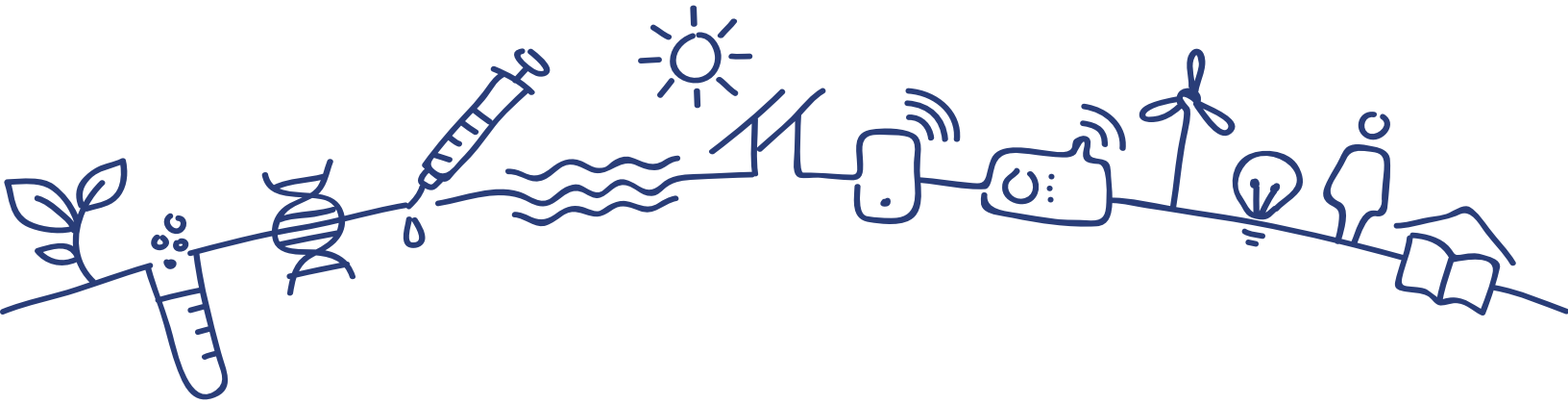
50 BREAKTHROUGHS

Critical scientific and technological advances needed for sustainable global development



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NOTES ON METHODOLOGY AND LAYOUT

Traditionally studies focused on future-facing topics have relied on surveys of experts, using approaches like the Delphi Method[1], a structured iterative process of interviews and reviews. Early in our study, we discovered two challenges with such a process. First, the absence of a broad, credible evidence base about what works has led to entrenched opinions. Second, such an approach would likely have led to a laundry list of 50 *technologies* or *devices*, rather than to a robust problem analysis which logically leads to the *breakthroughs* required—agnostic to specific technologies.

Hence, this study employs a six-part approach to reach its conclusions:

1. Describe and analyze the 5-10 most important contextual facts about the specific problem.
2. Identify the key challenges, which have kept effective solutions from becoming a reality.
3. Identify, based on input from recognized topic-specific experts, the most promising interventions to overcome those hurdles.
4. Determine the dependence of each of these interventions on: policy reforms, infrastructure development, education and human capital development, behavior change, access to user finance, an innovative business model, and finally, a new breakthrough technology.
5. We focus on interventions with a significant dependence on a breakthrough technology, and identify the important parameters the technology needs to fulfill. Based on the underlying technical challenges, we then estimate the time-to-market by when these breakthroughs may become deployable products.
6. Finally, we identify the most important hurdles to sustainable, large-scale deployment, based on many of the factors listed above (e.g., policy reforms, etc.), and score the difficulty of deployment on a 5-point scale: simple, feasible, complex, challenging, and extremely challenging. The purpose of this final analysis is to encourage technologists and funders to understand these challenges before making major investments in their work.

Each chapter is divided into three parts: Core Facts and Analysis, Key Challenges, and Scientific and Technological Breakthroughs. The 5-point scale and the complexity we ascribe to each of the factors and constraints relevant to the deployment of a particular technology are illustrated in **Table A**. The lowest score (feasible) is reserved for cases when the particular constraint is not relevant to deployment; the constraint is given the highest score (extremely challenging) if it can be a serious bottleneck to deployment. The aggregate score reflects the overall degree of difficulty, considering the collective weight of the individual constraints. The methodology is clearly subjective. **Exhibit A** is a sample of how we have illustrated the difficulty of deployment for each breakthrough across the study. This particular sample highlights a CHALLENGING breakthrough.

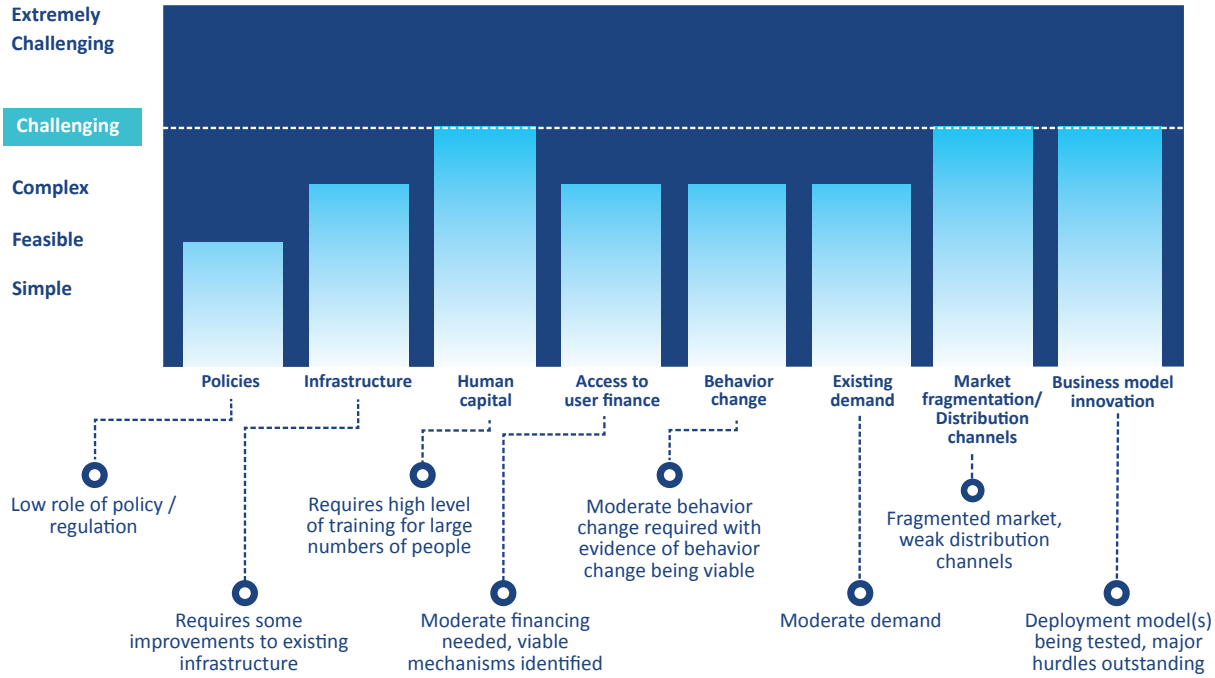
[1] A structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts who anonymously reply to questionnaires and subsequently receive feedback in the form of a statistical representation of the 'group response', after which the process repeats itself. The Delphi method is based on the assumption that group judgments are more valid than individual judgments. It was originally developed by the RAND Corporation in the 1950's to forecast the impact of technology on warfare.

Table A

	Simple	Feasible	Complex	Challenging	Extremely Challenging
Policies	Minimal role of policy/regulation	Low role of policy/regulation	Regulated market with supportive policies	Highly regulated market with policy changes required	Highly regulated and controversial changes required
Infrastructure	Minimal need for infrastructure	Dependent on existing infrastructure	Requires some improvements to existing infrastructure	Requires moderate improvements to infrastructure	Requires major improvements to infrastructure
Human capital	Minimal need for human capital development	Low-moderate need for human capital development	Moderate need to train a limited number of people	Requires high level of training for large numbers of people	Requires national scale training programs
Access to user finance	Financing not required	Limited financing required	Moderate financing needed, viable mechanisms available	Significant financing required, limited mechanisms available	Significant financing required, no identified mechanism
Behavior change	No behavior change required	Minimal behavior change required	Moderate behavior change required with evidence of behavior change being viable	Major behavior change required, potentially on daily basis	Significant behavior change needed on daily basis, changes contrary to cultural norms
Existing demand	Strong existing demand	Existing demand	Moderate demand	Low demand, needs to be built	Extremely low demand or not a perceived need
Market fragmentation/ Distribution channels	Highly concentrated market or well defined channels	Fairly concentrated market and/or well defined channels	Moderate fragmentation of customers, under-developed channels	Fragmented market, weak distribution channels	Highly fragmented, challenging to reach customers
Business model innovation	Clear deployment models existing at scale	Deployment model in process of scaling	Deployment model(s) being tested	Deployment model(s) being tested, major hurdles outstanding	No identified deployment model, major hurdles identified

Exhibit A

Breakthrough – Difficulty of deployment



EDUCATION

Across the three main levels of education—primary, secondary, and tertiary—there are a number of recurring themes that reduce access to education and/or diminish the quality of education. These include, but are not limited to, low government budgets that lead to a dearth of adequately equipped schools and qualified teachers, a lack of accountability to meaningful outcomes and readiness for the job market, potential discrimination against segments of the population based on either gender or religion (e.g., in many cultures adolescent girls and women are discouraged from seeking an education), and the high opportunity cost of enrolling and staying in school for individuals of secondary school age, or older, instead of earning a living. Fundamental solutions to the problem will require systemic improvements in infrastructure, better teacher training and certification, and ensuring accountability. However, one particular technology can play a powerful role.

- 'Smart' electronic textbooks, customized for various age groups and educational levels, with curated and up-to-date content, 'wiki' interfaces for vernacular and other locally relevant and gender-inclusive material, visual and dynamic learning tools for students, interfaces and tools for teachers, student-teacher interaction and peer-to-peer collaboration. These smart e-textbooks can be delivered on tablet devices or on smartphones, the prices of which are steadily falling.

Education is the foundation of long-term development. A well-educated population, trained in technical topics such as the sciences, medicine, engineering and jurisprudence, is essential for advancing a country's industries, institutions and laws, without prolonged external assistance. A workforce skilled in running businesses can serve as the engine of a strong private sector economy. A populace educated in the arts and humanities contributes to the society's cultural wellbeing. Unfortunately, educating a country's population takes, quite literally, a generation. Building the necessary infrastructure and systems can take even longer. As a result, it can be very difficult to design effective and sustainable education programs, and even harder to measure their long term impact. This chapter examines the design of education programs across the age continuum: primary (age 6-14 years[1]), secondary or youth (15-19 years), and post-secondary (focused on readiness for the job market).

CORE FACTS AND ANALYSIS

PRIMARY EDUCATION

The target of the 2nd Millennium Development Goal (MDG) is to "Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling" (UN, 2012). Since this declaration, primary enrollment has increased dramatically in developing countries (UNESCO Institute for Statistics, 2012),[2] and out of the 8 MDGs, the 2nd MDG has shown the strongest progress.

1 Despite enrollment gains, more than 57 million children of primary school age remain out of school

As shown in **Exhibit 1**, primary school enrollment in sub-Saharan Africa has increased from 58% in 1999, to 78% in 2012. In South Asia it increased from 75% to 90% during the same period. Notwithstanding this seeming progress, several major challenges remain. As of 2011, more than 57 million children around the world, out of the approximately 655 million children of primary school age, remained out of school **(Exhibit 2)**. These children are concentrated in Nigeria (8.7 million), the Democratic Republic of Congo (about 5.5 million), Pakistan (5.4 million), Philippines (1.5 million), India (1.4 million), Niger (1.2 million), Côte d'Ivoire (1.1 million), and Burkina Faso (0.9 million). In addition, a number of smaller countries have a very high prevalence of out-of-school children (OOSC); these include Eritrea (65%), Afghanistan (63%), Mali (34%), and the Central African Republic (29%). Of the total number of out-of-school children globally, 51% are expected to never enter school, 30% are

[1] There is some variation across countries in the upper age for primary schools.

[2] Please note that UNESCO combines regions in a manner somewhat different from other institutions like WHO. For example, data for South and West Asia are combined; also, instead of combining data for all the countries in the Middle East and North Africa region, some of these data sets separate the data for Arab States.

expected to enter school in the future, and the remaining 19% were in school but have left. It is also worth noting that after very strong gains in the early part of the millennium, the reduction in the overall number of out-of-school children appears to have stalled at 57-60 million. This is likely because these out-of-school children either live in extremely remote areas that are difficult to reach, or are from very vulnerable populations and face extremely challenging hurdles in attending school.

Primary school enrollment by region

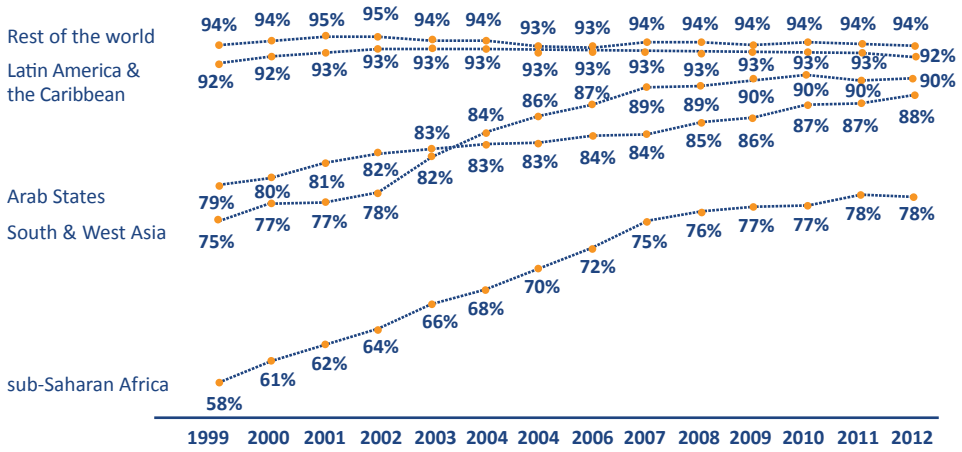


Exhibit 1: Primary school net enrollment has increased dramatically in sub-Saharan Africa and South (and West) Asia since 1999.

Out-of-school children of primary school age

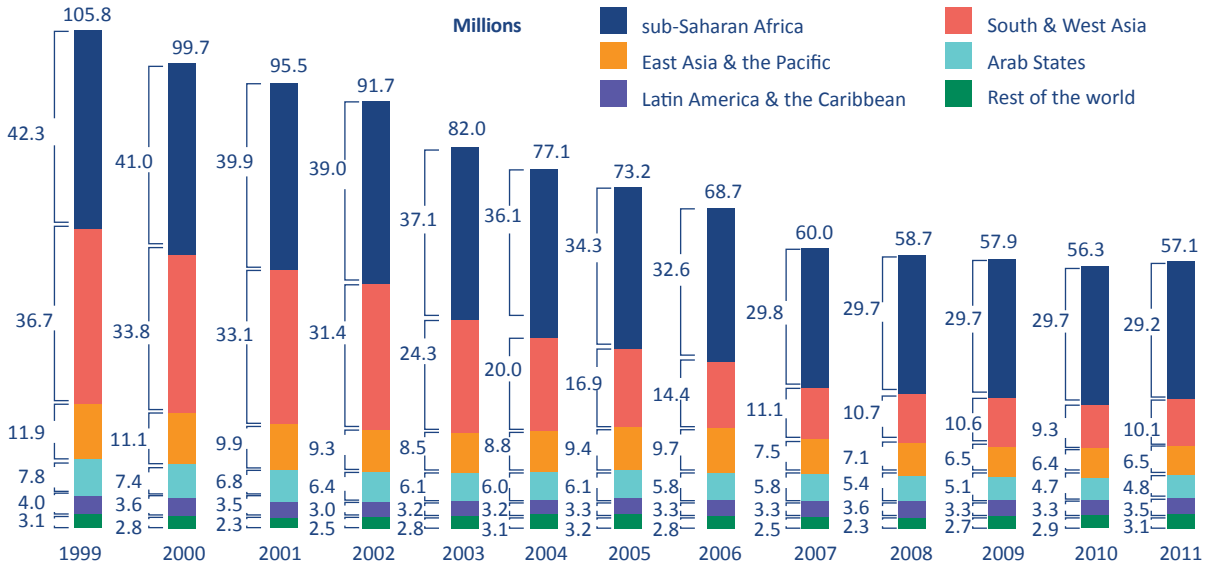


Exhibit 2: Despite the increase in primary school enrollment rates, around the world over 57 million primary school age children remain out of school. Most of these children are in sub-Saharan Africa and South and West Asia.

2 At least 123 million enrolled primary school children receive education of subpar quality

Quality of education is difficult to measure. Not only is there limited agreement on appropriate metrics for determining quality, but most developing countries do not collect standardized data on student performance. Based on the little data that is available, both sub-Saharan Africa and South Asia have major gaps along the key drivers of education quality.

Attendance

In addition to the children who are out of school, a very large number of students in developing countries, despite being nominally enrolled, do not regularly attend school. **Exhibit 3** shows that 30% of enrolled primary school students in sub-Saharan Africa and 23% in South Asia do not regularly attend school (UNICEF, 2012). Around the world, about 138 million children enrolled in primary schools do not attend regularly, mostly in the developing world.

Primary school absentee rates

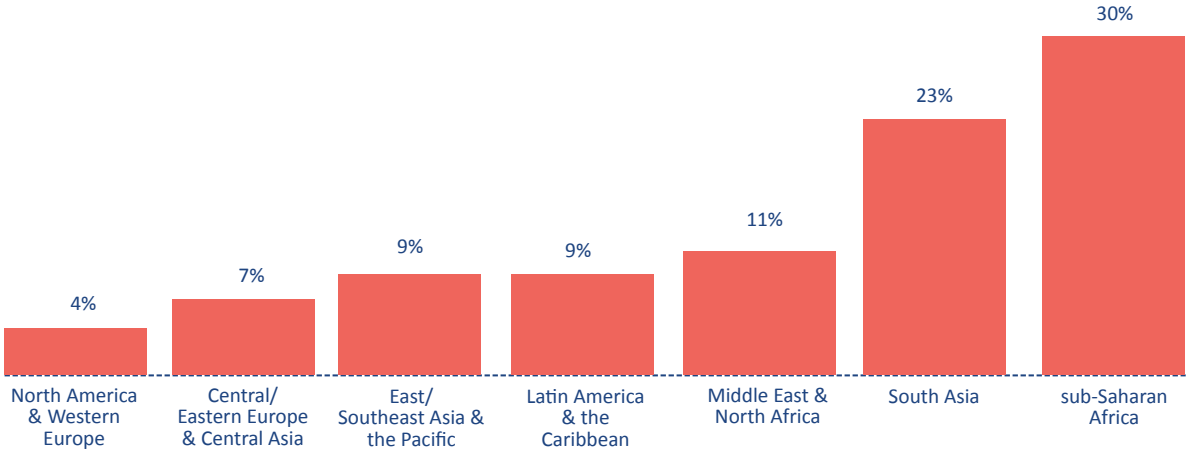


Exhibit 3: According to a 2011 UNICEF study, 30% of enrolled primary school students in sub-Saharan Africa and 23% in South Asia do not attend school regularly.

Student-to-teacher ratios

The more students there are in a class, the less attention the teacher can give to each student. As **Exhibit 4** shows, the average student-to-teacher ratio in sub-Saharan Africa is 44.7, and 39.1 in South Asia. In comparison, the average ratio in North America and Western Europe is 13.9 (UNESCO Institute for Statistics, 2012).

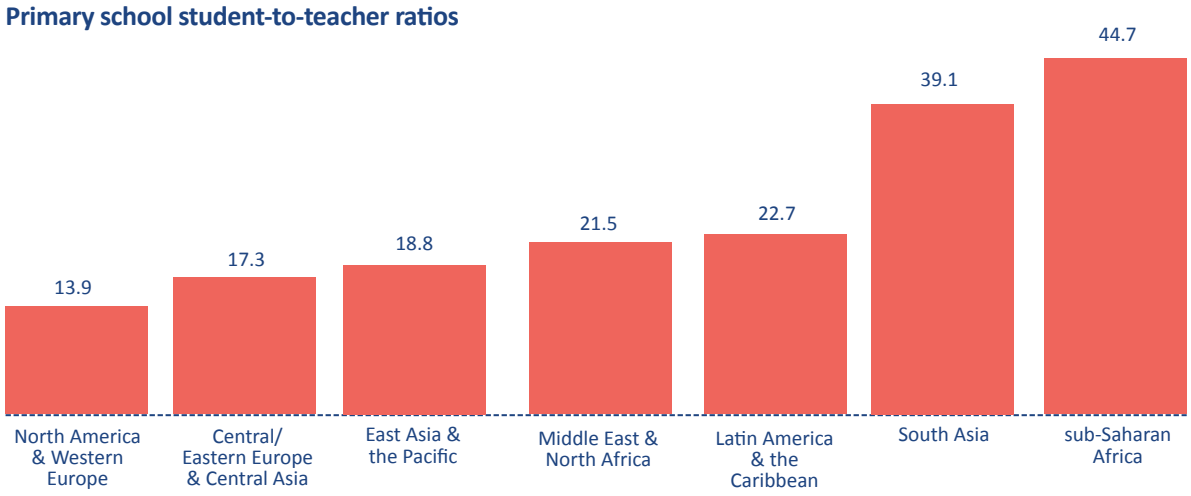


Exhibit 4: Student-to-teacher ratios (2005-2010 average), a key determinant of education quality, shows that there are far fewer teachers in South Asia and sub-Saharan Africa.
Note: data for China and India is not available.

Teacher qualifications and training

Teachers' qualifications and training determine their teaching ability, and are hence an integral contributor to overall education quality. **Exhibit 5** shows findings from a UNESCO study of teacher qualifications from 100 countries (UNESCO, 2006), categorizing them according to the minimum education level required for teaching in primary schools. These qualifications are characterized in terms of the International Standard Classification of Education (ISCED) levels; ISCED 2 refers to 9 years of schooling, ISCED 3 refers to 12-13 years, ISCED 4 to 13-15 years, and ISCED 5 refers to advanced degrees. According to the survey, almost half the countries in sub-Saharan Africa require only ISCED levels 2 or 3 (i.e., a secondary-level education, or less), and only 8% require an advanced degree. In some South Asian countries, the requirements are even less stringent. Despite the less stringent requirements in these regions, only 63% of primary school teachers in South Asia, and 75% in sub-Saharan Africa, meet the basic required qualifications.[3] Further, only an average of 10% of teachers across the range of surveyed African countries receive any form of on-the-job training (UNESCO, 2006) **(Exhibit 6).**

[3] Please note that the UNESCO survey on teacher qualifications (UNESCO, 2006) does not include data for India and Pakistan (the two largest South Asian countries), and is therefore not representative of the entire region.

Minimum training requirements for primary schools by HDI decile

Percent of countries in each region, with minimum required training at ISCED levels 2-5

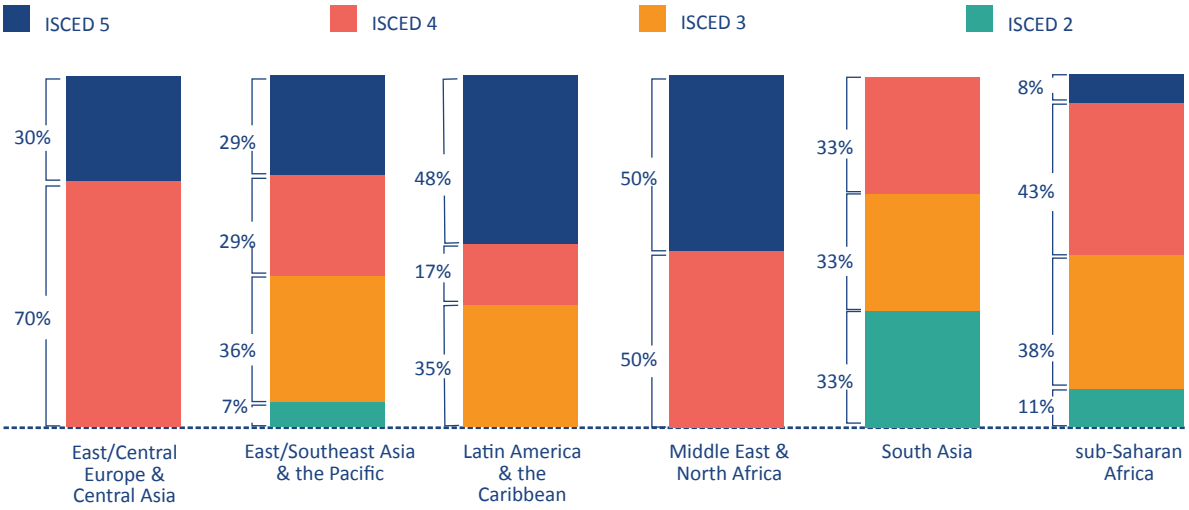


Exhibit 5: The minimum qualifications for primary school teachers varies across countries and regions. The qualifications are according to ISCED levels. ISCED 2 refers to 9 years of schooling, ISCED 3 to 12-13 years, ISCED 4 to 13-15 years, and ISCED 5 to advanced degrees. In sub-Saharan Africa, only 8% of countries require ISCED 5. The requirements in most South Asian countries are, likewise, low. Please note that this UNESCO study does not include India and Pakistan, South Asia's two largest countries.

Primary school teachers who have received specific training in teaching

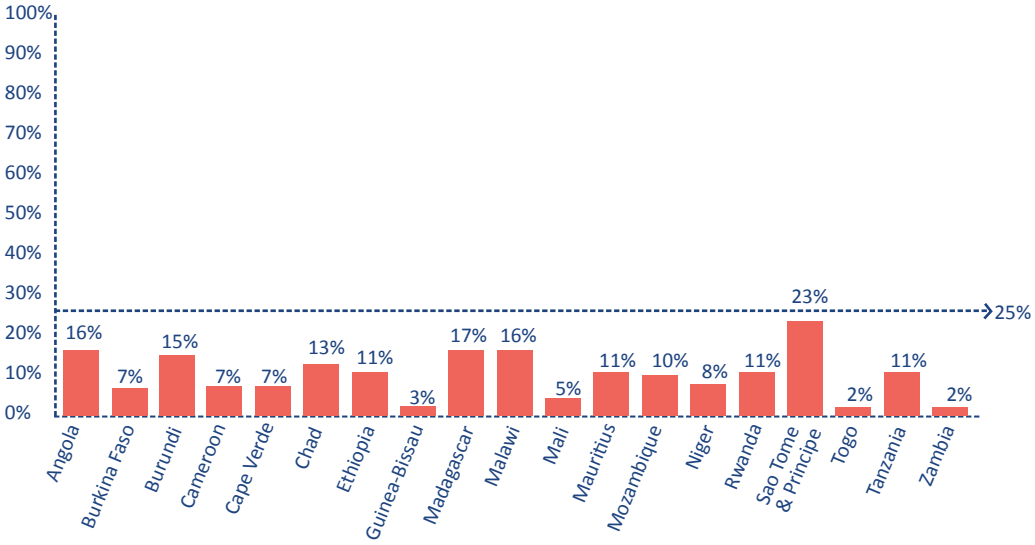


Exhibit 6: New data from UNESCO (which is still sparse) shows that across several African countries, only 10% of teachers receive education-specific training.

Judging only by the number of teachers who do not meet the minimum national standards, we estimate that approximately 123 million[4] students enrolled in primary schools—18% of students enrolled globally, and almost 25% of those enrolled in South Asia and sub-Saharan Africa—do not receive an education of adequate quality. This is, most likely, a highly conservative estimate given that many of these minimum standards would be considered inadequate by experts. Moreover, teacher training is only one of the several drivers of quality.

3 A number of low income parents send their children to private schools, especially in urban areas

One of the more contentious debates in international development is the role of government versus the private sector in providing education to the poor, especially at the primary level (Colclough, 1996). Proponents of public (i.e., government-run) education believe that it is the only meaningful way to provide free (or affordable), universal, and equitable education for the poor. Detractors argue that public systems lack accountability for quality or financial management and that private schools are much more accountable (Tooley & Dixon, 2005) (Tooley, 2009) (Lutyens, 2011). Our study does not take a stance on that debate, nor do we believe that the two approaches are mutually exclusive. Across all income groups in sub-Saharan Africa and South Asia, 16% and 18% of primary school students, respectively, are enrolled in private schools (UNESCO Institute for Statistics, 2012) **(Exhibit 7)**. More interestingly, a targeted study of the urban poor in India, Nigeria and Ghana found that 72% of low income students go to private schools, of which 68% do not receive any financial aid (Tooley & Dixon, 2005) **(Exhibit 8).**

Percent of primary school students attending private school

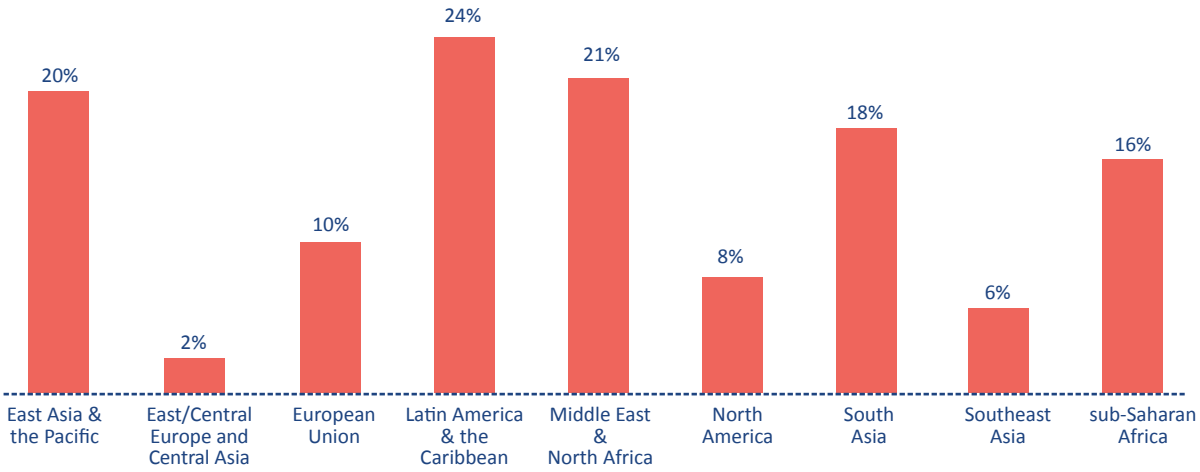


Exhibit 7: In general, there appears to be no correlation between the poverty level in a country, and overall enrollment in private schools; 16% of primary school students in sub-Saharan Africa and 18% in South Asia attend private schools.

[4] LIGTT analysis based on UNESCO data.

Public vs. private school enrollment of low income students in urban areas of India, Ghana and Nigeria

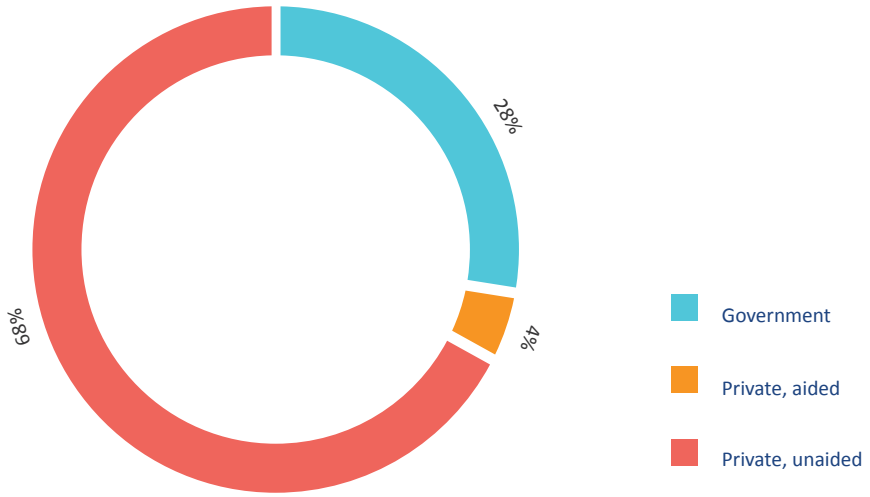
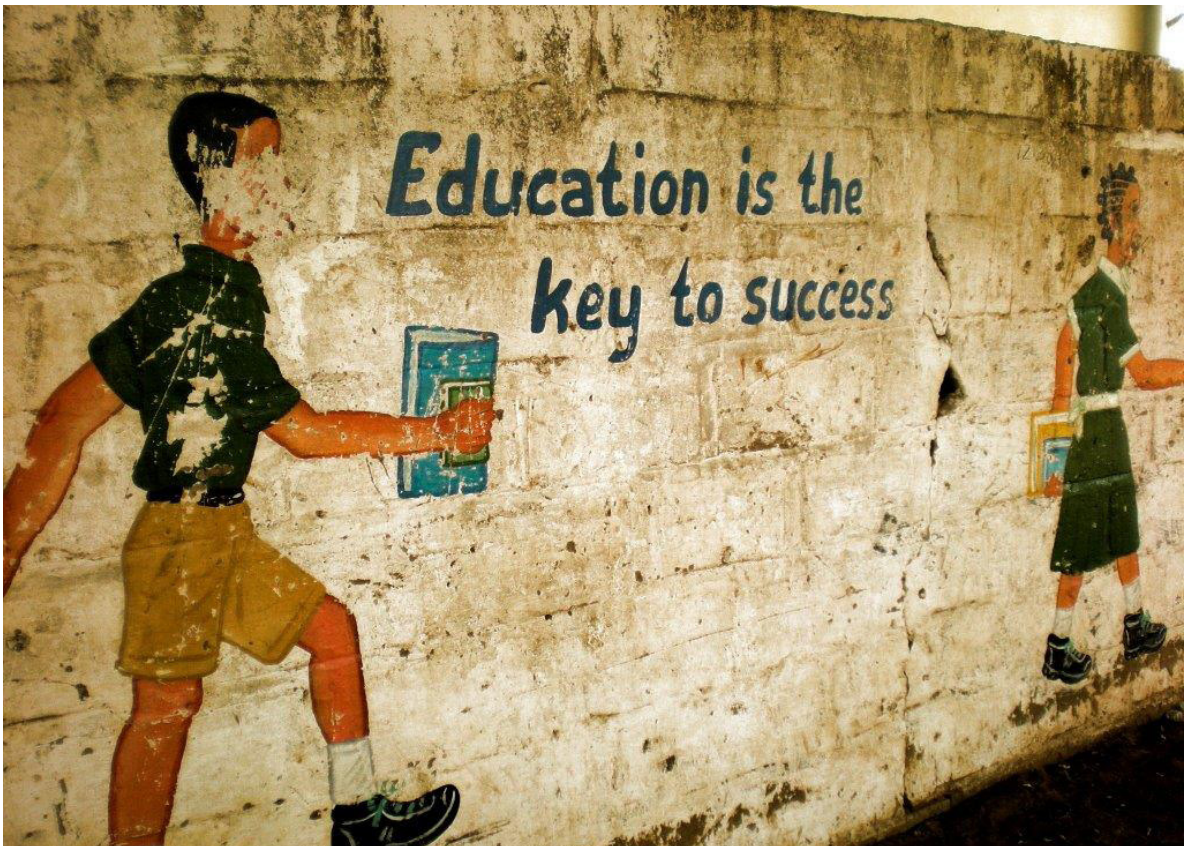


Exhibit 8: Targeted studies in India, Ghana and Nigeria show that 72% of surveyed households among the urban poor rely on private schools.



SECONDARY (YOUTH) EDUCATION

Secondary schooling—or other formal education—for youth, has not received global priority at the same level and scale as primary education has. Also, there is no standard age group which formally defines youth. Some institutions start their definitions as early as 12 years and others begin at 15 years; some end at 19 years, and others extend the definition to include individuals as old as 24 years. This section uses the age range typically associated with the secondary school years: ages between 15 to 19 years. The global population of individuals in that age range is about 606 million **(Exhibit 9)**. Of these, 88.4 million live in sub-Saharan Africa, and another 167.1 million live in South Asia (UN Department of Economic and Social Affairs, 2014).

The opportunity cost of going to school at this stage increases. Low income students who enroll in secondary school are of an age at which it is not uncommon for them to start working to support their families. Students often have to forego immediate income-earning opportunities for an education that may not position them for improving their livelihoods or income, especially in the near term. Consequently, the relevance of secondary education—and how it can help these students increase their immediate and long term income potential—is extremely important.

Public expenditure on secondary education, relative to primary education, differs vastly between countries and between regions. The data shows that there is significant variability in the ratio of primary to secondary expenditure between countries within a low income region, and between different low income regions. For instance, in South Asia, average government expenditure on secondary education is 79% of that on primary education; in sub-Saharan Africa, it is 188%. It is therefore difficult to draw a general conclusion about the overall quality of secondary education based simply on expenditure levels. However, metrics like student-to-teacher ratios suggest significant quality gaps **(Exhibit 10).**

Global youth population

Exhibit 9: Globally, there are 606 million youth in the 15-19 year age group. About 256 million of them live in South Asia and sub-Saharan Africa.

Student-to-teacher ratios in secondary schools

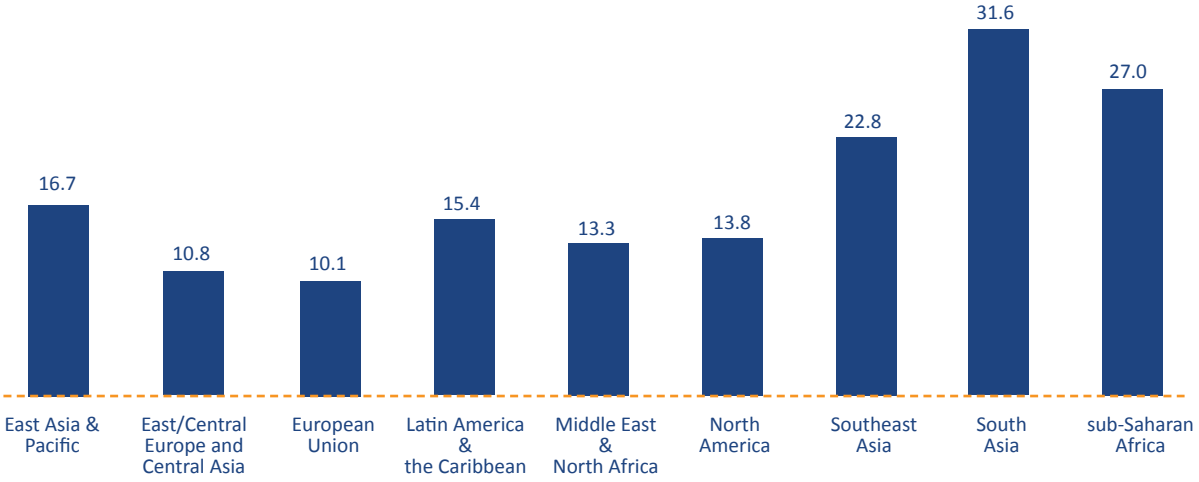


Exhibit 10: Secondary school student-to-teacher ratios in South Asia and sub-Saharan Africa are much higher than in other parts of the world, and likely reduces the overall quality of education.

4 Enrollment in secondary schools is significantly lower than that in primary schools

Perhaps the most significant and telling statistic about youth education in developing countries is the dropoff in enrollment rates between primary and secondary education, as shown in **Exhibit 11.** In sub-Saharan Africa, secondary enrollment is 29%, a drop of 46 percentage points compared to primary enrollment; in South Asia, it is 33%, a 36 percentage point drop from primary enrollment (UNESCO Institute for Statistics, 2012).

5 The gender gap is more pronounced at the secondary school level

As girls enter youth, many societal challenges begin manifesting themselves. These challenges have been discussed in detail in the section on Gender Equity. As **Exhibit 12** shows, the percent of enrolled secondary students who are female drops to 43% in both South Asia and sub-Saharan Africa, from 46% and 47% respectively (UNESCO Institute for Statistics, 2012).

Dropoff in enrollment rates between primary and secondary school

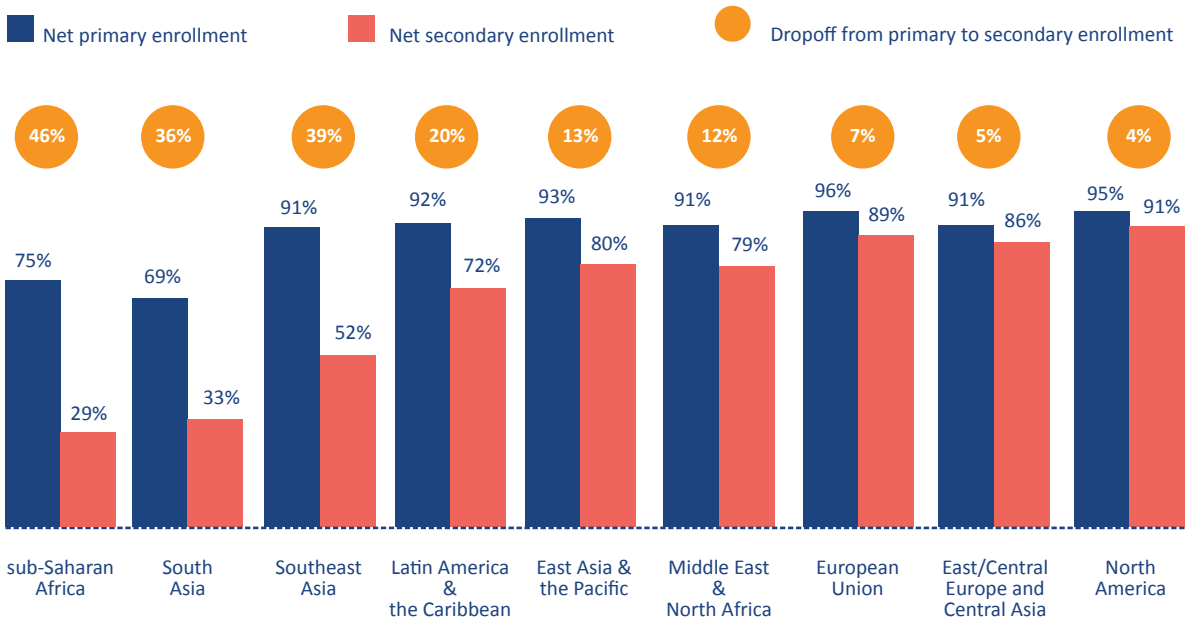


Exhibit 11: A significant number of students in sub-Saharan Africa and South Asia, who get a primary education, do not start secondary school.

Percentage of female students in primary and secondary school

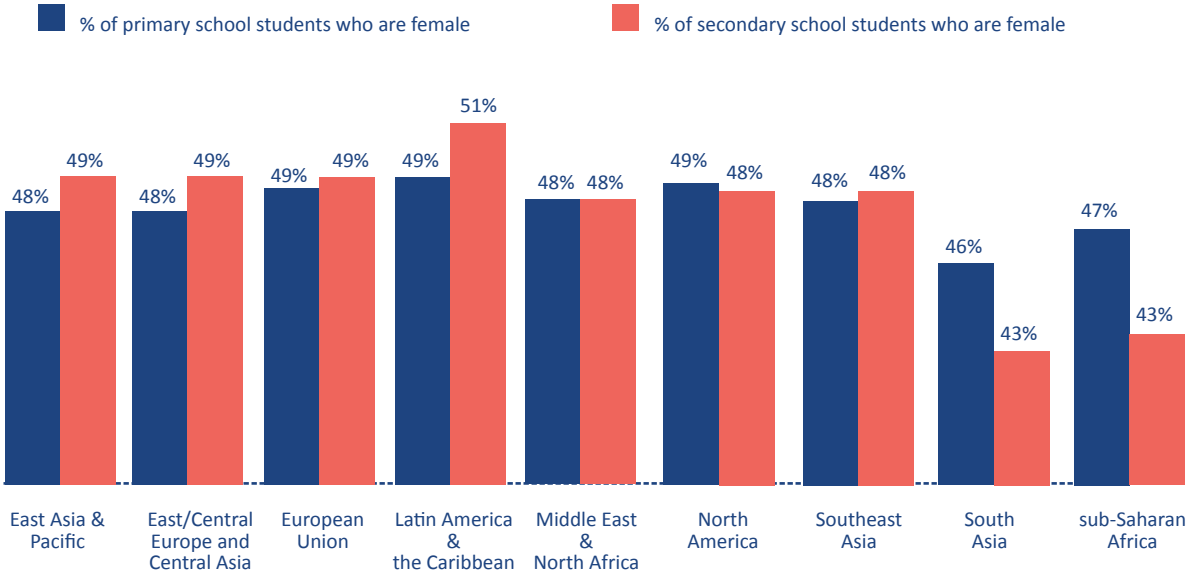


Exhibit 12: While the gender gap in primary education is minimal it begins to grow in secondary school, in both sub-Saharan Africa and South Asia.

6 The role of private schools is more prominent in secondary education

Middle and upper income students in developing countries often choose to pay higher fees and attend private secondary schools. What is interesting, however, is that a large number of students even at the lower end of the income spectrum, appear to prefer private schools (Tooley & Dixon, 2005) (Tooley, 2009). As **Exhibit 13** shows, participation in private schools in sub-Saharan Africa and South Asia at the secondary level jumps dramatically compared with the primary school level (UNESCO Institute for Statistics, 2012).

Percentage of secondary school students attending private schools

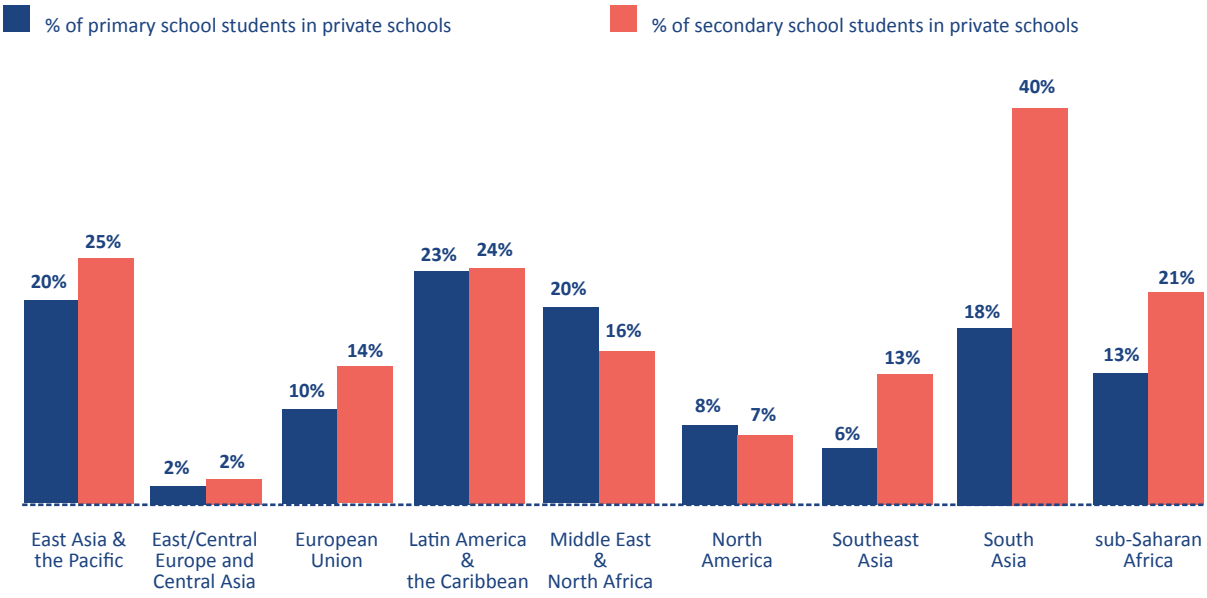


Exhibit 13: In sub-Saharan Africa and South Asia, there is a significant increase in the percent of students who go to a private school at the secondary level when compared with the primary level.

7 Technical Vocational Education and Training (TVET) programs are gaining momentum as an alternative—or a complement—to traditional secondary school education

Traditionally, secondary schooling curricula have emphasized preparation for higher education, focusing on topics like science, mathematics, and literature. Recently, there has been a trend towards improving the employment prospects of secondary school graduates, leading to noticeable growth in TVET programs.

TVET programs typically have three components (UN Department of Economic and Social Affairs, 2011) (Leke, et al., 2010) (Alemu, 2012):

- General life and workplace skills, such as financial literacy and workplace etiquette.

- Training for jobs in specific industries such as plumbing, furniture making, and various other trades.
- Entrepreneurship training, so that individuals can build their own businesses.

Examples of programs which offer different flavors and combinations of these components, include: Junior Achievement Worldwide (which, through affiliates like INJAZ Al-Arab, relies on community volunteers from various professions to train and mentor youth using a standardized curriculum), Fundacion Paraguaya (which focuses on entrepreneurship, supported by microfinance), Go For Gold (a program in South Africa which prepares graduates for employment in the construction sector), Aflatoun (which helps teenagers learn financial literacy and entrepreneurship through a learning-by-doing model), and the African Leadership Academy (which incorporates aspects of African History, leadership development and entrepreneurship in a standard secondary school curriculum).

TVET is a new trend, however, and very few secondary schools in developing countries incorporate TVET into their formal secondary education curricula. In addition, only a small number of youth in developing countries enroll in formal TVET programs outside of secondary schools (Betcherman, et al., 2007). Note that TVET programs are not just for students of secondary school age, they can extend to students in older age groups, as well as to adults.

Out of the 256 million youth (ages 15-19 years) in sub-Saharan Africa and South Asia, about 62 million—based on an estimate of the percentage of students with access to trained teachers (UNESCO Institute for Statistics, 2012)—are enrolled in secondary schools of seemingly adequate (or superior) quality; 33 million are enrolled in schools of inadequate quality; about 5 million are enrolled in some formal TVET program, outside of the secondary school system (although data on TVET enrollment is sparse); 95 million are literate but get little to no formal TVET or secondary education, and the remaining 62 million are not literate enough to participate in any formal secondary level education even if it were accessible (UNESCO Institute for Statistics, 2012)[5] **(Exhibit 14)**. Of these 256 million youth, approximately 55% (141 million) are engaged in paid work (Betcherman, et al., 2007).

Youth across the education spectrum in South Asia and sub-Saharan Africa [6]

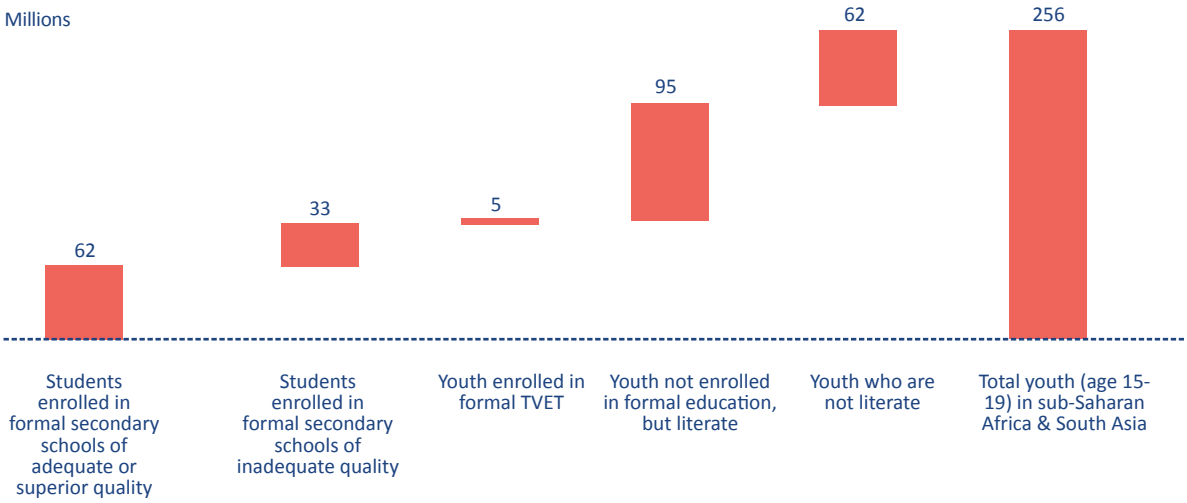


Exhibit 14: 95 million youth do not receive any formal post-primary education and only a small number (5 million) receive TVET.

[5] Note that statistics for education and literacy for youth 15-19 do not exist in any single source. These estimates are based on data available from multiple sources for different age ranges (chiefly the UNESCO Institute for Statistics), but normalized for the 15-19 age group.

[6] LIGTT analysis based on different sets of data.

TERTIARY EDUCATION

In order to become competitive in the global economic ecosystem, it is essential for countries to have a large workforce with advanced education in a broad range of areas such as engineering, the sciences, medicine, and business management. The most salient fact about post-secondary or tertiary education in developing countries is that a very small portion of the population participates in it. Furthermore, even those with advanced degrees are not guaranteed appropriate jobs **(Exhibit 15)**. Tertiary enrollment in both South Asia and sub-Saharan Africa is extremely low. The enrollment rate among women and men in sub-Saharan Africa is 5% and 7% respectively, and in South Asia it is 10% for both men and women **(Exhibit 16)**.

Education levels of the unemployed population in South Asia and sub-Saharan Africa

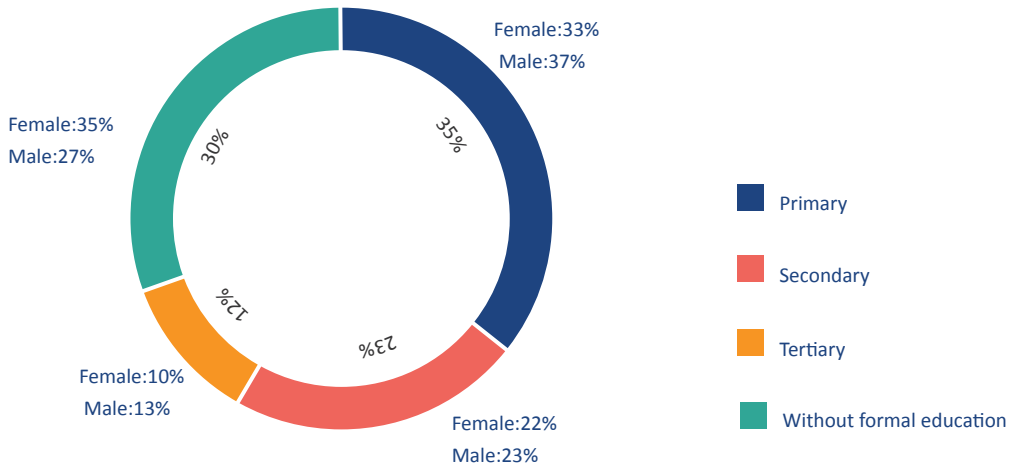


Exhibit 15: In South Asia and sub-Saharan Africa, education does not guarantee employment; 23% of unemployed individuals in these regions have a secondary education, and another 12% have a tertiary education. The data is not significantly different across gender lines. Note that the data does not discuss underemployment, which can also be a major issue.

Tertiary level education enrollment rates

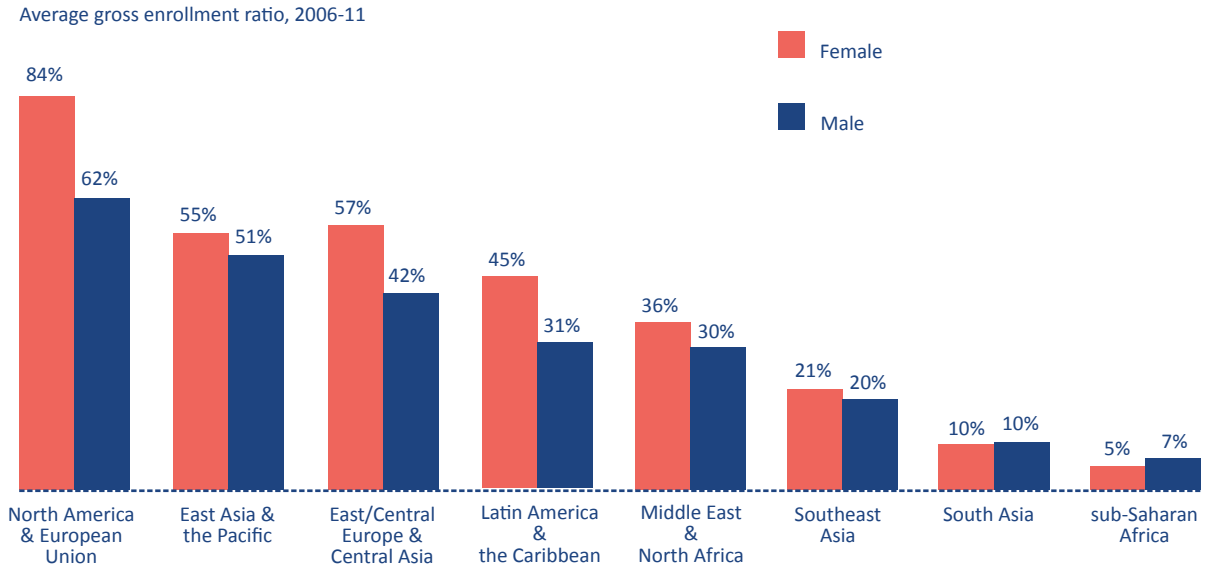


Exhibit 16: Tertiary enrollment in sub-Saharan Africa and South Asia is a fraction of that in industrialized countries, across both genders.

8 The majority of college students in developing countries are enrolled in public institutions

In most developing countries, youth with secondary schooling generally have two educational tracks to follow: a 3 or 4 year undergraduate program, provided at colleges and universities, or a post-secondary TVET program. The latter are typically small and fragmented, can vary in duration from a few months to 2 years, and provide education at a level somewhere between undergraduate degrees and secondary-level TVET. Currently, the majority of students receiving undergraduate education in developing countries are enrolled in public universities (World Bank: Task Force on Higher Education and Society, 2000). Higher education programs in developing countries face a number of challenges: limited resources, curricula that are not aligned with the demands of the job market, lack of accountability, and incentives that are not aligned with outcomes. Unlike primary or secondary education, there are limited opportunities for NGOs to make a significant difference in undergraduate-level education; the depth and breadth of expertise and resources required to create a university-level institution is beyond the means of most NGOs. Notable exceptions include Aga Khan University, which operates in several countries in Asia and Africa, and BRAC University in Bangladesh; both are part of two of the world's largest NGOs.

9 The focus of tertiary education in Africa is on humanities and social sciences, more than on technical areas like engineering and medicine; this is at odds with employment prospects

Over the past two decades, South Asia's largest country and economy, India, has witnessed considerable economic growth. By many accounts, this has been powered by the large technically trained workforce and a dramatic increase in the number of institutions providing relevant tertiary education (Dinakar, 2007) (CLSA, 2008). This phenomenon, however, is not uniform across income groups in South Asia; it is even less promising in sub-Saharan Africa (Chynoweth, 2012).

Exhibit 17 shows the academic disciplines in which college students in sub-Saharan Africa typically enroll. The social sciences (including business and law) and humanities (including the arts) account for 48% of all enrollment, education for 14%, and the pure sciences for another 10%. Only 6% study engineering, manufacturing and construction, another 7% are in health and medicine, and only 3% are in agriculture (UNESCO Institute for Statistics, 2012). In order to be relevant to students and help them gain meaningful employment, the academic coursework offered will need to closely match the industrial sectors and functional areas with the greatest opportunity. **Exhibit 18** shows an illustrative analysis of these industries in Africa, based on the intersection of the share of national economic growth and the multiplier factor. According to this analysis, the most attractive sectors are: agriculture and agribusiness, wholesale and retail, transport and telecom, and financial services.

Cross-referencing the tertiary enrollment data **(Exhibit 17)** against the industries which offer the best opportunities for employment **(Exhibit 18)** in Africa, shows that fewer than half of the students who invest in tertiary education in sub-Saharan Africa get the education they need to meet the human capital needs of the industries that offer the best job prospects **(Exhibit 19)**. Not surprisingly, many multinational corporations in Africa have trouble finding local talent to fill executive roles and seek expatriates from other countries (typically from the US or from the EU) to fill such roles (Chynoweth, 2012).

Academic disciplines of tertiary level students in sub-Saharan Africa

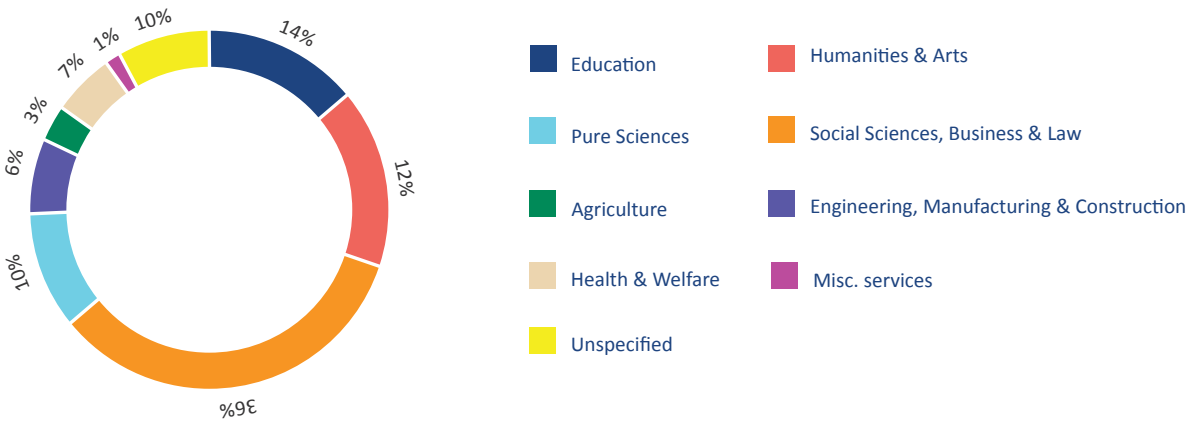


Exhibit 17: Almost 75% of students enrolled in tertiary education in sub-Saharan Africa focus on social sciences, business & law (36%), humanities & arts (12%), education (14%), and the pure sciences (10%). Only 6% are in engineering and related fields, 7% in health, and 3% in agriculture.

Industries in Africa with the greatest opportunity for future job placements

Ranked by share of recent econmic growth (2002-07) vs. employment multiplier

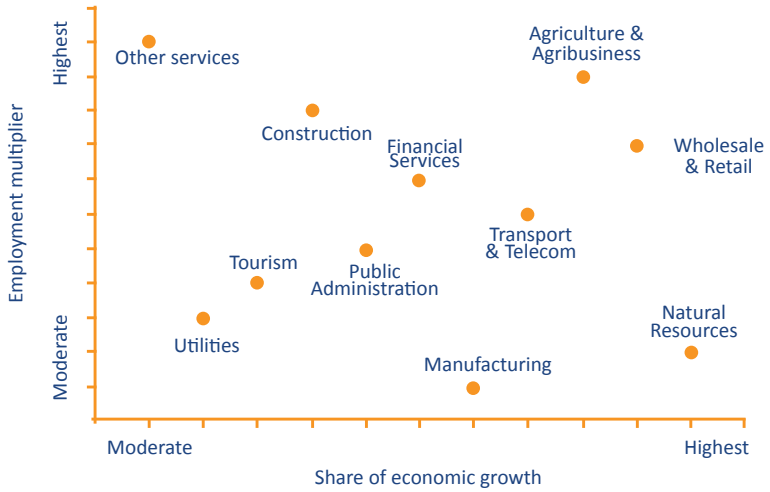


Exhibit 18: Illustrative analysis mapping industries based on their potential for creating local jobs, along two dimensions. The agriculture & agribusiness and the wholesale & retail sectors offer the best opportunity, while the natural resources and manufacturing sectors are growing strongly without creating many local jobs.[7]

Cross-reference of current tertiary enrollment in sub-Saharan Africa against needs of high-potential industries

Assessment of how well the tertiary education system meets industry human capital needs

HIGH-POTENTIAL INDUSTRIES	ACADEMIC DISCIPLINE OF ENROLLED STUDENTS							
	Education	Humanities & Arts	Social Sciences, Business & Law	Pure Sciences	Engineering, Manufacturing & Construction	Agriculture	Health & Welfare	Misc. services
Agriculture & Agribusiness	Low	Low	Medium	Low	Low	High	Low	Low
Wholesale & Retail	Low	Low	High	Low	Low	Low	Low	Medium
Transport & Telecom	Low	Low	Medium	Low	High	Low	Low	Low
Financial Services	Low	Low	High	Low	Low	Low	Low	High
Construction	Low	Low	Low	Low	High	Low	Low	Low
Public Administration	Low	Low	Medium	Low	Low	Low	Medium	High
Natural Resources	Low	Low	Low	Medium	High	Low	Low	Low
Tourism	Low	Low	Low	Low	Low	Low	Low	High
Manufacturing	Low	Low	Low	Low	High	Low	Low	Medium
Utilities	Low	Low	Low	Low	Medium	Low	Low	Medium

Exhibit 19: Tertiary education systems in sub-Saharan Africa do not appear to be geared toward the human capital needs of the industries which offer the highest opportunities for employment.

[7] This illustrative analysis uses incomplete data from multiple sources, and is not meant to be the kind of rigorous assessment required for a thoughtful education policy.

KEY CHALLENGES

PRIMARY EDUCATION

There are a number of reasons why such a large number of children in lower income countries do not receive adequate education at the primary school level. The entire spectrum of challenges can be split across two overarching issues. First, the lack of access to an education. Second, the quality of education.

1 Lack of access to education is driven by 7 factors

Access to schools is the first step toward an appropriate education. Lack of access—even of inadequate quality—is caused by several, sometimes overlapping, factors.

There simply aren't enough schools

Many remote, sparsely populated, and isolated areas simply do not have schools within reasonable reach. Public school systems in poorer countries are not adequately funded, leading to an overall lack of infrastructure. Annual public spending per student in sub-Saharan Africa and South Asia is $331 and $396, respectively, a small fraction of that in higher income regions **(Exhibit 20)**. Furthermore, only a portion of that budget actually goes to directly educating children while the rest of it goes toward paying for system overhead (e.g., the education ministry, administrators, etc.). Even as there is limited data to show the actual distribution of funding between direct instruction-related activities and system overhead, the dismal condition of many schools is indicative of the allocation and distribution of funds. Many schools across Africa[8] do not even have basic amenities such as electricity (only 24%), potable water (50%) and toilets (61%) (UNESCO Institute for Statistics, 2012) **(Exhibit 21)**. In addition, there is a severe lack of textbooks; 2.6 and 2.3 students, respectively, have to share a single textbook for Mathematics and Reading. It is important to note that in these lower income countries, there are also examples of school systems, which appear to provide quality education for $100 or less per year per student (Kristoff, 2010).

Public expenditure on primary education

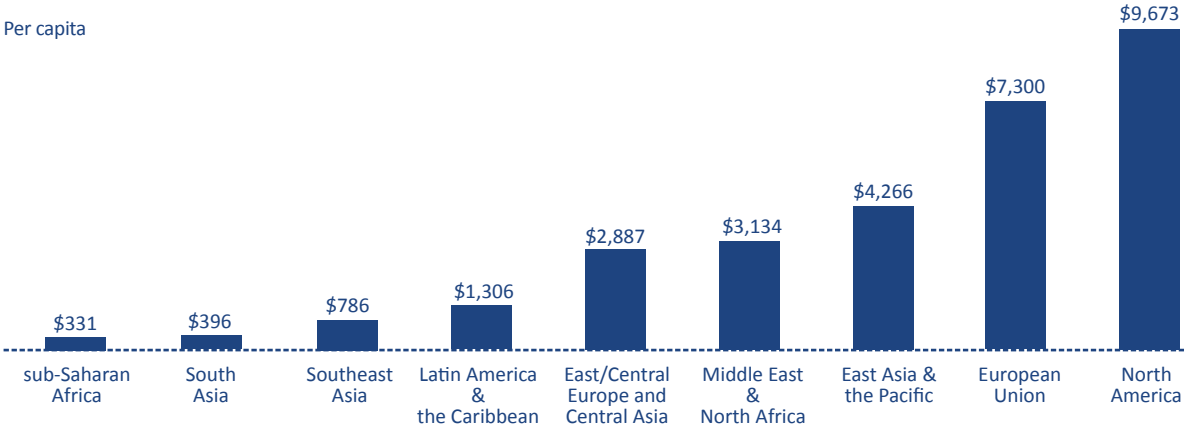


Exhibit 20: Government expenditure on primary education in sub-Saharan Africa and South Asia is a small fraction of that in wealthier countries.

[8] The data represents schools from Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Côte d'Ivoire, the Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Madagascar, Malawi, Mali, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Tanzania, Togo, and Uganda.

Basic amenities in primary schools

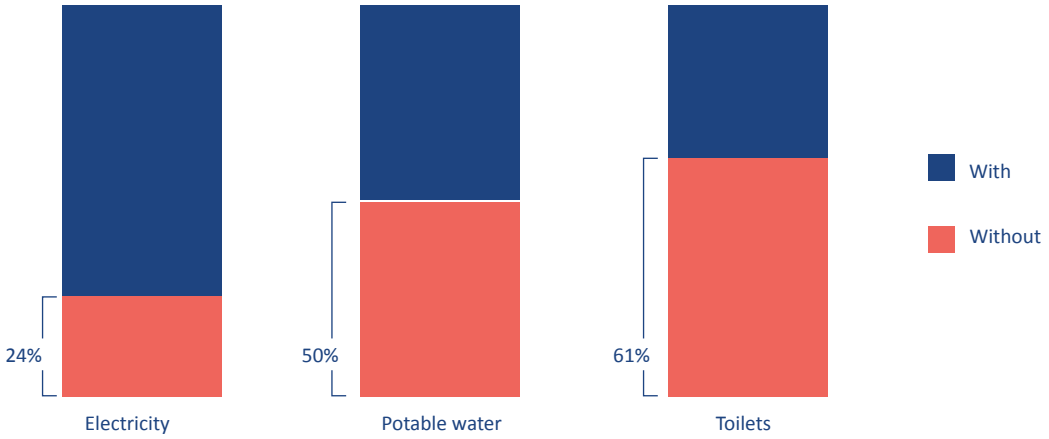


Exhibit 21: Most schools across Africa (according to new, somewhat sparse, data collected by UNESCO), do not have even the basic amenities.

There is a low (perceived or actual) value of education, especially compared with the opportunity cost of attending

The relatively low levels of financing notwithstanding, there is strong evidence suggesting that even the available funds are not spent efficiently or effectively in many countries (Lutyens, 2011) (Tooley, 2009) leading to schools of very poor quality. As a result, many parents do not find schooling attractive or useful in any way and simply pull their children out of the schools.

A large number of children cannot afford school, and are engaged in child labor

Globally, over 300 million children between the ages of 5 and 17 years are engaged in employment (Diallo, et al., 2010), most of whom work to financially support their families. Child labor is a significant contributor to children being out of school. A study conducted by UNICEF across a number of African countries (Gibbons, et al., 2005) found that an average of 21% of out-of-school children are engaged in labor **(Exhibit 22)**.

Minority groups are often excluded, intentionally or through neglect

In many countries with high ethnolinguistic fragmentation, many minority groups can find themselves disenfranchised, and their children deprived of opportunities for education. This can happen either because of passive underinvestment by the government in particular geographies where the ethnic minorities are concentrated, or because of active discrimination (IRIN, 2011).

Some cultures traditionally have not valued education

Some communities have traditionally not considered participation in formal education a priority. For example, throughout South Asia, which has one of the highest out-of-school populations in the world, formal education of girls is discouraged (Latif, 2000). In addition, nomadic populations across the world have also tended to deprioritize formal education (Carr-Hill, 2005).

Poor health and nutrition can prevent children from going to school

While there is limited data on how many children stay out of school because of ill health, a number of programs (NUEPA, 2008) (Chege, 2012) have found that providing hot, nutritious meals to children on school-days markedly increases their participation in schooling.

Prevalence of child labor among out-of-school and school-going children

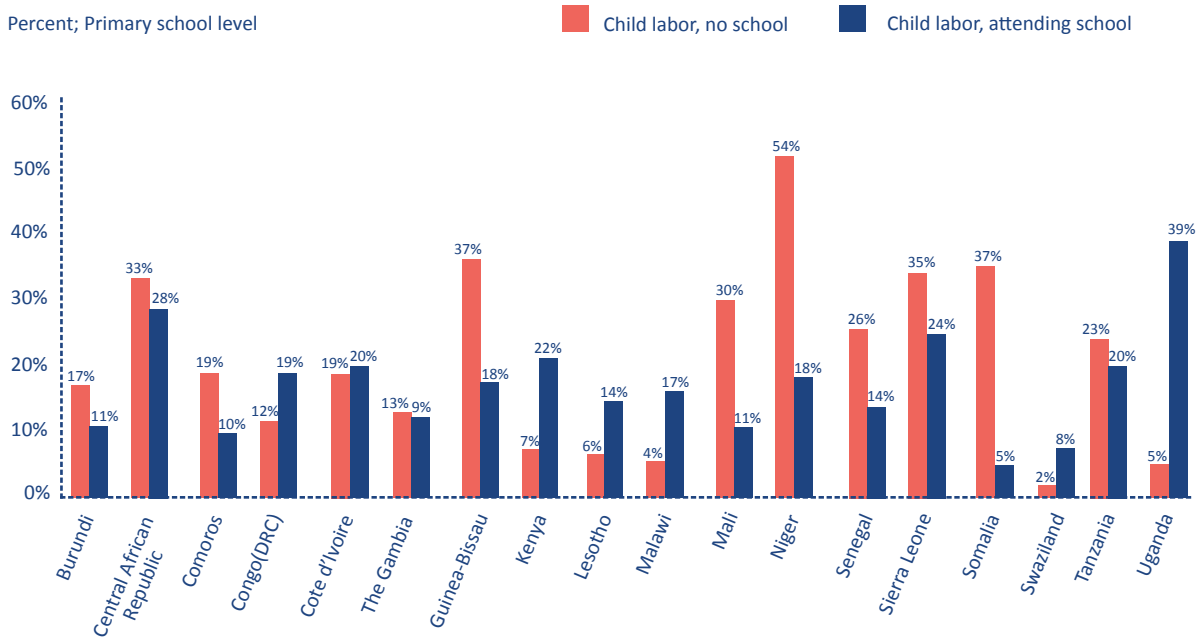


Exhibit 22: A large number of out-of-school children—approximately 21% in a study across a number of African countries—are engaged in child labor.

There are a number of hurdles specific to some population segments

The challenges described above tend to affect children living in different contexts, and from different population segments, in different ways.

Remote and hard-to-reach areas: For children who live in remote or hard-to-reach rural areas, access is a core concern. The majority of people in sub-Saharan Africa and South Asia live in rural areas, and less than 20% of the roadways in these areas are paved (World Bank, 2011). These areas typically have a low density of schools, few qualified teachers (with limited incentives for qualified teachers from urban areas to relocate), little in the way of transportation to help students reach schools in nearby towns, and poor local governance to oversee the quality of education. There is also a high incidence of child labor in rural areas. More than 60% of all children work in agriculture, two-thirds of whom work, unpaid, for their family (Diallo, et al., 2010).

Urban slums: The situation is markedly different for children living in urban slums. Urbanization is a growing phenomenon in sub-Saharan Africa and South Asia. Children in poor, urban settings face a range of issues which are different from issues poor children face in rural settings (Mander, 2009). People living in urban slums are often separated from their communities and (typically informal but traditional) social safety nets. The physical environments in which the urban poor are forced to live in are more vulnerable (with few assets, and little security for the assets they do own) and degraded than those in rural areas. Because urban economies tend to be more monetized than rural economies, the urban poor find themselves needing to pay cash for many more things than their rural counterparts. The urban poor also tend to be subject to far greater levels of violence from state actors (e.g., the police) as well as criminals. Children are often also subjected to many forms of exploitation or violence, with many of them being forced to beg. Children of first generation migrants to urban

areas can be even worse off, since they do not have a permanent place of residence, or necessary documentation. This indirectly excludes them from being able to access whatever little they otherwise can in the form of state-provided education and healthcare facilities. All of this put together, creates a very precarious environment for children to live and grow in, let alone seek an education.

Refugee and displaced populations: Even more vulnerable are children among refugee and internally displaced populations. Refugees and displaced people living in refugee-like situations do not have access to many services provided to populations living under more normal conditions. They are far removed from their own homes and assets, and often do not have a clear legal status where they live (whether in camps or urban settings). As of 2009, 31% children of primary school age were out of school in the major refugee camps around the world. The out-of-school rate was 37% among urban refugees. In total, more than 450,000 refugee children of primary school age are out of school (UNHCR, 2009). Since refugees usually do not have a steady source of income, most of the services they (and their children) receive, are provided by charitable agencies, and basics like shelter and food take precedence over education.

2 Quality of education remains poor and there is limited emphasis on outcomes

The gains made through the increasing rates of access and enrollment are undermined if the quality of teaching is subpar, schools are mismanaged, and learning outcomes achieved by children fall below minimum required age-appropriate benchmarks. A few factors play a central role in the overall quality of education that children receive.

There aren't enough well-trained teachers

As **Exhibit 5** and **Exhibit 6** illustrate, the required minimum qualifications for primary school teachers in most developing countries are low, and there is very limited on-the-job training once they begin teaching.

Accountability and incentives are often not aligned with actual education outcomes

A commonly cited problem, especially in government-run school systems, is that neither the school systems nor the teachers are accountable for actual education outcomes. Studies have found that the root causes for this lack of accountability are the excessive power of teachers' unions, and the general bureaucratic challenges that any large public system faces (Tooley, 2009) (Lutyens, 2011). In addition, low income parents are often not in a position to evaluate the quality of education, and rely on external indicators such as cleanliness of the buildings and toilets.

Teachers do not have adequate tools for instruction

Teachers need a range of tools—building blocks, maps, a variety of books, photographs, and ideally, computers—to offer children the breadth and depth of knowledge they require to be competitive in the long run. As **Exhibit 21** shows, many schools across Africa do not even have basic amenities such as electricity, potable water, and toilets (UNESCO Institute for Statistics, 2012). There are also severe shortages of textbooks and other school supplies. Tools such as computers are available only to students attending the most elite of schools.

SECONDARY EDUCATION

Globally, most hurdles that make primary education for the poor challenging, also apply to secondary education. In addition, there are 4 hurdles specific to secondary education.

3 There can be a high opportunity cost to secondary schooling. 152 million youth are from households below the poverty line of $1.25 per day (International Labour Organization, 2010). For youth living in such or even somewhat better conditions, there can be a significant opportunity cost to attending school. Income generated by these youth often constitutes a significant portion of their families' aggregate income. Not surprisingly then, 43% and 54% of youth in South Asia and sub-Saharan Africa, respectively, work to support themselves and their families (Betcherman, et al., 2007).

4 Secondary education is often not perceived as adding value. Almost by definition, the job market in low income countries is meager. Almost a quarter of unemployed people in sub-Saharan Africa and South Asia have a secondary education (International Labour Organization, 2010) **(Exhibit 15)**. This creates a disincentive for investing time in secondary education, especially considering the opportunity cost of forgone income. For most of these youth, formal secondary level education is not viewed as relevant for dramatically increasing incomes.

5 In the past, the global community has not emphasized youth education. There has not been as much emphasis—in global or national agendas—on youth education, as on primary schooling. For example, there is no Millennium Development Goal to promote youth education, nor any other concerted global effort.

6 Gender discrimination grows, as girls enter youth. Gender-based discrimination begins to play an increasingly major role as girls enter adolescence and early youth. Traditional practices force many young women from low income families to marry or take on other household responsibilities including caring for younger siblings or the elderly.

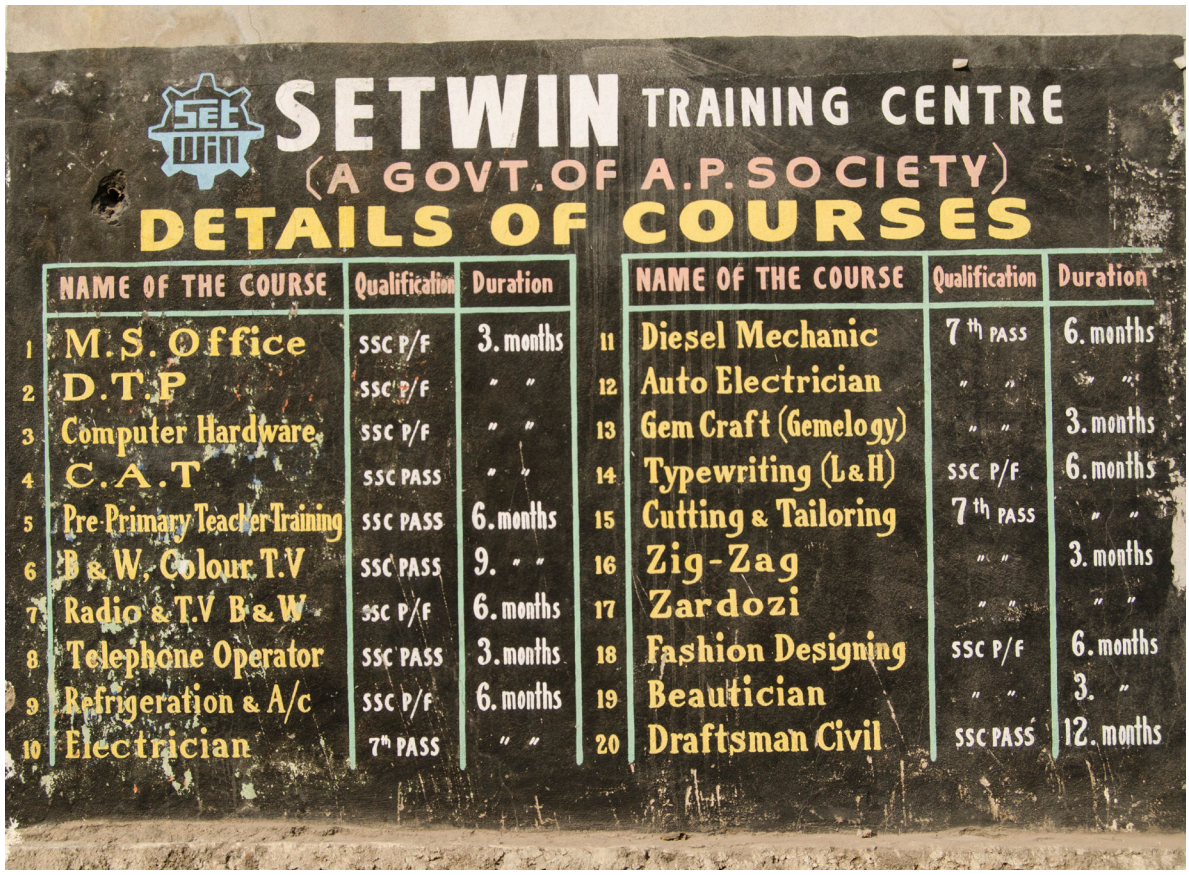
TERTIARY EDUCATION

The challenges of providing affordable, quality and relevant tertiary education to low income populations in developing countries, are an extension of the challenges in secondary education.

7 There is a very high opportunity cost to higher education. Low income individuals older than 19 years face an extremely high opportunity cost of spending years in school rather than earning a living.

8 Curricula are not aligned with employment opportunities. The majority of colleges and universities do not prepare students for the demands of the job market, with respect to growth industries, or functional specialization. As a result, many of the most attractive roles in the private and NGO sectors are occupied by expatriates from industrialized countries.

9 There are not enough jobs. The economies in most countries in sub-Saharan Africa are not strong enough to absorb a large number of graduates with advanced degrees. Consequently, there are few clear incentives for individuals to invest in higher education. This, in turn, creates a vicious cycle with the two aforementioned challenges.



SCIENTIFIC AND TECHNOLOGICAL BREAKTHROUGHS

Solving the broad problem of education requires fundamental, systemic improvements on three key fronts. First, infrastructure—construction of a large numbers of schools with appropriate amenities. Second, human capital—training and certification of all teachers. And third, policy changes—to ensure the system is accountable to students and parents, and the curricula are relevant. In all likelihood, achieving this will require a combination of both private and public systems, with the former leading the charge in innovation, and the latter, to ensure universal and equitable access. While the role of technology may not be central here, 1 breakthrough can play a powerful part in achieving dramatic improvements in overall access to quality education and learning outcomes.

'Smart' electronic textbooks, customized for various age groups and educational levels, with curated and up-to-date content, 'wiki' interfaces for vernacular and other locally relevant and gender-inclusive material, visual and dynamic learning tools for students, interfaces and tools for teachers, student-teacher interaction and peer-to-peer collaboration. These smart e-textbooks can be delivered on tablet devices or on smartphones, the prices of which are steadily falling.

While 'smart' devices like touchscreen phones and increasingly powerful tablets are well on the path to becoming as ubiquitous as the basic mobile phone, digital educational content has not kept pace. There are isolated pockets of exceptional content (e.g., videos by the Khan Academy), but there is very little in the way of curated and structured material which is suited to country-specific curricula for various stages of education, and ready for use off-the-shelf. Grade-specific 'smart' electronic textbooks with the following features can be a very powerful way of compensating for systemic gaps in infrastructure, human capital, and policy. Potential features include:

- Digitized textbooks across all disciplines, based on the curricular standards established by existing school systems (e.g., international standards like A-level/O-level and International Baccalaureate, and national standards like ICSE or CBSE in India).
- A repository of regularly refreshed supplementary material that may be curated from 'best of' writings, recordings of experiments, instructional videos, research papers, recordings of historical or public events.
- A dynamic, interactive, customized, intelligent and adaptive learning mechanism in which students' performance on problem sets determines the pace of content and learning, using a rules engine which inserts introductory material and remedial problem sets, as required.
- A peer-to-peer 'wiki' collaboration platform, which allows students and teachers to exchange ideas, engage in virtual Q&A, and share relevant curated or created content, including local language and gender-inclusive content and videos.

In principle, all ecosystem ingredients are already present to create such e-textbooks, and various versions are available in industrialized markets. However, the control exerted by publishers and local school boards in markets like the US, appears to have contributed to the relatively slow emergence of disruptive innovations in content delivery. As a result, there are few platforms that can be immediately transplanted

to a developing country context. Still, with targeted investment and collaboration we believe something like this should be market-ready within 2-3 years.

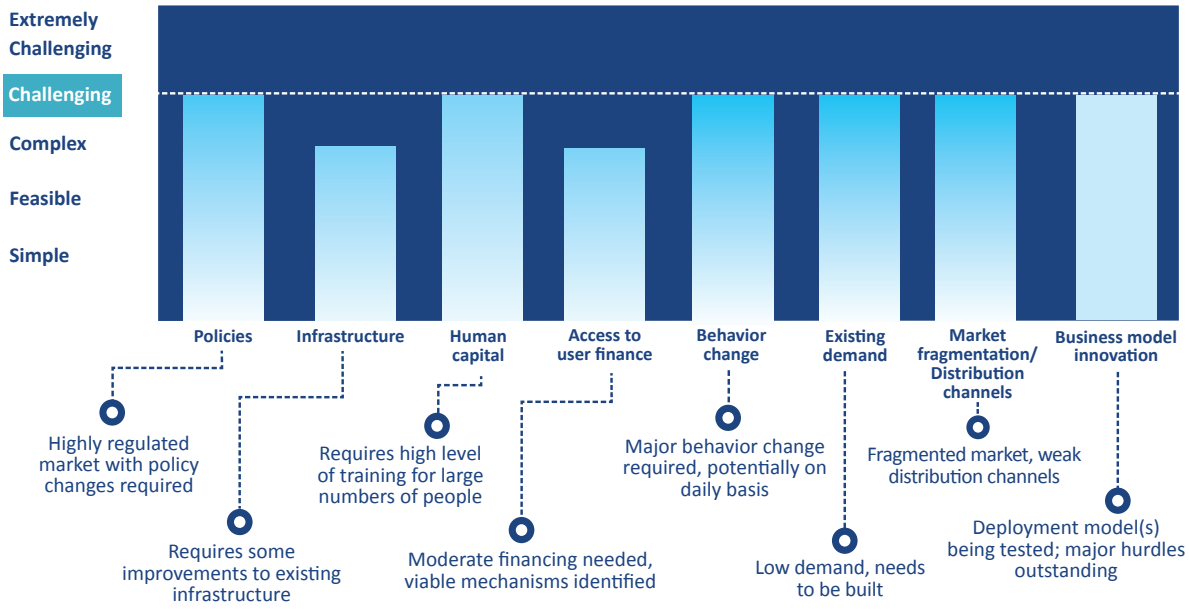
Meanwhile, tablet computers are becoming increasingly affordable and readily available. Tablets—and to a somewhat smaller extent, smartphones with touchscreens—offer the perfect platform through which such a breakthrough can be deployed on a large scale. Both devices have significant advantages over traditional keyboard-based computers, especially for children. Not only are they light, portable, and very easy to carry (even by small children), their touchscreen interface makes them more intuitive to use. Compared to keyboards, which require a certain literacy level and can be very cumbersome for children or other users who are unfamiliar with them, tablets are easy to interact with and handle. Already existing, standard applications make it possible to access visually rich and dynamic content on the web and easily share it. Utilizing in-built tools, applications and other programs, children can easily customize pictures they take or content they create and share it as well. This creates a rich, highly personalized and empowering experience for children. As technology advances, tablets will come with higher storage capacities, making them conducive for processing large amounts of data and content, and—like personal computers and laptops—capable of storing individual and customized usage histories. Although there is still a long way to go before tablets and smartphones can be considered affordable to the very poor, they are close to being affordable at a community level, so that they can be shared by groups of students in a school. The section on Digital Inclusion discusses the prospects for truly affordable devices, and what it will take to get there.

Despite the momentum in the global information and communication technology revolution, there will be a number of challenges such smart textbooks will have to overcome, once they are introduced to the market:

- Educational ministries and school systems will need to recognize the value of such a technology and its compatibility with existing curricula.
- Demand needs to be built with teachers and students, who will need to change daily behavior, and learn to use them effectively. Rapid adoption of mobile technologies suggests this is possible.
- Some effort will be required to ensure the availability of power (to charge the devices), and wireless connection.
- Despite the falling costs of tablet devices, some financing will be necessary for lower income students.
- Even though schools systems—especially public schools—operate through some form of centralized control, the market is still highly fragmented.
- There is no business model precedent; deployment models will need to very innovative to address all aforementioned hurdles.

Considering all of the above factors, we believe that deployment will be CHALLENGING.

Breakthrough 1 – Difficulty of deployment



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