, and an increasing demand at the household level is leading to widespread private investment.

However, there is great diversity in availability, access and use of technology within the developing world, even among the world's poorest countries. For example, India, with a per capita GDP of $1,192 and a diverse and robust economy, is a lower-middle-income country where technology plays a significant role in the country's development.[54] While there are parts of the country that do not share this success, several regions exemplify the power of technology in helping move development forward. Karnataka for example, was the first state in India to implement an ICT-specific policy in 1997. As a result of strong political will and investment in ICT infrastructure, the state is often cited as India's leader in IT and biotech-

nology.[55] Within this region, examples abound of how technology can play a transformative role in improving people's lives. Neighboring Pakistan, on the other hand, with its per capita GDP of $955 and its increasing security and economic troubles, provides an example of uneven progress in the uptake of technology in improving lives, and, although there are some bright spots, there is much potential for improvement.[56] Both countries contrast sharply with impoverished Malawi. One of the poorest countries in the world, with a GDP per capita of $310 and an economy highly dependent on agriculture, Malawi boasts a great interest in technology, but persistent and numerous obstacles keep the country from realizing its technological vision.[57]

Technologies themselves are being updated and developed at a dizzying pace, leading any assessment of what is currently possible to almost certainly be soon outdated. A number of actors are involved in financing these upgrades, including bi-lateral and multilateral organizations, private companies and governments themselves. Technology projects that are well designed often build necessary upgrades into the initial cost assessment and others, such as Uruguay's most recent phase of Plan Ceibal, which has put a computer in every classroom across the country, makes upgrading a significant part of the project itself. [58] It's important to note that as an upper-middle-income country with a GDP per capita of $10,590 and a significant amount of financing at its disposal, Uruguay has the ability to integrate technology upgrades into its projects, whereas many developing countries do not.[59] There are a number of enabling conditions—from infrastructure to human capital—that are essential for the effective use of current and future technologies. It is in these conditions that many of the current barriers to effectively deploying technology in the developing world exist.

Rapid Pace of Change

The overall pace of change and rapid increase in access to technology in the developing world has been quite impressive, although such growth can vary widely between developing countries.[60] Worldwide, a rapid growth in the use of technology has been supported by a corresponding decline in the cost of technology.[61] Nearly 30 years ago, Gordon Moore predicted this rapid pace of change in technology when he posited what popularly became known as Moore's Law. Moore's Law states that the number of transistors on a chip will roughly double every two years, making the technology more powerful and smaller.[62] The added power of additional transistors increases processing speed and memory capacity, dramatically reducing the costs per computing function or operation.[63] This factor, together with a very competitive market, has driven incredible and affordable technical developments over the years.

Growth in the technology sector in the developing world is typically associated with access to electricity. In 2007, developing and emerging countries consumed 46 percent of the world's electricity supply, although they accounted for roughly 82 percent of the world's population.[64] This number is projected to jump to over 61 percent by 2035, representing a significant increase in both demand for and use of electricity and energy.[65]

Although Africa has a history of underinvestment in infrastructure like the electrical grid and roads, increases in demand for electricity and energy are leading to increases in investment and development, particularly from the private sector.[66] For example, Ghana is currently investing in the use of smart grids—which use digital technology to transmit power to individual consumers—to cut costs of electricity consumption and improve energy efficiency.[67] Each year, more and more homes in the developing world are able to access the electrical grid. This trend is also seen in Asia. In the past few years the Philippines, for example, has undertaken the construction of over 180 power grids and mini-grids that are designed to increase consumer access to electricity across its small islands.[68] In Vietnam, the government's rural electrification program increased access to power from 51 percent of its rural households in 1996 to 95 percent of rural households by the end of 2008—a roughly 90 percent increase in just over 10 years.[69]

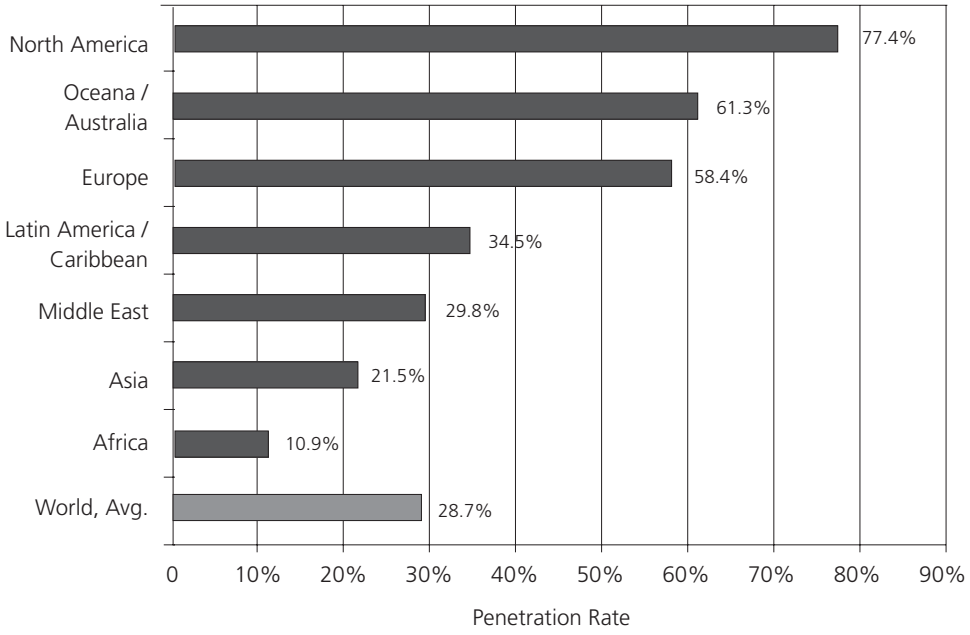
As access to electricity has increased, demand for and access to the internet—particularly to wireless internet—has expanded dramatically in the past several years in the developing world. Undersea cables along East Africa have played a huge part in increasing access while decreasing wireless costs. Accenture predicts that these undersea cables will increase bandwidth by 2400 percent, reduce cost by 90 percent compared to 2006 rates, and achieve a total 50 to 90 percent reduction in per unit connectivity cost within the first few years of implementation alone.[70]

While internet access in the developing world still reaches only the few and continues to be far behind that of developed countries, as seen in Chart 1, the growth rate over the last decade has far outstripped the pace of change in developed countries. For example, in Norway, a high-income country, 82.5 out of every 100 residents have access to the internet, which represents an increase in growth by 228 percent from 2000.[71] In Guatemala, 14.3 out of every 100 people have access to the internet, which is an astounding 2,350 percent increase since 2000.[72] In India, only 4.5 out of every 100 people have access to the internet, although this number has increased by 850 percent since 2000.[73]

Mobile phone coverage reaches a large segment of the population and has probably seen the biggest increase in the developing world over any other form of technology, in part due to private investment and the relatively low purchase cost.[74] Chart 2 below illustrates the growth of mobile phone subscriptions worldwide, compared to other forms of ICT. In Africa, for example, mobile phone penetration represented only 7 percent of the population in 2004. In just 4 years, this percentage grew to represent 38 percent of the population in 2008.[75] In Kenya, mobile phones took less than 20 years to reach 80 percent of the population, while fixed telephones took 100 years to reach the same proportion of the population, and "older" forms of technology took even longer.[76]

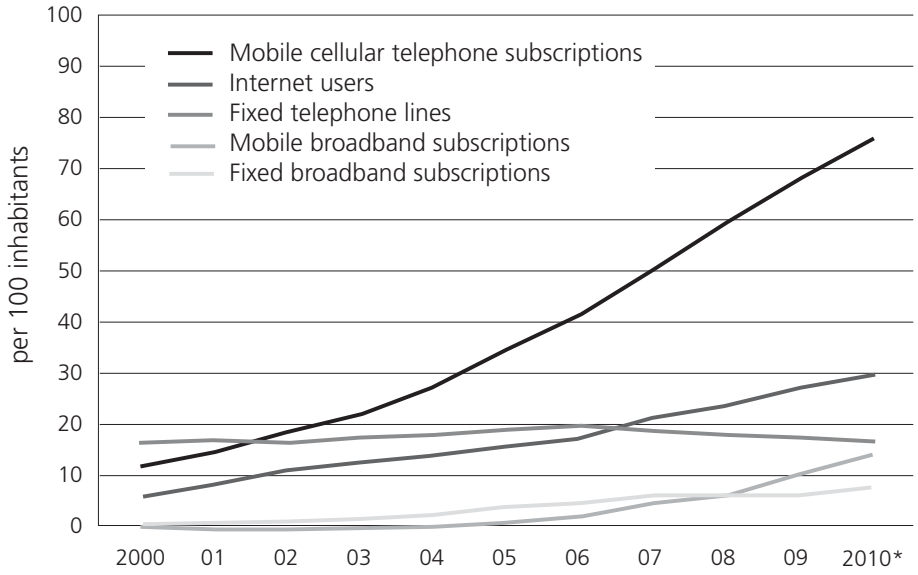
In Pakistan, 56 out of every 100 people have access to a mobile or fixed phone line through individual subscriptions, which represents an astounding 2,632 percent growth percentage from 2000 to 2010.[77] In addition, 90 percent of the population is covered by some kind of mobile phone network, so the potential for Pakistan's mobile phone penetration is even greater. In India, while

Chart 1: World Internet Penetration Rates by Geographic Region



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Penetration Rates are based on a world population of 6,845,609,960 and 1,966,514,816 estimated internet users on June 30, 2010.
Copyright 2010, Miniwatts Marketing Group

Chart 2: Growth of ICT Worldwide 2000-2010



Source: ITU, http://www.itu.int/ITU-D/ict/statistics/
**Estimate*

61 percent of the population is covered by a mobile network, 34 out of every 100 people have access to a mobile or fixed phone line, representing an increase of 979 percent since 2000. In Malawi, only 13 percent of people have subscriptions to a mobile or fixed phone line, although this represents an increase of 1,949 percent from 2000 to 2008, and in this resource-poor country 93 percent of the population is covered by a mobile phone network.[78]

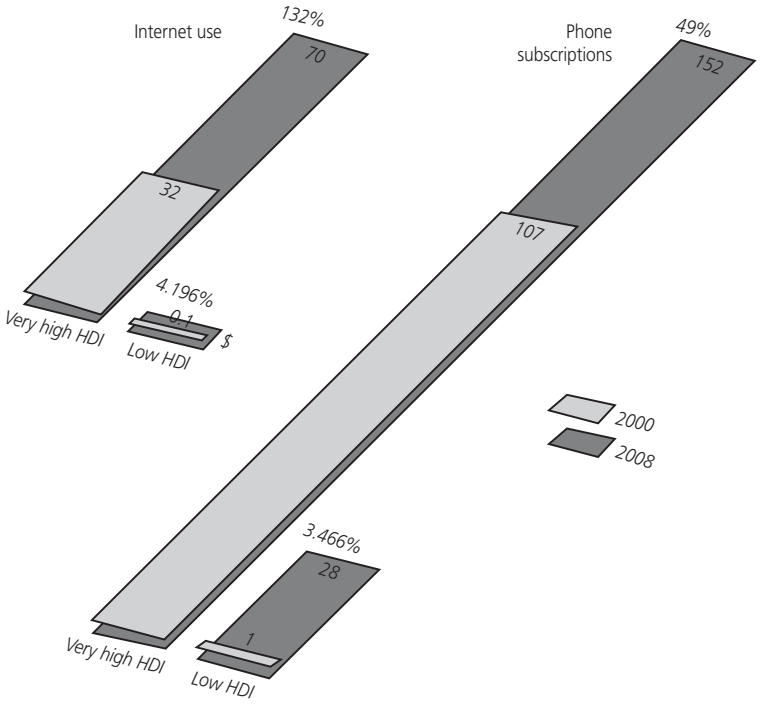
The potential for further growth for the mobile phone sector in the developing world is great. Chart 3 illustrates the increase in both internet use and phone subscriptions. It shows that while countries ranking high on the U.N.'s Human Development Index have a higher proportion of their population with access to the internet and mobile phones, access in countries that are ranked quite low on the Human Development Index has expanded exponentially over the last decade.

Enabling Conditions for Effective Technology Use

Even with the extraordinary growth in access to technology, its use in multiple sectors of society is uneven through the developing world. There are important enabling conditions that vary from country to country and help determine the degree to which technology can be leveraged to help improve the physical, economic, and social well-being of people in developing countries. These conditions are often interconnected and can frequently help explain why some countries are better able to effectively use technology than others. In the provinces of Delhi and Karnataka in India, for example, a number of conditions, such as strong political will in developing and implementing IT policies, and robust ICT infrastructure and human and technical capacity, are present and have helped spur the deployment of technology towards useful ends. Whereas in Malawi, while several conditions are in place, such as high-level political will and sound policies, the lack of resources, dependence on external donors and poor infrastructure are proving to be difficult barriers to surmount. While the physical and economic conditions—such as basic infrastructure and the availability of financing for technology projects—it is often the willingness and capacity of key actors and personnel that prove to be equally, if not more, important in enabling effective use of technology. In any given context, understanding the enabling conditions is an important ingredient for being able to select where and how technology could be useful for improving people's lives. Below is a list of some common conditions needed.

- **Access to electricity.** As discussed above, demand for and access to electricity has increased across the board. Yet many rural areas still do not have access to electricity.[80] A lack of public infrastructure including roads, transportation and construction has prohibited the extension of the power grid to remote rural areas. Even where rural residents have access, actual power use is unreliable at best, especially if not accompanied by a generator. This unreliability is also present in some urban settings, such as Islamabad, where electricity often fails. There are alternatives to accessing electricity from the electrical grid, of course. A lack of infrastructure has not prevented all businesses and organizations from using electricity; power generation sources such as solar panels, batteries and even hand

Chart 3: Growth in Internet Use and Phone Subscriptions in Very High and Low Human Development Index Countries From 2000 to 2008

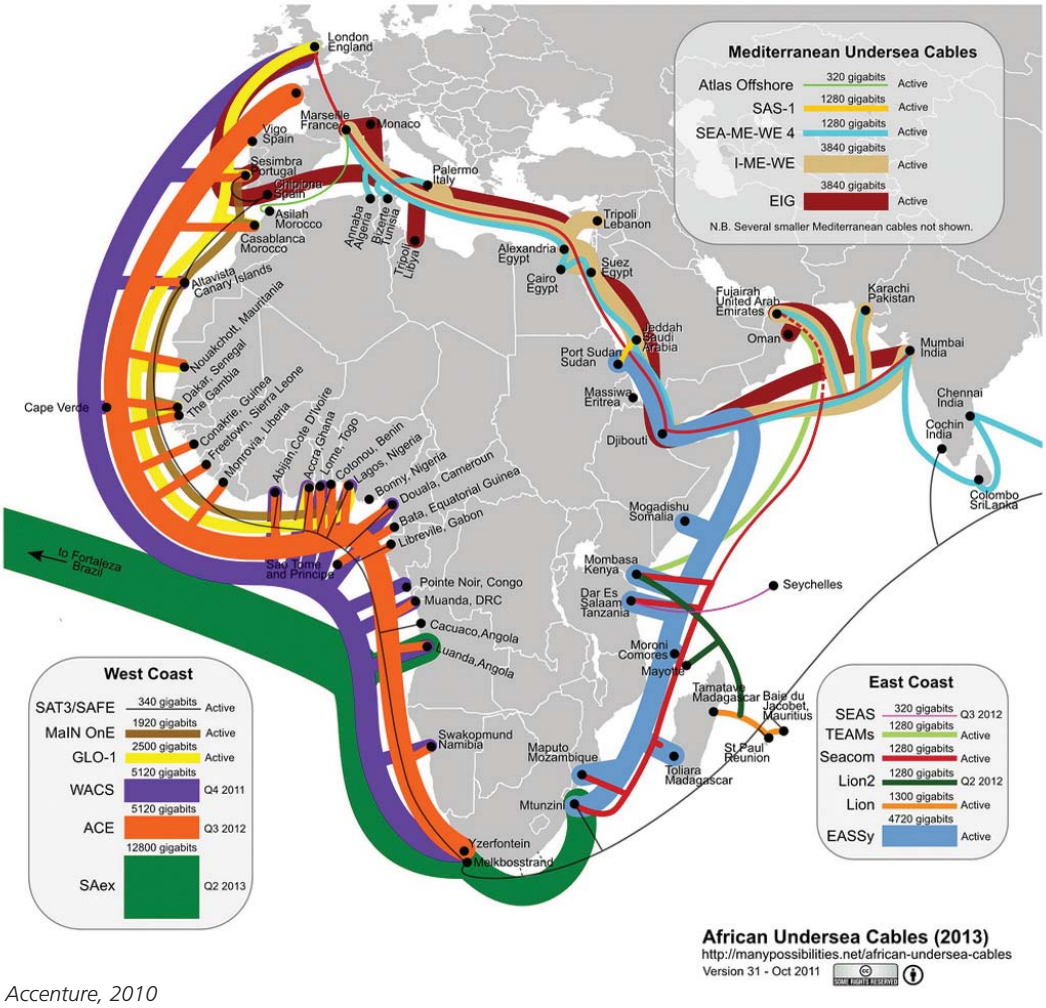


Source: UNDP[79]

or bicycle cranks can provide enough power for small technology. In India, for example, the Hole-in-the-Wall project to stimulate student learning with technology uses solar panels to power community computer terminals located in slum areas that typically have limited access to the electricity grid.[81]

- **Connectivity.** As with electricity access, demand for and access to the internet and wireless capabilities has grown tremendously, although there are still many areas that do not have internet capabilities. The biggest reasons for this are a lack of access to the Internet and the high cost of gaining access when it is available, especially in rural areas.[82] Undersea cables laid in East and West Africa are projected to decrease cost and increase availability of wireless internet as mentioned above, although these benefits have yet to be realized.[83] Figure 2 below illustrates the geographical location of these cables. With the increasing use and reach of mobile phones, it has been suggested that connectivity can be extended through smart phones and other mobile devices—especially those with wireless routers, which provide access to other devices to get online.[84] There are a few cyber "hotspots," such as the island nation of Mauritius, which boasts a wireless network that covers 90 percent of the population, although most of the developing world is still struggling to catch up.[85]

Figure 2: Sub-Saharan Undersea Cables, Projected to 2011



Source: Accenture, 2010

- **Human resource capacity.** In regions where access to technology is available and electricity reliable, some communities struggle to maintain their technology systems due to a lack of human resource capacity. The science and technology field is growing rapidly, but developing countries continue to struggle to attract, recruit and train skilled and qualified workers to maintain its IT systems once they are put into place.[86] In many countries, for example, computer labs are placed in schools without considering the total cost of ownership (TCO). Officials often neglect to train teachers in how to use the computers and how to integrate them into their classroom practice. In addition, there are often no available and skilled personnel who know how to maintain and troubleshoot problems with computers, so computers can go unused because no one knows how to fix them when they break down.[87] Projects like the United States Agency for International Development's (USAID) support for ICT in Macedonia can help to provide greater resource capacity by train-

ing young people to serve as technicians within their own classrooms.[88]

- **Political will and management.** Developing countries also struggle to implement technology initiatives due to a lack of political will. This barrier can take two separate but related forms: a lack of policy infrastructure and a lack of a government technology champion(s). There are in fact many countries that have some form of ICT policy in education. According to the most recent data, 51 out of 54 countries in Africa have such policies.[89] Although many countries have ICT policies in place, it is difficult to assess their quality or their impact on ICT infrastructure and ICT-related projects and programs, including education. South Africa is often cited as having some of the better ICT policies on the continent, while a handful of countries, mainly those struggling with armed conflict, including Somalia, Chad and the Democratic Republic of Congo, have no ICT policies.[90] Neglecting to provide a clear policy framework for ICT planning and implementation can often impede the success of integrating technology throughout various sectors. Even in countries that have a specific policy infrastructure for the integration of ICT into various sectors, these policies often do not create any projects or initiatives because of a lack of technology champions, or government officials who believe in and are invested in seeing technology take hold in their countries. Some countries also suffer from inter-ministerial jurisdiction issues relating to technology, where responsibility for governance and implementation is unclear and thus does not go anywhere.[91]

- **Financial resources.** Many developing countries simply do not possess the financial resources to support significant technology sector reform or expansion. Malawi is one of the poorest countries in the world and although the country possesses significant political will to expand its technology sector—technology growth policies and specific policies that address technology in education, health and other sectors are in place—the government does not have the ability to move projects or initiatives forward because it does not have the financial resources to do so.[92] This scenario is replicated in other resource-poor developing countries, particularly in ones that do not receive a great deal of development aid from the donor community to establish technology in their countries.[93] On the other hand, connectivity costs and costs per unit for computers, mobile phones and other devices are decreasing, making the possibility of widespread investment in technology more feasible.

- **Link between infrastructure availability and ability to integrate.** A final barrier involves the often significant lag time between local or regional technological infrastructure availability and the ability of the local government, private enterprise or civilian population to integrate that technology into their daily lives.[94] Largely agrarian societies and nations without an effective national ICT plan typically struggle with this barrier. It is also generally an issue where significant human resource gaps in technology also exist, as well as where infrastructure is available but high capital costs prevent access except by the wealthy.[95]

  Djibouti, for example, houses two separate earth stations that receive and transmit satellite messages and is the landing point for three undersea internet cables that connect to Asia, the Middle East and Europe. However, it does not currently have a national ICT

plan, nor has it been able to integrate these technological assets in a way that provides economic development.[96] The nation has only one internet service provider and, according to the UNDP Human Development Index (2010), only 2.3 out of every 100 people have access to the internet. Disparities in access and ability to integrate technology are problems even within large countries that have experienced rapid progress in technological innovation. Although India, for example, has favorable national ICT policies in place, several largely rural states lack technological infrastructure and access to the internet due to high capital costs.

Effective Use across Sectors

One constructive way of thinking about the potential use of technology in education is to examine how it is used in other sectors. There are many examples that illustrate how technology helps to improve systems and outcomes. These examples point to the potential for technology, if used well and chosen smartly, to add value in a range of different developing country contexts. Technology has been used in agriculture to provide farmers up-to-date information on weather forecasts and market prices, and in tourism for marketing and recruiting potential visitors. It has also been used extensively in the health sector. For example, various technologies have helped to improve, expand and increase basic healthcare access to populations who otherwise have little opportunity to visit a physician or a clinic.[97] One such case comes from South Africa where a project called Cell-Life, backed by the local mobile corporation Vodacom, utilizes a specially-designed platform that allows public health workers to monitor HIV treatment and to identify significant health problems before they become too difficult. HIV counselors are able to load information regarding patient symptoms as well as external factors that could have an impact on the patient's health, such as a shortage of food and water. The information is then downloaded into a secure database at the clinic, where it's accessible to health practitioners.[98]

Mobile phone technology has also been utilized to revolutionize banking systems, where access to traditional banking for many communities is especially limited. M-Pesa, for example, is a mobile money transfer system that is run by Safaricom through a partnership with Vodafone, and was originally launched in Kenya. M-Pesa allows users to deposit, transfer and withdraw money using the SMS tool on their mobile phones.[99] M-Pesa currently reaches an estimated 38 percent of the Kenyan population, with plans to expand further. The platform is also available through Safaricom in Tanzania and South Africa, with a pilot project currently underway in India. Afghanistan's M-Paisa platform, available through a partnership between Roshan and Vodafone, is being utilized to pay the salaries of some security civil servants in the most dangerous regions of the country; it has been highly successful in cutting corruption and ensuring that police officers are paid their full salary.[100]

Summary

The use of technology to help address educational problems facing the developing world will be profoundly shaped by the status of technology in general. The rapid pace of change and daily innovations in technology suggest important, and perhaps as yet unimagined, possibil-

ities for harnessing the power of technology to improve learning for all. However, crucial to this success will be how different countries or regions address the enabling conditions needed to ensure successful uptake and use of technology. What specific technologies are available and, depending on the context, are the most promising for adding value to educational systems and processes is where we turn our attention to next.

EDUCATION AND TECHNOLOGY IN THE DEVELOPING WORLD

As technology infrastructure and content is changing and improving, there is a great deal of excitement around the potential for technology to dramatically reduce some of the biggest problems in education in the developing world. In its new education strategy, USAID has placed a particular focus on promoting technology as a positive force for education reform and improvement.[101] E-reader initiatives, like Worldreader.org's project in Ghana and subsequent expansion to Kenya and the Philippines, have generated a great deal of interest in the potential of e-readers and tablet computers to replace textbooks in the developing world. At least one country in the developed world—South Korea—is implementing plans to completely replace physical textbooks with digital ones, generating excitement for this initiative as an example of what may happen in both developed and developing countries in the future.[102] Private companies, such as Nokia, are getting behind mobile technology innovations in education in the developing world, and many countries are making ICT an important policy priority for educational reform. Such excitement is well-placed given the great potential of technology, although some experts caution that greater research attention should be given to determine its effectiveness in order for technology to meet all of these promises.[103]

Before addressing the question of the effectiveness of technology in education, a brief review of the different types of technology being considered in the educational contexts of the developing world is necessary.

Technology types and their prevalence

A wide range of different technologies exist and are deployed for educational purposes with a correspondingly wide range of costs for their deployment. By far, the most prevalent information technology in the developing world is the radio. Most families have access to a radio and as much as 80 percent of the developing world population listens to the radio at least once a week.[104] Radio is also one of the most widely used technologies for education, particularly in rural areas of sub-Saharan Africa and South Asia. Mobile phones are the second most common technology with educational implications, followed by television and computers. In 2010, mobile phone penetration reached 70 percent of the developing world population and is projected to steadily increase.[105] The International Telecommunication Union (ITU), the U.N.'s agency for information technology places this increase in an interesting perspective, noting that there are now more cell phone subscriptions than there are toilets in the developing world.[106] At least 30 percent of all households in the developing world have access to television, although this number ranges considerably between countries.[107]

The prevalence of a technology does not, however, indicate that it is the most frequently used, the cheapest to use, or the most effective technology for educational purposes. Computers are quite prevalent, despite their comparatively limited availability outside urban areas and their high costs. Often policy-makers prioritize the use of computers because they believe it is an important skill in a knowledge-based economy, and frequently education policies use the term ICT and computers inter-changeably.[108] Below are descriptions of many of the technologies that can be used in education.

- **Radio.** A so-called "old technology," radio and radio instruction has been utilized across the developing world as a tool to help facilitate learning and increase access to educational opportunities, particularly in rural areas or sparsely populated regions that struggle to provide quality teaching. Interactive Radio Instruction (IRI) has been especially effective in providing important educational opportunities in developing countries. For example, Southern Sudan Interactive Radio Instruction is an initiative funded by USAID and administered by the Education Development Center (EDC) under the auspices of the South Sudan Ministry of Education, Science and Technology. It administers half-hour long daily lessons in English, local language, mathematics and life-skills through its Teaching Village and also provides a program that gives in-service teacher training.[109]

  Research has shown that IRI significantly improves student learning outcomes. A report that gathered student learning data from IRI programs between 1975 and 2000 found that interactive radio instruction inside schools improved student learning 10 to 20 percent over control groups that did not use interactive radio instruction.[110] Radio has also proven to be extremely cost effective compared with other types of interventions that attempt to improve teacher quality and deliver effective classroom instruction.[111] A study of an IRI initiative in Honduras, for example, concluded that the project cost US$2.94 per student in the first year and dropped to US$1.01 in the years following. As early as 1989, a study found that IRI was more cost effective than other interventions that increased the number of textbooks or provided on-site teacher training.[112] A later study in South Africa found that English-language IRI projects cost between one-third and one-half less than other English language programs.[113] IRI has also been successful in bridging achievement gaps between marginalized and mainstream students; students from rural areas performed on par with students from urban areas and girls performed as well as boys after participating in IRI projects.[114] Additionally, radios are even useful in places that have very limited access to transmission lines; satellites can download radio programs and other material that can be stored and used later, after the satellite is out of range.

- **Television.** While television is seen more often in households in developing countries than in the classroom, it can provide an important role in supporting quality instruction and learning within the classroom. Television is used to supplement classroom instruction with educational videos that teach and support lessons in language learning, mathematics, history, life skills and among other subjects. Text2Teach, an initiative from Nokia based in the Philippines, provides teachers with mobile phones that are pre-loaded with

educational videos and lessons. Teachers are able to link the phone to a projector or TV so that the videos can be shared with the classroom. As access to the internet increases, there will probably be little need for pre-loading the phones as teachers will be able to download new content directly. One interesting policy development in the future would be to enable teachers to download content for free, thereby rapidly expanding their ability to easily acquire new materials. This might require nation by nation changes in policy. In India, the national telecaster Doordarshan and Indira Ghandi National Open University (IGNOU) set up an educational television channel, DD-Guyan Darshan, which broadcasts round-the-clock educational television programs designed for school-age children, youth, students in higher education, and young people who are seeking career opportunities.[115] The wide availability of the programs allow for flexibility of use: teachers can utilize relevant programs in the classroom or students can watch them from their homes or libraries. The Discovery Channel's Global Education Partnership has made particular efforts to improve student learning and teacher training through its Learning Center projects. In Namibia, for example, Learning Centers that used the Discovery Channel's educational programs were able to improve student motivation, improve concentration and memory, and increase English language skills and creativity. In some cases, these Centers experienced increased retention and matriculation rates.[116]

- **Computers.** Personal computers (PCs) are one of the most frequently cited and used forms of technology in education in the developing world and act as indicators of technological progress according to many nations' ICT-in-education development plans.[117] They are used at all levels of education, although mainly in secondary and post-secondary settings.[118] Computers can be a significant investment for schools in developing countries. Prices vary from country to country and, until recently, could cost over $1,000 each.[119] Initiatives and Moore's law have resulted in bringing these prices down, with some considerable success; low-cost PCs are now available for as little as $100, although some note that total cost of ownership (TCO) typically raises the price to around $200.[120] New technologies, including N-Computing, which provides a virtual desktop to computers at low cost to the consumer, could also present exciting opportunities for schools and classrooms.[121]

Hardware is not the only cost associated with computers and computer labs, however. As discussed above, many donors and education officials do not consider the TCO when they establish computers and computer labs in schools, including professional development, support and maintenance, connectivity for internet, software, replacement costs and retrofitting the building to support the use of computers.[122] Perhaps due to the cost concern, smaller laptop computers are being increasingly provided as an alternative to larger desktop computers. One Laptop Per Child (OLPC) is one of several initiatives that attempts to provide children in developing countries with opportunities to interact with this important learning tool, although there are TCO concerns, including teacher training and software upgrading, associated with OLPC as well. Several countries, particularly in the Small Island Developing States (SIDS) of the Caribbean, are providing schools with moveable laptop carts that can travel from classroom

to classroom instead of a stationary computer lab. This makes it easier to integrate the computers into the classroom learning, provides schools with more space and cuts down on the cost of retrofitting buildings.[123]

Studies on the learning effectiveness of computers in classrooms have been mixed. Most studies note that simply having a computer in the classroom does not have a significant impact on student learning outcomes.[124] There could be many reasons for this: teachers who are unfamiliar with computers are less likely to integrate them into their instruction, in some cases computers may not be perceived as particularly central to the learning process or perhaps the computers are of low-quality and are equipped with outdated software. On the other hand, some studies suggest that computers can help to increase student performance in math and reading when they are used as a tool to supplement classroom learning and when they complement teachers' pedagogical philosophies.[125] In Ecuador, for example, an evaluation of a computer-aided instruction program in Guayaquil showed that the program had a statistically-significant positive impact on the math scores of primary school students.[126]

- **Mobile Phones.** Cell phones and smart phones have been seen as increasingly useful educational tools in developing countries. Current costs for the less expensive smart phones in developing countries range from $150 to $200, although some companies are designing future products with a predicted cost of $75.[127] High mobile service penetration and increasing access to mobile phones have enabled some innovative projects that take advantage of "m-learning," or learning through mobile phones. Students can download information to their phones, send and receive texts to and from their teachers, practice language and math skills alone and with peers, and many other learning activities. Early evaluations of some m-learning initiatives seem promising and experts project that as the cost of using mobile and smart phones decrease, they will become an important part of learning in developing countries.[128] Increasing research and development in mobile phone technology, including independent evaluations of their effectiveness in educational settings, is thus particularly important, as it may very well become the technology of the future for developing world education systems.

  Mobile phones also have the potential to facilitate in-service teacher training for teachers in rural areas who are unable to travel to central training sites. A project in Bangladesh used mobile phones to support distance teacher training in the Patuakhali District. Teachers participated in a two-week long on-site course, after which they returned to their schools. Each week they participated in a mobile conference with their instructor and class members and submitted assignments via their mobile phones. Initial findings were promising: teacher subject area scores improved from pre-test to post-test and head masters reported noticeable improvements in classroom practice.[129]

- **Tablets and e-readers.** Tablet PCs like the iPad and e-readers are becoming a trend in education technology, and many experts see an important future for them in developing countries, due to the relatively low procurement cost and the ability to store a large amount

and a wide variety of documents. Instead of procuring numerous books and building a school library, theoretically learners could have the world's libraries at their fingertips through an e-reader, expanding access to material while reducing cost, as the previous example of the Worldreader.org project in Ghana illustrated. The cost of tablet PCs and e-readers starts at $150, although this cost is projected to very quickly decrease.[130] One company in India is said to have produced a tablet PC that costs $30-35 to manufacture and, with government subsidies, could be provided to individual students at as little as $10.[131] Tablet PCs provide many of the same interactive features as computer terminals and laptop computers, but are much smaller, easier to transport and store, and are considerably less expensive. E-readers have fewer features than tablet PCs, but are also typically less expensive and are designed to allow users to download, store and read books, newspapers, magazines and other print media. The device requires a power source in order to re-charge the battery, although this can be satisfied through electricity or alternative energy sources such as solar, wind, geo-thermal, and human exercise, among others. Infrequent access to power is not a barrier to e-reader use, as an e-reader can last up to a week on a battery that has been charged for at least an hour.[132] Some e-readers include internet capabilities for the purpose of downloading reading material, which is useful but not necessary for their functioning. Materials can be transferred to multiple e-readers via a USB device from a computer, for example, although the initial download does require internet access. Conceivably, e-readers could include entire curriculums involving multiple text books that could be updated regularly. This presents a very powerful alternative to traditional books and textbooks, which can be costly and difficult to store and share, as there are typically different books for each subject.

- **Multimedia Projectors.** Multimedia projectors are devices used to project documents and/or computer images onto a wall in an effort to display the image to an entire classroom. They allow the teacher to interact with the material along with the students, or model his/her teaching in a way that effectively communicates the lesson to the students. Internet access is not required, unless the teacher wishes to display a feature on a website, or stream an online video. Materials can also be downloaded on to a USB device, which can then be inserted directly into the projector for display in the classroom. Projectors range in cost from $700 to $1800 and replacement bulbs for the projector can cost up to $400 a piece.[133] As with computers, initiatives to drive down the cost of projectors have led to some exciting innovations and one handheld projector—called the "pico-projector"—is reported to cost as little as $199.[134] Design that Matters is a non-profit organization that is also attempting to help solve the cost issue by taking advantage of innovative and collaborative technological designs to provide low-cost multimedia projectors to classrooms in developing countries. The overall cost of projectors, including both handheld pico-projectors and the larger models, is predicted to decrease in the next few years as a result of these low-cost solutions. A simple mechanically or solar powered generator can provide a stable source of electrical power. This could be a powerful technology for rural or urban slum schools in developing countries that may have unreliable access to electricity or internet connectivity.

- **Open Educational Resources.** Open Educational Resources (OER) are "teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits the free use and repurposing by others".[135] Although UNESCO officially coined the term OER in 2002, Open Educational Resources, including items in the public domain and materials from some projects like Multimedia Educational Resource for Learning and Online Teaching (MERLOT) , were openly available software and digital content several years before.

  In developing countries, OER can be utilized in a variety of forms. Some organizations, such as the Khan Academy, produce short educational videos that serve as self-learning tools, curricular supplements or the core teaching materials in classrooms where teachers may not be qualified in particular subjects. In the last six months, there have been over 60 million downloads of Khan Academy videos from the Khan Academy and YouTube sites.[136] In the United States, open textbooks have been used to replace traditional textbooks at both the secondary and tertiary level as a cost-savings measure.[137] OER has also been used to support professional development and teacher training, as with the Teacher Education modules in Sub-Saharan Africa (TESSA).

  OER can also be used to establish, build or support the knowledge economy of universities in the developing world by providing access to thousands of important academic journals and other literature. The Massachusetts Institute of Technology OpenCourseWare (MIT OCW) initiative provides syllabi, high quality lesson plans, assessments, simiulations and other curricular content for all their 1800 courses, These materials are free for use in universities and secondary schools and in homes everywhere in the world. In addition to MIT OCW, well over 100 other universities across the world, including many from developing countries, provide OCW on the web.[138] Recognizing the issue of limited bandwidth in developing countries, the University of Iowa provides a digital library called eGranary, which compresses hundreds of thousands of web pages into an independent hard drive that can be used offline.[139] OER can be extremely cost effective compared to the mediums it purports to replace: textbooks, other print media, professional development workshops and onsite classrooms, to name a few.[140] One expert notes that production costs of OER used by teachers are typically less than OER used by learners and that resources utilizing text, audio and video are less expensive than simulations and interactive content.[141] Another expert notes the flexibility that OER can provide for students, particularly at the tertiary level; Students can access content online according to their individual schedules and can receive updates in relevant subject information much faster than with textbooks, which must be reprinted at great cost to accommodate new information.[142]

- **Cloud Computing.** While not a hardware technology, cloud computing offers a range of possibilities for educational purposes. Cloud computing allows organizations to increase computing capacity or add computing capabilities without needing to invest in infrastructure or train additional personnel. Simply put, it acts as an off-site, online server and offers a robust

and flexible way to store important data or programs and to save money without requiring additional service personnel or physical storage technology. For example, in the San Juan Province of Argentina, the Ministry of Education is developing an education management information system (EMIS) that utilizes cloud computing features involving data centers, networks, thin client terminals and other elements. The system was piloted in 2008 for 192 schools around the capital city and the Ministry of Education is considering expanding the service to reach an additional 350 schools.[143]

Assessing the Usefulness of Technology in Education

No matter how sophisticated, elegant, or robust a specific technology is, it is only useful in educational settings if it improves educational processes and outcomes. One way to determine if technology adds value to education comes from the Information for Development Program (*info*Dev) at the World Bank, which assesses the impact of technology in three areas: (a) student outcomes, such as higher achievement in school subjects or the learning of entirely new skills needed for a developing economy; (b) teacher and classroom outcomes, such as development of teachers' technology skills and of their knowledge of new pedagogical approaches, as well as improved attitudes toward teaching; and (c) other outcomes such as increased innovativeness in schools and increased access to adult education and literacy for community members."[144]

Although not explicitly included above, it is important to incorporate information about how technology affects the inclusion of marginalized children and youth—such as the rural poor, children with disabilities, and ethnolinguistic minorities—into education systems, in addition to simply increasing access to adult education opportunities for members of the community. Finding ways to bring learning opportunities to young people left out of primary and secondary education systems would add tremendous value. Indeed, international agreements such as the Salamanca Framework for Action of the World Conference on Special Needs Education advocates that, in the case of young people who are traditionally marginalized, schools and communities should provide extra support for students with special needs.[145] Perkins International, for example, provides opportunities for blind children to have access to Braille technology in order to learn how to read.[146] Technology provides unique and powerful opportunities to address and to help overcome the full range of educational barriers, including disabilities, materials, distance, language and management.

Pinpointing the full arena in which technology may be deployed is important in determining its potential to add value to education. Most often policy-makers and educators consider the ways in which technology can help with classroom practices. However, there are also a number of ways in which technology could assist with the management of education systems. The idea of "front-office" versus "back-office" deployment of technology is useful to ensure that the entirety of educational activities potentially benefiting from technology is considered. Front-office deployment of technology includes using mobile phones, computers, radio, television, e-readers and other applications to directly support student learning or teacher development. Back-office use of technology

includes the use of digital databases and EMIS systems to increase management and bureaucratic efficiency, and the use of mobile phones, the internet and other ICT to facilitate important communication between schools, teachers, parents and others. Both front and back office actions contribute in different ways to the ultimate outcomes at the student, teacher, and school levels and would each need to be assessed with a different set of metrics.

There is, however, a general rule of thumb that can be applied across the board to interventions in education to assess whether technology adds value. It requires understanding the relevant outcomes and the direct and indirect costs when: 1) no technology is used; 2) only technology is used; and 3) a blend of technology and traditional practices is used. If the outcomes are the same or greater when no technology is used as they are when a blend of technology and traditional instructional practices is employed, then it is often better not to use the technology. For example, if students' interest in, and mastery of, a subject is equally good whether a teacher, for example, gives a fifth-grade science lesson through lectures, small group work, and taking students outside to examine plants (no technology) or gives the same lesson but adds a video (blend of technology and traditional practices), then it is likely a better and more cost-effective choice not to incorporate video in the lesson. In this case, the video only adds to the existing costs of teacher and classroom, but does not add value. On the other hand, if the outcomes are the same when no technology is used by the teacher as they are when technology is used alone, without a teacher, then the more cost-effective option may well be to use technology. For example, if students equally enjoy and perform well on a college course that is taught online as they do when the same course is taught in person within the school, then it may be advantageous to pursue the online option. An online course can be developed once and then taught over and over with very little recurrent costs, whereas the annual cost of an in-person course is usually much higher, given the need to cover salaries, space, and other costs each year. Obviously, where there is a clear outcome and cost benefit to any of the three strategies noted above, then that is the strategy to be pursued. Often, however, no clear-cut advantage emerges, in which case this general-rule approach to assessing the added value of technology is a good way to ensure that the most strategic and cost-effective option is chosen.

In many cases, blended learning, or the instructional approach that combines online or computer learning with the aid of an instructor, has been found to be superior to approaches that use only in-person instruction or only computer-aided instruction.[147] Recently SRI, for the U.S. Department of Education, carried out a meta-analysis of studies on the use of full technology courses. SRI pooled the results of over 40 studies, selected from a sample of over 900, on the basis of their quality and design. The meta-analysis focused on full higher-education courses and found that teacher-only courses were not as effective as courses where technology was used. Moreover, blended models using both technology and teachers were more effective than either teacher-only or technology-only courses. The differences were all statistically significant. Most of the studies were carried out using technology developed prior to 2005, so it is reasonable to expect that the newer courses will be even more effec-

tive. A sample of studies of secondary school use of technology carried out by SRI found similar trends, though the sample was too small for statistical treatment. [148]

Another set of studies examined the effectiveness of a complete technology statistics course that is part of Carnegie Mellon's Open Learning Initiative (OLI). In two initial studies, researchers found that students that used only the OLI course performed as well as students in a traditional instructor-led classroom setting. In a third study, the researchers examined the hypothesis that students using the cognitive tutor might be able to accelerate their learning compared to those in a traditional classroom. The study found that students who participated in the accelerated learning model (only one-half a semester for the full-semester course) with online coursework in statistics and two hourly sessions a week for questions and review with an instructor outperformed students who participated in the traditional instructor-led class (for a full semester). The result is that the students in the "hybrid model" learned more material in half the amount of time.[149] Such blended learning practices are different from traditional models because they use the teacher as a coach rather than as a primary source of information, with students directing their learning themselves through the use of online coursework.

Although blended learning is primarily used in the developed world, the model has great potential to be useful in the developing world, particularly in regions that have a lack of qualified, content-area-trained secondary and tertiary teachers. Blended learning has the added value of offering specialized content information that may not be accessible otherwise, with teachers acting as facilitators of that information, guiding students through particular coursework as needed. This could be especially helpful in rural schools that house a variety of age-groups or in low-cost private schools in city slums; students could learn grade-appropriate skills and knowledge at their own pace, with a teacher available to offer coaching assistance at all levels. Rather than replacing the teacher, as some have intimated, technology has the potential—if deployed well—to support and extend the capacity of the often overburdened and overstretched developing-country teacher.

Developing World Experience of Technology in Education

Stories of failed technology interventions in education abound. There are many reasons for this. Surely some of the failures arise because decision-makers and implementers fail to follow the general rule of ascertaining if the use of the technology can be expected to add value. Other failures occur because they do not take full account of the enabling conditions needed for successful interventions. Still others fail due to uncontrollable circumstances. For every technology skeptic, however, there is a technology enthusiast. Within any given context, it is equally possible to find someone who declares that a newly-developed technology will solve a particular educational issue or revolutionize the practice of education as it is to find someone who argues that introducing technology would at best be a distraction and at worst divert precious human and financial resources towards activities doomed to fail.

The truth lies somewhere in between these two perspectives. Better understanding of what have been the main

shortcomings of technology in education is an important first step in assessing what strategies, if any, are needed to enable technology to effectively advance educational outcomes and processes. A vast array of reporting and academic studies on technology and education gives some insight into what some of the most common critiques are of the use of technology in education.

Common Critiques:

- **Value added:** Technology does not add value to educational outcomes or processes and technology investments can crowd out other investments that could bring value.
- **Infrastructure and Equity:** The infrastructure needed for technology to be successful is weak and often only available for the developing-country elite, including trained technicians who are able to troubleshoot and maintain technology.
- **Reliability and Sustainability:** Technology often breaks down and quickly becomes out of date. Its short shelf-life makes it little more than an ultimately unproductive distraction for users. Additionally, technology interventions and programs are frequently not sustained over time after initial pilots.
- **Ease of Use:** Technology is difficult to use. Often it is too complicated or not available in the needed languages.
- **Teacher support:** Teachers are frequently not trained or supported to use the technology.
- **Political symbolism:** Often technology projects are promoted for political reasons—and sometimes used as a status symbol—and are therefore not well thought-out and become problematic.
- **Role of the teacher:** Technology seeks to replace the human dimension, or teachers, in the education process.

We review each of these in turn to assess past experience and future possibilities. We are interested in understanding the critiques as well as evaluating whether there are relevant responses or counter-examples. Ultimately, we are interested in developing a better understanding of if, when, and how technology can serve to advance education in the developing world.

A common critique of the use of technology in education is that it does not **add value** to educational processes or outcomes. This, of course, is the crucial test of whether technology should figure at all in education and whether, ultimately, it merely represents an added cost, extra teaching burden, or does little to address any of the multiple struggles to improve learning for students. If this is the case, there can be little doubt that it should not be used. It is interesting to note the range of findings related to the use of computers in education. Some spectacular disasters have been reported. Indeed, many visitors to schools in developing countries can find a desktop computer that has broken down, has no source of power, or the teacher does not know how to use it, and collects dust underneath a desk. For example, Mike Trucano of the World Bank relates his experience of meeting a senior teacher at a school in Delhi who acknowledged that his school had had two computer labs for the preceding seven to eight years. The computer labs were closed and locked, however, and the comput-

ers laid unused and gathering dust because the school did not have any teachers who were trained well enough to use them.[150] Indeed, many studies conclude that "simply putting computers into schools is not enough to impact student learning."[151]

Even when efforts are made to develop a program to accompany the presence of computers, improved learning in academic subjects is not guaranteed. Take, for example, the effort to integrate ICT skills in education in the Small Island Developing States (SIDS) of the Caribbean. The Organization of Eastern Caribbean States Education Reform Unit (OERU) played a significant role in encouraging the development of national ICT in education policies in SIDS, which emphasized the achievement of ICT skills as well as overall improvement in academic performance. The resulting emphasis placed on learning ICT skills led to a range of interventions, including the establishment of computer labs in most primary and secondary schools, although some of the SIDS, such as Dominica, have installed computer labs without specific national ICT policies in place. There was substantial leadership from the respective governments, including a new component on computer skills in national secondary completion requirements and a specific curriculum for learning computer skills. Despite enthusiasm, leadership, and resources, the results of this substantial effort have been somewhat mixed. The program did successfully boost students' knowledge of computer skills, but the technology was not maximally leveraged to help improve learning in other areas. The computer labs thus far have served only to teach computer skills and, because computer lab teachers felt quite protective of "their space," were not used by other teachers (e.g. math, science, history) to help supplement their lessons. Ultimately, while the region-wide effort to integrate ICT in education did allow students to develop important computer skills, learning in core subjects such as biology, chemistry, English and math remained stationary or declined. From 2004 to 2010 for example, the percentage of students who passed the IT portion of the CSEC exam grew from 42 to 81 percent while the number of students who passed the English portion remained at around 55 percent during the same period.[152]

Additional components of the effort, including using computers to improve information management, also were not highly successful. Government officials did not have the knowledge base and skill set to effectively negotiate good contracts with the hardware and software providers, resulting in several expensive and unserviceable contracts being signed. For example, an EMIS pilot project in St. Lucia procured database software from a Canadian company that appeared to fit the island's needs. Unfortunately, the teachers and administrators ran into a range of problems with the software, including drop-down display items that were not translated from French to English, and difficulty in navigating the database. Gaible notes that the project's problems probably stemmed from the focus on procuring a software product instead of identifying an appropriate vendor and vendor contract who could provide a product that matched St. Lucia's needs.[153]

Ultimately, overlooking the human-resource capacity, or lack thereof, among school administrators and teachers, and within the ministries of education, was an important reason that parts of the effort to integrate ICT in schools

in the Caribbean have not been as successful as hoped. As an important enabling condition, supporting human-resource capacity is crucial for the success of technology-related education projects.

There are however a number of examples where a smart program design and careful consideration of the enabling conditions have meant that computers in schools added value to educational outcomes and processes. Consider the Education Development Center's Interactive Radio Instruction (IRI) project in Indonesia. The project was designed to support early childhood development, particularly in meeting school readiness requirements. It resulted in increased scores in Language and Cognitive Development categories between pre- and post-tests, where IRI learner scores increased by 21 points, while control learner scores increased by 13 points. The program saw improvements not only in student learning and school readiness outcomes, but also in teacher practice.[154]

Another common critique of technology in education is that the technical **infrastructure** in many developing countries is too weak to adequately support effective use of technology for most of the population. Many are quick to point out that where infrastructure exists it is largely skewed towards benefiting the wealthy communities. This critique is well founded. In Africa and Asia, invariably the rural and poorer communities are much farther behind in terms of connectivity, electricity, and other essential enabling conditions. For example, of India's 51 million internet users, only 11 million are from the rural regions, where 70 percent of the population resides.[155] While internet usage and access to computers is increasing in Pakistan, recent data show that 25 percent of Pakistan's urban schools have access to a computer, compared to only 5 percent of rural schools.[156] Malawi's rural-urban divide in access to the electricity grid is very sharp: while 20 percent of the nation's urban population has reliable access to electricity, only 1 percent of its rural population does.[157]

However, both radios and mobile phones require substantially less infrastructure and are much more prevalent than computers. Ownership is also not nearly as tied to socio-economic class as other forms of technology. Radio is ubiquitous with at least 95 percent of the global population covered by terrestrial analogue radio. Recent data suggests that a large number of households in the developing world are taking advantage of this wide coverage, with 75 percent of households having a radio and listening to it often.[158] Mobile phones, as discussed above, are increasingly becoming a main mode not only of communication, but also of doing business. This has led to some experts to argue that a better way of pursuing technological advances in education is through mobile phone technology, not computers.[159]

There certainly are good examples of well-designed and effective projects that reach some of the poorest communities and hardest-to-reach areas using both these technologies. For example, through the MoMaths project in South Africa, teachers use text messages and social-media platforms to track and assign homework activities and to send students important messages regarding upcoming tests and other announcements. The MoMaths project was such a success during its initial phase that it was expanded and exported to schools in Finland.[160] The

long-running USAID-Education Development Center's Interactive Radio Instruction (EDC IRI) programs in India, Indonesia, Mali, Pakistan, South Sudan, and throughout the developing world, which broadcast English, local language, math, and teacher development programs, have been quite successful in the classroom. Information gathered from IRI projects spanning from 1975 to 2000 demonstrate that these programs have a noticeable impact on student learning and teacher effectiveness compared to traditional in-person classroom instruction.[161] More recent data confirms this evaluation. According to a study of EDC IRI programs since 1972, if the average student in a control group participated in English language IRI programs, they would have performed in the 96th percentile of their peer-age scores in the English language at the end of one year, compared to the 50th percentile if they did not participate in the program. The effects of participating in math IRI programs, based on information gathered from Haiti, India, Sudan and Zambia for grade 1 were statistically significant, demonstrating that the program noticeably improves student math scores. Likewise, in Mali, teachers who participated in IRI professional developing programs were much more likely to use cooperative learning methods (93 percent in 2007 compared to 36 percent in 2003 prior to the program) and were more often observed using group work in the classroom during non-IRI lessons (75 percent in 2007, up from 18 percent in 2003).[162] These projects were successful because they were relevant to the communities in which they were implemented and were able to use existing infrastructure to add value, by increasing access to learning opportunities for marginalized communities.

Linked closely with the infrastructure concern is the apprehension over the **reliability** of the technology itself and the **sustainability** of technology interventions. For a technology to add value it must work consistently over time, otherwise the users, whether they are teachers, education managers or others, will likely stop using it. As mentioned previously, research has shown that, particularly with computers, the total cost of ownership is much higher than the mere cost of the technology—hardware and software—itself and often decision-makers forget to use this more expansive formula. Total Cost of Ownership (TCO) involves not only the initial technology purchase but all the costs associated with keeping the purchase running efficiently throughout its five to seven year lifespan.[163] For computers and computer labs, TCO includes professional development for teachers and staff, technical support and maintenance, internet connectivity, software, replacement costs and building retrofits to support computer set-up, among others. Some experts estimate that decision-makers should plan to invest 30 to 50 percent of the original hardware and software costs annually to support ongoing use of the technology (this figure excludes initial building retrofits). TCO for computer labs in developing countries can range from roughly $20,000 to nearly $50,000, depending on how many computers are procured for the individual school, in addition to personnel and other costs.[164] In schools in Namibia, TCO was found to be three times higher than the mere cost of the hardware itself.[165] Ensuring that TCO is resourced and planned for is essential to guarantee not only a reliable technology that will be used consistently but also a program model that has a better chance of being sustained over time.

Another common critique is that technology is often difficult to use and primarily in English. For a technology to be effective it must first be **easy to use,** otherwise people

will be much less likely to incorporate it into educational processes. With complicated or not-readily accessible technologies, such as some software and data applications, it is harder to attain widespread incorporation in the classroom. Learning to use a computer is not necessarily intuitive, which is why TCO models include the cost of personnel training. Many of the technological innovations deployed in education are based in English, including most distance learning and other e-learning projects, many OER libraries, and online professional development and teacher training courses. It is estimated that up to 80 percent of online content is only available in English. This has been commonly noted as preventing the wider use of certain technologies. For example, in the rural regions of South Asia, English proficiency is not high and the low level of online content in native languages represents a serious barrier to the use of the internet for educational purposes.[166] There are notable exceptions, such as radio and mobile learning, which can be easily translated into appropriate languages. Translation via Google translator or freetranslation.com is recently much improved and has the capacity to address, in some ways, the language barrier. Moreover, many OER, including MIT OCW and the Khan Academy materials, are being translated into a variety of languages.

One area that is clearly crucial for the success of many technology interventions is **support for teachers** in understanding and using the technology in their work. There are many examples where attention to this important enabling condition is missing and thus the intervention fails. For example, in the EMIS pilot project in St. Lucia discussed above, the lack of computer skills due to poor support for teacher training in using the technology and the online database was cited as one of the project's primary challenges. Teachers were not accustomed to using a computer to record important classroom- and school-based information and none were given release time or incentives for participating. The lack of teacher computer skills combined with a very slow network led to high levels of frustration for the project's duration.[167]

In addition to successful interventions placing a heavy emphasis on supporting teachers' capacity to use the technology, there is a range of ways in which technology can support teachers in doing their jobs. One of the best examples of this is the OER movement that has blossomed rapidly over the last decade. OER assists teachers by providing free, relevant and high-quality professional development and teacher-training courses, as well as access to free classroom resources, lesson plans, and a large number of literary journals and academic resources. This applies not only to primary and secondary education teachers, but to professors at higher education levels. For example, several programs that have been quite successful include the Commonwealth of Learning's Virtual University for Small States of the Commonwealth (VUSSC), Teacher Education in Sub-Saharan Africa (TESSA), the United Kingdom's Open University (OpenLearn), PhET science simulations, Hippocampus courses and homework support, among many others.[168]

Teacher development programs themselves—both pre-service and in-service—can also be delivered using a range of technologies. For example, TESSA is an interactive website that offers free training modules for teachers. Two handbooks, "Working with Pupils" and "Working with Teachers," are offered in four different

languages and are available to a number of nations in Sub-Saharan Africa. Content modules are available for a variety of subjects, including literacy, numeracy, science, social studies, the arts, and life skills. Auditory components and online community forums are also available to help teachers with their training skills. TESSA has affiliations with 18 organizations including 13 higher education institutions in nine Sub-Saharan African countries, which use the materials in a variety of ways. For some, the TESSA materials provide the core of a new course. Other institutions have revised existing programs to include TESSA materials. The flexibility and open nature of the materials enables them to be adapted readily to different contexts and so far have reached 200,000 educators throughout Africa.[169]

There is also a concern that technology is **politically "sexy**" and its use represents joining the 21st century and progress. While it is important to have political leadership and champions within the government to lead technology work, there is also a risk that this opens up the possibility for misguided high-level decision-making. Often, negotiations about technology interventions can happen at very senior levels without adequate involvement of the education personnel actually running and managing systems. In this case, it is much more likely that a country will first select a technology that they would like to use, and then look for an educational problem to which to apply it, rather than the other way around. For example, according to the World Bank's *info*Dev survey of ICT in education in Africa, most developing-country policies focus on increasing access to computers in classrooms. Typically, less effort is spent on training teachers in facilitating the integration of ICT into content-related instruction and learning, and in some cases, such as those discussed above, computers lie unused in computer labs due to a lack of training.[170] Rarely does this "technology first" approach result in the best selection of technology for the problems at hand.

An underlying concern about the deployment of technology is a fear that teachers will be replaced by machines. The **teacher's role** in education is likely to shift over time but there remains a critical need for educators. In the developing world, teachers at the primary and secondary levels are often responsible for a broad range of social, cultural, and emotional-development issues. In regions with a high incidence of HIV/AIDS, teachers can help students learn to cope with the impact of the disease on themselves and on their families. Female teachers in Afghanistan often serve as role models and confidants for their female students, who feel comfortable expressing their thoughts and opinions when they are in the classroom.[171] Teachers will clearly remain an important feature of the educational landscape in the developing world, even if their roles or the types of practices in which they engage in the classroom shift from, for example, less didactic methods to coaching, mentoring, or facilitating individual and small group inquiry.

The one exception, however, is in higher education. As discussed above, there are a number of studies that examine online learning at the higher education levels. However, while the results of individual studies are mixed, on average students using online platforms alone perform as well as their counterparts in classrooms where there is no on-line learning. And, as previously

mentioned, students in blended learning contexts—where they make their way through online coursework while teachers act as coaches—on average outperform students in teacher-only and technology-only conditions. Over time we expect that the effectiveness of online courses will dramatically improve. This could shift effectiveness more in the direction of technology alone as an educational mechanism and reduce the traditional role of teachers. A simple way to add a coaching element would be to make it available online either with professional coaches or with peer discussion forums. Programs of instruction such as those of the Khan Academy can also be used as an online tutor. While we lack good data from the developing world about the effectiveness of blended learning or on-line learning without a teacher, the results should be transferable. The nature of higher education lends itself to this form of learning because students are often allowed and, in fact, required to direct their own pace of learning, and, in some places, students receive credit only for work produced or on the basis of assessments, rather than for participation or attendance. Online learning also has the potential to encourage individualized work and research, which is an important component of many higher education institutions and programs.[172]

Finally, even in the context of conservative behavior often found in higher education institutions in the developing world, there is a mix of innovative programs. Four particularly interesting examples are the University of the People, a US-based online university that offers free courses to students; the VUSSC, a network of 32 small states discussed above, which uses the Creative Commons license to design courses for students in developing countries; Carnegie Mellon's Open Learning Initiative (OLI), which offers coursework in a variety of subjects and can be used on its own or act as a supplement to existing courses; and the OpenCourseWare Consortium, a network of over 100 higher education institutions that place course materials on the web for free use.[173] The University of the People is unique in that it has the ability to offer higher education degrees without charging tuition fees, while OLI charges a small usage fee to participating institutions. OLI additionally provides continual student and instructor feedback and offers a rigorous evaluation component. As we have discussed, the OLI initiative has carried out research that demonstrates learning gains comparable to or exceeding those of more traditional in-person classroom experiences.[174] This flowering of new programs and offerings presents an exciting possibility for increased access to quality higher education for young people in the developing world. Students all over the world now have the potential to have access to high-quality coursework and instructors, even if their home institutions do not have the capacity to accommodate their needs.

The technologies that can be mobilized to help advance education in the developing world are numerous and expanding. The potential for using different forms of technology to assist with a wide range of problems—from integrating marginalized girls into the education system and improving central ministry information management, to providing high-quality textbooks and learning materials at low cost and allowing on-going professional development for teachers—is great. At the primary and secondary levels, mobile phones, radios, and e-readers, among others, are all emerging as important low-cost

technology for improving teaching and learning processes and outcomes. These new technologies are serving as an important complement to the more traditional focus on computers and e-learning. The influence of technology is perhaps especially poised to unlock barriers within higher education in the developing world. With Open Educational Resources, substantial courses and programs becoming available online, and results show good learning outcomes from e-learning, the availability and cost structures of traditional higher education services are beginning to change. Here the role of the computer and e-learning is central, with other technologies playing a somewhat lesser role.

The essential ingredient for harnessing this potential of technology to advance education in the developing world is its smart and strategic deployment. Any number of things can and will go wrong in using technology in education. But most problems, including the seven main critiques discussed above, can be addressed with careful planning and a basic knowledge of the pitfalls to avoid, as discussed below.

SEVEN PRINCIPLES FOR SMART USE OF TECHNOLOGY IN EDUCATION

Reviewing the array of critiques in the literature and assessing the ways in which they have been addressed reveals a set of guiding principles that should inform technology programming in the developing world.[175] These are meant to be a very easy-to-follow set of seven basic principles that can help guide educators and education policy-makers in developing countries, as well as the external actors that support them, such as foundations and bilateral donors, in smartly and strategically designing and implementing technology interventions.

1. **Educational problem first.** First, identify the educational problem that needs to be addressed, and then assess which, if any, is the best technology to do the job.[176] Start with the problem, not the technology. Too many projects attempt to integrate technology into education before they decide what problem they want the particular technology to address. As a result, a project can fail to successfully solve the problem in question, sometimes because deploying technology is not in fact the best or most cost-effective solution. Ensuring that both front-office and back-office education barriers are equally considered in relation to technological solutions will expand the set of issues that can potentially benefit from technology interventions. Addressing the problem first ensures that all necessary actions will be considered prior to establishing the desired technology.

2. **Added value.** If technology is to be deployed to address an educational problem, make sure that the technology will add value to other existing solutions. There are a number of different dimensions in which technology can add value, including expanding educational access and opportunity; improving student-, teacher-, and school-level outcomes; and a variety of back-office activities. Using the general rule of thumb discussed above is an important first step in assessing the usefulness of deploying a technology. Unfortunately finding the necessary comparative information on technology interventions, especially in developing-country contexts, can sometimes be difficult. This, among other knowledge gaps in the status

of technology in education in developing countries, suggests that on-going research and evaluation is urgently needed.

3. **Sustainability.** Carefully considering the full range of enabling conditions is essential to design and implement an intervention that will last over time. This includes factoring in the total cost of ownership, the ultimate relevance of the technology to the particular location, access to appropriate infrastructure, and human resource capacity. Teachers and school administrators, so often forgotten in the roll-out of technology interventions, are essential for sustaining the use of technology. Also significant is the issue of scalability. Is the intervention specific enough to adequately address local problems and general enough to be scaled up to a provincial, or regional level, or scaled out to other sectors such as health? Will the project be relevant and accessible with the passage of time, or will external factors or lack of relevance eventually lead those involved to abandon it?

4. **Multiple uses.** Where possible, select a technology and design an intervention so that the technology can be used for multiple purposes. This will enable a greater number of individuals to benefit from the technology, but it can also justify the high start-up costs for such interventions if it is utilized for a variety of purposes. For example, a computer lab in a school should not only be reserved for learning ICT skills but also be at the disposal of the math and science classes for enriching their work, and/or available to teachers for their own professional development, or opened for use after school hours by the community for informal education, or for other such uses.

5. **Lowest Cost.** While there may be many different types of technologies that can provide the assistance sought, other things being equal, it is best to select the least expensive option for the job(s) desired. Very little is gained by opting for the more expensive option, especially if there is a reliable and cheaper option available. This is not to indicate that quality should be sacrificed for the sake of lower cost; obviously a more expensive model of technology that is high-quality will last longer and cost less in the long run than a low-quality, low-cost model that needs more frequent upgrades and repairs. On the other hand, there are many instances in which lower-cost devices achieve the same results as more expensive ones. For example, in many rural regions in developing countries, radio now is much more cost-effective than computers for improving student learning. If a lower-cost technology is available to solve a particular problem, even though it might be less "politically sexy," it should be used.

6. **Reliability.** Before deploying a technology, ensure it is reliable and will not rapidly break down. Nothing slows a project down more than unresolved problems. Part of assessing the reliability of a technology includes making sure that associated and necessary elements, such as access to electricity or internet connectivity, adequately skilled staff and maintenance personnel, options to update or upgrade technology, and others, are in place. The technology should also be adequately and appropriately vetted before it is established: Was the technology used successfully in a similar environment or location? What were the challenges associated with it? How were they resolved? Did the technology break down or did it stand up to its constant use? These questions should be answered before a technology is deployed.

7. **Ease of Use.** Finally, in educational interventions, technology should be easy to use. Perceived ease of use has in fact been cited for many years as among the three most important determining factors for technology uptake, according to the Technology Acceptance Model.[177] Excessively complicated technologies can present barriers to implementation and the ultimate success of the intervention, especially if extensive training is required to learn how to operate the particular technology. As indicated above, some database applications require the use of advanced knowledge, skills and training to operate. This is not to say that such applications should be completely left out; when used appropriately they can be extremely useful for education management purposes. On the other hand, the relative ease of use should be considered before a project is implemented to determine whether or not, or what kind of, training is required. This process will help to ensure that the technology is effectively and efficiently utilized.

If followed, these seven guiding principles can help avoid many future problems and, more importantly, can help leverage the power of technology in educating young people in some of the poorest regions of the world. Given the rapid pace of technological change, it is unlikely that the issue of technology in education will go away. Instead, we are likely to see a blossoming of new and creative ways for harnessing what technology has to offer.

In the next several years a range of strategies that we can only dream of today may become common place, and the developing world may well be the source of some of the most cutting-edge uses of technology within the education sector. Perhaps teachers will all be paid directly through mobile banking on their cell phones, cutting expensive back-office management costs, diminishing corruption, and helping ensure teachers receive timely salaries in full. In Afghanistan, the Ministry of Education, together with USAID, is already beginning to explore this possibility. Perhaps teachers of secondary-school science or other specialized subject matter will simultaneously teach students physically present in their classrooms and students at remote rural schools joining the lesson by video or Voice over Internet Protocol (VoIP), like SKYPE, thereby helping to address the shortage of secondary-school teachers, especially in low-density and poor regions. In Tanzania, the Ministry of Education and Accenture are beginning to explore just this strategy for expanding access to quality secondary learning for rural communities. Perhaps a bright, young woman who has graduated from secondary school, with excellent intellectual potential but little money and with family responsibilities, will attend college online, getting important accredited training that will allow her to contribute to her country and community. The Open University program in the UK is providing precisely this opportunity for a number of enterprising young people from Jordan to Bangladesh.

Given the power of this future vision, it is important that the path to get there not be riddled with poorly-conceived and poorly-structured applications that would only serve to discredit the promise of technology and to dissuade policy-makers from investing in its potential. Following these seven principles is an initial step for ensuring this does not happen.

ENDNOTES

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