Mathematics Education in Sub-Saharan Africa: Status, Challenges, and Opportunities

CAMBRIDGE EDUCATION

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June 2016

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Acknowledgements

The author would like to thank all those who have contributed to the conduct of the study and to the preparation of this report.

First and foremost, thanks are due to Sukhdeep Brar, former senior education specialist at the World Bank, who developed the concept and secured support and funding for the study. Thereafter, Sukhdeep made major contributions to the collection of resources, report writing and peer review processes. Thanks are also due to Ryoko Tomita, World Bank economist, who assumed responsibility for the study and saw it through to completion.

The study was conducted by Cambridge Education where thanks are due to John Martin, Jawaad Vohra and, in particular, Elisabetta Naborri who co-ordinated all study activities including the surveys conducted in six focus countries.

Special thanks are due to the international experts Kwame Akyeampong and Ernest Ampadu who helped in the design of the study and checked the accuracy of the report's mathematical and pedagogical content.
In addition, the author is most grateful to the national experts who co-ordinated the classroom observations and the application of teacher questionnaires in the study's six focus countries: Napthalin Achubang Atanga (Cameroon); Pierre Gambembo Gawiya (DRC); Steve Dele Oluwaniyi (Nigeria); Emma Furaha Rubagumya (Rwanda); Caroline Taliba (Uganda); and, Candid Services PLC (Ethiopia). Thanks are also due to Ayesha Khan who analysed the in-country data and organised the information presented in Appendix A of this report.

Finally, our thanks go to the World Bank's peer reviewers Marguerite Clarke and Andrew Ragatz. Their corrections and proposals for revision enhanced the quality of the final report which, we hope, will be of interest and value to its readers.

About the author

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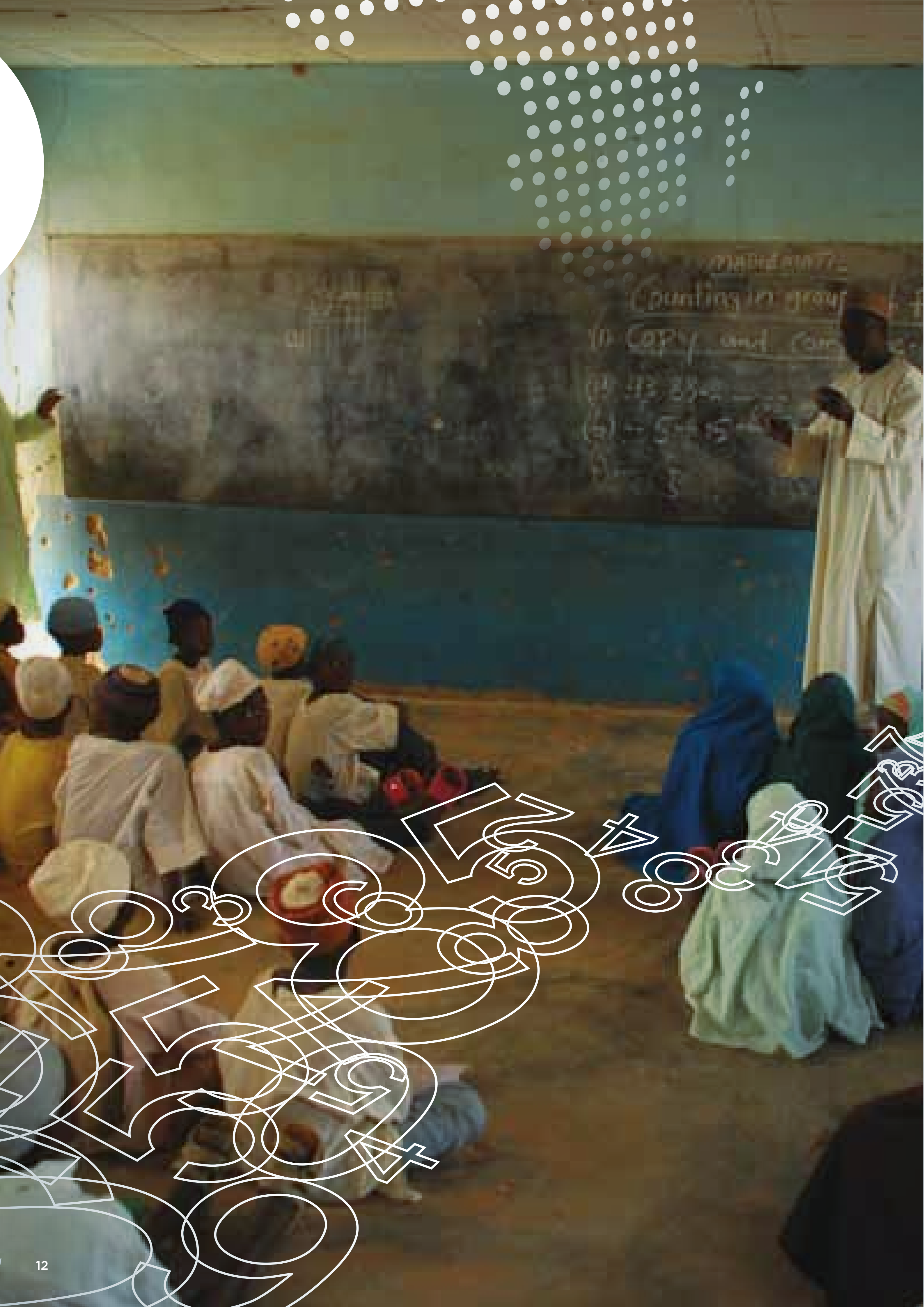
Abbreviations and acronyms

AIMS	African Institute for Mathematical Sciences
AIMSSEC	African Institute for Mathematical Sciences School Enrichment Centre
CAI	Computer Assisted Instruction
CAR	Central African Republic
CCSS	Common Core State Standards (USA)
CCSSO	Council of Chief State School Officers (USA)
CEI	Centre for Education Innovations
CML	Computer Managed Learning
CONFEMEN	La Conférence des Ministres de l'Education des pays ayant le français en partage
CRFPE	Centre Régionale de Formation de Personnels de l'Education de Dakar
CSEE	Certificate of Secondary Education Examination (Tanzania)
DRC	Democratic Republic of the Congo
ECCD	Early Childhood Care and Development
ECCE	Early Childhood Care and Education
EFA	Education For All
EGMA	Early Grade Mathematics Assessment
ELM	Emergent Literacy and Maths (programme)
GBP	(Great) British Pound
GNP	Gross National Product
ICT	Information and Communications Technology
IEA	International Association for the Evaluation of Educational Achievement
ILSA	International Large-Scale Assessments
IMF	International Monetary Fund
IMO	International Mathematical Olympiad
IMU	International Mathematical Union
IRT	Item Response Theory
KCPE	Kenya Certificate of Primary Education
LAC	Latin American and Caribbean
LMIC	Low- and Middle-Income Countries
MED	Microsoft Education Delivery (platform)
MLA	Monitoring of Learner Achievement
NA	National Assessment
NAEP	National Assessment of Educational Progress (USA)
NAT	National Assessment Test (The Gambia)
NC	Numbers Count (UK)
NCLB	No Child Left Behind (USA)
NCERT	National Council for Educational Research and Training (India)
NCTM	National Council of Teachers of Mathematics (USA)

NGA	National Governors Association (Center for Best Practices) (USA)
NGO	Non-Government Organisation
NLSA	National Large-Scale Assessments
NQT	Newly Qualified Teacher
OECD	Organisation for Economic Co-operation and Development
OER	Open Educational Resources
PASEC	Programme for the Analysis of Education Systems
PIRLS	Progress in International Reading Literacy Study
PISA	Program for International Student Assessment
PLE	Primary Leaving Examination
PRIMR	Primary Maths and Reading Initiative
RESAFAD	Réseau Africain de Formation à Distance (Sénégal)
RCT	Randomised Control Trial
RSA	Republic of South Africa
SABER	Systems Approach for Better Education Results
SACMEQ	Southern African Consortium for Measurement of Educational Quality
SC	Save the Children
SD	Standard Deviation
SE	Standard Error (of a Mean)
SES	Socio-Economic Status
SSA	Sub-Saharan Africa
STEM	Science, Technology, Engineering and Mathematics
TAC	Teachers' Advisory Centre (Kenya)
TESSA	Teacher Education in Sub-Saharan Africa
TIMSS	Trends in Mathematics and Science Study
TLM	Teaching and Learning Materials
TTI	Teacher Training Institution
UIS	UNESCO Institute for Statistics
UK	United Kingdom (of Great Britain and Northern Ireland)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
USAID	United States Agency for International Development
USD	US Dollar
WAEC	West African Examinations Council
WASSCE	West African Senior School Certificate Examination
ZIMSEC	Zimbabwe Schools Examinations Council



Mathematics Education in Sub-Saharan Africa:

Executive summary

The World Bank commissioned this study in support of its efforts to improve mathematics education in the countries of Sub-Saharan Africa (SSA). It was commissioned in response to a growing recognition that countries in SSA will need to boost performance in the Science, Technology, Engineering and Mathematics (STEM) subjects if they are to realise their full potential in a competitive global market increasingly shaped by the use of new technologies. At present it is feared that the region's economic development is being impeded by the limited availability of high-quality education. In particular, poor performance in mathematics in primary and secondary schools is seen as a significant barrier to improved economic and social outcomes both at the level of the individual and of the nation.

Key objectives

The study's first key objective was to document the current state of mathematics education across this vast and diverse region drawing primarily on research reports and evidence from international, regional and national assessments of learner achievement in mathematics. Evidence from the literature was supplemented with data gathered in six countries via classroom observations and the application of teacher questionnaires. The focus countries were Cameroon, Democratic Republic of the Congo (DRC), Ethiopia, Nigeria, Rwanda, and Uganda. The second key objective was to identify interventions which, evidence suggests, have the potential to successfully improve mathematics education either directly or indirectly through raising the general quality of education. The third key objective was to extract the main findings and to present them along with a range of suggestions for the consideration of national educational policy makers and the various stakeholders with roles to play in improving mathematical outcomes in schools and other educational institutions. These include inter alia, international development banks and aid agencies, non-governmental organisations (NGOs) and philanthropic institutions working in the field of mathematics education, and the national and international assessment and research communities responsible for gathering, analysing and interpreting data. It is these stakeholders who will inform the decision making process, formulate policies, and implement reforms to guide and support the practitioners – especially teachers of mathematics – who, ultimately, will improve the mathematics education of learners.

Report structure

Chapter 1 of this report lists the constituent countries of SSA and describes the study's research questions and methods. Chapter 2 explores the economic and social arguments for making the improvement of mathematics education in the region a priority. Chapter 3 presents evidence as to current levels of numeracy and mathematical competence in the countries of SSA from a wide range of assessments. Chapter 4 looks at factors which have the potential to raise mathematical achievement indirectly by improving the quality of schooling in general. Chapter 5 considers the effectiveness of various interventions targeted specifically at improving mathematical outcomes. Chapter 6 and Chapter 7 are dedicated to issues concerning the capacities of serving teachers of mathematics and the pre-service training arrangements for those preparing to teach mathematics in schools. Chapter 8 describes assessment practices and their potential roles in improving learning outcomes. Chapter 9 gives an overview of a range of more recent initiatives designed to improve mathematics education both in SSA and beyond. Chapter 10 summarises the study's main findings and sets out some suggestions for overcoming barriers to progress. Finally, Appendix A sets out the findings of the in-country surveys. In particular, it includes descriptions of 'signature mathematics lessons' for each country compiled from data gathered during classroom observations.

Main findings

Investment in education yields significant returns for individuals, communities, and nations. Returns are maximised when the education system promotes the acquisition of critical cognitive skills - linguistic literacy, mathematical literacy, and problem solving skills. In an increasingly technological world, mathematical literacy (and its precursor, numeracy) is emerging as the most important of the cognitive skills. Unfortunately, a large body of evidence shows that mathematics education in SSA is in a precarious state. The learning deficit between countries in the region and international norms is so large that, without extensive and sustained interventions across all phases of education, the gap may never be narrowed let alone closed (Beatty and Pritchett, 2012).

Outcomes in mathematics are inextricably linked to the general quality of schooling offered to learners. Providing access to high quality schooling for all would inevitably raise average achievement levels in mathematics. The term 'quality of schooling' covers many factors: adequate financial resources; good physical structures; access to utilities and services (e.g., potable water, electricity, and internet services); availability of teaching and learning materials (TLMs) and educational technologies; effective school managers; and, above all else, well-trained and highly-motivated teachers. Financial investment in schools serving disadvantaged communities is of particular importance when it comes to improving educational outcomes and addressing issues of inequity. Spaull (2011) uses SACMEQ data to show that the socio-economic status (SES) of the school is a significantly more important factor in determining outcomes than the SES of the student and their family. Notwithstanding the above, in SSA mathematics education requires special attention for three reasons. First, it is a priority because the economic strength of a nation depends on the capacity of its education system to produce workers and consumers who are mathematically literate. Secondly, the learning deficit in mathematics for most countries in SSA is huge and shows no signs of diminishing. Thirdly, widely held negative attitudes towards mathematics together with an expectation of failure represent a significant barrier to progress.

The factors that contribute to low levels of student achievement in mathematics in SSA are numerous, varied, and interconnected in complex ways. There is no magic bullet. Any solution will require simultaneous actions on many fronts. Mounting a comprehensive and coherent campaign to raise the quality of mathematics education will require careful planning and significant investment. Even with a suitable plan in place the inertia associated with large education systems will be difficult to overcome: governments and other stakeholders will need to sustain their efforts over the long-term. There is no quick fix.

Whilst many problems will need to be addressed, probably the most important group of interventions will be those concerned with equipping existing and future teachers of mathematics with the knowledge and competences necessary to help learners acquire deep understanding of mathematical concepts. Enhancing in-service training opportunities and ensuring that teachers have access to high quality TLMs and educational technologies will bring some benefits. However, in the longer-term steps must be taken to reform the initial teacher training programmes for teachers who will teach mathematics at the primary or secondary levels. Without radical reform, inadequate initial teacher training will remain part of the problem and poorly prepared teachers will continue to serve as a brake on progress towards better outcomes in mathematics.

Increasingly, new technologies seem to hold possible solutions for many of the problems associated with raising educational quality in general and mathematical standards in particular. However, as yet it is not clear which approach will deliver the greatest returns in the context of SSA; cost effectiveness and long-term sustainability remain concerns. In particular, investing heavily in inflexible hardware configurations and/or committing to single-source commercial software packages would appear to be a risky strategy. On the other hand, harnessing the internet simply to deliver a wide range of resources to educational institutions, teachers, students and their parents is relatively cheap and likely to bring benefits with few attendant risks.
A number of interventions are suggested below. It should be noted that the order in which they appear is not intended to suggest a hierarchy of priorities. All, and others besides, will need to be included in any comprehensive action plan.

Suggested interventions

1. Raising the status of education in mathematics to that of a national priority

Governments should explicitly classify the raising of standards in mathematics (and other STEM subjects) as a national priority. This priority should be made clear in all national strategic plans and be reflected in all ministerial action plans. In practice, ambitious strategic objectives may be difficult to achieve but they will serve as a signpost indicating the desired direction of travel and guiding the actions of, for example, ministries of education.

Budgets for education in SSA tend to be severely constrained but the evidence is that increased per student expenditure is associated with better mathematical outcomes. Therefore, additional funding, over and above that for general education, should be allocated to interventions specifically targeted at improving mathematical outcomes at the primary, secondary and tertiary levels as a matter of priority.

International agencies that support governments in the implementation of educational reforms (e.g. development banks, donors, NGOs, philanthropic organisations, etc.) should reflect this shift in priorities in their policies and actions. For example, international development banks and aid agencies should require those preparing any support programme to state if/how proposed interventions will address the issue of promoting increased engagement with, and achievement in, STEM subjects.

2. Changing attitudes towards mathematics

Prevailing negative attitudes towards mathematics should be challenged both within the education sector and in the wider public arena through a comprehensive and sustained public relations campaign. The three key messages should be: (a) It pays to invest in the mathematical education of children because, amongst other benefits, success in mathematics is linked to greater economic returns; (b) Everyone can be successful in mathematics - you don't need to be born with a special ability; (c) Hard work in and out of school will bring better results in mathematics.

Special attention should be paid to changing the view that mathematics is predominantly a subject for boys. Schools, institutions of further and higher education, and potential employers should reinforce the message that careers in STEM-related fields offer valuable opportunities to all regardless of gender. Highlighting good female role models, using gender-appropriate learning materials, and adopting interactive teaching methods will help to improve the confidence (i.e. self-efficacy) of girls in mathematics and, hence, their achievement.

3. Improving initial teacher training

It is vital that new entrants to the teaching profession are properly prepared. Unfortunately, many TTI in SSA produce graduates who, as evidenced by the poor outcomes of their students, are not effective teachers of mathematics. In addition, TTI which fail to reflect the philosophy and methods of modern mathematics curricula in their courses serve as a block against progress towards raising levels of mathematical competence in schools. These must be transformed so that they become part of the solution.

Four key areas are in urgent need of reform: revising curricula of TTI; revising the way in which those curricula are delivered; making better use of new educational technologies; and, crucially, changing the profile of TTI tutors – especially those who are preparing teachers for the primary phase of education.

The curricula of TTI should be reviewed and revised to ensure that they (a) help trainees to develop a far deeper understanding of the mathematical concepts they will teach even if this means sacrificing the breadth of the content somewhat; (b) pay due attention to the development of pedagogical content knowledge, i.e. knowledge of the specialised teaching and learning processes associated with mathematics; and (c) provide trainees with practical strategies for working with learners who approach mathematical problems through various standard and non-standard routes. In short, the curricula of TTI and the way in which they are delivered should reflect best practice in the classroom.

Revising curricula and teaching programmes for TTI is important. However, it is not clear that the current managers and tutors of TTI are in a position to deliver a radically different approach to preparing new teachers. One significant deficiency appears to be a lack of tutors having first-hand experience of teaching in primary school classrooms. Correcting this will be neither easy nor quick. Selected tutors from those currently in post should be trained through a suitable professional development programme (including a practicum) to become qualified specialists in mathematics education. Financial incentives should be offered to those who successfully complete a certified course in, e.g. 'the teaching of mathematics in primary schools'. In addition, recognised career paths should be established, with incentives, to encourage outstanding teachers and/or principals from the primary sector to become specialist tutors in TTI.

There is an immediate opportunity to strengthen teacher training through the use of educational technologies but many TTI do not seem well-placed to take advantage of this. Without intervention, there is a danger that TTI will fall further behind and will not be able to prepare their trainees to make use of e-learning and m-learning tools. Governments should encourage partnerships between TTI and, for example, NGOs to build capacity and incorporate new technologies within the courses offered to prospective teachers. Fortunately, some examples of good practice are emerging in SSA. For example, in some countries TTI are already incorporating open educational resources (OER) made available by the Teacher Education in Sub-Saharan Africa (TESSA) initiative in their taught programmes.

The inertia of large organisations such as TTI may make it difficult to make significant progress quickly. However, individual trainees could respond far more quickly if they were encouraged to take greater responsibility for their own professional development. Therefore, TTI should formally and systematically advocate and facilitate self-development as an adjunct to their taught courses. Most importantly, trainees should be given free access to a wide range of materials and resources relevant to effective mathematics teaching. These should include both traditional TLMs (e.g. textbooks, teachers' guides, and exemplar worksheets) and e-based learning materials for both teachers and students. The key to this is for TTI to allow trainees free and unlimited access to the internet so that they can see, for example, video clips of model lessons and download materials for their own education and for use in their practicum.

4. Supporting practising teachers

Whilst the reform of initial teacher training is of paramount importance the needs of the existing teaching force must not be neglected. Existing in-service teacher training programmes for teachers of mathematics should be strengthened and, where necessary, new programmes should be developed. As a matter of principle, such training should form part of a formal continuum of professional development which "starts with pre-service education; includes periods of school-based enquiry and practice teaching; continues into an induction/mentoring period of introduction into full-time teaching; and is followed up with a continuous program of career-long professional development, support and supervision" (USAID, 2011, p.6).

All in-service training programmes should meet the criteria set out by Walter and Briggs (2012) who suggest that "The professional development that makes the most difference to teachers: (1) is concrete and classroom-based; (2) brings in expertise from outside the school; (3) involves teachers in the choice of areas to develop and activities to undertake; (4) enables teachers to work collaboratively with peers; (5) provides opportunities for mentoring and coaching; (6) is sustained over time; and (7) is supported by effective school leadership" (Walter and Briggs, 2012, p1.).

Programmes designed to improve the effectiveness of teachers of mathematics should provide participants with the pedagogical skills necessary to move from a teacher-led, rules-focused approach to a more collaborative exploration of mathematical problems. However, given the generally poor preparation of teachers in SSA, pedagogical content knowledge should not be ignored since this is required if teachers are to recognise the various levels of understanding that their students may display (USAID, 2011).

In addition to formal training, peer support and collaboration between mathematics teachers appear to be of particular importance in promoting better teaching and learning. An interesting development is the recent introduction, in South Africa, of a "1+4" teacher development plan which ensures that mathematics teachers meet regularly to discuss effective teaching strategies. If this initiative is shown to yield significant improvements in learner achievement, other countries should consider ways of promoting collaboration among subject teachers.

5. Providing more and better mathematics textbooks

In countries where the ratio of mathematics textbooks to students is significantly worse than 1:2 there is probably benefit to be gained in investing in the provision of more books (Fehrler, Michaelowa and Wechtler, 2007). Fredriksen and Brar (2015) suggest practical strategies for meeting the demand for textbooks in countries where financial constraints are severe. However, research shows that simply supplying more textbooks will not raise mathematical achievement significantly - the textbooks have to be the right ones and teachers have to be trained in using them effectively.

Determining whether a textbook is likely to be effective in the teaching of mathematics requires rigorous evaluation in advance of publication. Currently pre-publication evaluation of textbooks tends to focus on alignment with the content of the curriculum, attractiveness to learners, physical quality and cost of production. However, there is little evidence that new textbooks in SSA are systematically evaluated as to their effectiveness as aids to learning i.e. that they are closely aligned with instructional objectives.

Ministries of education should require all proposed textbooks to be subjected to a comprehensive evaluation by trained reviewers - including practising teachers of mathematics. This requirement may add to the initial costs of production, but this may be a small price to pay for greater returns in terms of educational outcomes.

Whilst there is currently a great need for physical textbooks in many countries of SSA, the internet offers a parallel route for allowing practising teachers, trainee teachers, students and parents free access to approved textbooks. For example, The National Council for Educational Research and Training (NCERT) in India not only commissions physical books but also provides e-copies for personal, i.e. non-commercial use, through its e-portal. In SSA, governments should, through their agencies, establish 'education portals' allowing free access to textbooks and supplementary learning materials.

6. Supporting mathematics teachers through technology

Many initiatives to turn the potential of digital technologies into improved teaching and learning have been launched in recent years. Unfortunately, it is not yet clear which, if any, of these will be most effective and/or sustainable in the long-term. However, technological tools are emerging that individual teachers can, with support, use to enhance their teaching of mathematics. Typically these teaching tools and materials are not being created by government agencies: they are being generated by not-for-profit organisations, academic institutions, and commercial entities. The available pool of such resources is constantly growing and changing so perhaps the best short-term strategy is not to be directive but simply to facilitate teachers' access to ideas, models, materials and tools. Ministries of education should establish national education portals through which teachers may be guided towards potentially useful resources.

In addition to an 'official' education portal, independent resource banks and online communities of mathematics teachers should be established in order to facilitate the sharing of resources that have been shown to work in the classroom. A good example of this is the resource-sharing website hosted by the Times Educational Supplement in the UK. Teachers from all phases of education and in all subjects upload resources they have made and used successfully. These can be accessed and used by teachers from anywhere in the world. The informal, decentralised, and uncontrolled approach advocated here may not sit well with more conservative policy makers. However, it reflects the reality of a digital universe where teaching communities are not limited by national borders and where the best teaching/learning materials emerge through a process akin to natural selection. That is TLMs which work well in the classroom are used and survive whilst poor TLMs 'disappear' through lack of interest.

7. Harnessing the power of assessment: regional and national assessments

Participating in international large-scale assessments such as PISA and TIMSS may bring benefits but for countries in SSA where it is known that achievement in mathematics currently lies far, far below international norms it is not clear that the potential benefits outweigh the costs. In the longer term, new initiatives such as PISA for Development and TIMSS Numeracy may make the proposition more attractive but, in the shorter term, more promising alternatives include participation in regional assessments and the development of national assessments.

The two regional assessments - SACMEQ and PASEC - have over recent years become increasingly sophisticated and potentially more powerful. SACMEQ and PASEC should strengthen their existing links through formal agreements, the adoption of common operational standards, and the use of a common reporting scale. This would move SSA towards a pan-African comparative assessment programme capable of measuring student achievement and monitoring trends over time. Countries which do not yet take part in SACMEQ and PASEC studies should be encouraged to do so through, for example, financial support and technical assistance from international agencies.

A number of countries in SSA have, with the encouragement of international agencies, implemented their own national assessment programmes over recent years. Unfortunately there is evidence that many of these are not fulfilling their intended purposes. They do not, in general, yield the information that policymakers require and there is little evidence that they are providing schools and mathematics teachers with sound, practical advice that can be used to improve learning. Therefore, all countries currently conducting national assessments should review these to ensure that they are fit for purpose and are providing value for the money invested in them. Where countries do not yet have the necessary technical expertise to enhance their national assessment programmes they should be supported through technical assistance provided through international agencies. Of particular concern is the absence of feedback to mathematics teachers and other practitioners. The agencies responsible for national assessments should take steps to ensure that their studies provide mathematics teachers with concrete examples of student performance at different achievement levels. Examples of test items, descriptions of alternative solutions and popular misconceptions, and supporting statistical data are all necessary if national assessments are to have a positive impact on classroom practices. Once again, external technical assistance may be necessary to put such a system in place.

8. Harnessing the backwash effect of high-stake examinations

In many countries of SSA, teaching and learning are dominated by the high-stake examinations which act as gatekeepers at the transition points of the education system. The agencies responsible for them are under great pressure to maintain the security of their systems and to ensure that individual students receive the correct result in a timely fashion. In focusing on this they neglect their role in enhancing education by providing materials and information to teachers and students.

Where they do not already do so, examining agencies should be required to make materials which would help teachers and students prepare for examinations in mathematics (and in all other subjects) freely available via the internet. Such materials should include examination programmes (syllabuses), reports of examiners and, most importantly, past papers (with their marking schemes). This could be implemented with little delay and at little cost. The West African Examinations Council's e-learning portal and the website of the Mauritius Examinations Syndicate already offer examples of good practice.

In addition to the above, governments and their ministries of education should instruct national examination boards and other assessment agencies to put in place comprehensive feedback systems to supply schools, teachers and other practitioners with both qualitative and quantitative information as to student performance in mathematics (and all other subjects).

Currently examination boards do not make disaggregated data (e.g. student responses and raw scores) available for external evaluation and/or analysis. This is a waste of potentially important information. Anonymised datasets should be made freely available to bona fide researchers wishing to conduct secondary analysis since, as Fehrler, Michaelowa and Wechtler (2009) conclude, "any kind of measures to enhance transparency about… learning outcomes appears to be valuable" (Fehrler, Michaelowa and Wechtler 2009, p.27).

9. Supporting student self-learning through technology

When it comes to knowledge and education, the internet has begun to undermine the hegemony of schools, teachers, ministry-approved textbooks, etc. Students who have access to the internet can now easily supplement their formal education with information from elsewhere. This should not be seen as a threat but as an opportunity to raise levels of achievement without significant additional investment from the state. This is particularly true in SSA where many students are currently being taught by teachers who lack confidence and/or competence in mathematics. Three initial steps are recommended. First, students, parents and local communities should be made aware of the possibilities for self-learning. They should be encouraged to access suitable learning materials – possibly through a user-friendly, national education portal. Secondly, key players in education, both government agencies and NGOs, should be encouraged to provide free access to existing open educational resources. Thirdly, NGOs and commercial partners should be encouraged to collaborate with, for example, ministries of education in the generation of age-appropriate learning materials compatible with the content and philosophy of national curricula for mathematics.

10. Promoting further research

Some of the questions which during the preparation of this report have emerged as being worthy of further investigation and research are described below.

How can countries in SSA monitor trends in mathematical achievement?

To date, national and regional assessments in SSA have not, in general, been able to provide sufficiently precise and reliable data on trends in student achievement. Key questions to be resolved are: 'Can a country establish a quick and effective way of monitoring mathematical achievement over time?' 'What will be necessary to establish sufficiently precise baseline measurements and how can subsequent measurements be systematically linked with those baselines?' 'How can existing national assessments be modified so that they can monitor trends over time?'

How do learners understand mathematical concepts as demonstrated by their teachers? How do they approach mathematical problems?

A number of research papers explore the various ways in which learners gain a deep understanding of a concept through exploring alternative routes towards solving non-standard problems. Others investigate issues associated with adopting a constructivist approach in the teaching of mathematics. However, little evidence has been gathered in the context of typical classrooms in SSA. Both of these issues should be subject to action research.

How effective are the textbooks currently being used to teach basic mathematics in SSA?

Quantitative research repeatedly suggests that the direct benefits of making mathematics textbooks available to all are, at best, small. One hypothesis is that investing in textbooks is of value only if the prescribed textbook is effective. There are, however, few rigorous evaluations of textbook effectiveness. Another hypothesis is that teachers in SSA are not trained to use the textbook to maximum effect. Both indicate areas where further study would be of value.

How can national assessments of student achievement in mathematics be improved so that they provide policy makers and teachers with the information needed to improve outcomes in mathematics?

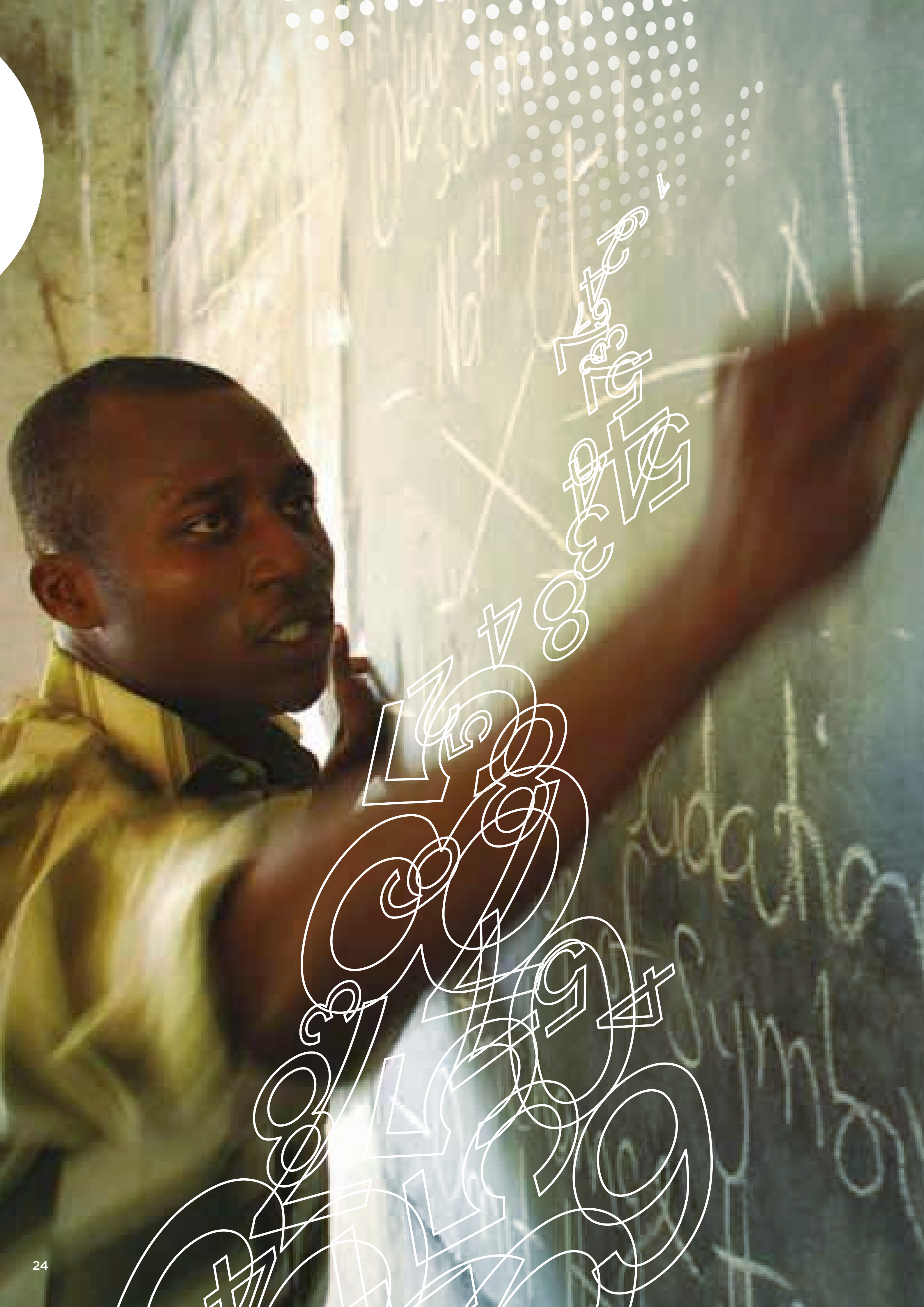
Whilst a significant number of countries across SSA carry out national assessments of learner achievement in mathematics, there is little evidence as to the technical quality of these. Few governments appear to be asking these fundamental questions: Do our national assessments serve their intended purposes? Do they offer value for money? Have they had a discernible impact on educational policy and/or practice? Answering these questions will require both qualitative and quantitative research.

Where OER have been used as the basis of, or to supplement, formal teacher education development programmes, have they been effective?

Open Educational Resources produced by international development partners have been used in some TTI as the basis of new initial teacher training programmes or to supplement existing programmes. In other cases, OER have been built into in-service professional development programmes for teachers. Independent evaluations of these initiatives are required to determine whether they have contributed to the production of better graduates or not. If such programmes can be shown to be effective and offer good value for money then the approach is more likely to be adopted by other countries and other TTI.

Which of the e-learning and m-learning technologies in the classroom have the greatest potential to raise levels of numeracy and mathematical competence? What are the challenges of introducing e- and m-learning technologies - especially in fragile states?

Over recent years, a significant number of initiatives to raise levels of numeracy and student achievement in basic mathematics through the use of digital technologies have been piloted across SSA. Few of these have been subjected to fully independent scrutiny. There is a need to evaluate any such initiative before investing in implementing it at scale. Evaluative studies should not only investigate the returns to learning but also the costs and risks associated with adoption on a large-scale. These are the key questions: Which technologies/approaches yield the greatest benefits in terms of improved outcomes? What are the costs associated with implementing a proposed technological solution at the regional and/or national level? Given the prevailing context, is the proposed technological solution viable and sustainable?



1 Introduction

1.1 Objective

This study was commissioned by the World Bank in order to support the improvement of mathematics education in the countries of Sub-Saharan Africa (SSA). Here the term 'mathematics education' is interpreted in its broadest sense covering not only the practices of teaching and assessing mathematics in schools and other learning institutions, but also the socio-economic and cultural contexts in which national policies related to the teaching and learning of mathematics are being developed, implemented and evaluated.

The study was commissioned in response to a growing recognition that countries in SSA will need to boost performance in the Science, Technology, Engineering and Mathematics (STEM) subjects if they are to realise their full potential in a competitive global market increasingly shaped by the use of new technologies. At present, it is feared that economic development is being impeded by the limited reach of quality education. In particular, poor performance in mathematics at the school level is seen as a significant barrier to improved economic and social outcomes at the level of both the individual and the nation.

In order to meet its key objective this study will document the state of mathematics education across the region and identify interventions that have the potential to successfully improve mathematics education in SSA. It is hoped that this overview of both the challenges and opportunities will prove of value to the various groups with roles to play in improving mathematical outcomes. These include inter alia: national educational policy makers; international development banks and aid agencies; non-governmental organisations (NGOs) and philanthropic institutions working in the field of mathematical education; and the national and international assessment and research communities responsible for gathering, analysing and interpreting data. It is these stakeholders who will inform the decision making process, formulate policies, and implement reforms to guide and support the practitioners – especially teachers of mathematics – who, ultimately, will improve the mathematics education of learners.

1.2 Defining Sub-Saharan Africa

The World Bank classifies 48 countries as being located in SSA. These are listed in Table 1.1.

Table 1.1: The Countries of Sub-Saharan Africa

Sub-Saharan Africa Countries			
Angola	Côte d'Ivoire	Madagascar	Seychelles
Benin	Equatorial Guinea	Malawi	Sierra Leone
Botswana	Eritrea	Mali	Somalia
Burkina Faso	Ethiopia	Mauritania	South Africa
Burundi	Gabon	Mauritius	South Sudan
Cabo Verde	Gambia, The	Mozambique	Sudan
Cameroon	Ghana	Namibia	Swaziland
Central African Republic	Guinea	Niger	Tanzania
Chad	Guinea-Bissau	Nigeria	Togo
Comoros	Kenya	Rwanda	Uganda
Congo, Democratic Republic	Lesotho	São Tomé and Principe	Zambia
Congo, Republic	Liberia	Senegal	Zimbabwe

1.3 Variation and commonalities across the region

The 48 countries of SSA exhibit huge variation in terms of their geographical, cultural, historical, and economic characteristics. The region includes large, land-locked countries such as Chad and Niger (both -1.3 million km^2) and small, island states such as Mauritius (-2000 km^2) and Seychelles (455 km^2). It includes highly populated countries such as Nigeria (~177 million) and Ethiopia (~97 million), and those with fewer than one million citizens such as Equatorial Guinea and Comoros. Some countries are relatively wealthy including oil-rich Gabon (GDP per capita ~USD 11,000) and mineral-rich Botswana (GDP per capita ~USD 7,000). By way of contrast, many are extremely poor including the Central African Republic (GDP per capita ~USD 360) and Malawi (GDP per capita ~USD 255)[1]. Whilst some countries in the region have established relatively stable and robust political and economic systems, the majority can be classified as 'fragile states'. Of the 50 fragile states identified by the OECD (2015a) worldwide, 28 are in SSA[2] with seven (Central African Republic, Chad, Democratic Republic of the Congo, Côte d'Ivoire, Guinea, Sudan, and Swaziland) being judged as being under threat in all five of the OECD's 'fragility clusters' i.e. violence, justice, resilience, institutions, and economic foundations.

1. Data extracted on 27 January 2016 from the World Bank's World Data Bank at http://databank.worldbank.org/. All figures relate to 2014.
2. The countries in SSA classified by the OECD as being fragile states are: Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Niger, Nigeria, Rwanda, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Uganda, and Zimbabwe (OECD, 2015).

Whilst variation in geo-economic contexts does contribute to differences in national levels of educational achievement, the differences, when judged against global norms, are relatively small. Indeed, with few exceptions, the countries of SSA appear to face remarkably similar problems in raising the quality of their education systems. In particular, all the countries of SSA face the same challenge; that of raising achievement in the critical area of mathematical literacy from disturbingly low levels. This echoes the findings of an International Mathematical Union (IMU) report on mathematics in Africa which concluded: "African countries… are broadly similar in key issues that concern our advisers – institutional and national conditions that help or hinder mathematical development. From their reports, it seems clear that these conditions are virtually the same throughout the continent" (IMU, 2009, p.1). Challenges typically observed include: low levels of investment; poor physical conditions in schools and inadequate teaching and learning materials (TLMs); shortages of well-qualified and trained teachers of mathematics – especially in rural areas and disadvantaged communities; examination and assessment systems which do not promote better achievement in mathematics and fail to provide mathematics educators with the information they need to improve student achievement; inadequate pre-service training programmes for teachers with teacher training institutions (TTI) ill-equipped to adopt new approaches towards the effective teaching of mathematics; and, institutions and teachers ill-prepared to adopt new educational technologies as they become available. It is these commonalities which make it possible to construct a single narrative for the otherwise diverse nations of SSA.

1.4 Research questions and methods

The study addresses the following research questions:

1. Why is mathematics education important in general, and in SSA in particular?
2. What is the state of development of assessments in SSA? Which countries measure learning outcomes in mathematics at different levels of school education and how? What do large-scale assessments reveal about mathematics learning in SSA?
3. How do countries compare in mathematics learning outcomes at pre-secondary level in SSA? Can we identify groups that perform better? How do countries compare in mathematics learning outcomes at secondary level in SSA? Can we identify groups that perform better?
4. What are the main factors that affect learning outcomes in general and, in particular, achievement in mathematics?
5. Are teachers in SSA sufficiently well-qualified and competent to teach mathematics? Are they adequately prepared by pre-service training courses to teach mathematical concepts effectively? What challenges do teachers face when teaching mathematical concepts in the classrooms of SSA?
6. Are the potential benefits of comprehensive assessment practices being harnessed? Are there differences in the quality of summative and formative assessments in SSA?
7. What interventions and/or innovations have been used in other countries that have shown notable improvements in mathematical outcomes? To what extent can potentially effective interventions from other contexts be transferred to SSA? Can new technologies be used to improve mathematical outcomes in SSA?

8. What were the systemic factors that have contributed to consistently high mathematics learning achievements in select countries from other regions, in particular East Asia?
9. What are the gaps in evidence and/or further areas of research that are required to (a) provide a comprehensive picture on the status of mathematics education in SSA (b) evaluate the effectiveness of interventions designed to raise standards?

The study will achieve this through a comprehensive literature review examining available information on the current status of mathematics education in SSA including: student learning outcomes; teacher capacities; availability of textbooks and other resources; and initiatives being taken to improve mathematics education in SSA. The literature review will also examine best practice in regions that show strong results in mathematics education and in countries that have registered notable improvements in recent years. Best practices from within Sub-Saharan Africa region will also be identified.

The literature review will serve as the predominant source of information. However, it will be supplemented by case studies in six countries chosen to represent a range of contexts in both Anglophone and Francophone systems[3]: Cameroon, Democratic Republic of the Congo (DRC), Nigeria, Malawi, Rwanda, and Uganda. In these countries, three mechanisms will be used to collect data: classroom observations; teacher questionnaires; and a questionnaire for institutions providing initial (pre-service) teacher training.

Classroom observations will focus on the question: "What happens in classrooms where mathematics is being taught?" Researchers will observe mathematics lessons for Primary Grades 3 and 6 and one Secondary Grade (9, 10 or 11) and will record their observations in a structured observation schedule. They will gather data on the classroom environment and resources, on the teacher who delivers the lesson, and on what students are doing at specific times during the lesson. Following each observed lesson the teacher will be invited to complete a questionnaire. In addition to information about, for example, the teacher's experience and working conditions in the school, the questionnaire will include a short attitudinal survey.

Finally, in each focus country three institutions providing pre-service training for teachers will be selected according to their size, prestige/reputation, and geographical location. The institutions' relevant curricula will be reviewed and a senior representative will be invited to complete an institutional questionnaire concerning the preparation of teachers who will deliver mathematics lessons at the primary or secondary levels.

In all cases, the samples will be small and non-probabilistic and so quantitative indicators will not necessarily be generalisable. However, the information gathered through classroom observations and questionnaires will be cross-referenced to complementary data from other sources. This will enable a more comprehensive picture of the state of mathematics education in each of the focus countries to be prepared.

3. Resource constraints meant that it was not possible to add a Lusophone country to the focus group. Information as to mathematical achievement is available for Mozambique through its participation in SACMEQ regional assessments (see Section 3). However, little information is readily available about mathematics education in the other highly populated Lusophone country of SSA – Angola (population ~24 million).

2 Context

2.1 Education, skills, and economic benefits

Over the past decade, Sub-Saharan Africa has enjoyed strong economic growth with an average regional GDP growth rate of 5.8%[4]. This growth is predicted to remain 'solid' even in the face of uncertainties in the global economy and volatility in the price of commodities (IMF, 2015, p.1). Notwithstanding this positive picture, there is a belief that countries within SSA are failing to realise their full economic potential and that a key impediment to this is the limited availability of high quality education.

It is well established that education brings economic benefits to the individuals who are educated and, indirectly, to those around them. In addition, investing in education brings many non-market returns including lower infant mortality (Boehmer and Williamson, 1995), smaller families (Janowitz, 1976), better health in children (Currie and Moretti, 2003), and less participation in crime (Machin, Marie and Vujić, 2010). Taking the private returns to education together with external, social benefits, it appears safe to conclude that investment in developing human capital through education offers returns which compare favourably with investments in developing physical capital (Colclough, Kingdon and Patrinos, 2009).

Quantitative estimates of the economic benefits which accrue to educated individuals in terms of higher earnings vary according to the methods used and the data available. However, recent estimates suggest that the average private rate of return to a further year of education in SSA is 12.4% (Montenegro and Patrinos, 2014, Table 3a). Returns vary across the phases of education with each additional year of primary schooling in SSA returning an average of 14.4% with a corresponding return of 10.6% at the secondary level[5]. At the tertiary level, private returns to education are even higher at 21.0% (Montenegro and Patrinos, 2014, Table 3b). These high returns are indicative of the scarcity of human capital relative to demand within the region's employment sector.

Traditionally, calculations of returns to education such as those cited above have been based on the number of years spent in education. However, there is now a growing awareness that whilst the duration of education may be an important factor in determining economic returns, the quality of that education must not be ignored. Indeed, Hanushek and Wößmann (2007) conclude that, "educational quality – particularly in assessing policies related to developing countries – is THE key issue" (ibid, p.1). In this context, Hanushek and Wößmann (2007) consider quality to be the extent to which education promotes the acquisition of cognitive skills deemed to be particularly relevant to employment, i.e. literacy and numeracy/mathematical skills[6]. Research undertaken in developed countries shows that

4. Data on percentage change in GDP (constant prices) for the period 2004-2014 from IMF World Economic Outlook Database, April 2015.
5. Returns to schooling depend not only on the levels of supply and demand in the employment market but also on the requirements of employers. As a result, the generalisation that returns to primary schooling in SSA currently exceed those to secondary level schooling may not hold for a particular country. For example, research in Ghana suggests that returns at the primary and junior secondary levels are now negligible and may even be negative (Palmer, 2007).
6. Green and Riddell (2012) include problem solving in their definition of cognitive skills in addition to literacy and numeracy / mathematical skills. In the OECD's survey of adult skills, the cognitive skills considered are: literacy, numeracy and problem solving in technology-rich environments (OECD, 2013b).

the returns on these skills are significant. For example, Green and Riddell (2012) show, using Canadian data, that "(an) increase in literacy and numeracy skills (of) half of a standard deviation is associated with an increase in earnings equivalent to an additional year of schooling" (Green and Riddell, 2012, p.3). Similarly, Crawford and Cribb (2013) find, using UK data, that "a one standard deviation increase in Maths test scores at age 10 is associated with earning 13.0% more per week at age 30 … compared with 10.1% for a one standard deviation increase in reading test scores" (Crawford and Cribb, 2013, p.4). Evidence as to the returns to cognitive skills in low-income countries in SSA is limited but several studies report positive estimates[7]. Glewwe (1996), for example, shows that it is cognitive skills, rather than years of schooling, that determine earnings in Ghana's private sector.

Linking the quality of education at the micro level to economic growth at the macro level is far from straight-forward. However, using mathematics and science test scores achieved in the OECD's Program for International Student Assessment (PISA) as indicators of quality, Hanushek and Wößmann (2007) find that "test scores that are larger by one standard deviation … are associated with an average annual growth rate in GDP per capita that is two percentage points higher" (Hanushek and Wößmann, 2007, p.32). Further analysis comparing low- and high-income countries suggests that "the effect of quality is considerably larger in the low-income countries" (Hanushek and Wößmann, 2007, p.36). Interestingly, they also find that in low-income countries, the duration of education when taken in conjunction with quality has a significant effect. This leads them to a simple but powerful conclusion: "Once there is a high-quality school system, it pays to keep children longer in school – but it does not if the school system does not produce skills" (Hanushek and Wößmann, 2007, p.36).

The implications for educational policy in SSA are clear. After having invested, with great success, in increasing enrolment rates at the primary level[8] and, more lately, at the secondary level, the attention of governments must now shift to raising the quality of education. In particular, national efforts should focus on developing schooling systems which promote the acquisition of key cognitive skills and deliver significantly higher achievement levels in literacy and mathematical skills.

2.2 Mathematics in SSA – a suitable case for treatment

Whilst policies are needed to promote better outcomes for all cognitive skills, mathematical education in SSA is in particular and urgent need of attention.

First, there is mounting evidence that having poor numeracy skills is a greater barrier to economic and social well-being than having poor literacy skills. Parsons and Bynner (2006), using UK data, found that "for women, while the impact of low literacy and low numeracy skills (on their life chances) is substantial, low numeracy has the greater negative effect, even when it is combined with competent literacy" (Parsons and Bynner, 2006, p.7). For men, they conclude that "there is no real difference between the effect (on life chances) of poor literacy and poor numeracy together and poor numeracy alone" (Parsons and Bynner, 2006,

7. For example, Boissiere, Knight, and Sabot (1985), Glewwe (1996), Jolliffe (1998), and Moll (1998) cited in Hanushek and Wößmann (2007, Table 3).
8. According to UNESCO (2015c), during the period 1999 to 2012 the enrolment of children in primary schools rose by 75% to 144 million.

p.7). Further evidence comes from the OECD's Survey of Adult Skills conducted in 2011-2012 across 22 countries and from the secondary analysis of data conducted by Hanushek et al. Data from this survey suggests that an increase of one standard deviation in literacy proficiency is associated with an average increase of 8% in hourly wages whilst the corresponding increase for an increase of one standard deviation in numeracy proficiency is 17.8% (OECD, 2013b, p.224).

Secondly, in recognition of the importance of mathematical skills in a competitive global economy, many high-income countries whose students perform at or around the international average are growing increasingly concerned about the gap between the mathematical achievement of their students and that of their peers in the high-flying economies of East Asia. However, the situation is far worse for nations in SSA where, as shown elsewhere in this report, standards in mathematics are currently extremely low in both relative and absolute terms. International data for countries in SSA is limited but that which is available makes for disturbing reading. For example, in TIMSS 2011, Grade 8 students from Korea, Singapore and Chinese Taipei scored, on average, more than 600 for mathematics – far above the TIMSS scale centre point of 500. All three participants[9] from SSA scored at least one standard deviation below the international average (Botswana [397], Ghana [331], and South Africa [352]) (Mullis et al. 2012 pp. 42-43). For SSA, the achievement gap in mathematics is so large that Beatty and Pritchett (2012) predict that it would take of the order of 130 years for countries in SACMEQ to reach the current average levels of the OECD if business continues as usual (Beatty and Pritchett, 2012, Table 5).

9. Ghana met the sampling criteria for Grade 8 students but its average score of 331 placed it at the bottom of the international rank order. Both Botswana and South Africa tested Grade 9 students and so their scores are not directly comparable with those of Ghana or other TIMSS participants.

2.3 Science, technology, engineering and mathematics: their importance to growth

Whilst this study focuses on the development of mathematical skills across the ability range and for a wide range of purposes, it is important to recognise the key role mathematics plays as one of the STEM subjects which are widely regarded as being critical to national economic development in an increasingly technological world. In the world's major economies there is a consensus that the industries that will, in the future, generate most growth and offer the most rewarding employment opportunities will be in sectors related directly and indirectly to technology, engineering, science and similar disciplines. Many western economies fear that they have already fallen behind the countries of East Asia where achievement in mathematics and science is far higher. As a result, investment in STEM subjects in schools and in institutions of higher education is seen as a priority across the industrialised world. For example, in the USA the President's budget for 2016 alone allocates more than three billion USD for enhancing STEM education in and beyond high schools (United States, 2015). In the UK, the government plan for growth in the period 2015-2021 pledges the equivalent of 8.9 billion USD in the support of scientific excellence and the development of technical skills and knowledge (United Kingdom, 2014). Similar commitments to extremely high levels of investment in STEM can be found across the world's developed economies.

In SSA, the importance of developing skills and knowledge in the STEM subjects to promote and sustain growth is now widely acknowledged (World Bank and Elsevier, 2014). Steps have been taken in recent years to increase the number of students and researchers involved in STEM-related activities and to raise the quality of work in this field. Some progress has been made in terms of the quantity and quality of research, but SSA started from a very low base and still has far to go. The region has also failed to close the gap on some of its potential competitors. The World Bank (2014) suggests that the reasons for the large and persistent gap between the demand for STEM skills and the supply include, "the low quality of basic education in Science and Maths within SSA; (and) a higher education system skewed towards disciplines other than STEM such as the Humanities and Social Sciences" (World Bank and Elsevier, 2014, p.4).

2.4 What type of mathematics is needed?

'Classical' mathematics curricula, many of which persist albeit in mildly modified forms in SSA, were developed to meet the perceived needs of the late 19th and 20th centuries. However, it is becoming increasingly obvious that they are not well suited to a 21st century dominated by the rapid expansion of new technologies. Borovik (2014) points out that such technologies incorporate mathematical algorithms and scientific principles that few are able, or need, to grasp. He suggests that "99% of people have not even the vaguest idea about the workings of 99% of technology in their immediate surroundings - and this applies even more strongly to technological uses of mathematics, which are mostly invisible" (Borovik, 2014, p.3). In this new reality, mathematics education need equip only a relatively small elite with the higher level skills required by the productive STEM-based industries. The vast bulk of the population needs an education which focuses on the development of 'mathematical literacy' and not, as in so many traditional curricula, on the mastery of procedures. For example, Borovik suggests that in a world where countries can import, rather than design and manufacture, high-tech components for their industries: "one can easily imagine a fully-functioning country where no-one has mastered, say, long division or factorisation of polynomials" (Borovik, 2014, p.4). This clearly has significant implications for curriculum design and delivery.

Mathematical literacy is defined in the PISA framework for mathematics as: "an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens" (OECD, 2013a, p.25). Ensuring that the vast majority of the population become mathematically literate yields economic benefits at the micro and macro levels. First, more numerate workers enjoy greater returns. Secondly, a workforce enlisted from school graduates with higher scores in tests of mathematical literacy typically generates greater national growth. Thirdly, a workforce equipped, through education, with better cognitive skills will adopt new technologies more rapidly than a less numerate workforce leading, potentially, to greater productivity (Riddell and Song, 2012).

2.5 Summary

Investment in education yields significant economic returns for individuals, for communities, and for the nation. However, such returns disappear when the quality of education is poor. Maximum returns are enjoyed when education promotes the acquisition of the cognitive skills required by employers. Of these, evidence suggests that numeracy is the most important when it comes to generating economic returns and spurring national growth. Educational strategies for ensuring that all learners leave school as mathematically-literate citizens should be a priority.

In an increasingly technological world, education systems need to produce a sufficient pool of young people educated in STEM subjects to meet the research, development and production needs of industry and commerce. Some education will take place in institutions of higher education and some will be industry-based. However, for these to succeed, good foundations in mathematics and the other STEM subjects must be laid in schools – especially in the early years of education.

The issues described above concern developed and developing countries alike. Some of the world's wealthiest nations are already investing heavily in order to catch up with the high-flying countries of East Asia. The scale of the challenge facing SSA, however, is dauntingly large. Average student achievement is so low that, at the current rate of progress, it will take several generations for the region to approach the levels currently enjoyed by more developed economies – by which time the gap in achievement may well have increased. Closing the achievement gap over a more acceptable timeframe will require truly radical reforms to the nature and organisation of mathematics education, and great innovation in the delivery of mathematics curricula.

3 Current status: learning outcomes in mathematics in SSA

3.1 Context and sources of information

Constructing a comprehensive picture of learning outcomes in mathematics across the numerous and varied countries of SSA is problematic because the available data is highly fragmented. The sources available to draw on are diverse in their purposes, their methodologies, and in their measurement and reporting scales. In short, there is no common metric and triangulation is difficult because bridges between data sets are, at best, tenuous. This problem would be more serious if the various surveys produced conflicting results but, as shown below, much of the available information points in the same general direction – towards low average levels of mathematical competence.

The sources available fall into four main categories: international (global) large-scale assessments; regional large-scale assessments; national large-scale assessments; and national examinations. Of these, international and regional assessments offer the best opportunities for drawing conclusions about relative and absolute levels of achievement in SSA. They have the added advantage, especially over examinations, of collecting student, teacher and school background data which can illuminate the key factors associated with better learning outcomes in mathematics. Table 3.1 gives an overview of the major international and regional assessment programmes being conducted in SSA.

Table 3.1: Overview of the major international and regional assessment programmes conducted in SSA

Title	Organisation	Target population and typical sample sizes	Reporting scale	Participation
Trends in Mathematics and Science Study (TIMSS)	Conducted under the auspices of IEA since 1995. Four-year cycle focusing on mathematics and science.	In-school students in Grade 4 and in Grade 8. Typical sample is of the order of 150 schools and 4,000 students.	IRT-based scale: originally set with centre 500, standard deviation (SD) 100	59 countries/education systems are participating in the 2015 cycle. The following SSA countries have taken part in TIMSS: Botswana, Ghana and South Africa.
Program for International Student Assessment (PISA)	Conducted under the auspices of OECD since 2000. Three-year cycle focusing on: reading literacy, scientific literacy and mathematical literacy.	In-school students aged 15 years. Typical sample is of the order of 150 schools and 4,500 students.	IRT-based scale: centre 500, SD 100.	65 countries/economies participated in the 2012 cycle. Of all countries in SSA only the a-typical island state of Mauritius has participated in PISA[10].
Title	**Organisation**	**Target population and typical sample sizes**	**Reporting scale**	**Participation**
Southern African Consortium for Measurement of Educational Quality (SACMEQ)	Conducted since 1995 at five- or six-year intervals. Focus is on mathematics and reading achievement.	In-school students in Grade 6 and teachers of Grade 6. The third SACMEQ cycle tested about 60,000 pupils across 14 countries i.e. approximately 4,000 pupils per country.	In 2000 (SACMEQ II) an IRT-based scale was introduced having a centre point of 500 and a standard deviation of 100.	The Consortium includes 16 Ministries of Education in Southern and Eastern Africa, Angola, Botswana, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania (Mainland), Tanzania (Zanzibar), Uganda, Zambia, and Zimbabwe.
Programme for the Analysis of CONFEMEN Education Systems (PASEC)	PASEC has offered 'diagnostic' assessment services to Francophone countries since 1993. Since 2013, PASEC has adopted a new model to allow for international comparisons. The focus is on mathematics and language (French or national language).	In-school students in Grades 2 and 6. Typical sample is of the order of 175 schools and 2,500 students.	Prior to 2013, results were reported as 'percentage correct' scores. The 2014 survey used an IRT-based scale centred on 500 with a standard deviation of 100.	Ten countries were evaluated in 2014: Benin, Burkina Faso, Burundi, Cameroon, Ivory Coast, Congo, Niger, Senegal, Chad, and Togo.
Title	**Organisation**	**Target population and typical sample sizes**	**Reporting scale**	**Participation**
Early Grade Mathematics Assessment (EGMA)	Conducted under the auspices of USAID. This is effectively an 'on demand' service rather than a fixed-term survey.	Countries can identify the target grade(s) but typically Grades 2 to 6. Typical sample size is of the order of 450 students at each target grade[11].	Mixed scales including speed of response ('automaticity') and proportion correct.	More than 40 countries worldwide have used EGMA and/or the complementary reading assessment EGRA. In SSA, countries that have used EGMA instruments include Kenya, Malawi, Nigeria, Rwanda, Tanzania and Zambia.
Uwezo[12]	Since 2009, Uwezo has conducted annual surveys focusing on basic literary and numeracy competencies.	School-aged children – including those who are out-of-school. Household surveys reporting on between 92,000 and 145,000 children per country.	Criterion-referenced assessment with results reported as 'percentage passing'.	Three countries: Kenya, Tanzania and Uganda.

10. Mauritius was one of ten countries/economies that took part in PISA+ which was a re-run of PISA 2009.
11. Note that 450 is the target sample size for each stratum of interest. For example, where a country wishes to report at the provincial level then ~450 students are required in each province.
12. 'Uwezo' is Kiswahili for 'capability'. The EFA Global Monitoring Report, 2015 classifies Uwezo as a national assessment. However, given that it was not specifically tailored to a particular nation's requirements, here Uwezo is placed in a separate category along with EGMA.

3.2 Mathematical achievement in the early years and across the primary phase of education

Over the past twenty-five years, SSA has seen much activity in the field of educational assessment for the purposes of measuring student learning, investigating the factors that contribute to better outcomes, and identifying trends in levels of achievement. At least fifteen countries have designed and implemented their own national assessment programmes[13] (UNESCO, 2015a, Table 1, p.305). A significant number participate in regional assessments such as SACMEQ and PASEC, but only a small number have participated in international studies. Much of this activity has focused on young learners and on the fundamental skills of literacy (especially reading) and numeracy. Measuring and monitoring these skills has become increasingly important as primary enrolment rates have expanded and concern has grown over the quality of the education offered by state and private providers – especially to young learners. Objective evidence as to the quality of mathematics education comes from a number of assessments, each with its own philosophy, methodology and objectives. Some of the key assessments and their headline findings are described here.

3.2.1 Trends in Mathematics and Science Study (TIMSS) at Grade 4

The mathematical component of TIMSS is one of the most respected large-scale international assessments of student achievement in mathematics. TIMSS assessments are generally considered to be 'curriculum based' (as opposed to PISA's 'literacy based' approach) with test instruments focusing on fundamental mathematical concepts common to most national curricula. A typical national sample comprises about 150 schools and 4,000 students for each target grade (Joncas and Foy, 2011). Student scores are generated using item response theory (IRT) and reported on a scale originally centred on 500 and having a standard deviation of 100. The technical rigour of TIMSS means that average national performances can be ranked and international comparisons made with a known degree of confidence.

TIMSS assesses two populations – those studying in Grade 4 and Grade 8. Of particular interest here is the younger population but, unfortunately, only one country in SSA has participated at this level. In 2011, Botswana applied the TIMSS instruments, but to an over-age population sampled from Grade 6. The national average score for mathematics was 419 – far below the scale centre point of 500. Because Botswana's sample did not match that of other participants it was not placed in the international rank order. However, some comparisons are of interest as shown in Table 3.2. This shows that average mathematical achievement of Grade 6 students in Botswana is much lower than that of Grade 4 students in any of the other upper-middle-income economies[14] that participated in TIMSS 2011.

Table 3.2: TIMSS 2011: Average mathematics scores for population 1 (Grade 4) for selected countries

Country	Average scale score (SE)	Rank (out of 50)
Kazakhstan	501 (4.5)	27
TIMSS centre point	500	-
Romania	482 (5.8)	33
Turkey	469 (4.7)	35
Azerbaijan	463 (5.8)	36
Thailand	458 (4.8)	38
Iran, Islamic Republic of	431 (3.5)	43
Botswana (Grade 6)	419 (3.7)	-

13. Many more countries in SSA have conducted at least one national assessment over the period 1990-2015. However, the 15 cited here maintain on-going pro grammes of assessments and have completed at least one assessment since 2012 [UNESCO, 2015].
14. World Bank classifications for the fiscal year 2016. Available at: http://data.worldbank.org/about/country-and-lending-groups#low-income.

3.2.2 SACMEQ

Established in 1995, SACMEQ is a consortium of ministries of education across the southern and eastern Africa region. The constituent countries are all, to a greater or lesser extent, Anglophone[15] except for Mozambique where the official language is Portuguese. Since its inception, SACMEQ has completed three cycles of student assessment and is currently completing the fourth - SACMEQ IV. The assessments focus on the achievement of Grade 6 students in the areas of literacy (reading) and mathematics. National measurements are based on a probabilistic sample drawn using methods comparable to those of TIMSS and PISA (SACMEQ, 2008). A nation's sample size will depend on the number of strata identified as being of interest. However, the average number of schools required is of the order of 185 giving a sample of about 4,000 students.

The SACMEQ methodology has evolved over time. In particular, the method of calculating student scores and reporting absolute levels of performance has become increasingly sophisticated. In SACMEQ II (2000), student scores were calculated using item response theory to give scores on a scale centred on 500 and with a standard deviation of 100. Moving to an IRT-based scale allowed SACMEQ to establish a baseline against which changes over time could be monitored. In SACMEQ III (2007), a number of items from the previous survey were included as 'anchor items' allowing results from the two surveys to be placed on the same scale[16].

In addition to average scaled scores, SACMEQ reports the proportion of the target population reaching well-defined, absolute levels of achievement. The levels descriptors for mathematics are shown in Table 3.3. Combining the two reporting methods brings SACMEQ into line with the best practice established by international studies such as TIMSS and PISA.

Table 3.3: SACMEQ levels and behavioural descriptors for mathematics

Level 1: Pre numeracy Applies single-step addition or subtraction operations. Recognises simple shapes. Matches numbers and pictures. Counts in whole numbers.
Level 2: Emergent numeracy Applies a two-step addition or subtraction operation involving carrying, checking (through very basic estimation), or conversion of pictures to numbers. Estimates the length of familiar objects. Recognises common two-dimensional shapes.
Level 3: Basic numeracy Translates verbal information presented in a sentence, simple graph or table using one arithmetic operation in several repeated steps. Translates graphical information into fractions. Interprets place value of whole numbers up to thousands. Interprets simple common everyday units of measurement.
Level 4: Beginning numeracy Translates verbal or graphic information into simple arithmetic problems. Uses multiple different arithmetic operations (in the correct order) on whole numbers, fractions, and/or decimals.
Level 5: Competent numeracy Translates verbal, graphic, or tabular information into an arithmetic form in order to solve a given problem. Solves multiple-operation problems (using the correct order of arithmetic operations) involving everyday units of measurement and/or whole and mixed numbers. Converts basic measurement units from one level of measurement to another (for example, metres to centimetres).
Level 6: Mathematically skilled Solves multiple-operation problems (using the correct order of arithmetic operations) involving fractions, ratios, and decimals. Translates verbal and graphic representation information into symbolic, algebraic, and equation form in order to solve a given mathematical problem. Checks and estimates answers using external knowledge (not provided within the problem).
Level 7: Concrete problem solving Extracts and converts (for example, with respect to measurement units) information from tables, charts, visual and symbolic presentations in order to identify, and then solve multi-step problems.
Level 8: Abstract problem solving Identifies the nature of an unstated mathematical problem embedded within verbal or graphic information, and then translates this into symbolic, algebraic, or equation form in order to solve the problem.

15. Countries are permitted to translate SACMEQ instruments into major national languages. For example, Tanzania (mainland and Zanzibar) translates the tests into Kiswahili and Mozambique translates the tests into Portuguese.
16. The validity of SACMEQ scores for monitoring progress over time at the level of the individual country is explored further in Section 3.4 below.

The measured outcomes for the 15 countries that took part in SACMEQ III (2007) are shown in Table 3.4. The countries in this table have been ordered by their average standardised score for mathematics. In addition to the average score, the proportion of students performing at or below the second level, i.e. 'emergent numeracy', is given. Students in this group are deemed to be "functionally innumerate (in that) they cannot translate graphical information into fractions or interpret common everyday units of measurement" (Spaull, 2011). Also included is the proportion of students at or below the 'basic numeracy' level.

Table 3.4: National average scores for mathematics for countries participating in SACMEQ III (2007)

Country	Average standardised score	Standard Error	Proportion (%) at or below Level 2	Proportion (%) at or below Level 3
Mauritius	623.3	5.83	11.2	26.7
Kenya	557.0	3.98	11.2	38.3
Tanzania	552.7	3.51	13.3	43.1
Seychelles	550.7	2.45	17.8	42.3
Swaziland	540.8	2.39	8.60	44.3
Botswana	520.5	3.51	22.4	56.4
Zimbabwe	519.8	4.98	26.6	57.3
SACMEQ III	509.7	1.16	31.4	63.0
South Africa	494.8	3.81	40.2	69.2
Zanzibar	489.9	2.35	32.4	73.4
Mozambique	483.8	2.29	32.8	74.2
Uganda	481.9	2.92	38.8	74.9
Lesotho	476.9	2.61	41.8	81.1
Namibia	471.0	2.51	47.7	81.7
Malawi	447.0	2.89	59.9	91.7
Zambia	435.2	2.45	67.3	91.8

The results show that Botswana's Grade 6 students perform significantly above the SACMEQ average. However, we know from the TIMSS 2011 results that Botswana's Grade 6 students perform far below their Grade 4 counterparts in countries beyond SSA. This suggests that, with the possible exception of Mauritius, all other countries in the consortium are likely to perform extremely badly in global assessments.

When we look at performance against the absolute levels of achievement of the SACMEQ framework, the picture is even less optimistic.

On average, 31% of Grade 6 students are classified as innumerate with this proportion rising to more than 40% in South Africa, Lesotho, Namibia, Malawi and Zambia. For 10 out of the 15 countries taking part, the majority of students fall short of SACMEQ's "beginning numeracy" level. The situation is particularly desperate in Lesotho, Namibia, Malawi and Zambia where at least four out of five children fail to reach this level.

Underlying these aggregate results, SACMEQ's rich dataset reveals significant variation amongst groups as shown in Table 3.5. Overall, the performance of boys is better than that of girls but the difference is significant at the 95% confidence level in just seven of the 15 participating education systems. Only in the Seychelles did girls outperform boys by a significant margin. Students studying in urban schools outperform their rural counterparts by a significant margin in 12 out of 15 education systems. The most consistent difference is found when comparing the results of students in the lower and upper quartiles of the socio-economic status (SES) scale. Here, students in the upper quartile outperform their less advantaged peers by a statistically significant margin in all countries except for Malawi. Secondary analysis of South Africa's data by Spaull (2011) reveals that whilst the socio-economic status of individual students is a significant factor in predicting achievement, it is far outweighed by the socio-economic status of the school in which the student studies (Spaull, 2011). This important finding is considered further in Chapter 4.

Table 3.5: SACMEQ III average mathematics scores by sub-group (SACMEQ, 2010a)

Country	Boys	Girls	Rural	Urban	Low SES	High SES
Botswana	517.5 (3.95)	523.6 (3.51)	501.1 (3.30)	538.8* (5.61)	479.0 (4.40)	553.1* (5.09)
Kenya	567.6* (4.27)	546.0 (4.34)	544.5 (4.28)	580.0* (7.52)	540.9 (4.26)	595.8* (7.57)
Lesotho	477.1 (3.02)	476.8 (2.80)	469.3 (3.03)	492.0* (4.43)	460.2 (3.31)	498.3* (3.87)
Malawi	452.7 (3.30)	441.1 (3.11)	443.7 (3.44)	457.6* (4.66)	444.7 (6.23)	454.4 (3.39)
Mauritius	616.1 (6.75)	630.7 (5.80)	613.2 (7.65)	634.1 (8.11)	554.2 (5.55)	719.2* (7.78)
Mozambique	488.2* (2.36)	478.6 (3.22)	477.6 (4.39)	487.5 (2.59)	470.8 (4.17)	510.8* (3.31)
Namibia	472.0 (2.76)	470.1 (2.62)	448.5 (2.18)	506.1* (4.66)	443.7 (2.74)	513.5* (4.88)
Seychelles	535.2 (3.53)	566.7* (3.31)	550.2 (4.56)	550.9 (2.91)	498.7 (5.06)	593.6* (5.25)
South Africa	491.2 (4.12)	498.4 (3.85)	456.7 (3.78)	533.1* (5.71)	446.2 (4.80)	578.6* (5.74)
Swaziland	545.5* (2.59)	536.2 (2.61)	535.6 (2.80)	552.9* (4.08)	533.4 (3.27)	552.4* (2.95)
Tanzania	568.5* (4.05)	537.5 (3.71)	542.1 (3.54)	575.7* (6.34)	540.4 (4.59)	579.4* (6.25)
Uganda	486.7* (3.27)	477.2 (3.16)	470.8 (3.17)	511.5* (5.08)	465.4 (3.77)	504.2* (4.29)
Zambia	440.8* (2.93)	429.2 (2.85)	428.6 (2.68)	447.2* (4.24)	424.5 (3.70)	463.1* (6.12)
Zanzibar	489.3 (2.37)	483.9 (1.86)	477.8 (2.03)	500.5* (2.60)	471.1 (3.79)	510.0* (2.51)
Zimbabwe	520.8 (5.80)	519.0 (5.25)	492.1 (4.10)	589.6* (6.57)	487.8 (5.86)	588.8* (6.99)
SACMEQ III	511.9* (1.28)	507.6 (1.21)	493.9 (1.49)	533.2* (2.05)	488.7 (1.47)	541.7* (1.91)

Note 1: Standard errors given in parentheses.
Note 2: * indicates that the difference between the two associated sub-groups is statistically significant at the $p<0.05$ level.

3.2.3 PASEC

Operating under the management of La Conférence des Ministres de l'Education des pays ayant le français en partage (CONFEMEN), the Programme for the Analysis of CONFEMEN Education Systems (PASEC) provides assessment tools to affiliated Francophone countries in Africa and Asia. Established in 1993, PASEC tools have, to date, been used in about 20 African countries to assess student achievement in French and Mathematics[17] (EPDC, 2015). Prior to 2014, PASEC instruments were primarily used by individual countries for diagnosis and research – the programme was not designed for making inter-country comparisons. For example, many countries chose to test their Grade 2 and/or Grade 5 students at the beginning and end of the academic year in order to monitor progress. Background data collected alongside the student assessments allowed countries to investigate the factors connected with educational achievement including, for example, repetition and double-shift schooling. National sample sizes vary but are typically around 175 schools and 2,500 students[18].

Evidence as to the relative and absolute levels of student achievement in mathematics from historic (i.e. pre-2014) PASEC assessments is limited and its interpretation problematic. Countries conducted their evaluations in different years and under different conditions. In addition, student scores were reported as 'percentage correct' and, hence, were test dependent. Notwithstanding these serious limitations, some attempts were made to compare countries using, for example, PASEC's historic '40% correct' threshold of minimum competence as a benchmark. Michaelowa (2001) points out that "the choice of this particular cut-off point is subjective, but motivated by the fact that the PASEC questionnaires are to a large extent based on multiple choice questions which would lead to almost 30% of correct answers even if answers were given at random" (Michaelowa, 2001, p.1703). Unfortunately, the average performance of many PASEC countries fell far below even this most modest of expectations with 7 of the 12 recording average scores below the 40% threshold and disturbingly close to the theoretical guessing level (CONFEMEN, 2010).

Since 2012, PASEC has been moving towards the introduction of new instruments which will enable countries to make more robust international comparisons. In particular, PASEC procedures and assessment frameworks are being brought into line with those of the SACMEQ IV project. The use of IRT to calibrate items will allow PASEC and SACMEQ to link their IRT-based score scales through the use of common anchor items. In addition, PASEC's adoption of the SACMEQ levels descriptors for mathematics will allow Francophone and Anglophone countries across SSA to compare the proportions of their students who reach, for example, minimum standards of numeracy. The technical challenges of, for example, ensuring appropriate sampling strategies and accurate translation will be daunting, but the collaboration has great potential. Evidence of a quantum leap in the quality and potential power of a reformed regional, large-scale assessment can be found in the recently published international report of the PASEC survey of 2014 referred to as PASEC2014 (PASEC, 2015).

17. Countries which have used PASEC tools include: Burkina Faso, Benin, Burundi, Cameroon, Chad, Congo, Congo-Brazzaville, Comoros, Côte d'Ivoire, Djibouti, Gabon, Guinea, Madagascar, Mali, Mauritania, Mauritius, Niger, the Central African Republic, Senegal, and Togo (CONFEMEN, 2015).
18. For example, the 2008 evaluation in Burundi sampled 176 schools and 2,625 Grade 5 students and in 2007, Senegal sampled 158 schools and 2,189 students.

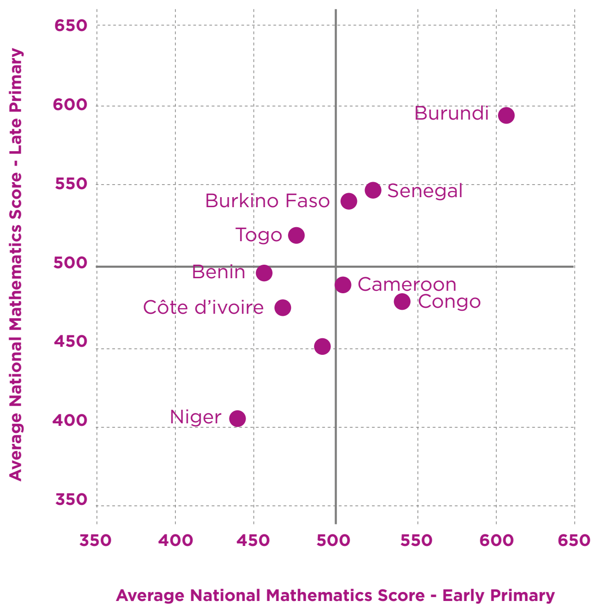
PASEC2014 covered ten countries: Benin, Burkina Faso, Burundi, Cameroon, Chad, Congo, Côte d'Ivoire, Niger, Senegal and Togo. In each country, two populations were defined: 'early primary' (Grade 2) and 'late primary' (Grade 6). Typical national sample sizes for the Grade 6 population were between 180 and 200 schools and about 3000 students. The degree of standardisation of both assessment instruments and procedures was far greater than in earlier studies bringing it into line with international best practice for comparative studies. Most significantly, relative outcomes were reported on IRT-calibrated scales and absolute outcomes were related to well-defined, criteria-referenced performance levels. The IRT-based reporting scale for 2014 was adjusted to give a group mean of 500 and a corresponding standard deviation of 100. This gives a baseline against which changes over time may be monitored provided that future test instruments can be firmly anchored to those used in 2014. In addition, PASEC2014 datasets are in the public domain[19] making secondary analysis by independent researchers possible. Three key findings are particularly relevant here.

First, across participating countries, absolute levels of achievement are low. PASEC2014 defines three positive levels of mathematical achievement for both the early primary and late primary populations. Each level has a detailed 'Description of Competencies' and the boundaries between levels are systematically linked to the IRT-score scale. The 'Sufficient Competency Threshold' lies between Levels 1 and 2. Students who fall below this threshold "risk encountering difficulties later in education due to insufficient mathematical competencies" (PASEC, 2015, p. 49). Unfortunately, in nine of the ten participating countries[20] more than half the Grade 2 students (52%) fell below the 'Sufficient' threshold and nearly a fifth (18%) could not even reach Level 1 (i.e. the minimum level of competence measured by the test instruments). The late primary population fared worse with 64% of students in nine reference countries (excluding Burundi) falling below the 'Sufficient' threshold and nearly a third (30%) failing to reach Level 1.

Secondly, the study confirms that national mathematics scores at the early and late primary stages are correlated to a moderately strong[21] degree ($r=0.74$ and rank order correlation $\rho=0.62$) as shown in Figure 3.2. This relationship suggests that countries which fail to equip their young learners with adequate mathematical skills in the earliest years of education will fail to close the gap on their more successful neighbours by the end of primary education.

19. For example, data for the Grade 6 population is available at: https://drive.google.com/file/d/0By7A35n7_l4dTDFBMHB3UkFqXzQ/view?usp=sharing [Accessed 19 January 2016].
20. Burundi is an exceptional case with 85% of Grade 2 students and 87% of Grade 6 students passing the 'Sufficient' threshold.
21. The product-moment correlation between national scaled scores is +0.74 and the Spearman rank order correlation is +0.62.

Figure 3.1: Relationship between national mathematics scores at the early and late stages of primary education (PASEC 2015, p.56)



Thirdly, the study reveals significant differences amongst the 10 participating nations. According to these results, the average performance in Burundi (for the late primary population) is approximately one standard deviation above the international average whilst Niger languishes one standard deviation below. To put this in perspective, 87% of Grade 6 students in Burundi reach the 'Sufficient' threshold whilst the corresponding proportion for Niger is just 7.6%. Even when the extreme case of Burundi is removed, significant differences remain. For example, Senegal has 59% of students passing the 'Sufficient' threshold compared with just 19% in Chad. The PASEC2014 report does not suggest reasons for the large variations detected but it provides valuable data for secondary analysis of inter- and intra-national differences.

3.2.4 National assessments

Over the past 25 years an increasing number of countries in SSA have carried out national assessments. The main advantage of large-scale national assessments over regional and international assessments is that they allow countries to tailor the research questions to address national priorities and issues of concern. In particular, tests can be better matched to national curricula and the general ability levels within the student cohort. The 2015 EFA Global Monitoring Report lists 29 countries in SSA that have conducted at least one national assessment since 1990 (UNESCO, 2015a). However, implementing a high-quality national assessment is both expensive and technically challenging. As a result, many of the countries listed in the EFA report have not yet established a continuous and sustainable system of national assessments for monitoring purposes. Table 3.6 shows 14 countries which have developed national capacity to carry out assessments targeted at particular grades and have repeated measurements on at least two occasions over the past decade. With the exception of Mauritius, all other countries direct considerable effort towards measuring student performance in mathematics/numeracy and language in the primary phase of education (i.e. from Grade 1 to Grade 6).

The national assessments used across SSA differ in their methods of sampling, evaluation, analysis and reporting. There has been little external evaluation of the quality of these national assessments and several of the reports reviewed as part of this study show serious technical weaknesses - especially in the areas of probabilistic sampling, weighting of scores, and the calculation of standard errors and their use in detecting statistically significant differences. Notwithstanding these shortcomings, investment in national assessment does provide policymakers with qualitative evidence as to the context in which their students are learning or, as is more commonly the case, failing to learn.

Table 3.6: National assessment programmes conducted by countries within SSA

	Title	Grade(s)	Subjects	Year(s)
Burkina Faso	Evaluation sur les Acquis Scolaires	3	French, Mathematics	Annually, 2001–2012
		5	French, Mathematics, Sciences	Annually, 2001–2012
Ethiopia	National Learning Assessment	4	English, Mathematics, Environmental Sciences	2000, 2004, 2008, 2012
		8	English, Mathematics, Biology, Chemistry, Physics	2000, 2004, 2008, 2012
Ghana	National Education Assessment	3, 6	English, Mathematics	2005, 2007, 2009, 2011, 2013
	School Education Assessment	2, 4	English, Mathematics	2006, 2008, 2010
Lesotho	National Assessment of Educational Progress Survey	3, 6	English, Sesotho, Mathematics	2003, 2004, 2006, 2008, 2010, 2012, 2014
Malawi	Assessing Learner Achievement	5	Chichewa, English, Mathematics	2005, 2008
		3, 7	Chichewa, English, Mathematics, Life Skills	2005, 2009
Mauritius	National Form III Assessment	9	English, French, Mathematics, Computer Studies, Physics, Biology, Chemistry	Annually, 2010 to 2014
Mozambique	National Assessment	3	Mother Tongue, Portuguese, Mathematics	2000, 2006, 2009
Namibia	National Standardised Achievement Test	5, 7	English, Mathematics	2009, 2011
Nigeria	National Assessment of Universal Basic Education Programme	4, 5, 6	English, Mathematics, Sciences, Social Studies, Life Skills	2001, 2003, 2006, 2011
South Africa	Annual National Assessment	1 to 6, 9	Literacy, Numeracy	Annually, 2011–2014
The Gambia	National Assessment Test	3	English, Mathematics, Integrated Studies	Annually, 2008–2014 Biennially from 2015
		5	English, Mathematics, Sciences, Social and Environmental Studies	Annually, 2008–2014 Biennially from 2016
		8	English, Mathematics, Science, Social and Environmental Studies	Annually from 2012
Uganda	National Assessment of Progress in Education	3, 6	English, Mathematics	1996, 1999, 2003, 2005, 2006, 2007, 2008, 2009, 2010
		8	English, Mathematics, Biology	Annually, 2008–2013
Zambia	National Assessment Programme	5	Literacy, English, Mathematics, Life Skills	1999, 2001, 2003, 2006, 2008, 2012
Zimbabwe	Early Learning Assessment (ZELA)	3	English, Mathematics	2012, 2013/14, 2015

The findings of three well-developed national assessments with regards to the mathematical achievement of students are described here for illustrative purposes[22].

In Ghana, the national education assessment programme assesses student competency in mathematics and English in Grades 3 and 6. The sample for the 2013 cycle covered all 10 regions of Ghana with a total, national sample size of 550 schools and approximately 37,000 students (MES, Ghana, 2014). The sub-domains for mathematics were: numbers and numerals; basic operations; measurement, shaping space; collecting and handling data. The tests were made up of multiple-choice items. Student scores were calculated as the percentage of correct answers. A threshold of 35% was set for a 'minimum competency' level with 55% defined as 'proficient'. It should be noted that these are arbitrary benchmarks and that the theoretical guessing level constitutes a significant proportion of these – particularly at the minimum competency threshold. In the 2013 study, 42.9% of Grade 3 students and 39.2% of those studying in Grade 6 fell below the minimum competency threshold. At the higher competency level, 22.1% of Grade 3 students and 10.9% of Grade 6 students were deemed proficient. No information is available in the published reports as to the absolute levels of achievement, i.e. which mathematical tasks the students at each level could and could not do.

Two countries in SSA – The Gambia and the Republic of South Africa have adopted a census approach to national assessment in which all students in the target populations are tested. Using a census approach is far more expensive than using a relatively small but representative sample. However, it avoids many of the problems associated with sampling, potentially yields more information, and offers the possibility of using data for both school accountability and monitoring the progress of individual students.

Since 2011, South Africa has tested all students in the target Grades 1-6 and 9. The scale of the exercise is vast with more than 25,000 schools participating in 2014 and a target population of 7,376,334 students. The items used are predominantly of the constructed response type. Student scores are calculated as a percentage of correct answers with an 'acceptable achievement' threshold set at 50%. In addition, above a minimum threshold of 30%, six qualitative levels are identified: elementary; moderate; adequate; substantial; meritorious; outstanding. In the 2014 study, 13.2% of Grade 3 students failed to achieve the elementary level in mathematics and only about two-thirds (64.4%) reached the level deemed 'adequate'. Of the students in Grade 6, 28.9% failed to achieve the elementary level and just over one-third (35.4%) reached the 'adequate' level (DBE, RSA, 2014). As in the case of Ghana, no information as to the absolute levels of mathematical achievement associated with the designated levels is available in the published reports.

National assessment has a relatively long history in The Gambia. In 2000 and 2002, students in Grades 3 and 5 were assessed using the UNICEF Monitoring of Learning Achievement (MLA) sample-based model. However, following the abolition of a high-stakes selection examination (Common Entrance Examination) traditionally held at the end of Grade 6, it was decided that all students in key grades should be assessed through a National Assessment Test (NAT). The main aims

22. These three examples were chosen because their reports were readily available. In other cases we could not find recent reports or other documentation.

were: to provide more information about the quality of student learning during the basic phase of education; to provide information about the performance of individual schools; and to maintain the motivation of teachers and students which was formerly boosted by the presence of the Common Entrance Examination (MBSE, The Gambia, 2015). Initially the NAT targeted core curriculum subjects at Grades 3 and 5 with both populations and all subjects assessed annually from 2008 to 2014. In 2012, the NAT was expanded to include all students in Grade 8. In order to improve efficiency, a new pattern of testing was introduced in 2015. The Grade 8 population is to be assessed every year but Grades 3 and 5 will be tested in alternate years (starting with Grade 3 in 2015).

In 2014, approximately 32,000 Grade 3 students. 27,000 Grade 5 students and 22,000 Grade 8 students participated in the NAT. The subjects tested were: English, Mathematics, and Integrated Studies (Grade 3), English, Mathematics, Science, Social and Environmental Studies (Grade 5) and English, Mathematics, Science, Social and Environmental Studies (Grade 8). The tests for mathematics are composed of four-option multiple-choice items and results are calculated as percentage correct scores. Two proficiency thresholds are set: 'minimum competency' at 40% of the maximum possible test score[23] and 'mastery' at 80% of the maximum possible test score. In the 2014 report, these thresholds are not linked to behavioural descriptors and so no information is available as to what students at these levels can and cannot do in mathematics. The final report gives average scores and standard deviations (but not standard errors) for the tests applied at each target grade but since these are test-dependent it is difficult to extract any meaningful information. For example, what can the reader make of the fact that the average score on the mathematics test for Grade 3 was 44.3% and that the standard deviation was 19.8%? The report uses these values to conclude without further explanation that "Achievement in Mathematics continues to be a challenge" (MBSE, The Gambia, 2015, p.57).

The use of test-dependent percentage correct scores in the NAT means that the results cannot be used to monitor trends. However, the report for 2014 compares average scores from 2012-2014 and uses these to imply that mathematical achievement has improved over time (ibid). It should be noted that an alternative mechanism for monitoring changes over time has been proposed, and piloted, for the NAT. This involves incorporating a set of common anchor items in tests used at four- or five-yearly intervals with outcomes to be linked by IRT scaling. The intention is that this method will be used, for example, to compare Grade 5 results from 2012 with those of 2016 and to compare Grade 3 results from 2012 with those of 2017. After sharing the report for 2014, the government has taken on board feedback and has actively sought to address these shortcomings in future NAT reports.

23. The report of the 2014 NAT makes no mention of the 25% theoretical guessing factor which represents a significant proportion of, for example, the minimum competency threshold score.

The examples from the Gambian NAT highlight an important general issue with implications for all countries trying to harness the potential of large-scale national assessments. The Gambia has followed international trends in assessment and has invested heavily in its national assessment system. It has put in place many of the technical and administrative procedures necessary for the conduct of a large-scale assessment and it has successfully embedded the NAT in its education system. However, the NAT is still some way from realising its full potential and, is not offering the government best value for money. To address this, two steps are necessary. First, the scope and quality of the information yielded by the NAT should continue to be reviewed by key stakeholders including policy makers and educational practitioners with the support of assessment specialists. In short, the stakeholders should ask "Is the NAT providing answers to the most pressing questions in our education system and, if not, how should it be transformed to provide the information that we need in forms we can understand and use?" Secondly, technical limitations and shortcomings in the reporting of results should be rectified through strengthening technical capacity and implementing rigorous quality control procedures. This may require the sustained use of international technical assistance until sufficient local capacity and experience is in place.

3.2.5 Examinations

Formal examinations are a dominant feature of education systems across SSA. Their key purposes are selection and/or certification of learner achievement at critical transition points. Typically, these lie between the primary and (junior) secondary phases, between the junior and secondary phases, and at the interface of (senior) secondary and tertiary education. Such examinations, conducted by national or regional assessment agencies, are generally well-established and tend to have extremely high public profiles. As such, one would expect them to be a rich source of information as to the current state of mathematics education in SSA. Unfortunately, this is not the case. The high-stakes associated with the main examinations and the significant risks presented by malpractice mean that examining authorities, not unreasonably, give priority to maintaining secrecy and security throughout the preparation, conduct, and result-processing stages of the examination. As a result, relatively little attention appears to be paid to the dissemination of quantitative and qualitative information about candidate performance at the subject level.

The problem alluded to above has four main dimensions. First, many of the examinations used to select students for opportunities at the next level of education and/or to place students in particular schools are 'group certificates'. This means that students' overall results are determined by aggregating their results from a number of predetermined subjects – including, without exception, mathematics. These aggregated results are of paramount interest for students, their parents, schools, and the general public and so it is these that are issued by examination boards and reported in the mass media. In many cases it is difficult, if not impossible, to find results by subject. Secondly, where results for separate subjects are published, they are generally aggregated by 'grade' or 'division'. However, the mechanisms by which grade thresholds (cut-scores) are determined are not transparent. In the case of countries using examination procedures derived from earlier colonial models, it is likely that the grading process involves an uncertain mix of norm-referencing and 'expert judgement'. This makes interpreting pass rates and other performance indicators problematic. In short, it is not possible to determine what the students receiving a particular examination grade know and can do in mathematics. Thirdly, because each test administration uses entirely new question papers without any systematic link to earlier tests, examination scores and pass rates cannot be used to monitor educational progress in a meaningful way[25]. Fourthly, the national and/or regional authorities responsible for high-stake examinations do not make primary data (e.g. student test scores and item statistics) easily available to bona fide researchers[26]. Even basic summative statistics (e.g. average scores, standard deviations, etc.) and overall test-score distributions are not published as a matter of course. This means that the measurement characteristics of subject-specific examinations cannot be independently evaluated and the absolute levels of mathematical achievement displayed by test-takers cannot be determined.

Two examples are given below for illustrative purposes.

In Uganda, students sit the primary leaving examination (PLE) at the end of Grade 7. The examination comprises tests in: English Language; Mathematics; Science; and Social Studies. Student scores on individual tests are graded as distinction, credit, or pass. Subject results are then converted into points (1 to 9, with 1 being best). These are then added to give an aggregate point score which is then converted into an overall grade for the PLE. Higher ability students with between 4 and 12 points are classified as being in 'Division 1'; those with between 13 and 23 points are in 'Division 2'; those with between 24 to 29 points are in 'Division 3'; and, those with between 30 to 34 points pass in 'Division 4'. It is this final classification which determines a student's place in the secondary education system and so is the focus of attention for all stakeholders (Kavuma, 2010). The absolute performance of students in mathematics, or any other subject, is, to all intents and purposes, lost in the grading and aggregation processes. Table 3.7 shows the subject-specific grading of the PLE in 2014 (UNEB, 2014).

Table 3.7: Results of the 2014 Primary Leaving Examination in Uganda by subject

Subject	Number of candidates	Pass (or above)	Credit (or above)	Distinction
Mathematics	585,906	85.8%	49.0%	5.8%
Science	585,707	85.5%	63.5%	7.8%
Social Studies	585,914	92.6%	75.5%	10.9%
English	585,926	83.9%	57.0%	7.2%

25. In the absence of better measures, examination pass rates are often cited as indicators of educational quality and of changes in national levels of achievement. For example, in the Ugandan Certificate of Education, it was reported that "performance in Mathematics dropped significantly" because the proportion of candi dates gaining the highest division fell from 4.1% in 2013 to 1.8% in 2014 (Ahimbisbwe, P., 2015). However, other plausible explanations include an increase in the difficulty of the questions and/or the effect of unintentionally setting slightly higher standards.
26. For the purposes of this study, examination boards in six countries were asked by World Bank representatives to supply basic statistical information for their main examinations in Mathematics. Two boards in Nigeria provided aggregated data but not the subject score distributions and grade thresholds requested. All other examining agencies failed to respond.

In Kenya, students sit the Kenya Certificate of Primary Education (KCPE) at the end of Grade 8. Children are tested in Mathematics, English, Kiswahili, Science, Social Studies and Religious Studies, primarily through multiple choice items but with extended writing in English and Kiswahili. “The marks in each subject are standardised” (KNEC, n.d.). Aggregated results are reported as a standardised score[27] on a scale with a mean of 250. Students who score 200 or more are generally assured of a place (“slot”) in a public secondary school. However, pressure on such places is exceptionally high with approximately 200,000 candidates for KCPE failing to gain automatic admission in 2014. No information as to the performance of students on individual subjects appears to be publicly available.

The more general role of examinations in mathematics education is considered in Chapter 8.

3.2.6 Early Grades Mathematics Assessment (EGMA)

The development of the EGMA Concept was co-ordinated by USAID under its EdData II programme. At its core lies a framework for the acquisition of mathematical skills by young learners based on extensive research (USAID, 2009). EGMA assessment instruments, methods and reporting procedures reflect the content of the framework. The EGMA measurement sub-domains for lower grades (e.g. Grade 4) are: number identification; quantity discrimination: missing numbers in patterns: addition and subtraction: word problems. For slightly older pupils (e.g. Grade 6), countries may choose to add, for example, multiplication and geometry. These, in general, correspond closely to the mathematics curricula for primary grades of countries in SSA and beyond. Results are reported separately for each sub-domain. Number (and proportion) of tasks completed successfully are reported. In addition, the numbers of addition and subtraction tasks completed successfully in one minute are reported as a measure of ‘automaticity’.

Tests are conducted on a one-to-one basis with tasks being presented orally by a trained test administrator. Students respond orally[28]. This feature of EGMA allows tasks to be presented in languages and dialects that the children understand rather than, as is often the case with written tests, in a language in which the child is not yet proficient. Test administrators use tablets and Tangerine® software to record assessment and questionnaire responses.
The optimum sample size for a population of interest (stratum) is of the order of 450, i.e. 40-50 schools with 10-12 students chosen randomly within each. For example, in Rwanda in 2011, two grades were tested (P2 and P4) in 42 selected schools. In each school, 10 pupils were to be selected in each grade giving an intended sample size of 420 per grade (USAID, 2012a). In Ghana in 2013, only one grade was tested but the population was stratified first by region (10) and then by language of instruction (e.g. 6 in Greater Accra). 45 schools were selected for each major stratum and fewer for, for example, very small language groups. This gave a total intended sample of 815 schools and 8,150 students. The achieved sample was 805 schools and 7,923 students (USAID, 2014, p.7).

In addition to student assessment, EGMA also collects background information from sampled students, teachers (one per sampled school) and school principals. This information is

27. Whilst the KCPE system is clearly norm-referenced, the implications do not appear to be fully understood by educational policy makers. For example, the 2014 results were announced by the Cabinet Secretary as being “relatively the same as last year (since)… 436.814 students got more than 251 marks, representing 49.61 percent of those who sat for the exam, compared to 49.71 percent last year” (Kenya Today, 2014).
28. For higher grades, some calculation questions may be presented in writing with students working out answers on paper.

primarily used to give a snapshot of the context in which mathematics is taught and learned. The methods used and the limited precision of the measurement procedure means that EGMA data is not generally well suited to identifying relationships between background factors and achievement levels[29]. However, the clarity of the EGMA structure and its criterion-referenced tasks lead to clear, comprehensible conclusions and, in many cases, stark headline findings for educational planners as exemplified below.
"The majority of children scored zero across the sub-tasks, indicating that they have not acquired foundation skills in Mathematics." EGMA in Bauchi and Sokota states, Nigeria, 2013 (USAID, 2013).

"Pupils were asked to compare single- and double-digit numbers, and to say which was the larger... . In Grade 2, 18% of pupils were unable to answer a single item, while in Grade 3, fewer than 12% could produce a correct response (to all items)." EGMA in Zambia, 2011 (USAID, 2012b).

"... on the missing number, addition level 2 and subtraction level 2 subtasks, there was a sharp drop-off in performance, with nearly 70% of the pupils unable to answer a single subtraction level 2 item correctly - the easiest of these being: 19 – 6 = □." EGMA in Ghana, 2013 (USAID, 2014).

"In P4, only 50% of the students were able to indicate the correct (geometrical) shape when given its attributes. Of P4 students, 56% were unable to name any of the shapes presented (in either English or Kinyarwanda). In P6, the majority of students could indicate the correct shape based on its attributes, but 38% could name only one of the shapes." EGMA in Rwanda, 2011 (USAID, 2012a).

3.2.7 Uwezo

"Uwezo is part of Twaweza, an independent East African initiative that promotes access to information, citizen agency and improved service delivery outcomes across the region" (Uwezo, 2014, p.2). It assesses what children know and can do in relation to selected objectives of the national Grade 2 curriculum in reading and basic mathematics in Kenya, Uganda and Tanzania. It is unlike any other major assessment of children's learning in SSA in that it assesses children in their homes. As a result, it includes in its sample not only those attending state and private schools, but also those who are out of school. Its assessment instruments are short and clear with numeracy tasks assessing counting, number recognition; comparison of numbers and basic operations (addition, subtraction, multiplication and division). Examples are given in Figure 3.2. The approach is child-centred with assessors not presenting the more difficult questions to children who have 'failed' on simpler tasks. In each sub-domain, children are allowed to choose which tasks they attempt.

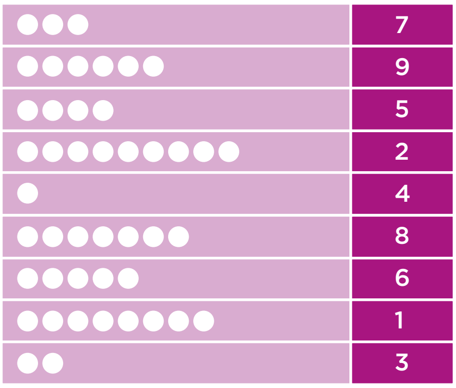
For example, in the multiplication task illustrated in Figure 3.2, the child can attempt any three of the items. Mastery (success) in this task is defined as two or three correct. (Uwezo, 2014). The criterion for 'passing' the numeracy test is success (at the defined mastery level) in all of the numeracy sub-domains. Uwezo's assumption is that children older than the target age for Grade 2 should be able to demonstrate mastery of the fundamental mathematical concepts of the Grade 2 curriculum. Unfortunately, the survey consistently shows that this is far from the case. In Uganda for example, only 44% of those aged

29. Notwithstanding this cautionary note, in some countries data has been analysed to relate outcomes to, for example, socio-economic status.

10-16 passed the numeracy test (Uwezo, 2014, p.13). (The corresponding pass rate was 68% in both Tanzania and Kenya.)

Figure 3.2: Examples of basic numeracy tasks used in Kenya for the Uwezo assessment of 2013

Count and Match



Multiplication

2x4=	3x2=	5x3=
4x3=	5x2=	5x5=
3x4=	4x5=	

Perhaps the greatest strength of Uwezo, like that of the original model established by ASER/ Pratham in India, is its capacity to produce simple, clear and powerful messages. Statements, such as those shown below, can be understood at all levels of the community and are difficult for politicians to ignore.
"Less than a third of children enrolled in Grade 3 have basic Grade 2 level literacy and numeracy skills" (Uwezo, 2014, p.4).
"A significant number of children do not possess foundational Grade 2 level skills even as they approach the end of the primary school cycle" (ibid, p4).

3.3 Standards in the secondary phases of education

As can be seen from the above, the past 20 years have seen rapid development of assessment systems for measuring the mathematical competences of students across the primary phase of education in many countries of SSA. This has coincided with rapidly growing primary school enrolment rates. However, as yet, there has been much less activity at the secondary level. The range of assessments is much narrower and, in particular, there are few which yield information as to absolute levels of mathematical ability. As at the primary phase, few countries in the region have participated in international large-scale assessments, but at the secondary level there are no regional large-scale assessments comparable to those of SACMEQ and PASEC. Some countries have started to develop their own national assessments for secondary education but these are less numerous and less well-developed than those for primary grades. The sources of information which do exist and their key findings are described below.

3.3.1 TIMSS at Grade 8

Just three countries in SSA have participated in TIMSS for Grade 8 students: Botswana; Ghana; and, South Africa. Botswana and Ghana have taken part in all three cycles since 2003. South

Africa participated in 2003 and 2011. All three countries are participating in the current 2015 cycle. Table 3.8 shows that their performances have consistently fallen far below international norms and have been placed towards the bottom of the international rankings. In the 2011 cycle, in order to better match the TIMSS instruments with the ability of their students, Botswana and South Africa selected their samples from Grade 9. Whilst these cohorts fared better than their predecessors, their average scores for mathematics still fell at least one standard deviation below the international mean. Ghana, the only country to select from Grade 8, finished at the bottom of the international rankings for the 42 participating countries/economies.

Table 3.8: TIMSS mathematics results for population 2 (Grade 8) for SSA participants 2003-2011

	Mean Maths score (SE)	Rank order/total participants	Mean Maths score (SE)	Rank order/total participants	Mean Maths score (SE)	Rank order/total participants
Botswana	366 (2.6)	42/45	364 (2.3)	43/49	397*(2.5)	
Ghana	276 (4.7)	44/45	309 (4.4)	47/49	331 (4.3)	42/42
South Africa	264 (5.5)	45/45	---	---	352*(2.5)	
International	467 (0.5)		453 (0.7)		469 (0.6)	

The 2011 TIMSS report provides information as to the absolute performance of students by reporting the proportion of the cohort reaching international benchmarks which are both fixed on the TIMSS reporting scale and defined by descriptive criteria. Four benchmarks are defined as in Table 3.9.

Table 3.9: Descriptions of the TIMSS international benchmarks for achievement in mathematics (Grade 8)

International Benchmark	Scale score	Descriptor
Advanced	650	Students can reason with information, draw conclusions, make generalisations, and solve linear equations. Students can solve a variety of fraction, proportion, and percent problems and justify their conclusions. Students can express generalisations algebraically and model situations. They can solve a variety of problems involving equations, formulae, and functions. Students can reason with geometric figures to solve problems. Students can reason with data from several sources or unfamiliar representations to solve multi-step problems.
High	550	Students can apply their understanding and knowledge in a variety of relatively complex situations. Students can use information from several sources to solve problems involving different types of numbers and operations. Students can relate fractions, decimals, and per-cents to each other. Students at this level show basic procedural knowledge related to algebraic expressions. They can use properties of lines, angles, triangles, rectangles, and rectangular prisms to solve problems. They can analyse data in a variety of graphs.
Intermediate	475	Students can apply basic mathematical knowledge in a variety of situations. Students can solve problems involving decimals, fractions, proportions, and percentages. They understand simple algebraic relationships. Students can relate a two-dimensional drawing to a three-dimensional object. They can read, interpret, and construct graphs and tables. They recognise basic notions of likelihood.
Low	400	Students have some knowledge of whole numbers and decimals, operations, and basic graphs.

At the international median the proportions of the cohort reaching or exceeding each benchmark are: Low 75%; Intermediate 46%; High 17%; Advanced 3%. However, in Ghana, only 21% of students could reach the lowest benchmark. By way of comparison, 36% of Moroccan students, 57% of Chilean students, and 61% of Tunisian students reached this minimum level. At the other end of the spectrum, 99% of Singaporean and Korean students surpassed the lowest benchmark. 50% of Grade 9 students from Botswana reached the low benchmark but only 1 in 4 (24%) of the South African Grade 9 sample was capable of reaching this level.

The TIMSS 2011 Grade 8 assessment included the following item which typifies performance around the low international benchmark: 42.65 + 5.748 = ? Internationally, 72% of students could solve this problem. However, only 36% of Ghanaian students were successful. Clearly the gap between the performance of students from SSA and that of their international peers is disturbingly large.

3.3.2 PISA

It is widely recognised that the literacy-based assessment frameworks of OECD's PISA programme reflect the demands of a modern, competitive, global market where new technologies play an increasing role. In particular, PISA's assessment of mathematical literacy for 15-year-olds is seen as providing important information to national policymakers trying to accelerate the development of human resources appropriate for the 21st-century. However, to date, the only PISA participant from SSA has been Mauritius. Mauritius took part in PISA+, the re-run of PISA 2009, and, in mathematics and science scored at a level commensurate with that of the two lowest performing countries of the OECD, Chile and Mexico. Approximately 50% of students from Mauritius reached the PISA baseline level of competence (Level 2) at which "they begin to demonstrate the kind of skills that enable them to use mathematics in ways considered fundamental for future development" (Walker, 2010, p. xiii). This compares with the OECD average of about 78%. In considering this outcome it should be noted that Mauritius is not typical of the SSA region. It is a relatively wealthy, small island state which boasts a traditionally strong education system regularly outperforming other countries within SACMEQ by a significant margin.

Table 3.10: Description of the PISA baseline level of competence (mathematical literacy)

PISA level	Scale score	Behavioural Descriptor for the baseline level of competence
2	420	At Level 2 students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and literal interpretations of the results.

Given the experience of Mauritius, it is highly likely that PISA would prove unsuitable for other countries in SSA with a significant mismatch between the demands of the assessment instruments and the ability level of students. However, a new assessment package - PISA for Development - is currently being prepared with the aim of increasing "developing countries' use of PISA assessments for monitoring progress towards nationally-set targets for improvement, for the analysis of factors associated with student learning outcomes, particularly for poor and marginalised populations, for institutional capacity-building and for tracking international educational targets in the post-2015 framework being developed within the UN's thematic consultations" (OECD, n.d.). In the medium term, this is likely to be a more appropriate monitoring tool for the region. To date, two African countries, Zambia and Senegal, have signed agreements to participate in the project's development and piloting phase. It will be interesting to see their progress.

3.3.3 National assessments

Whilst nearly 30 countries in SSA have, on at least one occasion, conducted a national assessment in the primary phase of education, only a handful have started to implement national assessment at the secondary level. Table 3.11 summarises the situation up to 2015.

Table 3.11: National assessment programmes conducted at the post-primary level by countries within SSA

	Title	Grade(s)	Subjects	Year(s)
Ethiopia	National Learning Assessment	10, 11	Mathematics, English, Biology, Chemistry, Integrated Studies	2010, 2013
Mauritius	National Form III Assessment	9	English, French, Mathematics, Computer Studies, Physics, Biology, Chemistry	Annually, 2010 to 2014
South Africa	Annual National Assessment	9	Literacy, Numeracy	Annually, 2011–2014
The Gambia	National Assessment Test	8	English, Mathematics, Science, Social and Environmental Studies	Annually from 2012
Uganda	National Assessment of Progress in Education	8	English, Mathematics, Biology	Annually, 2008–2013

As at the primary level, these national assessments differ significantly in their purposes and methods. There has been little external evaluation of these assessment programmes and there are some doubts as to their technical rigour particularly when it comes to making comparisons amongst groups and/or monitoring changes over time. Key areas of concern are limitations in sampling procedures, reliance on 'percentage correct' reporting scales, non-standardisation of tests, and the treatment of weights and standard errors. In general, the assessment agencies responsible seem to require greater capacity in the field of psychometric testing if they are to provide national assessment services which are fit for purpose. The examples below illustrate some of the key issues.

In 2010, Ethiopia conducted its first sample-based national assessment for Grade 10 and Grade 12 students (NAE, Ethiopia, 2010). The Grade 10 sample comprised 140 schools and approximately 5,600 students. The Grade 12 sample comprised 73 schools and approximately 2,800 students. Selected students took tests in five subjects: English, Mathematics, Biology, Chemistry and Physics. Student performance at the subject level was reported as a percentage correct score. These raw scores were then added to give an overall score. An arbitrary minimum threshold of 50% was set by the Education and Training Policy of Ethiopia (ibid). In addition, four levels of achievement were defined on the basis of standardised scores (z-scores). For example, 'Basic' covered the z-score range 0 to +1. The proportion of students reaching each of these four levels was reported without reference to the fact that they were norm-referenced[30]. Table 3.12 summarises the results for mathematics.

Table 3.12: Summary statistics for the mathematics tests used in the Ethiopian national assessment of 2010

	Grade 10	Grade 12
Number of cases	5525	2660
Mean (%)	34.7	54.3
SD (%)	14.18	16.4
Median (%)	31.7	53.3
Skewness	1.23	0.113
Proportion above 50% threshold	14.7%	57.7%
Proportion 'Below Basic Level'	60.7%	50.4%

30. If the tests used in the Ethiopian national assessment had produced normal or near normal score distributions, the proportions falling at each level would have been known in advance. In the event they differed slightly because the tests produced positively skewed score distributions. This fact is not mentioned in the report which gives the impression that the percentage reaching each level is indicative of absolute levels of achievement.

Unfortunately, the use of a test-dependent, proportion correct reporting scale, coupled with an arbitrary minimum threshold and norm-referenced ‘proficiency’ levels means that the national assessment yields little useful information as to absolute levels of student achievement in mathematics. It does not help that the report does not include examples of the multiple-choice items used in the mathematics tests nor does it provide appropriate item statistics.

The report also reveals the dangers of applying inappropriate statistical techniques to data when drawing comparisons and investigating contributory factors. For example, the national sample used in Ethiopia is comparable in size to that used for large-scale international assessments. However, when analysis is done in order to compare regions, the sample sizes become dangerously small. For example, results are given for the region of Dire Dawa on the basis of just 107 students. These students are clustered in a small number of schools giving an effective sample size much less than 100. This is probably too small for valid comparisons to be made but the report offers no caveat.

The National Form III Assessment in Mauritius does not include many of the elements usually associated with large-scale national assessments in that it does not collect information on background factors likely to affect learning outcomes. Its main aim is to measure learning achievement and to provide diagnostic information so that schools and teachers can improve the quality of learning (MES, Mauritius, 2015). The impression is of a mock examination rather than a national assessment targeted across the full ability range. That having been said, the report on student performance does provide teachers with qualitative information as to how students performed on specific test items. This, coupled with the fact that the tests used are placed in the public domain, is likely to have a positive influence on future teaching/learning.

In South Africa, assessment at Grade 9 is an extension to the annual national assessment programme used across Grades 1-6 described above. All students in the target grade are tested (1,042,133 in 9,208 schools in 2014). Scores are calculated as the percentage of correct answers. In addition, above a minimum threshold of 30%, six qualitative levels are identified: elementary; moderate; adequate; substantial; meritorious; outstanding. These levels are not explicitly linked to specific mathematical competences but relate to raw score thresholds. In order to reach the minimum positive threshold (‘elementary’), a student must score 30%. In the 2014 study, a staggering 90% of Grade 9 students failed to achieve the elementary level in mathematics (DBE, RSA, 2014, p.81). Indeed, the average score on the test was just 11%. Clearly there is a catastrophic mismatch between the demands of the test items and the abilities of the students. The fact that the test in mathematics failed to produce a reasonable distribution of scores, especially at the lower end of the ability range, indicates a serious technical flaw in this element of the national assessment programme. Put simply, a test like this which is far too difficult for the average student will yield little reliable information as to what that student can do. If we accept that the tests were prepared by subject specialists on the basis of the curriculum’s content and objectives, the only conclusion we can draw is that the overwhelming majority of students are failing to master the essential elements of the prescribed mathematics curriculum.

3.4 The learning deficit and change over time

Evidence gleaned from international, regional and even national assessments of achievement in mathematics suggests that the learning deficit between students who study in the countries of SSA and their international peers is great. Results from TIMSS show that Botswana, Ghana and South Africa appear towards the bottom of the international rank order even when they select over-aged students. Botswana, the highest performing of the three, fares significantly worse than, for example, competitor nations from Latin America. For example, in the 2011 TIMSS for Grade 8, Botswana's average score of 397 was significantly lower than Chile's score of 416 - even though Botswana sampled Grade 9 students. The situation was equally bad for the younger population where Chile's Grade 4 students outperformed Botswana's Grade 6 students by more than 40 points. Unfortunately, this suggests that the nine countries of SSA that Botswana outperformed by a statistically significant margin in SACMEQ III are even further behind.

In PISA+, the performance of Mauritius was comparable to that of Mexico, Chile, Bulgaria and Thailand showing that Mauritius is within touching distance of significant economic competitors. However, it should be noted that in SACMEQ III students from Mauritius outperformed all their regional peers by a margin of almost three-quarters of a standard deviation. While Mauritius may be approaching the performance of the weakest countries in the OECD, the other countries of SSA lag far behind.

Having established that mathematical outcomes across SSA are poor in both relative and absolute terms, the key questions are: Is there any evidence that things are getting better, i.e. that mathematical standards are improving? Are there any signs that the learning deficit is getting smaller?

Monitoring trends in educational standards poses many technical challenges and is problematic even for the most sophisticated of international large-scale assessments. The fundamental cause of these difficulties is the fact that, under normal circumstances, the changes we can expect to see over relatively short periods of time are small - especially in large systems. For example, Korea, a country which has been particularly successful in improving its educational outcomes, raised its TIMSS Grade 8 mathematics score by just 32 points over the period 1995 – 2011 (Mullis et al., 2012). This represents an improvement of less than one-third of a standard deviation over 16 years. Therefore the challenge facing those who wish to detect such changes in SSA is not only to measure student achievement accurately and repeatedly, but also to estimate, with precision, the errors inherent in the measurements used to calculate differences. Without appropriate estimation of measurement errors there is a danger that false positives or negatives will be reported. This caveat is particularly important when considering the findings of national and regional assessments which do not fully meet the technical requirements of, for example, TIMSS and PISA. The main areas of concern when evaluating evidence from various sources as to changes in mathematical standards in SSA are: inadequate sampling and weighting procedures; the use of different and/or uncalibrated tests for repeated measurements; the comparison of scores based on different metrics (e.g. test-dependent percentage correct scores); missing or inappropriate estimation of errors of measurement. Such shortcomings mean that many reports of rising and/or falling standards available in the assessment reports evaluated for the purposes of this study must be disregarded or, at best, treated with caution as is made clear in the regional and national examples below.

3.4.1 TIMSS

Only three countries in SSA have participated in an international large-scale assessment (TIMSS Grade 8) on more than one occasion. However, only Ghana has consistently sampled from the target grade allowing standards to be monitored over time. Botswana and South Africa moved to drawing a sample from Grade 9 in 2011 making comparisons with earlier results impossible. For Ghana, the average score appears to have risen significantly over time as shown in Table 3.13. However, it should be noted that the TIMSS report for 2011 excludes Ghana from its description of trends over time. This is because the average score estimates for Ghana are considered unreliable because more than 25% of students have achievement which is too low for accurate estimation by the TIMSS assessment instruments.

Table 3.13: Ghana: TIMSS mathematics results over time for population 2 (Grade 8)

Ghana: TIMSS grade 8 mathematics			
	2003	2007	2011
Average score	276 (4.7)	309 (4.4)	331 (4.3)
Change from previous cycle	-	33*	22*
Change from 2003 base	-	33*	55*

3.4.2 SACMEQ

As mentioned previously, the method of calculating student scores in SACMEQ surveys was changed in the second cycle (SACMEQ II) in order to establish a test-independent baseline for the 14 participating entities. Item difficulties and student achievement scores were calibrated using IRT (Rasch) allowing them to be placed on a common scale. The initial calibration was adjusted to give a group average[31] of 500 and a standard deviation of 100. In the following cycle, SACMEQ III, a number of items from the previous survey were included as 'anchor items' allowing results from the second survey to be placed on the original scale. In theory, this allowed changes over time to be detected and compared. Indeed, the average mathematics score for the 14 ministries participating in SACMEQ II rose from 500.1 to 509.7 between the two surveys – a small but statistically significant improvement. However, comparisons at the level of individual countries reveal surprising volatility[32] as shown in Table 3.14. For example, between the two surveys the average mathematics score in five countries rose by about a quarter of a standard deviation or more (Lesotho, Mauritius, Namibia, Swaziland and Tanzania). Over the same period the average score for Mozambique dropped by nearly half a standard deviation (0.46 SD). However, this decline has been attributed to "rapid structural changes in the education system during this period that resulted in massive increases in Grade 6 enrolments without corresponding increases in human and material resources" (SACMEQ 2010b, p.2). It will be interesting to see if the results of the SACMEQ IV survey provide more robust evidence of trends in mathematical outcomes across the reference group of countries.

31. Each participating entity was given equal weighting in the calculation of the group average.
32. In international large-scale survey such as TIMSS and PISA the reference group of countries tends to be relatively stable and changes of the order reported for SACMEQ II-III would be viewed with some scepticism. One possible source of instability could be the difficulty of achieving comparable samples in the two cycles. For example, Ercikan et al (2008) observe that in SACMEQ II participating countries applied different exclusion rules (for example, Malawi excluded private schools and inaccessible state schools) and that 7 of the 14 countries failed to reach the effective sample size target of 400 students.

Table 3.14: Comparison of average mathematics scores in SACMEQ II and SACMEQ III by country

Country	SACMEQ II (2000)		SACMEQ III (2007)			
	Average Score (Maths)	SE	Average Score (Maths)	SE	Change (SD)	Significant ($p<0.05$)
Botswana	512.9	3.15	520.5	3.51	+0.08	
Kenya	563.3	4.64	557.0	3.98	-0.06	
Lesotho	447.2	3.24	476.9	2.61	+0.30	**
Malawi	432.9	2.25	447.0	2.89	+0.14	**
Mauritius	584.6	6.32	623.3	5.83	+0.39	**
Mozambique	530.0	2.08	483.8	2.29	-0.46	**
Namibia	430.9	2.94	471.0	2.51	+0.40	**
Seychelles	554.3	2.68	550.7	2.45	-0.04	
South Africa	486.3	7.26	494.8	3.81	+0.09	
Swaziland	516.5	3.41	540.8	2.39	+0.24	**
Tanzania	522.4	4.2	552.7	3.51	+0.30	**
Uganda	506.3	8.17	481.9	2.92	-0.24	**
Zambia	435.2	3.54	435.2	2.45	+0.00	
Zanzibar	478.1	1.26	489.9	2.35	+0.12	**
SACMEQ Average	500.1	n/a	509.7	1.16	+0.10	
Zimbabwe	-----	-----	519.8	4.98		

3.4.3 Uwezo

One of the strengths of Uwezo is that it assesses children in their homes using short, criterion-referenced tests of key mathematical concepts. Results are reported as the proportion of the cohort mastering or 'passing' the test. There is, as far as one can see, no estimation of the errors inherent in the results. As a consequence, Uwezo is not well suited to monitoring short-term changes, i.e. over periods of one or two years. Notwithstanding these limitations, Uwezo does report explicitly on trends over time. According to the 2013 report, Uwezo 'data show that there have been no significant changes in outcomes at regional aggregate level or in each country' (Uwezo, 2014, p.19). However, at the country level some changes are quantified as summarised in Table 3.15.

Table 3.15: Average scores for mathematics in South Africa's annual national assessment 2012-2014

Country	2009/2010	2010/2011	2011/2012
Kenya	67	69	68
Tanzania	46	63	68
Uganda	51	52	44

The key problem here is that some of the reported changes are unfeasibly large. In large, stable systems we do not expect to see changes of this size from year to year. For example, is it plausible that Tanzania should see a five percentage point jump in the proportion of students mastering basic numeracy in one year? Similarly, what could cause an eight percentage point fall in the mastery rate in Uganda?

3.4.4 National assessments

Well designed, national large-scale assessments offer countries the opportunity to monitor progress in the achievement of their students. However, detecting relatively small changes and showing that they are statistically significant requires the use of sophisticated measurement and analytical techniques. Many of the national assessments from SSA evaluated in the preparation of this study have technical limitations which make it difficult to have complete confidence in the trends reported. One of the main problems is that new tests are developed for each cycle of the assessment and, without IRT-based calibration, it is extremely difficult to compare scores. For example, the annual national assessment in South Africa reports trends in average test scores as shown in Table 3.16. The figures are used to conclude that South Africa is, in general, making progress in mathematics education across the primary grades. However, the report explicitly recognises that 'there is… no control over the comparability of the tests and, consequently, on the comparability of the results on a year-to-year basis' (DBE, RSA, 2014, p.15). Without further evidence it is impossible to decide whether the apparent improvement of scores is due to better teaching and learning, easier tests, greater familiarity with the test format, or some other factor.

Table 3.16: Average scores for mathematics in South Africa's annual national assessment 2012-2014

Mathematics: average score (percentage correct) by year			
Grade	2012	2013	2014
1	68	60	68
2	57	59	62
3	41	53	56
4	37	37	37
5	30	33	37
6	27	39	43
9	13	14	11

The problem of linking across different tests is also recognised in the technical report of the 2013 national education assessment in Ghana. Here, a number of items from the 2011 assessment were included as anchor items in all variants of the 2013 test in order to link scores through an equi-percentile frequency estimation method (MES, Ghana, 2014, p.22). The outcomes are shown in Table 3.17. However, as recognised in the report, significant changes were made to the length of the mathematics tests between 2011 in 2013. This casts some doubt on the precision of the equivalent scores. Notwithstanding this, the work done on test linking in 2013 has laid a more robust baseline for future measurements of change.

Table 3.17: Average mathematics scores on the 2013 Ghana National Assessment with equivalent averages for 2011 estimated through a procedure based on the use of common anchor items

Grade	2011 (equivalent % correct score)	2013 (% correct score)
Primary 3	38.6	41.1
Primary 6	39.5	38.2

Standard errors are not reported for the scores and the technical report states that 'pupils in 2011 and 2013 performed similarly on their respective assessments. The 2013 mean (percent correct) score was not dramatically above or below the 2011 score equivalents' (ibid, p.26).

In the examples of South Africa and Ghana cited above, we see that the teams responsible for these national assessments are grappling with the technical challenges of constructing tests having appropriate measurement characteristics and linking scores across the two administrations with sufficient precision. Progress is being made but, to date, national assessments offer little reliable data to prove conclusively that mathematical standards are rising, falling, or remaining static in the countries of SSA.

3.5 Summary

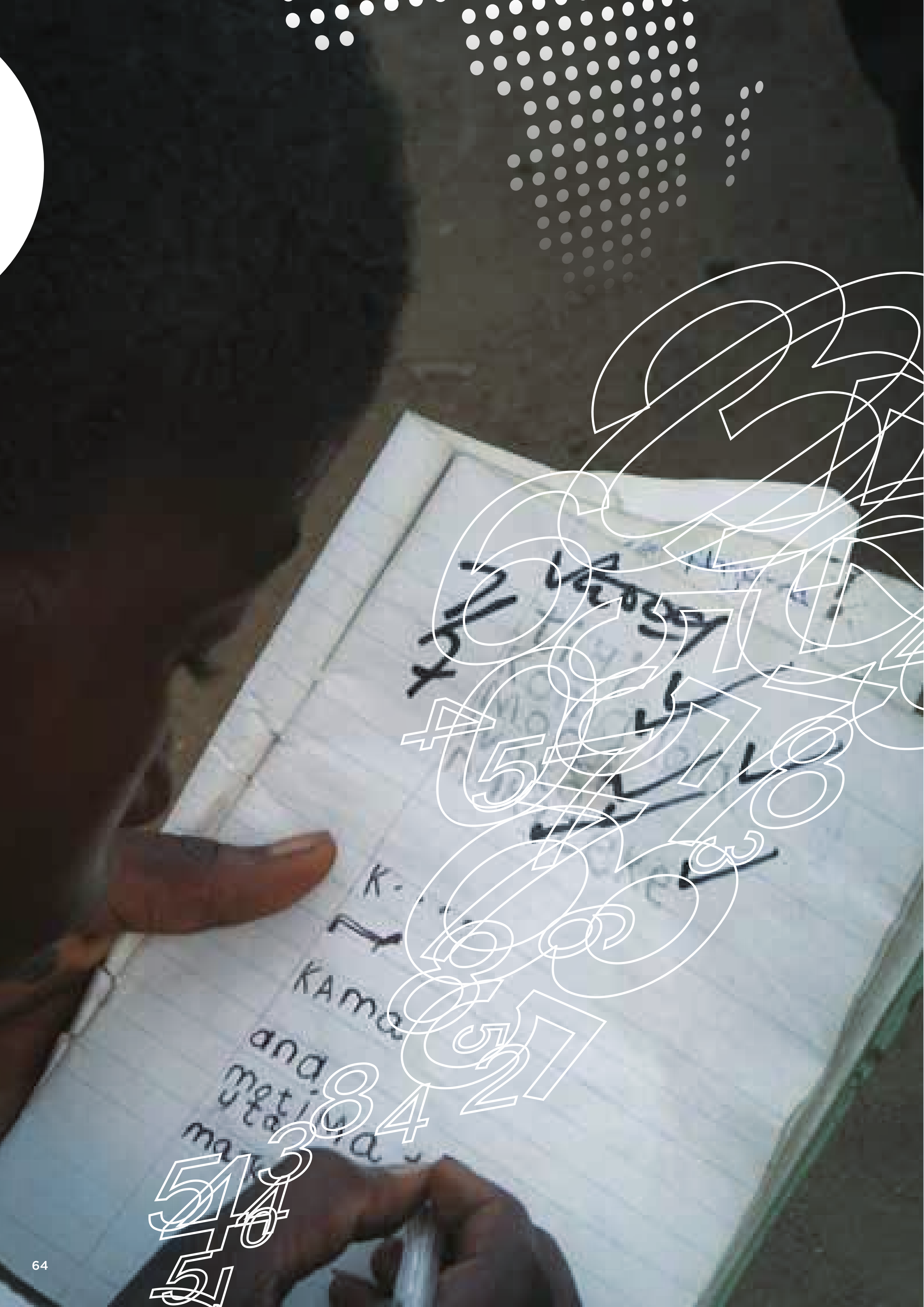
Evidence as to the state of mathematics education in SSA in terms of student achievement comes from a diverse and growing number of sources. The limited information available from international comparative assessments suggests that all major countries in SSA would appear towards the bottom of the international rank order. The international learning deficit is large and there is little evidence that the gap is starting to close.

Criterion-referenced assessments such as Uwezo and EGMA show that in many SSA countries the majority of students are failing to master fundamental mathematical concepts in the earliest years of education. SACMEQ and PASEC results confirm that in many countries of the region the problems of the early years persist and far too many students in Grade 6 remain innumerate. It is critically important that firm foundations are laid in the primary grades if higher mathematical standards are to be achieved at the secondary and tertiary levels.

At present few countries in SSA have comprehensive data on the mathematical achievement of their students. In particular, they have limited information as to what students know and can do in concrete terms. There is a need for countries to engage in high-quality assessment activities at the regional and international levels. However, care should be taken to select assessments which are aligned to the current low levels of student achievement. For example, the new TIMSS Numeracy assessment and the forthcoming PISA for Development are likely to be more suitable than TIMSS and PISA.

Over the past 20 years, many countries in SSA have started to implement national assessment programmes. In order for these to provide high-quality data for the purpose of strategic planning, stringent technical standards must be met. Therefore there is a need for countries to develop the necessary technical capacities and to implement rigorous quality assurance procedures in order to ensure that assessments are fit for purpose and that conclusions drawn on the basis of qualitative evidence are sound.

Regional and national assessments conducted in the past were not well-designed for detecting, with precision, relatively small improvements in learning outcomes. As a result, there is little reliable evidence as to whether mathematical standards in SSA are improving, are stagnant, or are declining. Some assessments – most notably SACMEQ - are now establishing more secure baselines but others will need to adopt far more sophisticated psychometric techniques if they are to provide reliable information as to the direction of travel.

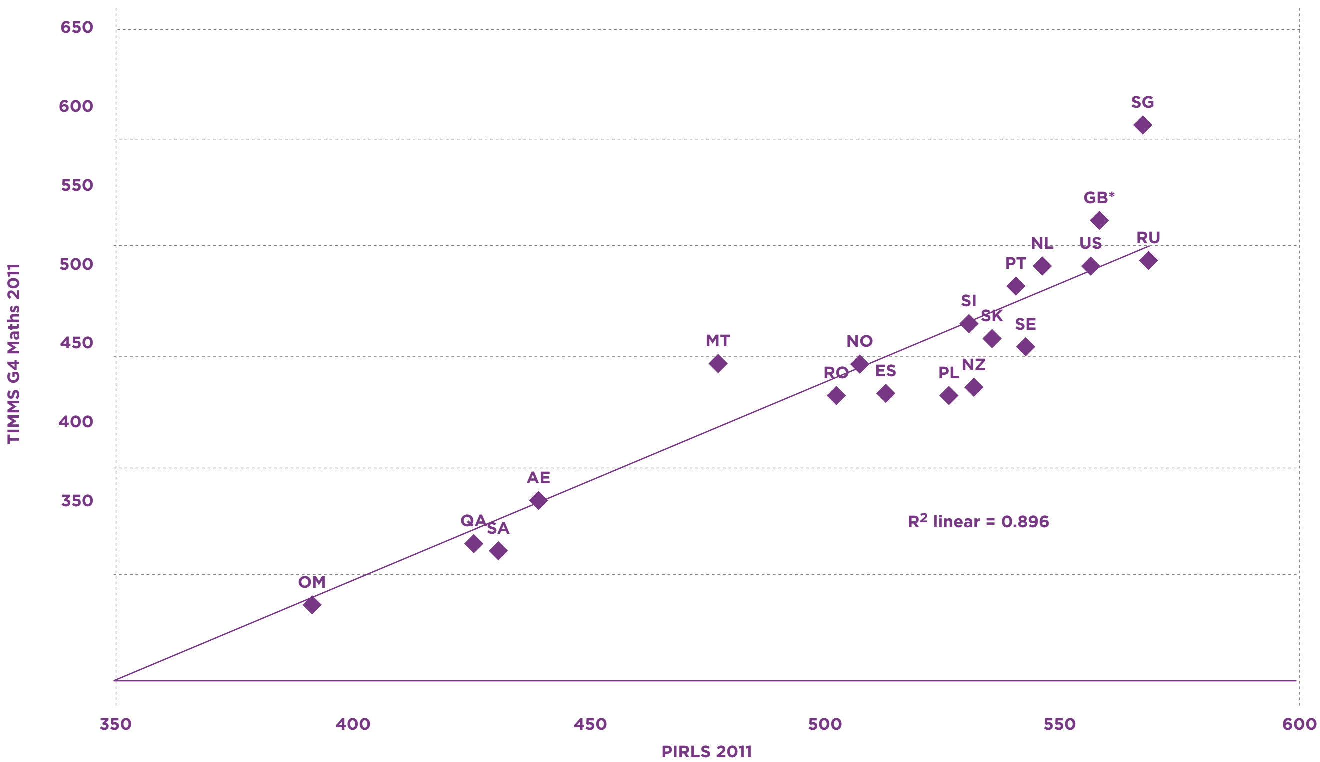


4 Factors affecting learning outcomes

4.1 Introduction

This study is specifically concerned with the state of mathematics education in SSA and in identifying strategies likely to raise standards of achievement in this vital subject. However, mathematics education is not an island in an ocean: outcomes in mathematics are intimately linked with those in other subjects. For example, Figure 4.1 shows that, at the national level, average PIRLS reading scores and average TIMSS Maths scores for the Grade 4 population are highly correlated (R^2 ~ 0.9).

Figure 4.1: Correlation of national average scores on the TIMSS 2011 mathematics assessment for population 1 (Grade 4) and the PIRLS 2011 assessment of reading literacy



Whilst some of this relationship may be causal in that students with better reading skills tend to fare better on any mathematics question that makes higher reading demands (Martin and Mullis, 2013), the key factor is undoubtedly the quality of the national education system and, therefore, the quality of a country's schools. The implication is that raising the general quality of schooling will inevitably have the effect of raising achievement in mathematics. Conversely, failing to address issues of general school quality will hamper specific attempts to raise mathematical standards. Fortunately, there is a great deal of research available, much of it based on data gathered through international large-scale assessments, as to what makes an effective education system and what makes a good school. Some of the key findings are summarised in this chapter. However, this is not to suggest that mathematics does not need special attention and subject-specific interventions. The pattern of achievement across subjects in different countries is not uniform. In a few, students are particularly strong in mathematics whilst in many others performance in mathematics is disproportionately weak. Table 4.1 shows selected results[33] of an analysis of the proportion of students reaching the TIMSS/PIRLS 'high' international benchmarks in reading, science and mathematics (Martin and Mullis, 2013). In some countries, most noticeably Hong Kong, Singapore and Chinese Taipei, performance in mathematics is significantly higher than in reading and science. However, in the majority of countries (20 out of 33) a smaller proportion of students reach the high benchmark in mathematics than in reading or science. Factors specifically affecting performance in mathematics are explored in Chapter 5.

Table 4.1: Comparisons of the proportion of a nation's Grade 4 cohort reaching the 'high' international benchmarks for TIMSS and PIRLS, 2011

Proportion of the Grade 4 cohort reaching the high international benchmark				
Country	Mathematics	Reading		Science
Hong Kong SAR	82%	67%		46%
Singapore	78%	62%		68%
Chinese Taipei	74%	55%		54%
Finland	50%	63%		65%
Hungary	37%	48%		46%
Czech Republic	30%	50%		45%
Italy	28%	46%		37%
Austria	26%	39%		42%
Sweden	25%	47%		44%
Croatia	19%	54%		30%
Poland	17%	39%		29%
Spain	17%	30%		28%

33. The top three countries in this table are those for which the performance in mathematics was at least 10% higher than that in reading or science. The nine countries below the line show a performance in mathematics at least 10% lower than that in reading or science (Martin and Mullis, 2013).

4.2 School quality

A wealth of research shows that background factors such as parental education levels and the socio-economic status (SES) of the family correlate positively with student achievement. However, recent research suggests that these are, in fact, less important than the quality of schooling experienced by students. For example, using a particularly rich Canadian data set, Green and Riddell (2012) find that parental characteristics "have only modest effect on (the acquisition of) cognitive skills, once we control for the individual's education" and that the impact of parental characteristics "arises indirectly through their powerful influence on the child's education" (Green and Riddell, 2012, p.3). Similarly, using the dataset from SACMEQ III for South Africa, Spaull (2011) finds that the SES of the school is a far more important factor than the SES of the student. In Spaull's words, "This means that placing a poor child in a wealthy school is likely to more than compensate for any negative effects of a poor home background" (Spaull, 2011, p.16). It should be noted that here the SES of a school is likely to incorporate aspects of 'school quality' that promote student achievement including, amongst others, effective school management and the employment of better qualified and more motivated teachers. The lesson for policymakers aiming to raise educational standards is that they should not be unduly distracted by home background factors which, in any case, they will find difficult to change, but should focus on providing high-quality, state-funded schools - especially for socially and economically disadvantaged communities. Parents from all parts of the socio-economic spectrum are prepared to invest in the education of their children particularly when they believe that the quality of schooling is high and will lead to significant returns. When trying to judge the quality of a school, parents tend to place greatest emphasis on two key aspects – academic achievement and the provision of a safe and pleasant environment (OECD, 2015b). For many parents in developing countries the key signifier of quality is the behaviour and effectiveness of their children's teachers. They want the school's teachers to be well qualified, dedicated to teaching and, most importantly, present in school rather than absent (Morrow and Wilson, 2014). In addition, they want teachers who 'take care' of their children both helping them to enjoy education and providing discipline (ibid). It is these aspects which contribute far more to the perception of a school's quality than, for example, its physical structure and resources. This chimes with the finding of the McKinsey report on the world's top school systems (McKinsey & Company, 2007) that "the three things that matter most (are): 1) getting the right people to become teachers, 2) developing them into effective instructors and, 3) ensuring that the system is able to deliver the best possible instruction for every child" (ibid, p.2).

4.3 Interventions for improving outcomes

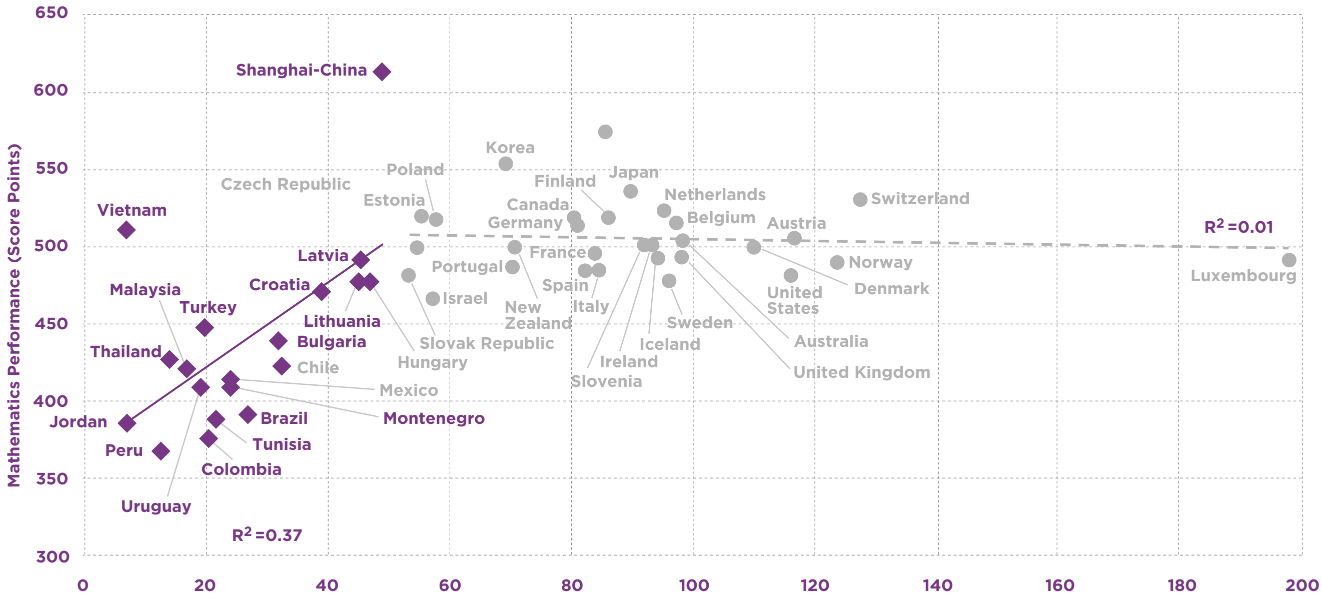
This is not the right place to revisit the vast amount of research which over the years has tried to identify the most effective methods for improving educational outcomes. However, some key findings, especially those of recent literature reviews (McEwan 2012, Conn 2014, Evans and Popova 2015), are worth restating here in order to provide more context for the mathematics-specific interventions discussed in the chapter which follows.

4.3.1 Expenditure on education

Evidence as to the effect of spending more on the education of students is mixed and for more affluent countries it is not clear that greater expenditure results in significantly improved outcomes. However, as shown in Figure 4.2, PISA data shows a significant positive relationship between per capita expenditure and student achievement for countries that spend less than about USD 50,000 in educating each student from the age of 6 to 15 (OECD, 2013c). For this group, increasing per capita spending by USD 10,000 is associated with an increase of approximately 25 score points, or one quarter of a standard deviation, in mathematics achievement. Countries in SSA fall firmly in the category where additional expenditure translates into better educational outcomes. Data[34] suggests that, in 2012, countries in SSA were spending an annual average of just USD 136 on each primary school student and USD 157 on each student in secondary education. One expects the spending in SSA to be far below that of the wealthy countries in Western Europe and North America (USD 7,943 for primary and USD 11,247 for secondary), but it is disturbing to see that it falls far below that of countries in Latin America and the Caribbean (USD 1,187 for primary and USD 1,017 for secondary).

It is interesting to note that Vietnam bucks the underlying trend. It is one of the lowest spending countries in this group and yet its average PISA score for mathematics is significantly above the international average. This apparent anomaly is considered further in Chapter 5.

Figure 4.2: Relationships between national spending on educating a student from the age of 6 to 15 and national average PISA scores for mathematical literacy (OECD 2013c, p.41)



Note: Only countries and economies with available data ar shown

4.3.2 Pedagogical interventions

There is strong evidence to suggest that the most effective interventions for raising the achievement of learners are those designed to change the ways in which teachers teach. In particular, actions which promote adaptive teaching, i.e. where teaching methods are adapted to better match the needs and abilities of individual learners. Conn (2014) finds that such interventions have a combined-effect size (~0.4 standard deviation) significantly greater than those which focus on non-adaptive teaching. Within this category, teacher-led methods, such as individualised instruction and the effective use of diagnostic assessment,

34. Source: UIS database. Note that for less developed regions this includes EFA countries only.

have a positive effect. Indeed, where teachers consistently use assessment for learning techniques, significant gains in student achievement are reported although, as discussed in the next chapter, effect sizes of between 0.5 to one standard deviation as reported by Black and Wiliam (1998) are probably optimistic.

McEwan (2014) also finds that interventions involving the adoption of programmes of Computer-Assisted Learning (CAL) programs show significant effect sizes (~0.15 standard deviation) independent of other overlapping interventions. Evidence as to the specific impact of technology-based interventions on achievement in mathematics is explored further in the chapter which follows.

Whilst the findings above give cause for optimism, it is important to recognise that interventions are most effective when they bring significant, positive changes to the daily experience of learners (Evans and Popova, 2015).

4.3.3 Strengthening accountability

Interventions related to teacher incentives and accountability can have a positive effect on learning outcomes but the effect sizes tend to be small and changes in teacher behaviour may not be as intended. For example, rewards for teachers linked to student results are likely to lead to teachers 'teaching to the test' as reported in one Kenyan programme (Glewwe, Ilias and Kremer, 2010). Gains have also been observed where contract teachers have been employed to supplement permanent, civil service teachers. McEwan (2014) reports effect sizes of the order of 0.1 standard deviation, but warns that some of this may be due to the smaller class sizes which often result from the appointment of contract teachers.

4.4 Summary

The quality of mathematics education cannot be considered in isolation from the overall quality of education. At the system level, success in mathematics correlates strongly with success in all other subjects. Therefore, investing in improving the general quality of schooling offered to all learners is a necessary condition for raising mathematical achievement – but it may not be sufficient.

Research shows that the quality of schooling offered to learners is the most powerful determinant of outcomes. Spaull concludes that "placing a poor child in a wealthy school is likely to more than compensate for any negative effects of a poor home background" (Spaull, 2011, p.16). One of the most important indicators of school quality is the professionalism of teachers. Indeed, research suggests that "students placed with high-performing teachers will progress three times as fast as those placed with low-performing teachers" (McKinsey & Company, 2007, p.12). The implication is clear: students – even those from disadvantaged homes and communities - will perform well if they are taught in a well-resourced school by a good teacher.

Comprehensive reviews of interventions aimed at raising learning outcomes suggest that those designed to improve the effectiveness of teachers have the greatest impact. In particular, activities and training focused on the use of adaptive teaching strategies and formative assessment methods appear to yield the greatest rewards. The challenge for countries in SSA is to apply these findings to the specific field of mathematics education.

5 Factors affecting learning outcomes in mathematics

5.1 Context

The central place of mathematics is fully recognised in the school curricula of SSA. It is a compulsory, core subject at primary and junior secondary levels. In some countries, mathematics also features as a compulsory subject in school leaving qualifications at the senior secondary level. The importance of mathematics is also reflected in the time dedicated to its teaching which is comparable to that allocated in more developed systems, and, in some cases, exceeds international norms (World Bank, 2008). Over the past 20 years, the revision and modernisation of curricula has been a feature of broader educational reforms with emphasis being placed on moving towards outcomes-based and competency-based curricular models (Westbrook et al., 2013). In reality, however, mathematics curricula in SSA remain defined by content and delivered, more often than not, by teacher-led methods.

At the primary level, the content of curricula corresponds to widely-accepted theories of the developmental/acquisition of mathematical concepts and appears to be closely aligned to that found elsewhere. For example, there is a large degree of overlap between primary school curricula typically found across SSA and the curriculum/assessment frameworks that underpin EGMA and TIMSS (Grade 4). At this level at least, the fundamental problem does not appear to be in the content of the intended curriculum but in its delivery. A wealth of evidence suggests that in classrooms across the region teachers are failing to help learners grasp the basic concepts of numeracy. This failure undoubtedly has a knock-on effect on achievement in mathematics at higher levels.

Beyond the primary level there is more evidence to suggest that curricula are not well aligned to the needs or abilities of the majority of learners. Here the delivered curriculum is dominated by the requirements of high stake, national examinations used to select students for further educational opportunities. In many cases, the failure rates for mathematics are extremely high suggesting that teaching strategies are ineffective and revealing great inefficiencies in education systems. For example, in Tanzania the Certificate of Secondary Education Examination (CSEE) marks the end of four years of secondary education (ordinary level). In 2012, of the ~400,000 candidates who appeared for the examination in Basic Mathematics only ~45,000 were successful representing a pass rate of just 12.1% (NECTA, 2013). In Zimbabwe, the 2012 pass rate for Mathematics O-level taken at the end of Grade 10 was just 13.9%. Of those who pass and go on to study mathematics at the senior secondary or advanced level, success in the final exams is far from being a formality. For example, in Zambia more than 6% of ~103,000 candidates scored zero (sic) in each of the two papers of the 2012, Grade 12 examination in mathematics (Lusaka Voice, 2013). These cases are typical of countries in SSA where examinations in mathematics have remained essentially academic in nature with the prime purpose of selecting students for further study in mathematics or mathematically-based subjects. Unfortunately, they do not appear to be providing those who are unsuccessful with essential transferable skills for continuing their studies in other fields or entering the labour market. This has been recognised in South Africa where an examination in 'mathematical literacy' was introduced in 2008 as an alternative to the traditional mathematics exam for matriculation. This was a response to two problems: prior to the change, 40% of candidates were choosing not to take any mathematics as part of their matriculation studies and, of those that did, the success rates were very low. Under the current system, the pass rate for mathematics is about 55% whilst that for mathematical literacy is closer to 85% (SABC, 2015). While this suggests that tailoring the curriculum and the examinations in this way has allowed more students to develop and demonstrate some mathematical ability, we should not forget that South Africa still appears towards the bottom of international rank orders for both mathematics and science.

When it comes to the delivery of the intended maths curriculum, across much of SSA little appears to be working. This is in contrast to the situation in the highflying countries, particularly those of East Asia, which consistently top international league tables of performance in mathematics. These prove that it is possible to teach mathematics effectively, raising a significant proportion of learners to very high levels of achievement. For example, more than 30% of 15-year-olds in Shanghai China, Singapore, Chinese Taipei, Hong Kong China, and Korea reach the two highest levels of the PISA achievement framework. By way of contrast, the OECD average shows less than 13% of students demonstrating this level of mathematical competence (OECD, 2014). The question being asked by many countries, developed and developing, is: what do we need to do in our education systems, in our schools and in our classrooms to close the gulf in mathematical achievement which is glaringly apparent in the results of international large-scale assessments?
The research evidence available is extensive and diverse. However, through recent meta-analyses a clearer picture is emerging of approaches and methods which appear to promote the acquisition of mathematical skills in learners. It should be noted that the effectiveness of any particular intervention will be context dependent – what works in one situation may not necessarily work in another. This is of particular importance when looking at mathematics education because the prevailing 'culture' appears to be a key factor in determining the effectiveness of teaching/learning behaviours.

The factors considered in this chapter include: attitudes towards mathematics and the teaching of mathematics; curricula; teachers of mathematics, textbooks and teaching resources; assessment; and the use of educational technologies.

5.2 Culture and attitudes

The great concentration of effective mathematics teaching found in East Asia has suggested to many that the culture in which teaching and learning take place may be the critical factor in explaining why other systems, notably those of Europe and North America lag behind. Three dimensions of this are: the value attached to education by the wider society; general perceptions as to the difficulty of mathematics as a subject; and the prevailing view amongst teachers as to the nature of mathematics and how learners acquire true understanding of mathematical concepts.

Much evidence, both anecdotal and research-based, suggests that families in East Asia place great value on education. Studies show that in pursuit of educational success they are prepared to invest much time, effort, and money in the education of their children (e.g. Marginson, 2014). Jerrim (2014) estimated the impact of these cultural factors by comparing the results of Australian students with parents of Asian origin with those of their peers from an Australian background having more in common with the cultures of Western Europe and North America. He finds that "Australian children with East Asian parents outperform their native Australian peers by an average of more than 100 PISA test points (equivalent to two and a half years of schooling)" (Jerrim, 2014, p.6). However, he suggests that there is no single, causal factor and that the climate in which students in East Asia learn is shaped by a number of interrelated factors including the "selection (by parents) of high quality schools, the high value placed upon education, willingness to invest in out-of-school tuition, a hard work ethic and holding high aspirations for the future" (ibid, p.6). Replicating this enabling environment through government action in countries where very different attitudes prevail may not be socially desirable, would certainly be extremely difficult to implement, and, if attempted, would probably take several generations to achieve. Clearly, trying to bring about wholesale and radical cultural changes is not the place to start when deciding how to raise mathematical achievement in the short- to medium-term.

The achievement of a society's learners appears to be linked to the attitudes towards the learning of mathematics generally held by that society's non-specialists (rather than maths educators). For example, the hard work ethic associated with East Asian cultures leads to a belief that success in education (and in mathematics and the sciences in particular) results mainly from application and perseverance. In western cultures there appears to be a general acceptance of the view that success in mathematics stems primarily from natural, inherited ability. In other words, students in East Asia are told that anyone can learn mathematics provided they are prepared to work hard enough whereas in many western cultures the dominant message tends to be that only those lucky enough to have natural ability can grasp mathematical concepts. Lim (1999) suggests that one consequence is that the first group comes to see difficulty in mathematics as a challenge to be overcome through endeavour whereas the second group sees the difficulty as an insurmountable obstacle. Findings from PISA support this with, for example, 84% of Japanese students saying they wouldn't be put off by difficult problems whereas only half of US students said the same (Schleicher, 2014). The powerful statement below summarises the situation in the UK but will resonate in many countries – including those of SSA. "It is culturally acceptable… to be negative about Maths, in a way that we don't talk about other life skills. We hear 'I can't do Maths' so often it doesn't seem a strange thing to say (Kowsun, 2008). Maths is seen as the remit of 'mad scientists', 'nerdy' boys, and the socially inept (Epstein et al., 2010). We talk about Maths as though it is a genetic gift possessed only by a rare few, and inaccessible to the general public" (National Numeracy, 2014, p.1).

In PISA 2012, first time participant Vietnam performed beyond the expectation of many with an average mathematics score of 511, significantly above the OECD average of 494 (OECD, 2014)[35]. With a GDP per capita of approximately USD 2,000 and a total spend on education of just USD 7,000 per student (ibid), Vietnam outperformed by a significant margin many far richer countries including, for example, the USA (PISA Maths score 481, GDP per capita USD 55,000, expenditure per student USD 116,000). Cultural factors have been suggested as one possible factor behind the country's success including the 'growth mind-set', shared by teachers, which holds that "abilities can be developed through dedication and hard work-brains and talent are just the starting point" (Dweck, 2006 cited in Philippines Basic Education, 2013). Other possible factors include the large investments

35. Bodewig (2013) suggests that Vietnam's result should be interpreted with some caution as "The net enrolment rate in upper secondary education stands at 60 percent, and only as few as a third of the students from the poorest 20 percent of the population are in upper secondary school. Since PISA assesses competencies of 15 year-olds in school, this suggests that it only captures those Vietnamese students that remain in upper secondary education – typically the better off, and likely better performing, students" (Bodewig, 2013, weblog).

that Vietnam has made in improving the quality of its schools (Bodewig, 2013) and the professionalism of its teachers (Bodewig, 2013 and Rolleston, et al., 2013).

When it comes to exploring attitudes towards learning mathematics there is a significant body of literature. Zan (2013), for example, shows that students who have a negative and/or distorted view of mathematics may reveal this in different ways. Some may demonstrate a profound lack of self-belief and an expectation of failure[36]. Others may have a fixed, instrumental view of mathematics which limits their willingness to bring other skills to bear on solving mathematical problems. Both constitute considerable barriers to learning but require different remedial actions. The first requires the teacher to instil confidence and reassure the student that success is possible. The second requires the teacher to change the student's perception of mathematics as a highly regulated, procedurally-led activity and to encourage a less rigid more creative approach (Zan, 2013). The suggestion that teachers can address this problem encourages optimism. However, one should not underestimate the degree of professionalism that this requires. Teachers who lack confidence in their own mathematical ability or who have themselves been brought up to believe that mathematics is all about procedures rather than relations will find it extremely difficult to bring about the desired attitudinal changes in their students.

The views of teachers towards the nature of mathematics and mathematics education alluded to above is also an area where cultural differences are to be found – some of which may be associated with learner achievement. Yu (2008) compared the views of British and Chinese mathematics teachers and found that, in general, British teachers "reflect the pragmatic understanding of theory in Mathematics teaching, (whilst) Chinese teachers generally reflect the scientific understanding of theory" (Yu, 2008, p.121). This means that whilst the British teachers focus on the appropriate application of theory, Chinese teachers place more emphasis on the introduction of new concepts and methods, and the position and function of proofs" (ibid, p.132)[37]. In her influential book on the teaching of elementary mathematics, Ma (1999) suggests that the difference between Chinese and US teachers is one of both approach and competence. It is true that Chinese teachers in Ma's sample did show more competence when it came to carrying out some computations (Ma, 1999 cited in Howe, 1999), but the more important finding was that they were prepared to use a range of techniques to help their students investigate and develop understanding of the concept of interest. US teachers, on the other hand, tended to focus on helping their students to master associated procedures. Ma's suggestion is that in order to teach elementary mathematics effectively, teachers need the confidence that comes through having a profound understanding of fundamental mathematics (PUFM) (Ma, 1999). She points out that Chinese teachers start to develop PUFM through high-quality early training and then develop this further through, for example, regular collaborative work with fellow teachers of mathematics. The conclusion is clear: effective teaching at the elementary level needs confident, well-trained teachers who possess both subject knowledge (i.e. concepts and procedures) and pedagogical knowledge (how to teach mathematics). The implications of this for SSA are explored further in Chapter 6.

36. Ashby (2009) shows that this lack of self-belief starts early in a child's education. His study on Grade 3 children showed that " low and middle achievers quickly resigned themselves to failure, without truly attempting all of the questions" and that "many of the children showed signs of anxiety whilst attempting the worksheets, shuffling awkwardly in their seats, glancing at their peers with worried expressions and making negative comments about the difficulty of the current task" (Ashby, 2009, p.9).
37. In an attempt to replicate the success of world leaders in mathematics education, the UK government's Department for Education established an exchange programme with the Municipal Education Commission of Shanghai. To date, two groups of Chinese mathematics teachers have spent time in British primary schools "to share their world-class approach to Maths teaching and help further raise standards in the subject" (United Kingdom, 2015). Anecdotal reports suggest that the exercise has " encouraged (British) teachers to change the way they approach lesson planning to develop a deep understanding and fluency in Mathematics" (ibid). but no systematic evaluation as to the impact on student learning has yet been carried out.

5.3 Gender and mathematical achievement

The third Millennium Development Goal was to achieve gender equality and the empowerment of women. The first target within this goal was to "eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015". Whilst significant progress has been made across the developing world, much remains to be done. This is especially true in SSA where gender parity in primary education has not yet been achieved and where the enrolment rates of females at the secondary and tertiary levels lag far behind those of their male peers (UN, 2015a). Whilst achieving equal access to general education for girls remains challenging, the situation in mathematics and other STEM subjects is further complicated by subject-specific gender issues. There are two main inter-related aspects: the underachievement of girls in mathematics especially at higher levels of the education system, and the under-representation of females in STEM study programmes at higher secondary and tertiary levels. It should be noted that these are of almost universal concern with some of the world's most highly developed nations trying hard to attract more females into STEM courses and, ultimately, STEM-based research, innovation and production. In such countries there is a consensus that promoting gender equality in STEM areas will bring multiple benefits. For example, the European Commission's Expert Group on Structural Change (2012) suggests that attracting more women into science and technology will, inter alia, increase the competitiveness of the workforce, assist in the development of new economic opportunities, improve the quality of research and innovation to the benefit of society, and contribute to social wellbeing and progress (EC, 2012). Clearly the economies of SSA should make best use of their female human capital, but they start from a point where gender disparities in, for example, mathematics education are great and deeply entrenched.

International and regional studies of learner achievement provide a wealth of information on the relative performance of males and females in mathematics. However, as shown by Saito (2011) outcomes at the primary and lower secondary levels are mixed making it difficult to draw firm conclusions. For example, the TIMSS 2007 results show boys in Grade 4 outperforming girls by a significant margin in 16 countries (with girls surpassing the boys in 8). However, in the Grade 8 population, the situation appears to reverse with girls outperforming boys by a significant margin in 16 countries (with boys surpassing the girls in 10). A similar pattern was observed in TIMSS 2011 with, overall, little difference between the average achievements of boys and girls at Grade 4 and slightly higher differences – in favour of girls – at Grade 8. Interestingly, girls from Botswana outperformed their male peers at both Grade 6 and 9 in this study (Mullis et al, 2012). Results from PISA 2012 show that in the mathematics literacy domain, boys aged 15 outperformed girls of the same age in 38 participating countries and economies and that across OECD countries the average difference was 11 score points to the advantage of boys (OECD, 2015c). One conclusion that can be drawn from the mixed pattern of results is that the data does not support the traditional view, still held by many, that boys are better than girls in mathematics due to hard-wired genetic differences. For example, in Hong Kong, Shanghai, Singapore and Chinese Taipei - jurisdictions which appear at the top of the PISA 2012 results for mathematics – "girls perform on a par with their male classmates in mathematics and attain higher scores than all boys in most other countries and economies around the world" (OECD, 2015c, p.15, emphasis added). Even in SSA there is strong evidence that, given the right opportunities, girls can outperform boys in mathematics. Most notably, in the Seychelles girls in Grade 6 outperform the boys by a statistically significant margin[38]. However, as shown by Saito (2011), SACMEQ III results show this to be an exception rather than the norm. Table 5.1 shows that whilst there is little average difference between the genders across all 15 participating school systems, boys outperform girls in 11 cases and in 7 of these the difference is large enough to be significantly significant.

Table 5.1: Gender differences by mean mathematics score for school systems participating in SACMEQ III (after Saito, 2011)

	Mean Maths Score (Girls)	Mean Maths Score (Boys)	Difference (Girls - Boys)	Statistically significant
Seychelles	566.7	535.2	+31.5	**
Mauritius	630.7	616.1	+14.6	
South Africa	498.4	491.2	+7.2	
Botswana	523.6	517.5	+6.1	
Lesotho	476.8	477.1	-0.3	
Namibia	470.1	472.0	-1.9	
Zimbabwe	519.0	520.8	-1.7	
Zanzibar	483.9	489.3	-5.4	
Swaziland	536.2	545.5	-9.3	**
Uganda	477.2	486.7	-9.5	**
Mozambique	478.6	488.2	-9.6	**
Zambia	429.2	440.8	-11.5	**
Malawi	441.1	452.7	-11.6	**
Kenya	550.9	576.3	-25.4	**
Tanzania (mainland)	537.5	568.5	-30.9	**
SACMEQ III	507.5	511.8	-4.3	

The results of the PASEC2014 study revealed a similar pattern with most participating countries showing boys outperforming girls at both measurement points in the primary phase of education (See Table 5.2).

Table 5.2: Gender differences by mean mathematics score for participating countries PASEC2014 (after PASEC, 2015)

	Difference in Maths Mean Score: Girls - Boys	
	Early primary	Late primary (Grade 6)
Burundi	+8.7	+33.1**
Benin	+5.3	+5.5
Congo	-4.0	-15.1**
Togo	-8.0	-8.0
Burkina Faso	-8.9	-13.3**
Senegal	-15.0	-18.8**
Niger	-17.5**	-7.2
Cameroon	-19.0**	+2.2
Cote d'Ivoire	-26.3**	-13.8**
Chad	-47.3**	-21.9**

38. It has been suggested that the large advantage shown by girls in Seychelles is a result, at least in part, of the rigorous streaming policies applied by the Ministry of Education (Leste et al, 2005 cited in Saito, 2011).

Saito (2011) analysed SACMEQ III mathematics results by school location and by school socio-economic status in order to identify differences in gender gaps. Whilst he notes a small number of exceptions in each case, the overall picture is that the gender differences that appear at the national level are there within the sub-populations. For example, in systems where boys outperform girls at the national level they are, in general, doing so in schools of low and high SES. Similarly, in countries where girls outperform boys at the national level (i.e. Botswana, South Africa, Mauritius, and Seychelles) they are doing so in both urban and rural schools. In other words, gender gaps appear to be related to the characteristics of the national system rather than, for example, school location and/or socio-economic status.

Whilst differences in average scores by gender are revealing, further analysis of PISA data indicates another potentially important issue. Evidence shows that girls at the upper end of the ability range underperform by a bigger margin than girls of average ability. For example, whilst the average PISA 2012 gender gap was 11 points in favour of boys, this rose significantly to 20 points for students in the top 10% of the ability range (OECD, 2015c). This is of concern because the girls in this group are precisely those who would add greatest value if they could be attracted towards further study and careers in mathematics and other STEM subjects.

The key factors impacting adversely on the performance of girls in SSA in mathematics fall into three main categories: generic factors associated with access to a safe learning environment; cultural and personal factors related to the perception of mathematics as a subject and as a career option; and, factors related to the teaching of mathematics in classrooms. Whilst many of these hinder the education of boys, they tend to have a disproportionately large impact on girls.

A good summary of the practical causes of disadvantages for girls is given by GIZ (2014). The main barriers to schooling cited include: poverty coupled with high costs for fees, uniforms and learning materials; long distances from home to school and the lack of affordable, safe transport; and the need for poor families to use children in the home and in the fields. A further disincentive is the fact that schools are often unfriendly and unsafe environments. Many schools in SSA lack appropriate sanitary facilities especially for girls at puberty (Saito, 2014). Security measures and safeguarding are weak with girls at risk of violence and sexual harassment whilst travelling to and from school. For many this risk is even present within school with the harassment by teachers of students (both genders) being perceived as a serious problem in, for example, Kenya, Malawi, Tanzania, Uganda, Zambia and Zimbabwe (Saito, 2013).

Schools in SSA, as elsewhere, tend to reflect the cultural values of the societies they serve. Unfortunately, this often means that the education of girls is seen as being less important than that of boys. Parents tend to have lower expectations of their daughters than their sons. This is a view shared by teachers who, in general, tend to have a better opinion of their male students and, consequently, pay less attention[39] to the girls in their classes (Stromquist, 2007 cited in GIZ, 2014). Such prejudice and the low expectations of society impact negatively on the self-confidence of girls. Unfortunately, the impact of this on the performance of girls in mathematics is particularly large and damaging. An analysis of PISA 2012 results suggested that 'self-efficacy in mathematics' is strongly related to achievement. Here 'self efficacy' is the extent to which a student

39. It should be noted that in the classroom observations conducted for this study in six focus countries (see Annex A) our observers detected no gender bias in the attitudes or actions of teachers.

judges her/his confidence to perform a series of mathematical tasks or solve mathematical problems. It was found that girls tend to have lower levels of self-efficacy and that the gender gap is wider in mathematics than in science. In other words, when presented with a mathematical problem, many girls believe they can't solve it whilst more boys, of the same ability, believe they can! Interestingly, this phenomenon is context dependent. For example, "67% of boys but only 44% of girls reported feeling confident about calculating the petrol-consumption rate of a car... However, no gender differences in confidence were observed when students were asked about doing tasks that are more abstract and clearly match classroom content, such as solving a linear or a quadratic equation" (OECD, 2015c, pp. 70-71). In addition to 'self efficacy' the PISA gender analysis also looked at 'self concept' which is a measure of a student's belief in her/his abilities – another factor strongly linked to mathematical achievement. Once again, girls displayed lower levels of self confidence. For example, 63% of boys disagreed with the statement "I am just not good at mathematics" whilst the corresponding proportion of girls was 52%. Similarly, 45% of boys reported that they "understand even the most difficult work in mathematics classes" whilst only 30% of girls agreed with the same statement (ibid). Clearly girls feel far less confident than boys when it comes to mathematics even in education systems with competent teachers and well resourced classrooms.

The inter-generational transmission of gender roles and its impact on achievement is explored by de San Román and de la Rica Goiricelaya (2012) using data from PISA 2009. They conclude that in societies where there is greater gender equality, girls perform better reducing their disadvantage in mathematics and simultaneously increasing their advantage reading literacy. Of the multiple indicators of gender equality and female empowerment that they use, 'participation in the labour market of the mother' is particularly significant. Whilst this of benefit to both boys and girls, the impact is higher for girls. One suggestion is that "mothers participating in the labour market are somehow breaking the traditional view of men working in the labour force and women staying at home. Then, the mother transmits to her daughter this break with the traditional gender role attitudes which make her feel that she is not inferior to boys and thus believe that she can compete also in those subjects a priori better suited to boys. This ultimately leads to girls developing better maths skills and hence reducing the gap with boys in maths" (de San Román and de la Rica Goiricelaya, 2012, p.18).

In addition to these cultural attitudes towards girls and mathematical education, there is evidence that some teaching methods promote higher levels of achievement to the advantage of girls. These include: presenting mathematical problems in gender-appropriate contexts; setting mathematical problems that promote deeper understanding; using collaborative methods in the classroom; and, using assessment methods which are not time-stressed. Research suggests that girls perform better on tasks set in context but, as shown by PISA data, the 'self efficacy' of girls is severely impeded when boy-friendly contexts are used (OECD, 2015c). Boaler (cited in Cech, 2012) presents evidence that boys typically outperform girls in schools where traditional methods based on memorisation of mathematical procedures and 'closed' assessment tasks. However, when 'open' tasks demanding deeper investigation are set and students allowed to collaborate on exploring them, then both boys and girls improve but girls more so thereby closing the attainment gap. The beneficial effect of less directive teaching methods is also found in the PISA 2012 data where the 'use of cognitiveactivation strategies' by teachers is associated with better performance for girls (OECD, 2015c). Boaler (2014) also argues that the traditional emphasis on speed in the teaching and testing of mathematics is detrimental to students regardless of gender because they "cause the early onset of math anxiety... and are especially damaging for girls" (Boaler, 2014, p.1).

The foregoing suggests that in addition to interventions designed to raise the general level of mathematical achievement, specific policies and actions should be put in place in order not only to maximise the achievement of girls, but also to engage them in STEM subjects at the highest levels.

5.4 Curricula

Over the past decade or two, efforts have been made to reform curricula in all countries of SSA. In mathematics, as in other subjects, attempts have been made to reduce curriculum overload and improve sequencing. In some countries, e.g. South Africa, the importance of setting clear targets was incorporated in outcomes-based models. Child-centred approaches have also been promoted as the best way to deliver the curriculum. There is, however, little local evidence to suggest that such curriculum reforms are effective – especially in raising mathematical standards. Slavin et al. (2009a) looked at studies evaluating the outcomes of mathematics curricula for elementary and middle/high schools. These represented different innovations and a range of supporting textbooks including a traditional textbook, a textbook advocating a step-by-step approach to teaching/learning, and an innovative textbook focusing on problem-solving. They found that 'there was very little evidence that it mattered which curriculum was used. None of them showed any strong evidence of effectiveness in comparison to the others' (Slavin et al., 2009b, p.4). A similar conclusion was reached by Tarr et al. (2008) who, using US data, found that on two separate measures, "curriculum type was not a significant predictor of student achievement" (Tarr et al., 2008, p247). These findings suggest that the content and organisation of the intended curriculum is not a significant factor in determining the achievement of learners. This is not entirely surprising given the large body of evidence suggesting that the dominant factor is the quality of teaching. Good teachers can help their students to reach high levels of competence even when the curriculum they are following is less than ideal. The implication for strategic planning in SSA is that reform of mathematics curricula may ameliorate the situation but it will not automatically lead to significantly better outcomes if there are fundamental problems in the delivery system. For example, research suggests that in many cases the institutions responsible for the pre-service training of teachers in SSA have not adjusted their own curricula and teaching practices to match the demands of the more modern curricula prescribed for schools. Indeed, Akyeampong et al (2011) suggest that TTIs do not always have access to, let alone use, essential materials including the curriculum documents, teacher guides and textbooks used in schools. Notwithstanding the above, mathematics curricula in SSA will need to be revised extensively if it is decided that, for example, the compulsory curriculum for all should focus on basic 'functional mathematics' with an elective course in 'true mathematics' being followed by the more-able minority. As described above, the South African Matric model requires candidates to enter for either 'Mathematical Literacy' or 'Mathematics'. The examination papers for the two subjects show the marked difference in approach. For example, a 'Mathematical Literacy' paper of 2015 included questions based on: the gross salary, pension contribution and tax position of an employee; returns from a small enterprise making and selling sweets; information about a road trip using a map; authentic statistics for births and deaths in South Africa for a given historical period; etc. (DBE, 2015a). In contrast, the corresponding paper for 'Mathematics' included questions on: quadratic equations; arithmetic and geometrical series; mathematical functions; differential calculus; etc. (DBE, 2015b). For many, the introduction of this model from 2008 has been a great success but there are detractors who hold that "Maths Literacy is not even a watered-down version of Maths. It is a dramatically less demanding subject which does not develop conceptual thought or problem solving" (Equal Education, 2016, p.1). However, it is far from clear that the more formal mathematics syllabus achieves this as examination failure rates are high and average test scores are low.

Implementing curricula which focus on equipping all learners with profound understanding of fundamental mathematics requires not only new curricular content and standards, but also new approaches to planning and delivering learning activities. Current thinking on this issue can be found in the Common Core State Standards (CCSS) for the USA[40] (NGA and CCSSO, 2010) and in the work of the US National Council of Teachers of Mathematics (NCTM) which links mathematical practice to the content and philosophy of the Standards. The Standards place the emphasis on mathematical proficiencies including: making sense of problems and persevering in solving them; abstract reasoning; constructing viable arguments and critiquing the arguments of others; mathematical modelling; looking for and using mathematical patterns and structure (ibid). This is a radical departure from typical practice in SSA where, as noted throughout this report, rote memorisation and repetition of familiar procedures are not only practised in the classroom but also rewarded in high-stake examinations. However, on their own new standards are not sufficient – new approaches to teaching/learning are also required. The NCTM provides advice and examples of good practice in Principles to Actions: Ensuring Mathematical Success for All (NCTM, 2014). One of the key messages is that teachers, preferably working in collaboration, should select tasks with an appropriate degree of complexity allowing students to explore problems which can be approached from more than one direction. Such tasks promote the development of competing arguments and, hence, 'productive struggle in learning'. The NCTM argues that "Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships" (NCTM, 2014, p.48). It should be noted that the success of such an innovative approach depends on the universal availability of well-qualified and highly professional teachers of mathematics – a condition which is far from being met in the vast majority of countries in SSA.

5.5 Teachers of mathematics

There are few who would disagree with the proposition that the most important factor, by far, in ensuring that learners achieve high standards in mathematics is the presence in the classroom of an effective teacher. Unfortunately, countries across SSA face huge challenges in attracting sufficient numbers of suitably qualified applicants to train as teachers. Those who are attracted to teaching as a career all too often receive inadequate training and, as a consequence, enter service ill-equipped to meet the considerable demands of the profession. Poor conditions of service and inadequate in-service support lead

40. As of August 2015, 42 states across the USA have adopted the CCSS in mathematics.

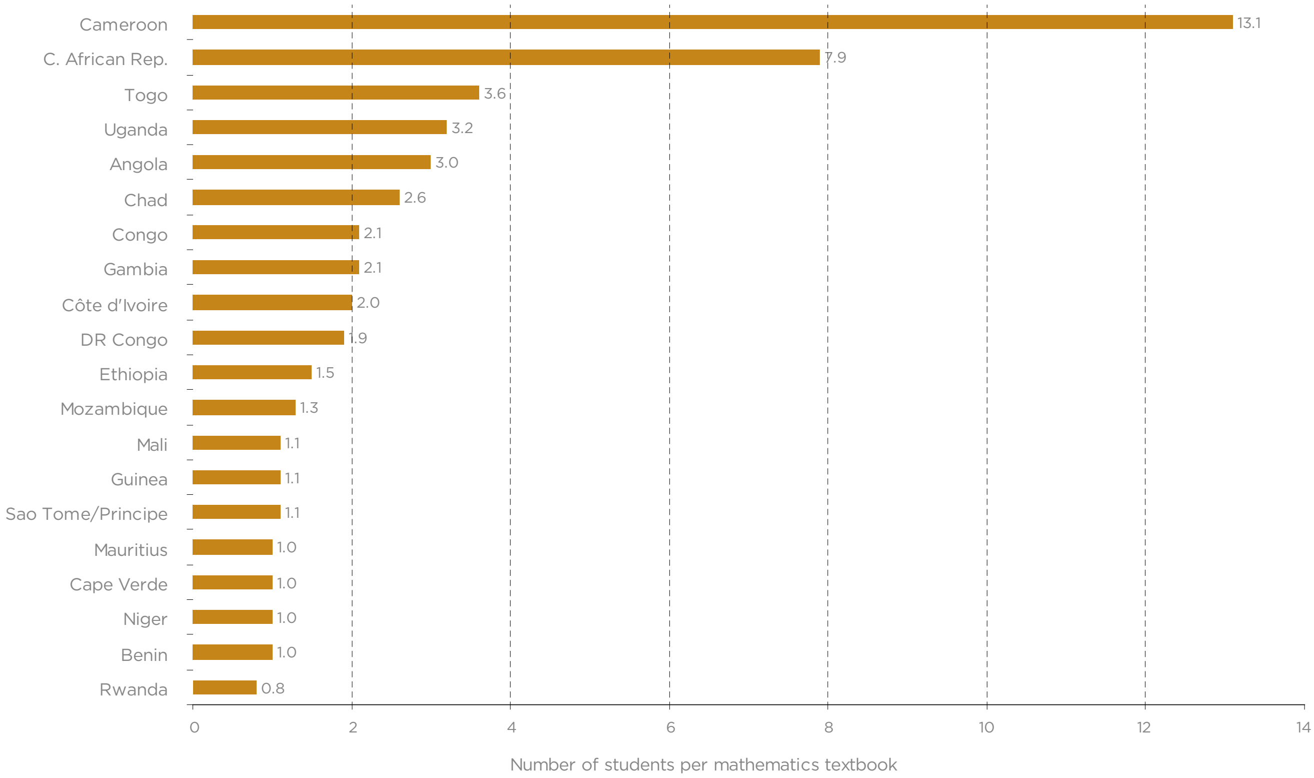
to low motivation making the retention of good teachers a major challenge (Mulkeen, 2010). The problems of attracting and retaining teachers affect all subjects but they are particularly acute in mathematics. For example, Mulkeen (2010) reports that in The Gambia 38% of teachers at the upper basic level were qualified to teach social and environmental studies but only 17% were qualified to teach mathematics – even though it is a compulsory, core subject in the curriculum. Similarly, in Lesotho in 2005-2006 only 8% of trainee secondary school teachers were studying mathematics as one of their two specialist subjects. As if this were not enough, many observers suggest that the teachers who are in the classrooms do not have the necessary mathematical knowledge and pedagogical skills to help their students master the subject. The competence of mathematics teachers is considered in Chapter 6 and the initial training of mathematics teachers is explored in Chapter 7.

5.6 Textbooks

The general consensus is that the availability of textbooks is a key determinant of learning outcomes especially in developing countries (Fuller, 1987). UNESCO uses the student:textbook ratio as a key indicator of the quality of schooling (UNESCO, 2015a) and the World Bank holds that, apart from the provision of qualified and committed teachers, making textbooks available to all students is likely to be a more cost-effective way of raising learner achievement than any other input (Fredriksen and Brar, 2015). This is particularly relevant in the case of mathematics education in SSA because not only are textbook shortages significant in many countries, but the textbook remains the main, if not only, teaching tool for many teachers. It is suggested that the provision of textbooks compensates for "the weakness of other quality inputs such as poorly-trained teachers, high level of teacher absenteeism, large class size, short effective school year, high illiteracy among parents, and the shortage of reading materials at home" (ibid, p.10). The positive relationship between textbooks and learning is considered by many to be self-evident and is also supported by a significant body of research (e.g. Fehrler, Michaelowa, and Wechtler, 2009). However, as discussed below, more robust quantitative studies of the relationship between access to textbooks and mathematical achievement suggest that the situation is, in reality, far more complicated.

The ratio of students to mathematics textbooks in the primary phase of education varies dramatically across the region as shown by Figure 5.1. For the 20 countries of SSA for which recent data is available, eight have textbook ratios close to unity and in a further six countries, up to two students share each textbook. In Central African Republic and Cameroon the shortages are far more severe with ratios of 8:1 and 13:1 respectively (UNESCO, 2015a).

Figure 5.1: The student:textbook ratio for mathematics in primary grades (UNESCO, 2015)



Information as to the availability of mathematics textbooks for students in Grade 6 is also available from SACMEQ studies. Table 5.3 shows that, on average, 22% of students in SACMEQ countries report having their own mathematics textbook i.e. they do not have to share their textbook in lessons. Once again the situation varies dramatically from, for example, Swaziland where every child has her/his own textbook to Tanzania where this is true for only 3% of students (Spaull, 2012).

Table 5.3: Relationship between textbook ownership and mathematical achievement (Spaull, 2012)

	% with own Maths textbook (rank)	Scaled Maths score (rank)
Swaziland	100 (1)	541 (3)
Lesotho	56 (2)	477 (7)
South Africa	36 (3)	495 (5)
Namibia	32 (4)	471 (8)
Malawi	24 (5)	447 (9)
Kenya	15 (6)	557 (1)
Uganda	14 (7)	482 (6)
Zimbabwe	12 (8)	520 (4)
Zambia	11 (9)	435 (10)
Tanzania	3 (10)	553 (2)
SACMEQ average	22	512

It is interesting to note that whilst Swaziland (100% with a textbook) has a relatively high average score for mathematics, so do Tanzania and Kenya with far lower proportions of students with sole access to a textbook. The fact that the rank order correlation for these countries is close to zero (ρ = -0.04) is compatible with the findings of quantitative research which suggest that the mere availability of mathematics textbooks has little impact on learner achievement as measured by test scores.

Glewwe, Kremer and Moulin (2009) find, using the results of a randomised trial conducted in Kenya, that owning or sharing a textbook has no significant impact on student achievement – except for students who, according to pre-intervention test scores, are already at the upper end of the ability range. Frölich and Michaelowa (2011) show, using African data, that whilst textbook ownership is not associated with significant learning gains, textbook sharing does bring benefits - presumably through peer interaction and knowledge sharing. Subsequently, Kuecken and Valfort (2013) analysed the SACMEQ II data for 11 countries and arrived at conclusions consistent with those of earlier studies: the availability of textbooks has no discernible impact on student test scores except for students in the top 30% of the distribution for SES. Moreover, the gains for this group are associated not with textbook ownership per se, but with textbook sharing. These findings raise a critical question: If, in general, textbooks aid learning, why don't current textbooks lead to better outcomes in mathematics? Little work seems to have been done on this specific question but Glewwe, Kremer and Moulin (2009) suggest two plausible explanations for their findings in Kenya. First, they report that official textbooks are written in English for use in classrooms where for most students this is their third language. This clearly presents a barrier to their effective use by teachers and learners. Secondly, the textbooks are written to match an academic curriculum which is beyond all but the most able students in this cohort under the prevailing conditions.

The policy implications of the research cited above are significant. First, if the aim is to raise learner achievement in mathematics then there is little point in investing in providing more textbooks unless those textbooks have been proven to be effective. Secondly, if the mathematics curriculum is not well matched to the capacities of the majority of learners then simply providing a textbook will not bridge the gap.

5.7 Assessment practices

The Systems Approach for Better Education Results (SABER[41]) is a World Bank-led initiative to support countries wishing to strengthen their education systems on the basis of common standards and comparative data. SABER offers partner countries tools for the systematic evaluation of practices in a number of domains – including that of student assessment. The SABER framework suggests that a comprehensive student assessment system should include four major components: classroom assessment; examinations; national large-scale assessments (NLSA); and, international large-scale assessments (ILSA). A country's status in each of these is evaluated against a scale having four, criteria-related categories: Latent; Emerging; Established; and Advanced. The underlying assumption is that all four forms of assessment can, when used properly, promote better outcomes in terms of higher levels of student achievement. Clarke (2012) gives a good overview of the research

41. For further information on SABER and links to SABER documents and case studies see http://saber.worldbank.org/index.cfm.

which supports this assumption.
At the macro level, information from international and national assessments can shape educational policies and, in some cases, spur the implementation of targeted reforms such as the "No Child Left Behind (NCLB)" strategy in the USA, and the "Every Child Counts" programme in the UK. Where national tests assess all students rather than a representative sample, they can be used to hold schools and, in some cases, teachers accountable for outcomes. Clarke (2012) reports that there is evidence of a "weak, but positive link between the uses of data from these assessments to hold schools and educators accountable (through, for example, league tables, monetary rewards, or staffing decisions) and better student learning outcomes" (Clark, 2012, p. 4). For example, Dee and Jacob (2010) in their evaluation of the impact of the assessment-based NCLB accountability system in the US detected a positive effect on elementary student performance in mathematics and noted that this was most evident for disadvantaged populations and low achievers. Interestingly, they could find no similar effect for reading literacy. Using mathematics scores from the National Assessment of Educational Progress (NAEP) for students in Grade 4, they found a positive effect size of 0.23 standard deviations (Dee and Jacob, 2010).

Of all the forms of student assessment, the strongest claims are made for classroom assessments where information is used for formative purposes, i.e. where the information is used by teachers and learners to identify strengths and weaknesses and to adapt teaching/learning strategies accordingly. This is commonly known as assessment for learning or assessment as learning, to distinguish it from summative assessments of learning. Clarke (2012) cites the findings of Black and Wiliam (1998) which relate to "high-quality, formative classroom assessment activities" with gains equivalent to an effect size of between 0.5 and one standard deviation (Clark, 2012, p.3). These gains are comparable to those found by Rodriguez (2004). It should be noted that subsequent scrutiny of Black and William's work combined with later research has cast some doubt on the reported effect sizes (Dunn and Mulvenon, 2009). However, there is a consensus that assessment for learning is associated with improved student performance. Stiggins and Chappuis (2004) suggest that in order for classroom assessment practices to "close achievement gaps" they should meet the four criteria reproduced below (Stiggins and Chappuis, 2004, pp. 5-6):

- Condition #1: Assessment development must always be driven by a clearly articulated purpose.
- Condition #2: Assessments must arise from and accurately reflect clearly specified and appropriate achievement expectations.
- Condition # 3: Assessment methods used must be capable of accurately reflecting the intended targets and are used as teaching tools along the way to proficiency.
- Condition #4: Communication systems must deliver assessment results into the hands of their intended users in a timely, understandable, and helpful manner.

It has to be recognised that the burden of implementing a high-quality classroom assessment system that meets these conditions ultimately falls upon teachers. Teachers may have many legitimate reasons for resisting change and there are significant technical barriers to introducing new assessment for learning strategies. Following Lock and Munby (2000), three major obstacles stand out: (a) overcoming/modifying traditional beliefs and practices to allow teachers to adopt new assessment practices; (b) developing teachers' knowledge and understanding of student-centred assessment methods; and, (c) overcoming/modifying any contextual factors in the school environment that mitigate against changes in classroom practice. Overcoming these obstacles will be particularly difficult in SSA where teachers, particularly those in the elementary phase, are, in general, poorly prepared, inadequately supported, and working under great pressure.

5.8 Educational technologies

In a world in which the lives of those in developed and developing countries alike are increasingly dominated by evermore sophisticated technologies, it is tempting to believe that the solution to the problem of poor student achievement in mathematics lies in the use of educational technologies in the classroom. Indeed, there are numerous examples of evaluation reports making spectacular claims for the impact of adopting particular programmes and/or hardware in schools. However, rigorous re-evaluation of reported findings suggests that whilst positive benefits are consistently found, the effect sizes are generally moderate.

Meta-analyses of research by Slavin et al. (2008 and 2009a) which reviewed studies of the use of technology in US elementary and secondary schools found positive effects at both levels. Observed effect sizes were, at best, modest (+0.10 for secondary schools and +0.19 for elementary schools). More optimistically, Li and Ma (2010) found that in US Grades K-12, mathematics achievement was raised through the use of technology with a significant effect size of +0.28 (Li and Ma, 2010 cited in Chueng and Slavin, 2011).

In their rigorous review of relevant studies, Cheung and Slavin (2011) looked at different types of intervention including: Computer Assisted Instruction (CAI) in which usual teaching practices are supplemented by computer-based materials and tools; and, Computer Managed Learning (CML) where an integrated computer system assesses students, assigns appropriate learning materials, tests and maps student progress. Of these two, CAI produced the larger beneficial effect (effect size = +0.18) with CML appearing to offer less benefit (effect size = +0.08). This reinforces the general consensus that technology is most effective when it accompanies high-quality teaching (Fouts, 2002). The implication is that ineffective teachers cannot be replaced by technology. Even competent teachers require additional training if they are to implement computer-assisted instruction in their classrooms successfully (ibid).

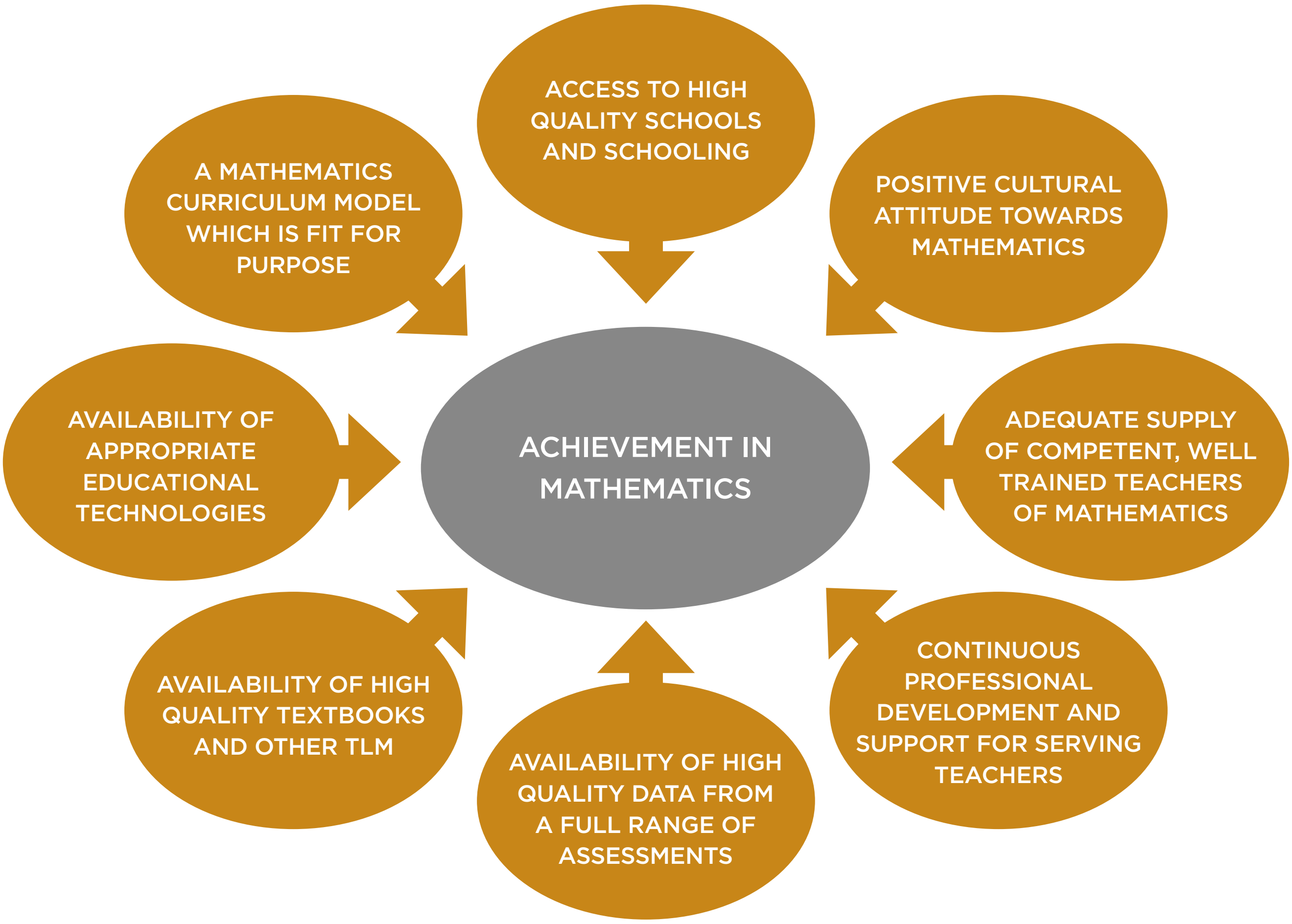
It should be noted that the greatest number of studies in this area, and those of the highest technical standards, have been conducted in the US and other highly developed countries. It is possible that the picture would be significantly different in, for example, the classrooms of SSA. There are some regional studies, some of which are referred to in Chapter 9, but these tend to be less rigorous and their findings should be treated with caution.

There is little recent evidence as to the cost effectiveness of technology-based interventions for raising mathematical achievement and that which is available tends to come from developed countries with more complete datasets and, it should be said, completely different environments from those typically found in SSA. In one study based on US data, Yeh (2010) finds that CAI yields greater effect sizes and is considerably more cost-effective than some other interventions including, for example, reducing class sizes and lengthening the school day. However, his main finding is that using computer-based, 'rapid assessment' applications to provide students with feedback as to their progress is by far the more cost-effective intervention of the 22 he included in his analysis. This may suggest that using technology to support assessment for learning and to supplement usual teaching practice might bring significant returns.

5.9 Summary

The factors impacting on achievement in mathematics are numerous and interconnected in complex ways. Therefore, addressing the acute problem of poor mathematical outcomes in SSA will require simultaneous and sustained actions on many fronts.

Figure 5.2: Key factors impacting on mathematical outcomes



At the primary level it is unlikely that the content and organisation of the intended curriculum is a major factor in the extremely weak performance of students in mathematics. The most serious problem occurs in the delivery of the curriculum. Ultimately, this resides in the inability of teachers to equip their students with the basic skills in numeracy. At higher levels, in many countries in SSA, low take-up rates and/or high failure rates in high-stake examinations are indicators of a mismatch between the curriculum (as reflected in examination syllabuses) and the achievement levels of candidates.

Whilst poor delivery of the curriculum impedes the progress of learners regardless of gender, there are additional factors which disadvantage girls to a greater extent than boys. Some of these stem from unhelpful views on the potential of girls to master mathematics whilst others relate to the use of classroom teaching strategies that do not encourage girls to engage and make the best use of their potential in this critical subject area.

Evidence suggests (Ma, 1999) that the most effective teachers of mathematics have not only great subject knowledge but also a profound understanding of fundamental mathematics. She suggests that in China, "to give a student a cup of knowledge, the teacher needs a bucketful of knowledge" (cited in Goldenberg, 2007). Is it possible for countries in SSA to move closer to this approach to the teaching and learning of mathematics?

Evidence as to the impact of textbooks and other learning materials on mathematical achievement is mixed. However, there is strong evidence to suggest that if teachers can be persuaded to implement assessment for learning in their classrooms (and are supported in doing so) then outcomes will improve.

It is tempting to believe that educational technology is the 'magic bullet' which will solve all the problems associated with mathematics education in SSA. Research suggests that this is not the case and that computer-based learning and assessment programs are most effective when they supplement high-quality teaching.

6 Teachers' capacities and teaching conditions

6.1 Introduction

The dominant factor in the acquisition of mathematical skills is the quality of schooling enjoyed by learners (Green and Riddell, 2012). The quality of schooling has a number of dimensions including school financing and management, physical infrastructure, the availability of teaching and learning materials and, critically, the presence of a professional and dedicated teaching force. Indeed there is a strong consensus that the most effective interventions in raising educational standards, especially in developing countries, are those that focus on developing the capacities of teachers and providing those teachers with an enabling environment: "The Dakar Framework recognised the pre-eminent role of teachers in providing basic education of good quality. It stressed that, to achieve EFA… governments need to enhance the status, morale and professionalism of teachers and enable them to participate in actions affecting their professional lives and teaching environments" (UNESCO, 2015a, p.196).

The success of governments across SSA in responding to Millennium Development Goals by increasing primary enrolment rates has amplified significantly the problems associated with attracting and retaining sufficient numbers of trained teachers, especially for the basic phase of education. Amongst teachers in service, Bennell and Akyeampong (2007) report low levels of job satisfaction and motivation leading to "far-reaching adverse impacts on the behaviour and overall performance of primary school teachers and thus learning outcomes" (Bennell and Akyeampong, 2007, p.x). They suggest that low motivation stems from a number of factors related to the perceived lowly status of primary school teachers and their poor working conditions. However, the teachers in their studies do not appear to be poorly motivated "through self-perceived inadequacies in their capacities as teachers" (ibid, ix). This echoes the results of teacher questionnaires applied in six focus countries for this study. The overwhelming majority of teachers (>90%) in all countries and at both the primary and secondary levels reported being both confident and well-prepared to teach the mathematics curriculum. (See Appendix A.) More objective observers suggest that the capacities of teachers, particularly in the teaching of mathematics, are inadequate both in terms of their subject knowledge and the pedagogical skills with which they are equipped. This has been linked with the recruitment of trainee teachers with low levels of general education and inadequate pre-service training (Lauwerier and Akkari, 2015). In this chapter we review evidence as to the capacities of teachers who teach mathematics and we explore the conditions in which they work. In Chapter 7, we review the effectiveness of the training programs used to prepare such teachers.

6.2 Evidence as to capacities

When considering the capacities of teachers charged with teaching mathematics to learners from Grade 1 upwards, discussions tend to focus on two key elements: mathematical competence and pedagogical competence. The first concerns the extent of the teacher's knowledge and understanding of mathematical concepts and the second concerns the skills and strategies that the teacher has for developing knowledge and understanding in her/his students. One of the challenges for those investigating in this area is to distinguish between teachers' perceived and actual levels of competence. The mismatch between the two is significant, but the undeniable fact is that the levels of mathematical competence achieved by students remain unacceptably low, indicating that teaching in this area is generally ineffective.

6.2.1 Mathematical capacity

Over the past two decades, many countries across SSA have expanded teacher numbers to meet greatly increased demand for primary school places, but have done so by recruiting those without proper qualifications and/or training. In many cases these unqualified teachers have been appointed to contract rather than established posts. Of the 34 countries in SSA with data for 2012, trained teachers constitute more than 90% of the workforce in 12 countries[42] but in a further nine[43] fewer than two-thirds of primary teachers are qualified (UNESCO, 2015a). Typically, untrained teachers contracted by communities need no formal qualifications and may not themselves have gone beyond primary education - with or without a qualification in mathematics. Table 6.1 shows the highest level of qualification gained by teachers according to data gathered for the PASEC and SACMEQ regional assessments. (For PASEC these are teachers of Grades 2 and 5, and for SACMEQ of Grade 6.)

Table 6.1: Summary of the highest level of academic qualification held by primary school teachers according to data collected in PASEC and SACMEQ surveys of learner achievement

	Less than primary school leaving certificate	With primary school leaving certificate	Upper secondary education but without Baccalaureate or A-level	Upper secondary with Baccalaureate or A-level	Tertiary level
PASEC (6 countries)	7.2%	18.7%	42.9%	31.0%	Not applicable
SACMEQ (14 countries)	10.8%	16.6%	45.3%	27.3%	5.5%

The figures in Table 6.1 suggest that at least one-quarter of those teaching the basics of mathematics did not study the subject in schools at the upper secondary level. These figures disguise significant variation amongst countries. For example, in Tanzania fewer than 5% of teachers in the survey had more than a junior secondary qualification whilst in Swaziland more than 80% had either A-level or tertiary level qualifications (Bonnet, 2007). There is also wide variation within countries, e.g. between rural and urban areas. In South Africa, the heritage of a racially segregated education system is evident in that 30% of Grade 6 teachers have only primary school education whilst, at the other end of the spectrum, 26% have enjoyed education at the tertiary level (ibid).

Given the large number of primary grade teachers with relatively low levels of qualification prior to any pre-service training, the question arises: do they know enough mathematics to teach mathematics? One major source of evidence comes from the second and third cycles of SACMEQ in which the mathematical knowledge of teachers was measured using a slightly extended variant of

42. Côte d'Ivoire, Mauritius, Burkina Faso, Namibia, Niger , Burundi, Tanzania, Cabo Verde, Democratic Republic of Congo, Madagascar, Malawi and Rwanda (UNESCO, 2015).
43. Liberia, Guinea-Bissau, Mali, Ethiopia, Equatorial Guinea, Angola, Benin and Senegal (UNESCO, 2015).

the multiple-choice test used for their students. The results were scaled to place teachers on the eight-level, criteria-related scale used to report student achievement. The results for SACMEQ II are shown in Table 6.2.

Table 6.2: Proportion (%) of teachers reaching the SACMEQ 'competency' level in mathematics

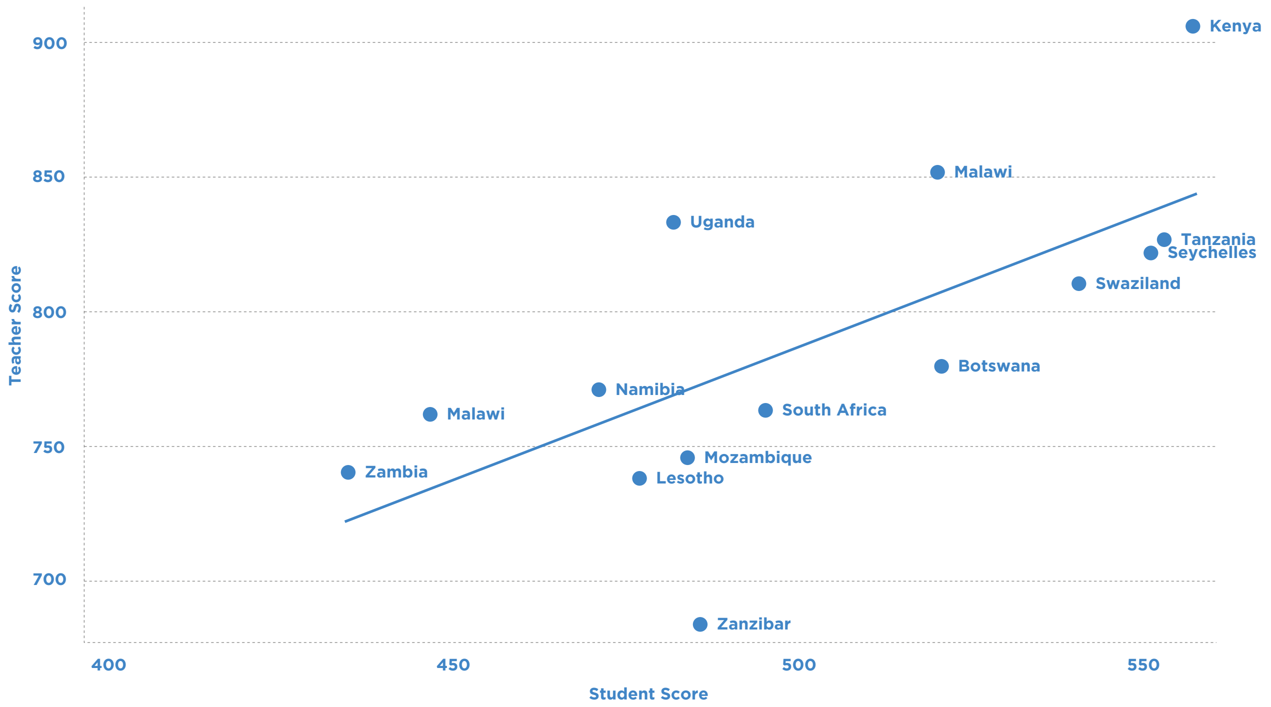
Percentage of teachers reaching the mathematics 'competency' level (SACMEQ II)								
Competency level	1	2	3	4	5	6	7	8
Botswana	0.0	0.0	0.0	2.3	5.1	26.4	47.9	18.4
Kenya	0.0	0.0	0.0	0.0	0.0	0.0	4.3	95.6
Lesotho	0.0	0.0	1.3	0.4	8.6	27.5	51.5	10.6
Malawi	0.0	0.0	0.0	1.8	6.9	10.5	51.3	29.4
Mozambique	0.0	0.0	0.3	2.9	4.6	16.3	44.3	31.7
Namibia	0.0	0.0	1.9	3.8	14.2	29.1	31.1	19.9
Seychelles	0.0	0.0	0.0	0.0	0.0	0.0	24.1	75.9
Swaziland	0.0	0.0	0.5	0.0	1.7	11.6	39.7	46.5
Tanzania	0.0	0.0	0.0	1.5	2.7	13.2	38.8	43.9
Uganda	0.0	0.0	0.0	1.2	5.3	11.4	27.9	54.2
Zambia	0.0	0.0	0.6	3.7	4.2	22.7	40.5	28.3
Zanzibar	0.0	0.0	6.3	6.2	19.3	30.0	28.9	9.3
Teachers (all)	0.0	0.0	0.9	2.0	6.0	16.7	36.0	38.5
Students (all)	6.2	34.3	29.8	14.6	7.5	4.6	2.2	0.9

Source: After Bonnet, 2007, p.28. Note that teachers in South Africa and Mauritius were not tested in SACMEQ II and so do not appear in this table.

Given that the teacher's test was not significantly harder than that applied to students, one would expect nearly all teachers to be performing at or near the highest level as indeed is the case in Kenya and the Seychelles. However, the table shows a great deal of variation and, in some countries, a significant proportion of teachers functioning at relatively low levels. Bonnet (2007) notes that, overall, "2.9% of students are taught by teachers who are not competent in Maths". On the face of it, this does not seem as bad as many observers have suggested. However, in categorising teachers as competent, Bonnet uses the 'Competent Numeracy' level of the SACMEQ scale which applies to students – a very low threshold to apply to teachers. Similarly, Bonnet reports that "2.4% (of students) have a teacher whose score on the Maths test is lower than their own" (Bonnet, 2007, p.29). Once again, the suggestion that 97.6% of students in the primary phase have a teacher whose maths test score is higher than their own is potentially misleading since in an effective education system one would expect teachers not just to score higher but to outperform all but the best students by a significant margin.

Results from the third cycle of SACMEQ, as shown in Figure 6.1, confirm that, at the national level, the average mathematics score achieved by teachers is strongly correlated (r = 0.69) with that of students (Altinok, 2013). Within countries the picture is far more complicated. For the majority of SACMEQ countries, the correlation between teacher achievement and student achievement is either absent or not statistically significant.

Figure 6.1: Relation between teacher and pupil score in mathematics in SACMEQ III (r=0,69)



Altinok (2013) does find five countries - Botswana, Kenya, Tanzania, Zanzibar and South Africa - where teacher knowledge is positively associated with student achievement in mathematics. However, only in South Africa is the relationship considered strong (r=0.42). Altinok's conclusion is that in some, but far from all, countries there would be a relatively small, but nevertheless significant, benefit to be accrued from raising the subject knowledge of teachers. In others, particularly South Africa, he suggests that one potentially beneficial policy intervention would be "to allocate (the) most able teachers (to) either rural areas or to low socio-economic level groups (or both when it is possible)" (Altinok, 2013, p.21). The special case of South Africa is investigated by Spaull (2011) who also uses the SACMEQ III data. He shows that the country exhibits a very wide range of teachers' mathematics scores from 612 (i.e. one standard deviation above the student mean score) to 991 (i.e. nearly four standard deviations above the student mean). In contrast to Altinok's findings, Spaull concludes that teacher knowledge – as measured by their test scores – is only a weak determinant of student achievement[44]. He estimates that the student mathematics gain from raising the weakest performing 10% of teachers to the level of the strongest performing 10% of teachers is only 18.3 points (Spaull, 2007, p.22). This means that the considerable effort required to teach the bulk of teachers more mathematics would probably result in only small gains which he estimates are equivalent in size to those associated with simpler interventions such as getting teachers to set and mark homework more frequently. Spaull suggests that "the ability to teach students well… is not very dependent on subject knowledge, but perhaps more on the teacher's ability to convey that subject knowledge" (ibid, p.23).

44. Filmer, Molina and Stacy (2015) used student and teacher scores on survey tests conducted in Uganda, Mozambique, Togo, Nigeria, and Kenya to estimate the effect of the mathematical knowledge of teachers on student achievement. They report that "a one standard deviation increase in teacher Mathematics knowledge increases student achievement by 0.105 standard deviations" (Filmer, Molina and Stacy, 2015, p.17). This relatively small effect size is not incompatible with Spaull's conclusions reported above.

Perhaps the most serious limitation of this approach to investigating the impact of a teacher's subject knowledge on the subsequent achievement of her/his students, is that the measure of knowledge used is restricted to the curriculum content that teachers are supposed to teach and students are supposed to learn. The SACMEQ test scores simply show that the vast majority of teachers have mastered the concepts and procedures required by the curriculum. They do not prove, however, that teachers have acquired what Ma (1999) calls the deep understanding of fundamental mathematics necessary to convey true understanding to their students. Alternative measures (see, for example, Hill and Ball, 2004) are necessary if we are to evaluate whether or not teachers in SSA understand to a sufficient degree how their students learn mathematics.

Akyeampong et al. (2011) suggest that the problem is rooted in initial teacher education (ITE) because "the approach of many ITE curricula on learning to teach mathematics in Africa tends to be one-dimensional beginning with an emphasis on subject knowledge leading to pedagogical content knowledge as the knowledge base" (Akyeampong et al., 2011, p.38). This approach influences how teachers perceive, or rather misperceive, their levels of competence in both mathematics and the teaching of mathematics (Ball, 1990 and, Hill and Ball, 2004 cited in Akyeampong et al., 2011). For example, primary grade teachers interviewed for this study are firmly convinced that they are competent teachers of mathematics because they know what their students are ultimately supposed to know. However, they manage to ignore the fact that most of their students reach, at best, only moderate levels of achievement. This cognitive dissonance is reflected in the fact that of the 294 primary teachers interviewed for this study across six countries, 91%[45] agreed or strongly agreed with the statement "I am a confident and competent teacher" and, at the same time, 83% agreed with the statement "Most pupils need additional tutoring in mathematics." (See Appendix A.) The role of teacher education in perpetuating this over optimistic view is explored further in Chapter 7.

6.3 Classroom conditions and pedagogical practices

Notwithstanding deficiencies in their subject knowledge, most teachers face significant challenges when they try to teach mathematics in the classrooms of SSA. General problems identified by UNESCO include poor physical facilities within schools, overly large classes and multi-grade teaching in the primary phase, and shortage of textbooks (UNESCO, 2012). There is, however, considerable variation across the region. Conditions range from those in Mauritius where all primary schools have electricity and potable water and where the pupil:textbook ratio is approximately 1:1 to those in, for example, Niger where 95% of primary schools don't have electricity, or Cameroon where the pupil:textbook ratio for mathematics is 13:1. Such problems, where they exist, impact on the quality of education and, inevitably, on student achievement in general.

A second major factor is the way in which mathematics is taught in classrooms across the region. Some data on typical teacher practice is available from regional assessment surveys and targeted research. In order to supplement this, classroom observations were conducted in six focus countries for this study. Key findings are included in this chapter with more detailed information given for each country in Appendix A. In addition, a TIMSS video study of mathematics lessons in seven developed economies[46] allows some comparisons to be made with observed practice in SSA (Hiebert et

45. In five of the six countries studied, 88% or more of primary teachers expressed great confidence in their ability to teach mathematics (100% in Uganda and DRC). Only in Cameroon was there a significant difference with just two-thirds (68%) agreeing with the statement 'I am a competent and confident teacher".
46. Australia, the Czech Republic, Hong Kong, Japan, the Netherlands, Switzerland, and the United States.

al., 2003). However, it should be noted that the TIMSS video study looked at Grade 8 classrooms and so caution should be exercised when considering how mathematics is taught in primary grade classrooms.

6.3.1 Class size

Research findings of the impact of class size on learner achievement is equivocal with many studies finding little or no evidence that smaller classes lead to improved outcomes (e.g. Moshoeshoe, 2015, Altinok and Kingdon, 2009, and Wößmann, 2006). However, in the context of SSA, large classes, particularly at the primary level, are generally considered to present a considerable barrier to achieving quality in education (UNESCO, 2015a). Of the 28 countries in the region for which recent data are available[47], 13 have average enrolments of more than 50 students in Grade 2 and, of these, four (Malawi, CAR, DRC and Tanzania) report an average class size of more than 85. There is also significant variation within countries. For example, in five of the six countries investigated for this study, the average observed class size was approximately 40. However, the number of students present ranged from just 5 to 98. The other country in our survey, Uganda, had an average of 66 students in observed classes. However, one class accommodated 120 students! The challenge of overly large classes is exacerbated by multi-grade teaching which remains a significant feature of many systems. For example, UNESCO reports that "in most countries reporting data, at least 10% of pupils are taught in such classes" with the number reaching nearly 50% in Chad (UNESCO, 2012).

Overly large and multi-grade classes present challenges to mathematics teachers especially in poorly-resourced classrooms. In particular, it makes it difficult to arrange effective group work with feedback, and to implement individualised diagnostic assessment with remedial interventions – both of which contribute to higher levels of achievement. If this applies to well-prepared teachers, how much truer will it be for poorly trained or even untrained teachers? Unfortunately, the financial costs of reducing class sizes and student:teacher ratios significantly in SSA are likely to prove prohibitive. For example, it has been estimated that reducing class sizes in line with EFA targets for quality teaching would require many countries in SSA to increase their expenditure on education by more than 4% of GNP (Benbow et al., 2007). Benbow et al. conclude "if we accept that large classes are currently irreversible, one must then develop strategies that take into consideration financial and technical realities. Are there ways to cope with large class sizes through less resource-dependent means?" (Benbow et al., 2007, p8.) The solutions they propose all depend on ensuring that teachers are well prepared in techniques of classroom management and in appropriate pedagogical techniques including small group work and peer-to-peer mentoring. This would have major implications for the reform of current teacher training practices as explored in Chapter 7.

6.3.2 Language of instruction

Language policies are of particular importance in SSA where each country typically has a number of important indigenous languages and, as a result of colonial rule, a legacy European language (i.e. English, French, Portuguese, Spanish and, from the Dutch, Afrikaans). At independence, different countries adopted radically different policies with regards to national/state languages. Batibo (2013) identifies five approaches: Inclusive; Partially Inclusive; Exclusive; Hierarchical; and, Adoption of the status quo ante. The nature of these and their implications for the language or languages of instruction are summarised in Table 6.3.

47. World Bank databank available at: http://data.worldbank.org

Table 6.3: Classification of language policies across SSA and their implications for medium or media of instruction (After Batibo, 2013)

Language Policy Type	Characteristics	Examples
Inclusive	Promotion, as far as possible, of all indigenous languages to a national level – including use in education.	Namibia: English, the state language, and at least 16 local languages are used to a greater or lesser extent in education.
Partially Inclusive	A selected number of indigenous languages are promoted for use, e.g., in education. Other indigenous languages are excluded.	South Africa (11 languages out of 23); Zambia (7 languages out of 38); Mozambique (6 languages out of 33)
Exclusive	A single indigenous language is selected as the national language and used exclusively in education.	Tanzania (Kiswahili); Botswana (Setswana); Malawi (Chichewa)
Hierarchical	Different languages are used at different administrative levels (e.g. national, provincial, district, etc.)	Zimbabwe adopted such a model but, in education at least, implementation was partial with Chishona and Sindebele dominant at all levels.
Adoption of the status quo ante	The language policies of the former colonial power are retained. Here the ex-colonial language remains the national medium of instruction.	Burundi and Chad (French); Angola (Portuguese); Equatorial Guinea (Spanish); Mozambique (Portuguese - but moving to include 16 indigenous languages by 2017).

Perhaps the most important aspect of such language policies is that concerning the language or languages to be used in instructing young learners and those in the primary stage of education. Policies vary from country to country[48]. In some, young learners entering school are immediately immersed in a language which is not that of their home. In many others, it is expected that learners will be taught in their mother tongue in the early years but that, before very long, there will be a transition to a preferred national language or an official 'international' language. Unfortunately, children who are taught and tested in languages that they do not fully understand are placed at a significant disadvantage (UNESCO, 2014). Where teaching beyond the early years is conducted in an international language or an unfamiliar African language, "both teachers and learners may often not be fluent enough to use the language as a medium of instruction" (Clegg and Afitska, 2010, p.iii). This presents considerable challenges to teachers in all subjects, but the problem is exacerbated in mathematics where both teaching and learning depend on teachers and students understanding the special 'linguistic register' of mathematics (Pimm, 1987, cited in Setati, 2002). This register extends beyond the specialised terminology of the subject to the correct use and understanding of, for example, logical connectors in the main language. Setati (2002) suggests that "the Mathematics register is not well developed in most of the African languages" and that teachers (in South Africa) would not invest the time or effort necessary to

48. National language policies in education change over time. A recent overview of the prevailing system can be found in Albaugh, 2012.

formalise spoken and written mathematics in the main language since "due to the dominance of English, this work would generally be seen or interpreted as a waste of time" (Setati, 2002, p.11). Without adequate preparation and support in this specialised area, many teachers use code-switching to help their students but the use of indigenous languages in this way is often condemned by the authorities (Clegg and Afitska, 2010).

Kazima (2008) describes two approaches towards meeting the challenge of dealing with mathematical terminology when teaching in an African language. In Nigeria and Tanzania, efforts have been made to produce glossaries in local languages of the mathematical terms used at primary level (Kazima, 2008). For example, the term 'percent' is translated into Kiswahili as 'sehenu za mia' (literally 'portion of hundred'). In Malawi, however, the national language Chichewa was not conducive to expressing key mathematical terms and so a decision was made to borrow words from English. For example, 'percent' is transcribed as 'pelesenti' and 'rectangle' rendered as 'recitango'. Kazima (2008) concedes that neither of these strategies has been systematically evaluated but suggests that "Malawi's strategy has the advantage of easiness" and that it is easier for learners when they move to Standard 5 where English becomes the language of instruction (Kazima, 2008, p. 60).

Clearly, the issue of language in teaching mathematics presents a significant barrier for both teachers and learners. First, this should be recognised in establishing policies for the language, or languages, of instruction where political/cultural factors tend to dominate (Setati, 2002). A set of principles to guide the formulation of such policies is suggested in McIlwraith (ed. 2013) including: "Learners should be taught in basic (i.e. up to lower secondary level) formal and non-formal education through the language they know best." (McIlwraith, 2013, p.7.) Secondly, any strategy for developing an appropriate register for teaching mathematics and/or using languages in the classroom should be should be systematically evaluated. Thirdly, teachers require sufficient formal training in the effective use of languages if they are to be effective (Clegg and Afitska, 2010). This is particularly true for teachers of mathematics where specialised terminology and the need to explain unfamiliar abstract concepts present significant challenges.

6.3.3 Availability of educational technologies

In a world where new technologies promise solutions to problems in all aspects of our lives, it is tempting to believe that the use of technology in the classrooms of SSA could bring about a quantum leap in the effectiveness of mathematics teaching overcoming the many deficiencies described in this study. Indeed, there is some encouraging evidence and the potential of technological approaches to the teaching and learning of mathematics is considered in Chapter 9 below. However, the current situation, as revealed by classroom observations conducted for this study, is not conducive to implementing radical technological solutions, at scale, in the short- to medium-term.

Data concerning the average number of computers in primary/basic schools was collected in the third cycle of SACMEQ conducted in 2007. At that time, the average number of computers per school for all SACMEQ countries was three[49]. However, this average is highly skewed by the data for South Africa which reported an average of 13 computers per school. By way of contrast, Lesotho, Malawi, Tanzania, and Uganda each had an average of

49. Spaull, N. 2012. SACMEQ at a glance series. Research on Socio-economic Policy (RESEP). Available at: http://resep.sun.ac.za/index.php/projects/

zero. Kenya, Swaziland and Zambia reported having one computer per school but it is far from clear that this computer was available for teaching. This picture is in line with the classroom observations made for this study where in four countries (Cameroon, Ethiopia, Rwanda and Uganda) no computers were seen in a total of 280 observed classrooms[50].

Even if modern technologies were available, it is far from certain that the majority of teachers would be competent in their use. For example, of the teachers questioned about their computing skills, the majority (ranging from 67% in Rwanda to 94% in DRC) classified themselves as being 'non-users' or mere beginners. As shown in Table 6.4, relatively few own or have the use of computers with internet access, but a sizeable proportion of our cohort do have a mobile phone with internet access. For example, in Ethiopia none of the 70 teachers interviewed had a computer but 57% reported having an internet-enabled mobile device. This suggests that providing information and teaching tools through mobile devices may offer the best opportunity for supporting teachers of mathematics - certainly in the short- to medium-term.

Table 6.4: Access to new technologies and self-reported computer competence of teachers interviewed for this study by country (See Appendix A)

	CMR	DRC	ETH	NGA	RWA	UGA
Proportion of teachers interviewed who consider themselves to be computer 'non-users' or 'beginners'.	71.0%	94.0%	82.4%	80.0%	67.1%	81.4%
Proportion of teachers interviewed who own (or have the use of) a computer with internet access.	31.4%	5.7%	0.0%	21.4%	20.0%	12.9%
Proportion of teachers interviewed who own a mobile phone with internet access.	48.6%	30.0%	56.5%	60.0%	61.4%	50.0%

6.4 Pedagogical practices

Over the past decade or two, one of the main themes in the general field of curriculum reform in SSA has been the promotion of student-centred approaches and more active interaction between teachers and learners. In particular, teachers have been encouraged to use group work and formative assessment to engage and support learners. However, there is a widely held view that practices in the classroom have not moved sufficiently far and that the delivery of the curriculum remains, to a great extent, teacher-led and passive. In the teaching of mathematics, two critical aspects have attracted much attention. The first concerns the consequences of the fact that the majority of teachers in SSA appear to hold the view that mathematics is predominantly about rules and procedures rather than, for example, the exploration of problems and proofs. The second concerns the nature of the interactions between teachers and learners and those amongst learners i.e. peer-to-peer.

Where the rules and procedures of mathematics are prioritised, teachers tend to adopt an instrumentalist approach in the

50. In DRC, one of 70 classrooms had a computer and in Nigeria two computers were available in the 70 classes observed.

classroom. The emphasis is placed on telling or showing learners what the rules are for solving a particular problem and, hence, what procedures are to be followed. The natural consequence is for the teacher to assume a dominant position and to hand the 'correct' procedure down to the learners. Students who can remember and reproduce this method are given credit in examinations by examiners who, in turn, are looking for a particular solution. It is argued that this procedural approach explains to a significant extent why students in the USA are outperformed by their peers in, for example, Japan and China where teachers encourage students to develop alternative approaches to problem solving (Stigler and Hiebert, 1999, and Ma, 1999). The question is do we see evidence of a unidirectional instrumentalist approach in the mathematics classrooms of SSA?

In a study of newly qualified teachers (NQT) in Ghana, it was found that whilst many were aware of the advantages of constructivist approaches, their practice in the classroom was "largely instrumental and without the kind of learner-centred focus which has the potential to allow pupils to construct their own understanding of the concepts" (Adu-Yeboah, 2011, p.57). Another manifestation of the teacher-led approach reported by Adu-Yeboah (2011) was the frequent use by teachers of 'demonstration' to explain a mathematical concept. However, following the demonstration, "pupils were not observed working with these teaching learning materials as part of a problem-solving activity that (tested) their understanding of the concept" (ibid, p.58). This directive approach does not allow students to explore alternative methods and, hence, develop deeper understanding. In addition, it does not allow students to make mistakes and reveal common misconceptions. This is important because "teaching becomes more effective when common mistakes and misconceptions are systematically exposed, challenged and discussed" (Swan, 2005 after Askew and Wiliam, 1995). The dominance of the teacher-led, transmission method of instruction was confirmed by the classroom observations conducted for this study. As described in Appendix A, by far the most frequently observed teacher actions in all six countries were 'writing on the chalkboard' and 'explaining a concept orally i.e. lecturing'.

In traditional teacher-led approaches to classroom management, most interactions are initiated by the teacher. These usually take the form of a question to which the class may respond in chorus (Mayaba, 2009 cited in Sepang, 2013) or which an individual student may be selected to answer. Such interactions are generally short and closed. If the offered answer is correct the teacher moves on. If the answer is incorrect the teacher may choose another student to respond or may immediately offer the right answer. In either case, the interaction is unlikely to lead to a deeper exploration of the root of the error or a wider discussion of alternative approaches to solving the problem. Peer-to-peer interactions are encouraged where, for example, groups of students are allowed to collaborate on the construction and evaluation of alternative approaches to solving a mathematical problem. In our classroom observations, direct questioning of students by the teacher was by far the most common form of interaction - all teachers asked direct questions throughout the lesson with students responding either individually or, especially at the primary level, as a group. It was also common for individual students to be invited to solve problems on the chalkboard whilst their peers watched. It was relatively rare to see students working in groups or even in pairs. The 'lesson signatures' described in Appendix A for each of the six countries surveyed reinforce the findings of other observers that mathematics lessons in the classrooms of SSA remain strictly teacher-led with little or no opportunity for individuals or small groups of learners to tackle non-routine problems or explore alternative routes to a solution.

6.5 Summary

The quality of teaching is a major factor in the quality of schooling and, as such, is a key determinant of learner achievement. High-quality teaching requires teachers who are well motivated, understand pedagogical theory, and have good classroom management skills. In addition, effective teachers of mathematics need good subject knowledge and the special skills needed to develop deep understanding of mathematical concepts in their students. In SSA the quality of mathematics teaching is poor as demonstrated by poor learning outcomes on a range of relative and absolute measures.

The root cause of the problem does not rest with the teachers. They themselves are the product of a poor general education system and many, particularly those intending to teach at the primary level, embark on their pre-service training without having mastered mathematics at school. Through their training they improve their knowledge of the curriculum to the stage where most (but not all) are ahead of their students as measured by student-level tests, but they do not have sufficient depth of knowledge to be truly effective teachers of mathematics.

As a result of the environment in which they were originally educated and subsequently trained, most teachers in SSA believe that mathematics is about learning the rules and remembering correct procedures. They see their role as transmitting these rules and procedures to their students and this view is reinforced by examination systems which reward those who can reproduce the 'correct' answer as defined by the official marking scheme. As a result of this instrumentalist approach, lessons are almost invariably teacher-led with few opportunities for students to engage in collaborative problem-solving and, hence, profound learning.

The weaknesses of teachers described above are exacerbated by the poor conditions in which many find themselves teaching. Average class sizes in nearly all countries of the region are far larger than those of, for example, Europe or North America but even these disguise the fact that many teachers in SSA are confronted with huge classes of 60, 70, 80 or even more. In addition, a significant number find themselves trying to teach multi-grade classes – a challenge even for a well-qualified teacher in a well-resourced school.

Language of instruction is a big challenge for all teachers especially where official policy is to teach young learners in a European language which is not the language of their home. However, it is a particular problem in the mathematics classroom where specialist terminology is required and where unfamiliar abstract concepts must be explained. Teachers receive little formal training in this difficult area and, in the absence of formal support, have to try to find their own solutions.

Changing the culture of mathematics teaching and providing teachers with the knowledge, skills and resources they need is a monumental task. It needs to be tackled simultaneously on several fronts. However, reforming the systems by which primary school teachers and specialist teachers of mathematics are trained is a condicio sine qua non.

7 Initial teacher education for those who will teach mathematics in the basic phase of education

7.1 Introduction

School teachers in the basic phase[51] of education clearly have a vital role to play in efforts to tackle the extremely low levels of numeracy and mathematical competence found across SSA. However, the recruitment, training and retention of such teachers remain serious challenges for many countries. UNESCO reports that nearly 7 in 10 countries in the region currently face an acute shortage of teachers and that the situation will be further exacerbated by a rising demand for school places and high rates of attrition in the teaching force (UNESCO, 2015b). It is estimated that "Sub-Saharan Africa … will need to create 2.2 million new teaching positions by 2030, while filling about 3.9 million vacant positions due to attrition" (ibid, Section 3). In response to this pressure, many countries have resorted to appointing contract teachers with no formal training or introducing alternative entry routes involving minimal training requirements. For example, UIS data reports that 50% or less of newly appointed teachers have received training to national standards in Benin, in Mali (46%), in Malawi (46%), in Angola (45%) and in Niger (37%) (ibid). When considered in conjunction with high student:teacher ratios an even more disturbing picture emerges. The 2015 EFA Global Monitoring Report estimates that "ratios of pupils to trained teachers are above 100:1 in Central African Republic, Chad, Guinea-Bissau and South Sudan, and above 40:1 in 38 other countries in sub-Saharan Africa" (UNESCO, 2015a, p.198). Whilst the priority must be to ensure that all teachers are trained, the quality of that training is also of concern. In this chapter we focus on the quality of the initial training that prospective teachers receive in relation to the teaching of mathematics.

In order to meet the great demand for teachers, some countries have introduced relatively short 'accelerated' training programmes for primary school teachers e.g. Liberia (9 months), Senegal (6 months) and Mali (45 days). However, most countries in SSA retain traditional, full-time college courses, typically of two or three years' duration, as the main route of entry into teaching at the primary/junior secondary level. The curricula for the TTI typically cover three domains: subject content knowledge; teaching methods; and, 'professional studies' incorporating elements such as theories of child development and learning, and classroom management skills. In addition to taught courses, all trainees take part in a practicum although the duration and nature of this varies from country to country. Assessment is generally through formal examinations of both subject content and pedagogical knowledge. The language of instruction in the TTI tends to be in the dominant European language (e.g. English or French) or in a state language such as Kiswahili in Kenya - notwithstanding the fact that early grades are usually taught in local languages. (See Akyeampong et al., 2011). The use of a European language of instruction can also present barriers to trainees. For example, in Francophone West Africa initial training is typically in French yet "the data show that the mother tongue of over 98% of trainee schoolteachers is not French" (World Bank, 2005, p. 53 cited in Lauwerier and Akkari, 2015).

51. Here the term basic education includes both primary and lower secondary grades. In SSA, many TTI prepare teachers for these levels only. A minority prepare specialist mathematics teachers for the upper secondary grades. In many countries an alternative route is offered by universities who prepare specialist teachers to degree level.

7.2 Issues related to the quality of initial teacher education

Entrants are not well qualified

Entry requirements for those enrolling on pre-service programmes vary from country to country. In some countries, e.g. Ghana, entrants must have a school-leaving qualification at the senior secondary level (i.e. senior school certificate, A-levels, or Baccalaureate) and in Zambia entrants are expected to have followed at least a short course at the tertiary level (UNESCO, 2015b). However, in many others, including Kenya, Uganda and Nigeria[52] the minimum entry requirement is the successful completion of basic school (i.e. school certificate, O-levels or the equivalent). According to the 18 TTIs surveyed for this study, the entry requirement implicitly includes the need for a 'pass' in mathematics at the junior secondary level or above. However, it is not clear what this means, in absolute terms, for the levels of mathematical competence that entrants can demonstrate. Indeed, most of the TTIs responding to our survey (56%) agreed with the statements "When they start their courses, most of our trainees have inadequate knowledge of the Mathematics curriculum" and "Our tutors have to re-teach the Mathematics content that our trainees should have learned in schools". This is reflected in the way in which the content of the curricula of TTIs is organised with much emphasis being placed on the teaching of mathematical topics rather than pedagogical skills.

Tutors have inadequate experience of teaching in basic education

There is evidence that teacher trainers in TTI rarely have experience of teaching at the basic level of education (Lewin and Stuart, 2002). In many countries, e.g. Uganda, Rwanda and Nigeria, the minimum requirement for new tutors is a Bachelor's degree making it increasingly unlikely that primary school teachers will progress through the ranks to become teacher trainers. Currently, most tutors within TTI have been secondary school teachers at some point in their career (Akyeampong et al., 2011). The lack of personal experience of teaching mathematical concepts from the basic school curriculum, especially in the poor conditions that prevail in many classrooms, surely presents a barrier to guiding new entrants to the profession. This is a situation which is exacerbated by the reported disconnect between the curricula of TTI and current approaches to delivering the mathematics curriculum in schools.

The curricula of TTI are not well aligned with school curricula

Akyeampong et al. (2011) argue convincingly that the curricula of TTIs are not well aligned with the school curricula which their graduates will be required to teach. Reasons for this include the separation of responsibility for curriculum development in schools and TTIs, the lack of recent and relevant experience of TTI staff at the basic school level, and the startling revelation that "neither college tutors nor trainees are likely have access to the materials, such as teacher guides and textbooks used in schools" (ibid, p.18). One of the main consequences of this disconnect, particularly with respect to the teaching of mathematics, is that recent reforms in approaches to the delivery of the curriculum in classrooms are not reflected in TTIs. The general trend across SSA for some considerable time has been to promote active, child-centred teaching and learning in contrast

52. The UIS Fact Sheet of 2015 lists Uganda, Rwanda and Nigeria as having a qualification at the senior secondary level as the official minimum requirement for trainees. However, TTI in these countries reported to us that their current minimum requirement is, in fact, successful completion of junior secondary education.

to traditional passive, teacher-dominated approaches. Traditional content-based programmes have tended to be reformulated as competency-based curricula and implicitly, if not explicitly, constructivist approaches to teaching/learning have been encouraged. Whilst practice in the classrooms of SSA may not yet have shifted significantly in this direction, this is the aspiration of those responsible at the national level for improving the quality of education and raising achievement. However, TTIs tend not to reflect new approaches in either the content of their curricula or the way they model good teaching practice. This is particularly true in the preparation of trainees who will teach mathematics in the basic phase of education.

Many TTI programmes place a great deal of emphasis on developing the mathematical knowledge base of trainees who, in many cases, enter college with poor subject knowledge and weak skills. A significant amount of time is dedicated to mathematics (at least 5 hours per week in the TTIs surveyed for this study) with the content organised according to mathematical topics drawn from the basic curriculum. However, relatively little time is specifically dedicated to how those topics should be taught. For example, in the programme for primary teachers in Rwanda, a ten-hour module on the critically important concept of 'number operations' dedicates eight hours to teaching trainees about everything from "Writing numbers of up to 7 digits in words and vice versa" to "Carrying out operations in other bases (base five, base eight)" and "Writing numbers in expanded form with concepts of indices and bases". However, the same module allocates a total of just two hours to "Identifying instructional materials to use in teaching operations on numbers" and "Teaching operations on numbers in the primary school". This reinforces the view that TTIs place the emphasis on raising the subject knowledge of their trainees to such an extent that strategies for teaching key concepts to young learners are largely neglected. Certainly the vast majority of the teachers interviewed for this study had a positive view of this aspect of their training with more than 80% agreeing with the statement "My own mathematical skills improved a lot as a result of my training". In reconciling this with the fact that assessments have repeatedly shown that teaching of mathematics in primary grades is largely ineffective we are led to conclude that TTIs do not equip their trainees with the profound understanding of fundamental mathematics that Ma (1999) suggests is essential for teachers. Perhaps part of the explanation for this rests in the way in which TTI tutors present mathematical concepts and teaching strategies to their trainees.

From the descriptions of observed teaching sessions given by Akyeampong et al. (2011) it appears that tutors in TTIs tend to replicate their own ideas as to what primary school teaching looks like but that this, all too often, fails to mirror best practice. For example, whilst tutors stressed the importance of using teaching and learning materials (TLM), their treatment of them was often superficial and/or uncritical (ibid). This, perhaps, is unsurprising if the tutors have never taught in primary classrooms and have little practical experience of how young people respond, or fail to respond, to various TLMs. This inability to take into account where young learners start from, the prior learning they have, and the misconceptions they hold is indicative of another deficiency – the failure of TTI tutors to model some of the key characteristics of the learner-centred, constructivist approaches advocated in curricula and supported by more modern TLM. Akyeampong et al. report that in Ghana "classroom interaction was organised around tutors posing questions and waiting for responses" and that in Tanzania "tutors tended to follow a standard approach to teaching: demonstration, practice, teacher assessment and home assignment" (ibid, p.39). These techniques are typical of the signature lessons we observed in six focus countries for this study (see Appendix A) and "very far removed from the contextualised, problem-solving approaches of the competence-based and thematic school curricula" (Akyeampong et al., p. 40).

Colleges are not well equipped to use new technologies or train prospective teachers in their use

As explored elsewhere in this report, educational technologies are increasingly seen as having great potential for raising the quality of education and, in particular, student achievement. The relatively poor schools of SSA are not yet equipped to make this a universal reality but one might reasonably expect TTIs to be leading the way in this field and at least demonstrating how such technologies might be used to advantage in the classroom. However, evidence gathered for this study suggests that most TTIs are not well equipped in terms of hardware, software, or competent staff[53]. Even where colleges report that they have resources, it was extremely rare to find that this was available for regular use by trainees. For example, no TTI reported that trainees had access to video material for the teaching/learning of mathematics and none had computer software specifically related to mathematics instruction (see Appendix A). Similar deficiencies were found in a needs assessment conducted for a joint project between UNESCO and the China Funds-in-Trust (CFIT) which aims to use Information and Communications Technology (ICT) to strengthen pre-service and in-service teacher training (UNESCO and CFIT, 2014). In the five countries surveyed for the project in 2014[54], all reported problems with unstable power supplies and inadequate and/or unaffordable internet services. In some countries, including Tanzania and Nigeria, TTIs are expected to be equipped with ICT resources – usually in the form of a dedicated computer laboratory. However, hardware and software are often outdated and trainee access to computer rooms may be severely restricted (ibid). There is little evidence to suggest that the tutors currently employed by TTIs have the knowledge, skills and experience necessary to deliver effective training in this area.

This may not constitute a serious problem in the short term because most graduates will start their teaching careers in schools where educational technologies are not available. However, in the not too distant future, technological solutions to the problems of raising educational outcomes are likely to be implemented in schools. TTIs will need to respond to this challenge.

Graduates of TTIs enter a non-supportive environment

Whilst not strictly a consequence of initial teacher training programmes, it is worth noting that newly qualified teachers (NQT) often find themselves teaching in schools where the environment is not conducive to using a range of TLMs or more sophisticated modes of engaging with learners. Pressure to cover an over-loaded curriculum leading to a high-stake examination often leads NQT to deliver lessons according to an inflexible

53. In four of our focus countries, Cameroon, DRC, Rwanda and Uganda TTIs reported that their technical resources are inadequate and that they do not use technology (i.e. video, broadcast material, computer software and applications, etc) 'extensively' in their training. In Nigeria and Ethiopia, some but not all TTIs reported that they had adequate technological resources and that they were using it 'extensively'.
54. Congo, DRC, Liberia, Tanzania, and Uganda.

structure and to use TLMs in a superficial way – if at all. There is evidence that NQT are sometimes discouraged by more experienced, and more cynical, colleagues who doubt the benefits of using, for example, teacher-made TLMs (Akyeampong et al., 2011).

7.3 Summary

Many countries in SSA face an immediate need to produce very large numbers of teachers to meet the growing demand for education. However, strategies for meeting numerical targets for newly qualified teachers must ensure that the quality of their training is not neglected. At present, there is evidence to suggest that graduates from TTIs are not well prepared to teach basic mathematics to young learners – they do not leave college with the necessary "profound understanding of fundamental mathematics" (Ma, 1999) and they do not develop the pedagogical skills associated with delivering a mathematics curriculum which presumes a constructivist or, at least, a learner-centred approach.

The problems facing TTIs are numerous and varied. Financial resources are limited, but there are three fundamental challenges which should be addressed without delay.

- There is a need for TTIs to develop and implement radically reformed curricula which reflect both the content and philosophy of the required curricula for schools.

- TTIs need to develop a cadre of tutors with the knowledge, skills and first-hand experience of classroom teaching necessary to deliver a reformed curriculum using active methods. First, tutors require training in how to teach prospective primary and secondary school teachers. Secondly, a recognised career path is required for those who wish to progress from successful careers in primary schools to posts within TTIs.

- TTIs need to acquire the resources and personnel necessary to train their trainees in the effective use of the educational technologies both in the classroom and for personal development.

If TTIs fail to meet these challenges there is a significant risk that they will continue to impede progress towards raising levels of mathematical competence in schools rather than being part of the solution.

8 Assessment practices

8.1 Introduction

As described in Chapter 5, the Systems Approach for Better Education Results (SABER) evaluation framework for student assessment identifies four important forms of assessment: Classroom Assessments; Examinations; National Large-Scale Assessments (NLSA); and, International Large-Scale Assessments (ILSA). The implication is that developing all four forms of assessment in a systematic way is likely to lead to better educational results at the national level. The structure of this chapter reflects the SABER framework and uses findings both from SABER evaluations and beyond to describe current assessment practices in SSA with special reference to mathematics.

8.2 Classroom assessments

The SABER student assessment framework defines classroom assessment as any form of assessment which "provides real time information to support ongoing teaching and learning in individual classrooms. Classroom assessments use a variety of formats including observation, questioning, and paper and pencil tests, to evaluate student learning, generally on a daily basis" (World Bank, 2013a, p.2). Such formative assessment practices, as argued in Chapter 5, offer an effective way of raising student achievement. The potential benefits have been widely recognised in educational reforms across SSA with many countries formally adopting policies for the implementation of classroom assessment and supporting schools through, for example, the publication of teacher guides and the provision of in-service training. However, there is much evidence to suggest that the reality of implementation by teachers has not matched the vision of policy makers. For example, in Sudan official guidelines have been published for classroom assessment at both the primary and basic levels but "classroom assessment practices are generally considered to be weak, as they provide little useful feedback to students. Limited systematic mechanisms are in place to monitor the quality of classroom assessment practices" (World Bank, 2013a, p.1). Similarly in Ghana "National syllabi… include guidelines for classroom assessment (and) there are some system-level mechanisms in place to ensure that teachers develop skills and expertise in classroom assessment; however, there are limited resources (such as tools and materials) available to teachers for conducting classroom assessment activities. Classroom assessment practices are generally known to be weak, and there are limited formal mechanisms in place to monitor their quality" (ibid, p.1). This and other evidence suggests that Paulo (2014) is right to conclude that in SSA "the powerful engine of assessment for improving learning remain(s) unharnessed" (Paulo, 2014, p.137).

Kellaghan and Greaney (2004) suggest that barriers to the adoption of formative assessment practices include: the tendency of teachers to dominate all aspects of teaching and assessment leaving little room for student-focused activities; poorly qualified teachers; large classes; poor facilities and shortages of teaching and learning materials (Kellaghan and Greaney, 2004). Paulo (2014) notes the negative influence of high-stake examinations which encourage teachers to focus on topics likely to occur in examinations and to emulate the format and nature of examination questions in their classroom assessments leading to "misalignment between systemic assessment priorities and assessment for learning reforms" (Paulo, 2014, p.144). Whilst it seems safe to assume that teachers of mathematics in SSA face all these generic challenges, there is little evidence as to the subject-specific problems they may face. For example, Kanjee (2009) notes that teachers are required to prepare their own classroom materials but that it is unrealistic to expect them to produce high quality assessment instruments for formative purposes especially if they are inexperienced, have few resources to hand and are under pressure of time. One approach to solving this problem is illustrated by the development in South Africa of subject-specific Assessment Resource Banks (ARB). Mathematics teachers can access sample assessment materials for a wide range of curriculum topics via the Thutong South African Education Portal[55]. Kanjee (2009) concludes that teachers value such materials and that their provision helps teachers to improve their classroom assessment practices (Kanjee, 2009).

8.3 Examinations

Throughout SSA, formal examinations tend to be the most firmly established and most highly developed form of student assessment (e.g. World Bank 2009, 2013a and 2013b). Their key purposes are selection and/or certification of learner achievement at critical transition points. Typically, these lie between the primary and (junior) secondary phases, between the junior and senior secondary phases, and at the interface of (senior) secondary and tertiary education. Given that many examinations serve as gatekeepers to limited and highly prized opportunities, the stakes associated with them are extremely high. As a consequence, the backwash[56] effects of examinations are widespread and profound. In theory, such effects may be positive or negative leading to what Braun and Kanjee (2006) refer to as the "paradox of 'high-stakes' assessment as an instrument of change" (ibid, p.2). For example, high-stake tests may motivate students to work harder and they may encourage teachers to focus on the most important concepts of the curriculum. On the other hand, high-stake tests encourage teachers to 'teach only to the test' and to ignore other vital elements of a young person's education. Also, examinations (especially those that set unrealistically high barriers) can demotivate learners and promote cheating.

Bachman and Palmer (1996) point out that test effects can be seen at both the micro and macro levels. Micro level effects are seen in the behaviours of individual students and teachers. Macro effects are seen at the level of the education system and in the behaviour of society as a whole. One of the most obvious macro effects in SSA is the prevalence of malpractice, whereby students, teachers, exam room invigilators, markers and/or others adopt illegitimate means in order to gain unfair advantage (Greaney and Kellaghan, 1996). National and regional examining agencies direct a great deal of effort towards preventing malpractice but reports of widespread cheating remain common throughout the region. For example, in South Africa, during the conduct of the 2014 Matric examinations, "more than 2,800 Matric pupils and at least 34 teachers and principals in KwaZulu-Natal and the Eastern Cape were allegedly involved in mass cheating" (eNCA, 2015). In Kenya, at the release of results for the 2015 Kenya Certificate of Primary Education (KCPE), the Chief Executive of the Kenya National Examinations

55. http://www.thutong.doe.gov.za/ (accessed 14 October 2015).
56. In educational assessment, the 'backwash' or 'washback' effect is the influence which a test or examination has on the teaching and learning which precedes it.

Council (KNEC) reported that “157 people have been prosecuted for engaging in examinations irregularities” and that those charged included “head teachers, their deputies, university students, parents, police officers and candidates” (Wanzala, 2015). And in Ghana, the West African Examination Council (WAEC) cancelled the results of 453 students for cheating in their West African Senior School Certificate Examination (WASSCE), investigated 119 schools for engaging in mass cheating, and withheld the results of candidates from 185 schools where “examination irregularities” were suspected (Citi fm, 2015). One of the consequences of the high public profile of examinations and the need to fight malpractice is that the examining authorities, not surprisingly, prioritise the secrecy and security of examinations at the expense of activities that could harness the power of examinations to promote better teaching and learning (Kellaghan and Greaney, 2004). Two major issues associated with examinations in general, and mathematics examinations in particular, are considered below.

Examinations do not, in general, reflect the philosophy of the teaching/learning curriculum and, in some cases, are not well-matched to student ability

A number of commentators have questioned the validity of the high-stake examinations that tend to dominate the education systems of SSA (Kellaghan and Greaney, 2004). Here the term ‘validity’ goes beyond the narrow concept of ‘content validity’ on which agencies responsible for the conduct of high-stake examination tend to focus. It includes multiple aspects associated with an examination’s ‘fitness for purpose’ including the extent to which assessment instruments and procedures reflect, and hence promote, the underlying philosophy of the intended curriculum. Kellaghan and Greaney (2004) report that “there are concerns about the extent to which (examinations) are biased toward the testing of competencies needed by students in the next cycle of education” and go on to ask “Do the examinations adequately reflect the goals of the curricula for those students (a majority in most countries) who will not proceed further in the education system?” (ibid, p.9). The World Bank (2008) highlights the view that examinations neglect many of the behavioural objectives and competencies explicitly required by modern curricula. “Modern curricula in SSA formally aim at learning outcomes like comprehension, application of knowledge, methodological and social competencies, and problem solving. Current assessment and examination practices are limited to the recapitulation of memorised facts. Assessment documents in some SSA countries claim that a wide range of assessment techniques are used to assess the different knowledge, skills and attributes, however, the reality looks remarkably different” (ibid, p.57). This is particularly true of examinations in mathematics where, in the most selective of examinations, questions tend to focus on abstract, academic concepts at the margins of the syllabus with students required to reproduce the preferred ‘correct’ procedure. In some examinations it is difficult to find a single, straightforward question based on the application of mathematical concepts to a problem set in a real-world context. This is a general characteristic of mathematics examinations at the lower and upper secondary levels which, in many countries, are associated with high failure rates. For reasons described previously, detailed test and item statistics for mathematics examinations in SSA are not widely available. However, the

Certificate of Secondary Education Examination (CSEE) Tanzania offers a pertinent, if somewhat extreme example. According to National Examinations Council of Tanzania (NECTA) (2014a) "The CSEE marks the end of four years of secondary education. It is summative evaluation which among other things measures the effectiveness of the education system in general and education delivery system in particular. Essentially, candidates' responses to the examination questions is (sic) a strong indicator of what the education system was able or unable to offer to the students in their four years of secondary education" (NECTA, 2014a, p.iii). With this in mind, it is disturbing to find that the pass rate for the Basic Mathematics examination in 2013 was just 17.8% (NECTA, 2014b, p.1). To put it another way, of the 352,179 candidates who sat the examination 289,613 (82.2%) failed to meet the minimum acceptable standard. Reasons suggested by NECTA for the high failure rate include "complete lack of knowledge", "partial understanding on the topics in the syllabus" and "failure… to show clearly the workings (and) formulas" (ibid, p.iv). However, evidence from the reports of examiners suggests that the question papers are not fit for purpose. For example, it is usually considered good practice to start an examination with an accessible and relatively easy question to set candidates at their ease. However, the first question on the 2012 examination for Basic Mathematics asked candidates to evaluate the expression below to three significant figures, using mathematical tables.

$$\frac{\sqrt[3]{0.0072}\times(81.3)^2}{\sqrt{23140}}$$

Is it a great surprise to find that of the 396,678 candidates who took this examination 291,164 (73.4%) scored zero on this task? This example raises three questions: Is the content and format of this question compatible with the philosophy and objectives of the basic mathematics curriculum? Does a question which is completely impossible for three-quarters of the cohort add significantly to the information function of the test? What impact does this type of question have on the future behaviours of teachers and on the motivation of future learners? Unfortunately, the NECTA examiners' report reveals that all 16 questions on this examination had similar measurement characteristics with approximately 90% of the cohort scoring zero on each item.

Examiners' reports also suggest that markers, when assessing student responses, are looking for a particular procedure and format for the presentation of working. It is not clear whether alternative approaches would or would not gain full credit. For example, a question told candidates that a shopkeeper selling an article at shs. 22,500/= makes a loss of 10% and asked them to calculate the price which would yield a profit of 10%. The examiners' report stated that "(many candidates) did not realise that they were supposed to calculate first the buying price (x) of the article… and thereafter calculate the selling price" (NECTA, 2013, p. 20). However, it is perfectly possible to solve this question directly without going through the intermediate stage required by the marking scheme. This is relevant because it echoes general concerns with the directive, instrumentalist approaches modelled by tutors in TTIs and exhibited by mathematics teachers across SSA. This is in contrast with a constructivist approach which allows for the possibility of different students choosing different routes to mathematically valid solutions.

A telling comment on the relevance of the mathematics tested in formal examinations to the lives of students comes from a report on the Uganda Certificate of Education examination of 2009: "This (question) was testing knowledge on the laws of logarithms, ability to manipulate the mantissa and characteristic. It is unfortunate that these days students are married to the calculator and do not see why teachers bother them by teaching logarithms" (UNEB, 2009, xi).

Information from examinations is not disseminated to subject teachers and other educational practitioners

Examinations generate a huge amount of data which, if properly analysed, can provide valuable quantitative information for educational policy makers and practitioners. In particular, statistical evidence combined with the subjective opinions of subject specialists can provide teachers with information about the strengths and weaknesses demonstrated by examination candidates. Teachers can then use this information to improve their teaching and, hence, improve student performance. Unfortunately, the examining authorities of SSA, with few exceptions, make little or no use of the data they hold and do not have systematic information feedback systems. In fact, in preparing this study it was extremely difficult to find any examination-related statistics beyond aggregated results tables[57]. At the primary level, results are generally aggregated across all subjects leading to an overall pass rate. Even when a separate pass rate for mathematics was reported no conclusions could be drawn as to, for example, average test scores and/or the mathematical competencies demonstrated by those who passed. At the secondary level, examination results were more readily available for individual subjects including mathematics but these were aggregated by reporting category (e.g. Grades A, B, C, etc. or divisions 1, 2, 3 etc.). Without further information, e.g. cut-off scores and/or performance criteria, interpretation of standards of performance in mathematics is impossible.

Notwithstanding the above, a few examining agencies do produce reports for subject teachers. Typically these are written by Chief Examiners and are general in nature. Information about the level of difficulty of particular questions is also given in general terms without specific statistics. For example, the Chief Examiner's report for an O-level mathematics paper in Zimbabwe says of performance on question 1: "(a) (i) Well done. (ii) Fairly done. Wrong comma placement was common. Common wrong answers were 0,05 and 0,0005. (b) Fairly done. 85 was a common wrong answer seen."(ZIMSEC, 2009, p. 1). It is difficult to see how teachers can use such general comments for diagnosis and effective remediation. In the few cases where specific suggestions are made, these tend to be trivial. For example: "Qn. 6 was not popular. Problems noted: Candidates could not obtain the translation which moved the object to the image position (and) did not extract the image co-ordinate from the location column vector. Suggestions: Teachers countrywide did not teach vector transformations. It is therefore important that all schools be impressed upon this topic" (UNEB, 2009, xiv). This is like the coach of a soccer team instructing his or her players to 'score more goals' – obvious but unhelpful.

57. In the preparation of this study, examination boards across our six focus countries were asked to supply test-score distributions and other statistical information related to their mathematics examinations. Only in Nigeria did two boards respond positively - WAEC, Nigeria and the National Business and Technical Examinations Board - but even here raw score test distributions and grade cut-scores were not provided making any meaningful evaluation of mathematical standards impossible.

The West African Examinations Council has taken a considerable step forward by making its traditional Chief Examiners' reports for the West African Senior School Certificate Examination (WASSCE) freely available through its online e-Learning Toolkit[58]. The standard reporting format is clear and provides subject teachers and students with a copy of the examination question followed by model solutions and observations as to the typical performance of candidates. There is scope for improvement in the presentation of, for example, mathematical functions and diagrams, and the observations would be strengthened by the inclusion of quantitative indicators of difficulty. However, the approach is fundamentally sound and could serve as a model for other national examination agencies.

The Mauritius Examinations Syndicate offers another notable example of good practice in its Chief Examiner's reports. First, these are published regularly and in a timely manner. This is in stark contrast with many other national examining agencies where reports do not appear to have been published for several years[59]. Secondly, separate reports are produced for each subject making them easier for subject teachers to use than the composite reports published elsewhere. Thirdly, and most importantly, the information they contain is of a high quality and potentially more useful for teachers - as illustrated in Figure 8.1 below (MES, 2014). Note that in this example the author is making it clear to subject teachers that there is no single correct solution to this task and that the scoring process rewards any mathematically legitimate alternative. This is compatible with an approach to teaching which challenges students to explore mathematical problems rather than instruction which trains students to replicate the correct/ preferred procedure.

Figure 8.1: Chief Examiner's report on the performance of candidates for the Mauritius Certificate of Primary Education examination on a particular mathematics question

Question 46
Most candidates were able to identify the missing terms in the sequences given. Part (a)(i) was found to be the easiest sequence to work out. A few high performing candidates interpreted this sequence in a number of unexpected ways. Although their approaches were more complex, the responses which they gave were mathematically correct and they were rewarded accordingly. These candidates started bt determing the L.C.M. of the denominators before they could identify a familiar pattern. They consequently obtained the following answers:

$$\frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \_\_\_ \longrightarrow \frac{6}{12} \xrightarrow{+2} \frac{8}{12} \xrightarrow{+1} \frac{9}{12} \xrightarrow{+0} \frac{9}{12}$$

OR

$$\frac{6}{12} \xrightarrow{+2} \frac{8}{12} \xrightarrow{+1} \frac{9}{12} \xrightarrow{+2} \frac{11}{12}$$

OR

$$\frac{1}{2} \xrightarrow{+\frac{1}{6}} \frac{2}{3} \xrightarrow{+\frac{1}{12}} \frac{3}{4} \xrightarrow{+\frac{1}{18}} \frac{29}{36}$$

58. WAEC e-learning toolkit available at http://waeconline.org.ng/e-learning/index.htm (accessed 3 February 2016).
59. For example, the most recent reports available from the websites of the Uganda National Examination Board and the Zimbabwe Schools Examinations Council as of October 2015 were for the examinations of 2009

8.4 International and regional assessments

8.4.1 International large-scale assessments

As described in Chapter 3, few countries from SSA have participated in international large-scale assessments (ILSA) of student achievement in mathematics. Those that have taken part in TIMSS have, without exception, fared badly falling far below international norms even when national samples have been drawn from over-aged populations. Only Mauritius has so far chosen to participate in PISA tests designed to measure the 'mathematical literacy' of 14-year-olds. Although its results were below the international average, its students performed at levels comparable to those achieved by their peers in OECD member countries Chile and Mexico. However, one should not be misled by this outcome – SACMEQ studies show that mathematical standards in Mauritius exceed those in other SACMEQ countries by a margin which is, in statistical terms, huge. Evidence strongly suggests that any other country from the region electing to join an international large-scale assessment should expect to find itself towards the bottom of the measurement scale and, hence, international rankings for mathematics. Therefore, the question to be addressed is 'would participation in TIMSS and/or PISA yield information which would be likely to contribute significantly to raising national achievement levels – especially in mathematics?' At the same time policy makers should ask 'would the costs[60] involved in joining and conducting an ILSA yield benefits representing good value for money? Gillard, quoted in an interview (Exley, 2014), said "For some countries it might well suit [them], but for other countries that are really still piecing their education systems together, the sophistication and the level of learning that (PISA) tests are directed at is likely to be pitched far higher than anything that has been achieved in those education systems. It's really not helping anybody improve their education system if the result is that none of the children do well on the test" (ibid). In the same article, van Leeuwen suggests that "(f)unding should be targeted on the marginalised and not on ranking countries with huge out-of-school populations. Sampling can be used to inform good policy, but assessment alone is no replacement for a coherent, inclusive and high-quality education system. The cure is not more thermometers. Given the critical shortage of teachers, it certainly is more practitioners" (ibid).

Suggested advantages associated with participation in, for example, PISA include a positive influence of findings on policy reforms; capacity building in assessment and psychometrics which can be used to strengthen national assessment systems; and the possibility of accurate monitoring of standards over time. Breakspear (2012) reports that whilst PISA findings do help to shape policy decisions in some countries, those that perform below the OECD average, e.g. Turkey and Indonesia, are less likely to report a significant impact (ibid). Bloem (2013) indicates that whilst participating in PISA undoubtedly offers significant opportunities for building technical capacity, low- and middle-income countries often lack the capacity to take full advantage of these opportunities (Bloem, 2013).

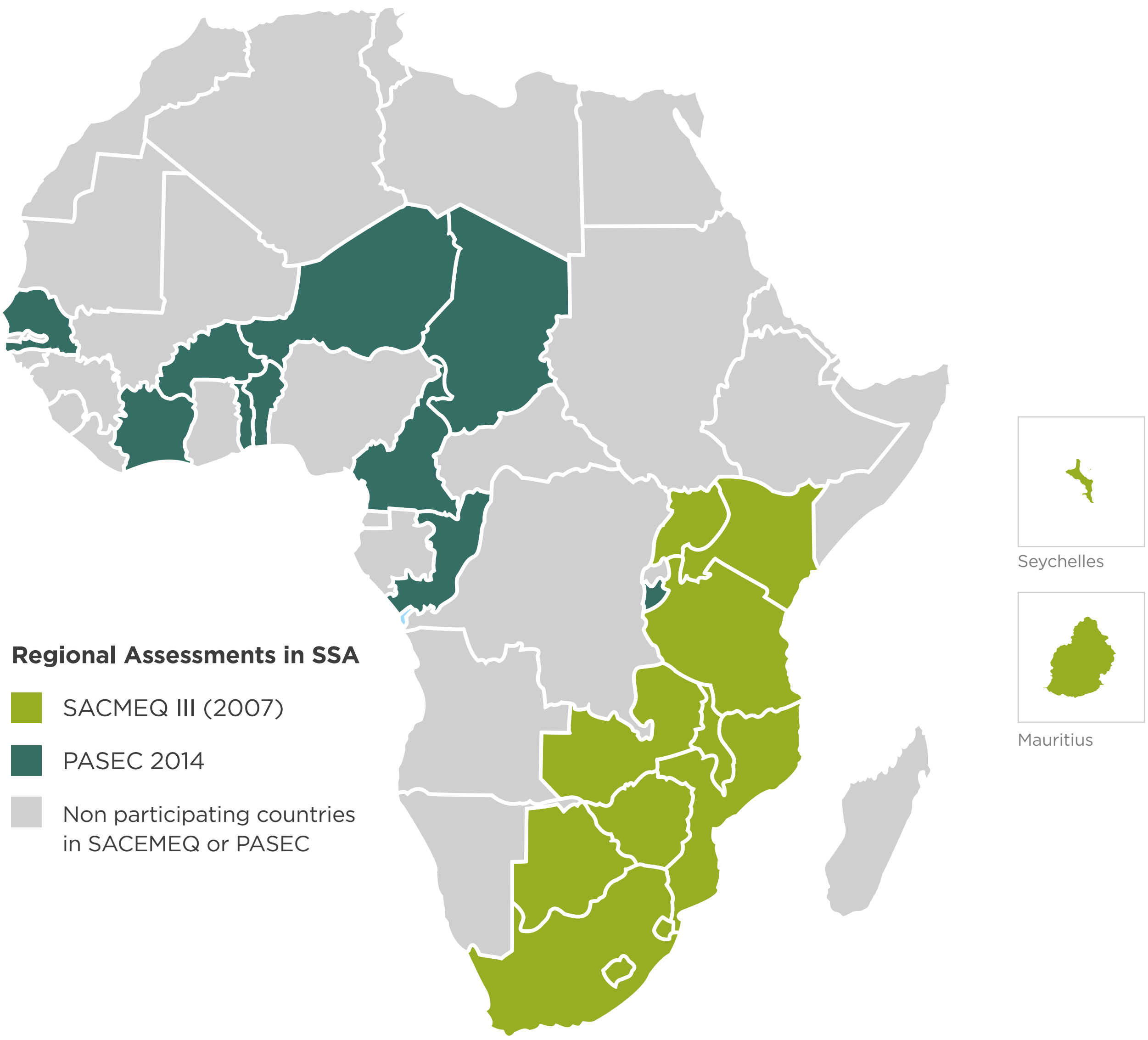
8.4.2 Regional large-scale assessments

The potential importance of SACMEQ should be clear from earlier chapters. Not only have

60. The international fee for participating in PISA 2015 was Đ45,500 per year for four years giving a total of Đ182,000 (USD-200,000). In addition, participating countries are required to pay all national costs covering, inter alia, preparation of test booklets, test administration, coding of student responses, data entry, etc.

SACMEQ surveys provided participating countries with snapshots of the achievements of their students, they have also yielded a wealth of valuable data which has allowed researchers to investigate the complex relationships that exist between learning outcomes and background factors. More recent developments, most notably the adoption of IRT-based reporting scales, are giving SACMEQ the potential to monitor changes in relative and absolute standards over time with increased precision. Parallel developments in PASEC assessments are also of great significance. For example, the release of the full PASEC database will allow researchers the opportunity to conduct high quality secondary analysis for francophone systems and to systematically link PASEC data with that of SACMEQ. If the considerable technical challenges associated with moving to measurement and analytical standards comparable with those of TIMSS and PISA can be overcome, then a SACMEQ/PASEC consortium will be in a strong position to assume the role of a pan-African assessment agency.

Figure 8.2: Coverage of the two major regional assessments of student learning: PASEC and SACMEQ



8.5 National large-scale assessments

The role of NSLA in providing information about the state of mathematics education in SSA was briefly described in Chapter 3. Here the focus is on the potential of such assessments to provide information which practitioners – especially teachers of mathematics and the developers of TLMs for mathematics – can use to improve teaching and learning. The reports of three, sample-based national assessments are critically reviewed: the Grade 3 NA of numeracy and literacy in Kenya (2010); the NA of Mathematics, English Language, and Biology at the 'Senior 2' level in Uganda (2013); and, the NA of Grade 10 and Grade 12 students in Ethiopia in Mathematics, English, Biology, Chemistry and Physics (2010).

The potential of an NLSA to provide valuable information to practitioners involved in mathematics education is perhaps best illustrated by reference to the National Assessment of Educational Progress (NAEP) of the USA. NAEP has been conducted regularly since 1969 and incorporates extremely high standards of test construction, test administration, statistical analysis of student responses, and reporting. NAEP provides policy makers, educational planners, and researchers with a great deal of general data on the outcomes of the education system and background factors. However, it also provides detailed information on student performance in each of the target subjects. For each round of NAEP, the information available to mathematics educators includes: a detailed description of the NAEP assessment framework (NCES, n.d.); a separate report on student performance on the mathematics tests; and examples of NAEP items in each mathematical sub-domain and at each reporting level of achievement (both in the report and online). Whilst it is unrealistic to expect the relatively new and less well-resourced NLSA of SSA to replicate the technical standards of NAEP, there are lessons that can be learnt and deficiencies which should be rectified.

Mathematics educators cannot use results reported as 'percentage correct scores' without access to the tests

In Uganda and Ethiopia, student achievement in the NA was reported as the proportion (%) of correct responses on the mathematics test. In Kenya, raw scores (number correct) were normalised through a linear translation to give a score on a scale with a mean of 300 and a standard deviation of 100. In both cases, the scores are test-dependent. This means that the reported results, e.g. average scores, can only be interpreted by reference to the particular tests used and the items therein. As far as we can ascertain, in none of the cases we studied were the tests used in the national assessments made available to teachers and other practitioners. What then are mathematics teachers to make of remarks such as "The mean score (for mathematics) was 44.1% with a standard error (S.E.) of 0.37" (UNEB, 2013, p.17) or worse still the baffling comment "(at) the national level, the mean score for Literacy and Numeracy was 297.58 and 295.6 respectively. Both are slightly below the standardised mean scores of 300" (KNEC, 2010, p.21)? Only in the Uganda report did we find reference to student performance on individual items but even here interpretation was difficult. For example, the report states that "fewer than 20% of the students were able to compute the initial amount of money deposited in a bank so as to earn an interest at a given rate" (UNEB, 2013, p.20). Here a mathematics teacher is likely to ask: 'Why did this particular task prove so difficult? Was there something unfamiliar about the way in which the task was presented? What were the common mistakes made by students?' Without seeing the item, the teacher is left in the dark.

In the case of high-stake examinations where new tests are set ab initio each year, question papers can be placed in the public domain allowing teachers to scrutinise the assessment tasks and adapt their teaching to better prepare future candidates. However, in national and international assessments it is common practice for test booklets to be collected after testing and then kept secret so that some items can be reused. In this case, sufficient examples of test items should be included in the report so that subject teachers can interpret the findings intelligently. An example of good practice from the 2011 NAEP report for students in Grade 4 is given in Figure 8.3. In addition to the limited number of examples included in the report, pools of 'released items' or practice tests should be provided so that the national assessment system has maximum benefit in the classroom.

Figure 8.3: Example of how information on student performance on a national assessment item can be presented to mathematics teachers and other practitioners (NCES, 2011, p.30)

Mathematics Content Area: Number Properties and Operations

Subtract: 6,090 - 4,843

Ⓐ 1,147 **Ⓑ** 1,247 Ⓒ 2,257 Ⓓ 2,853

This multiple-choice question from the 2011 mathematics assessment asks students to answer a subtraction problem involving two 4-digit numbers. The problem requires students to regroup twice to obtain the correct answer of 1,247 (Choice B). Students were not permitted to use a calculator to answer this question.

Seventy-four percent of fourth-grade students answered this questio correctly. The most common incorrect answer (Choice D), selected by 13 percent of the students, resulted from not doing any regrouping and just subtracting the smaller number from the corresponding larger number at each place value. Choices A and C, while selected less frequently, represent different regrouping errors.

Percentage of fourth-grade students in each response category: 2011

Choice A	Choice B	Choice C	Choice D	Omitted
7	74	5	13	1

The table below shows the percentage of fourth-grade students performing at each achievment level who answered this question correctly. For example, 73 percent of fourth-graders at the *Basic* level selected the correct answer choice.

Overall	Below *Basic*	*At Basic*	*At Proficient*	At Advanced
74	40	73	90	97

Where the assessment purports to set absolute standards of performance, concrete examples are required for interpretation

In addition to percentage correct scores, all three national assessments reported on the proportion of students reaching certain levels of achievement. However, the definitions of these levels were generally unclear. Where criteria-related descriptors were offered, no details were given as to the standards-setting process by which the cut-scores between levels were located.

In the case of Ethiopia, the national education and training policy specifies the minimum (acceptable) achievement level as a test score of 50%. The report confirms that only 14.7% of the cohort achieved the minimum level on this test. This tells us little since if easier test items had been selected then the proportion of successful students in this population would have been higher and vice versa. In addition to this achievement threshold, the Ethiopia report also reports on the proportion of students reaching four so-called standards: 'below basic', 'basic', 'proficient' and 'advanced'. Students with a score lower than the population mean are placed at the 'below basic' level. Students with scores less than one standard deviation above the mean are deemed to be at the 'basic' level. The thresholds for the 'proficient' and 'advanced' levels are at two and three standard deviations above the mean respectively. These are simply norm-referenced standards and tell us nothing of what mathematical competencies the students at these levels can and cannot demonstrate.

The Grade 3 assessment in Kenya does describe four levels of mathematical achievement as shown in Table 8.1 (KNEC, 2010, p.25). It then reports the proportion of the cohort at each level. Unfortunately the report gives no details as to how student test scores were linked to the levels' descriptors.

Table 8.1: Descriptors for the four levels of mathematical competence used for reporting purposes in the Kenyan national assessment for mathematics in Grade 3

Level	Description of Competency	% of pupils
Level 1	Applies single step addition or subtraction operations (e.g. add numbers without carrying over, subtract without borrowing). Counts in whole numbers.	4.6
Level 2	Applies a two-step addition or subtraction operation involving carrying over and borrowing. Applies simple multiplication operations involving multiples of 10. Recognises simple fractions.	43.7
Level 3	Translates information presented in a sentence into one arithmetic operation. Interprets place value of whole numbers up to thousands. Interprets simple common everyday units of measurement such as days, weeks, litres, metres and shillings.	48.1
Level 4	Translates information presented in sentences into simple arithmetic operations. Uses multiple arithmetic operations (in the correct order) on whole numbers.	3.6

In Uganda, three proficiency levels are defined: 'basic', 'adequate' and 'advanced' described in terms of what students can and cannot do. However, as in the Kenyan case, there is no description of the process by which test score thresholds are set for these levels. In both cases the assessment reports fail to provide mathematics teachers with items which exemplify what students at each level can do.

This would be a first step towards providing teachers with a more comprehensive 'item map' linking mathematical tasks with student ability. Examples of such item maps can be found in the mathematics reports of TIMSS and PISA. Figure 8.4 shows the item map for Grade 4 mathematics constructed using data from the 2011 NAEP in the USA.

Figure 8.4: Exemplar item map linking three levels of positive achievement (Basic, Proficient and Advanced) with the IRT-based scaled scores and selected items from the NAEP assessment for Grade 4 Mathematics 2011 (NCES, 2011, p.29)

Grade 4 NAEP Mathematics Item Map

Level	Scale Score	Content Area	Question Description
	500		
	//		
ADVANCED	330	**Number properties and operations**	Compose numbers using value to determine winners of a game
ADVANCED	317	**Geometry**	Divide a square into variuos shapes
ADVANCED	293	**Measurement**	Solve a story problem involving time (calculator available) (shown on pages 32 & 33)
ADVANCED	291	**Algebra**	Identify the growth relationship from a table (calculator available)
ADVANCED	290	**Data analysis, statistics and probability**	Compare two sets of data using graphs
	282		
PROFICIENT	279	**Algebra**	Recognise and extend a growing pattern
PROFICIENT	278	**Number properties and operations**	Order fractions with unlike denominatiors
PROFICIENT	276	**Measurement**	Draw a line segment of a given length
PROFICIENT	275	**Number properties and operations**	Use place value to determine the total amount
PROFICIENT	269	**Geometry**	Compare simple figures to identify a common property (shown on page 31)
PROFICIENT	261	**Number properties and operations**	Identify and use factors to solve a problem in context (calculator available)
PROFICIENT	259	**Number properties and operations**	Use place value to find a sum
PROFICIENT	254	**Data analysis, statistics and probability**	Creata a pictograph of a set of data (calculator available)
PROFICIENT	250	**Measurement**	Find areas of a scale drawing on a grid
	249		
BASIC	243	**Algebra**	Label sections on a grid from a list of coordinates
BASIC	240	**Number properties and operations**	Determine the sum of numbers represented on a number line (calculator available)
BASIC	239	**Number properties and operations**	Explain a property of divisibility
BASIC	232	**Number properties and operations**	Compute the difference of two 4-digit numbers (shown on page 30)
BASIC	230	**Number properties and operations**	Solve a story problem involving division (calculator available)
BASIC	226	**Data analysis, statistics and probability**	Identify the most likely outcome from a given spinner (calculator available)
BASIC	221	**Geometry**	Describe a real-world object in terms of a geometric solid
BASIC	216	**Measurement**	Identify measurements needed to determine area
	214		
	211	**Number properties and operations**	Compute the difference of fractions with like denominators
	195	**Algebra**	Determine numerical value of an unkown quantity in a whole number sentence
	180	**Geometry**	Identify a figure that is not symmetric (calculator available)
	175	**Measurement**	Identify the appropriate measuring device for a given attribute
	//		
	0		

8.6 Summary

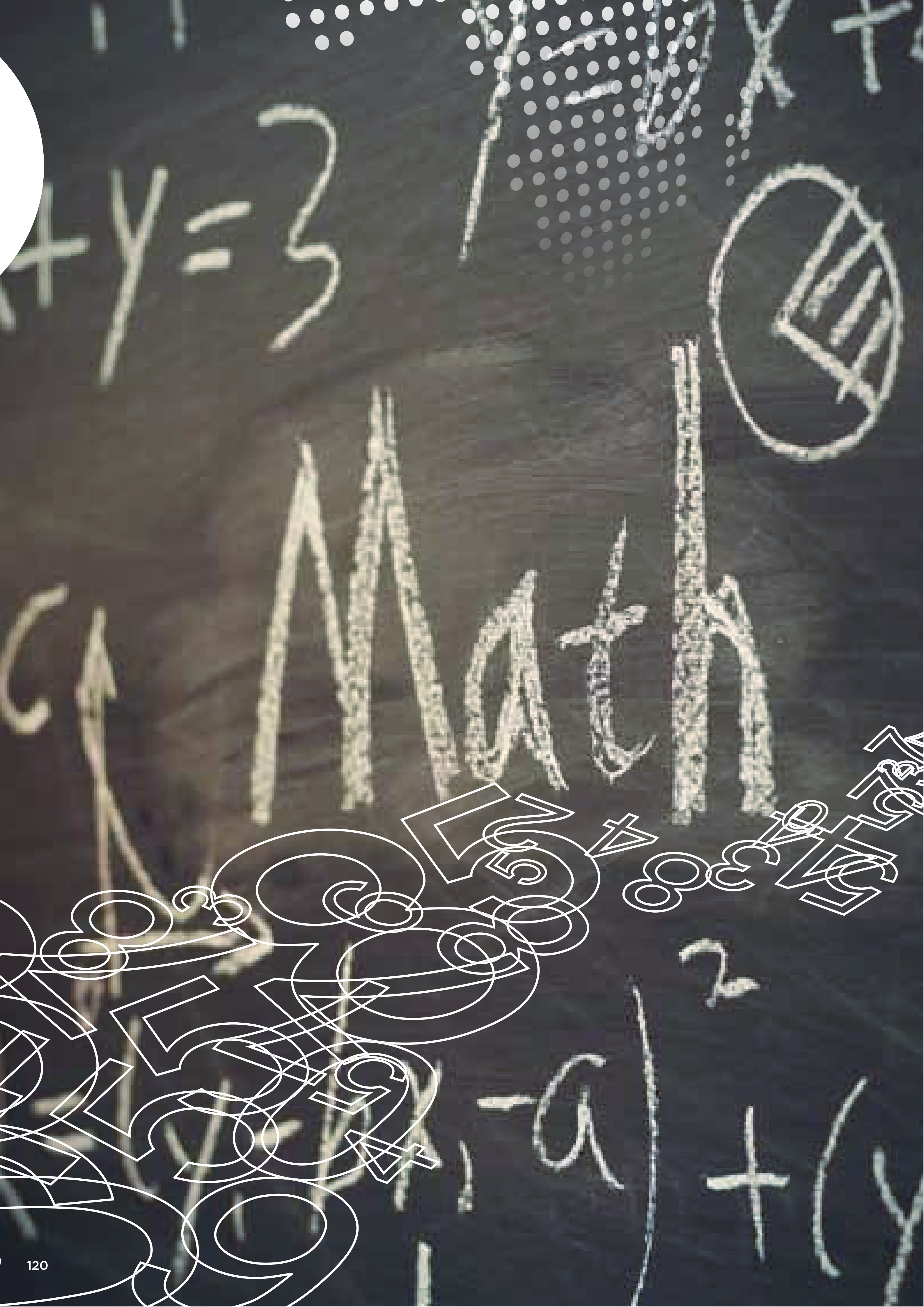
Good assessment has a positive effect on teaching and learning. However, in SSA the potential benefits of assessment are not being exploited. Moreover, some aspects of the high-stake examinations used in the region serve as a significant barrier to progress. High-stake examinations need to be reformed so that, over time, their content better reflects the curriculum's central learning objectives and its underlying philosophy. There is also an urgent need to ensure that the demands of the examinations are more closely aligned with the ability levels of candidates. In the short-term, the agencies responsible for examinations in mathematics should make assessment-related data and other information freely available for subject teachers and other practitioners.

Effective assessment in the classroom is an effective way of raising levels of achievement. However, changing teachers' attitudes towards formative assessment and, hence, reforming assessment practices in the classrooms of SSA, is likely to prove difficult. Teachers of mathematics will need effective training and a lot of support – especially through the provision of high-quality, user-friendly assessment materials.

Participation in international assessments such as TIMSS and PISA can provide a country with high-quality information about the status of mathematics education both in absolute and relative terms. However, for countries which are relatively poor and where student performance is known to be very low it is not clear that the potential benefits outweigh the costs.

National assessments of numeracy and mathematics have the potential to provide information which practitioners, especially mathematics teachers, can use to understand what students across the ability range can and cannot do. Providing statistical data is not enough since without concrete examples, teachers cannot interpret the numbers intelligently and, hence, improve their teaching strategies. Teachers need access to the national assessment tests or, if this is not possible, a sizeable pool of exemplar items.

From a strategic point of view, improving assessment practices appears to offer a cost-effective way of raising outcomes in mathematics. Some of the changes advocated above with regards to examinations and national assessments can be implemented in the short-term without incurring major costs. However, the vitally important task of introducing diagnostic and formative assessment practices in classrooms is likely to prove a major challenge and will require greater effort sustained over the long-term.


Math

9 Initiatives and innovations

9.1 Introduction

The scale and scope of the challenges facing mathematics educators in SSA described in this study are generally well recognised, as is the urgent need to address them. Throughout the region there are many examples of initiatives designed to improve the quality of teaching and learning in mathematics. Partners in these include governments, international aid agencies, NGOs and philanthropic groups, and even some commercial enterprises. A number of recent government-led initiatives are being implemented at the national level. However, many more potentially interesting innovations are being tried on a small scale. Of these, some report large, positive effect sizes but these should be treated with some caution. Evaluations are not always fully independent of the implementing agency and analytical/statistical techniques may not meet recognised technical standards. More importantly, innovations that are effective on a small scale may not be feasible at full scale or sustainable in the long-term once external funding sources have been removed. Notwithstanding this caveat, examples of current and/or recent initiatives are given in this chapter simply to illustrate some of the approaches currently being explored. The inclusion of a particular example here should not be taken as an endorsement of that approach. Indeed, most of these initiatives have not yet been rigorously evaluated as to their impact on student learning, their cost-effectiveness, or their long-term sustainability.

The challenges that mathematics educators in SSA face are not confined to the region or just to developing countries in general. Many highly developed countries are concerned that if they do not improve their own levels of achievement in mathematics and the other STEM subjects, then they will fall further behind the dynamic economies of East Asia. As a result, they have launched major initiatives to address two problems that they share with countries in SSA: levels of mathematical achievement across the education system that lag behind those of their international competitors, and a general lack of interest amongst students (especially girls) in pursuing further studies in STEM subjects at higher levels. Here we include several examples of initiatives in mathematics education from developed countries. These, however, should be interpreted with regard to the context of SSA. Initiatives that appear to yield positive outcomes in highly-developed countries may depend on the pre-existence of good resources and, most importantly, a well-educated, well-trained and relatively well-paid teaching force – conditions which are not generally met in SSA.

9.2 Early years and primary grades

Pre-primary education

Early Childhood Care and Education (ECCE) was the first Education For All goal and its fundamental importance is confirmed by the UN's 2030 Agenda for Sustainable Development (UN, 2015b) where the commitment is made to "ensure that (by 2030) all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education" (UN, 2015b, p.17). There is a wealth of evidence showing that children who have attended pre-school demonstrate higher levels of achievement throughout their time in school. Bailey (2014) reiterates that measures of early mathematics skills are "the strongest early predictors of children's Maths achievement years later" (Bailey, 2014). Results from OECD PISA confirm that the advantages enjoyed by students who have attended a pre-school are still[61] statistically significant when their mathematical skills are measured at the age of 15 (OECD, 2014).

Pre-primary enrolment in SSA has increased over the past 15 years but still remains relatively low, e.g. 19.5% in SSA compared with 74% in Latin America and the Caribbean (Shaeffer, 2015). Ghana represents a notable exception having effectively introduced universal pre-primary education by extending compulsory basic education to include kindergarten classes. Details as to how this was achieved and of the resulting challenges are to be found in Shaeffer (2015).

Save the Children, Emergent Literacy and Maths (ELM) programme

One initiative which includes specific measures related to early years' numeracy skills is the Emergent Literacy and Maths (ELM) programme being implemented by Save the Children (SC) in Bangladesh, Ethiopia and Rwanda[62]. The programme "raises awareness of (emergent literacy and maths) skills and how they develop through play and joyful learning, trains early childhood care and development (ECCD) teachers on how best to support them and mobilises communities to promote these skills at school and at home in order to ensure school readiness" (SC, 2012, p.1). The evaluation report for Bangladesh suggests that the programme's multi-faceted approach (including health and nutrition) produced significant gains in the general readiness of children to attend school. In particular, by exposing children to early mathematics concepts such as shapes and numbers, their readiness to start mathematics in schools was significantly enhanced (SC, 2012).

In Ethiopia, the programme focused on the use of an ELM 'toolkit' with facilitators of early childhood care and development (ECCD) centres being trained on the use of programme materials and play-based techniques. Early mathematics concepts included: number and quality identification; counting; concepts of time, direction, space and shapes. Skills included: sorting; looking for patterns; and, problem solving. Children[63] were tested before and after the intervention using a 68-item test.

Table 9.1: Findings of an evaluation of the impact of ECCD interventions in Ethiopia based on test scores pre- and post-intervention (Save the Children, 2014)

Group	Test score (%) before	Test score (%) after	Gain
Control (no exposure to ECCD)	20.5%	22.4%	1.9%
Group 1 (exposure to ECCD but without use of ELM materials, etc.)	29.3%	43.2%	13.9%
Group 2 (exposure to ECCD with use of ELM materials, etc.)	27.8%	76.9%	49.1%

61. Bailey (2014) points out that the positive effect on mathematical achievement associated with having attended pre-school diminishes over time and that other factors may be larger than pre-school attendance in causing improved achievement in mathematics.
62. Save the Children has plans to roll out its ELM toolkits in Nepal, Indonesia, Afghanistan, Bangladesh, Pakistan, China (Borisova, n.d.).
63. Exact sample sizes are not given but the evaluation report suggests that the target was 120 in the control group and about 180 in each of the treatment groups.

The results are shown in Table 9.1 (SC, 2014). Save the Children reports that it is to support the use of its ELM materials in other countries whilst also piloting a new “parent outreach component to the toolkit focused on building parental capacity to support ELM skills at home” (SC, 2014, p.2).

Primary education

In order for a country to enjoy high standards in mathematics at the secondary and tertiary levels, firm foundations must be laid in the early years of education. As a result, many initiatives for improving outcomes focus on the primary phase of education. Some are specifically targeted at young learners in developing countries but others have been designed to address the concerns of advanced economies where there is a perceived learning deficit. Here we include one example from SSA and one from the UK.

Primary Maths and Reading (PRIMR) Initiative, Kenya

The Primary Maths and Reading (PRIMR) Initiative 2011-2014 was led by the Kenyan Ministry of Education, Science and Technology and was funded by USAID/Kenya. It was implemented by RTI, International. The programme partners developed new TLM based on the school curriculum and developed the professional capacities of school principals and teachers. In particular, teachers were trained in the use of interactive teaching methods and, thereafter, supported through the periodic visits of ‘instructional coaches’ trained under the programme.

The PRIMR evaluation found that the impact on children’s reading skills, as measured by EGRA tests, was positive and highly significant with an effect size for reading fluency of 0.73 (USAID/Kenya, 2014). According to the authors of the evaluation report “this equates to more than 1 year of gain for pupils in control schools” (ibid, p.xii). However, the impact on the children’s numeracy skills, as measured by EGMA tests, was far less impressive. A moderate gain was detected for number identification and missing number tasks but there was no discernible impact on, for example, the more difficult topic of quantity discrimination. Students in the treatment group did, however, demonstrate significantly greater fluency (i.e. number correct per minute) in addition and subtraction tasks. The PRIMR evaluation report offers no clear explanation as to why numeracy skills were apparently less susceptible to improvement than reading skills.

Some of the key lessons identified by the evaluation team are given below (USAID/Kenya, 2014, pp.73-74):

- “(Teachers’ Advisory Centre) Tutors’ visits to schools were critical for supporting teachers and improving pupil’s outcomes. Proper training of TAC Tutors is essential so that they can effectively support teachers. The results also indicated that schools visited frequently were likely to have stronger pupil performance.”
- “Training of teachers is a complex task that must assume teachers are adult learners who learn best by doing and interacting with other professionals. This implies that teacher training should be organised around modelling and practice, and that having brief training sessions with follow-up refresher meetings is more effective than longer training courses.”

- "Evidence suggested that most of the teachers supported by PRIMR had not attended professional development courses or in-service courses for several years since leaving college or becoming teachers. The PRIMR Initiative's regular professional development through training and other activities filled a demand for increased instructional practice and support."

- "Changes in instructional approaches: Old habits take time to change, and the shift from traditional teaching to more active, sequenced, pupil-focused approaches was the central focus of PRIMR. Some teachers continued to use two approaches concurrently at the beginning of PRIMR, in part because of concern about whether the lessons properly covered the material that would appear in the national end-of-year examinations. Advocacy was needed to change the mind-set of some teachers."

Numbers Count, UK

One of the main aims of the UK government's Every Child Counts initiative of 2007 was to develop an early intervention programme for learners in the first two years of schooling who fail to master the basics of numeracy (Torgerson et al., 2011). The programme which emerged was known as Numbers Count (NC). NC was a 12-week programme in which children in the target population (i.e. low achievers in the bottom 10% of the ability range) spent 30 minutes of each day with a trained NC teacher in addition to the normal mathematics lessons of their school's curriculum. These sessions were given on a one-to-one basis. Before starting work, NC teachers were given training on the teaching methods to be used, on identifying specific learning difficulties through diagnostic assessment, and planning effective lessons and activities. Thereafter, NC teachers were given on-going support through a professional development programme and a quality assurance system (ibid). The main aim of NC specialist teachers was to "use shape, space and measures, and handling data as contexts for the development and application of children's number skills" in order "to give children confidence in number and an understanding of patterns and relationships so that they (could) extend learning to other aspects of Mathematics in their class lessons" (ibid, p.3). The NC programme was piloted in 65 schools across the country and subjected to a comprehensive, independent evaluation based on a randomised controlled trial. The evaluation found that students in the group subjected to the NC programme did gain significantly higher test scores than those in the control group with an effect size of 0.33. According to Torgerson et al. (2011) this is equivalent to seven additional weeks of learning (resulting from a 12-week intervention). However, the costs involved in implementing the programme were great. The reported cost for each child in the programme was GBP 1,353 (equivalent to ~USD 2030) and the cost for each week of numeracy learning gained was £193 (~USD 290) per child (ibid, p.78). This led the evaluation team to conclude that "the costs of the delivering the programme... are relatively high compared to other Mathematics interventions" and that "the relative cost may preclude it as a realistic option for many schools" (ibid, p.112).

9.3 Upper secondary grades and the secondary/tertiary interface

Borovik (2014) argues that modern, technology-based economies lead to an hourglass-shaped demand for mathematics education with the vast majority only needing the skills associated with mathematical literacy and a smaller group requiring a deep understanding of mathematics at a far higher level. The consequences of this are recognised and explored in the International Mathematical Union's 2014 report on the state of Mathematics education in Africa (IMU, 2014a). Much of the report focuses on the challenges facing mathematics educators in universities. However, it also points out that secondary schools play a vital role in preparing students for further studies and that across SSA this part of the education system is not working well. It suggests that most countries do not have enough specialist mathematics teachers qualified at the graduate and post-graduate levels to properly prepare potential university candidates. It also suggests that the pressure generated by rapid expansion at the primary level and now reaching the secondary level is exacerbating this problem and that, in some cases, the shortage of mathematics teachers has been "eliminated artificially by a process of 'inferior substitution': that is, surplus teachers (in other subjects) and temporary teachers are assigned to teach Mathematics, even though they are not qualified to do so" (IMU, 2014a, p.3). Initiatives related to the training of teachers are discussed in the section which follows.

The IMU report also identifies the lack of systems for identifying and tracking mathematically gifted students as a problem. It acknowledges that implementing such systems would not solve the deep rooted problems of mathematics education in SSA but it might "make a small but concrete contribution to mathematical development of African countries" (ibid, p.3). In preparing this study we looked for evidence of significant initiatives designed to find gifted and talented students of mathematics at the secondary level but could find none. This reflects the conclusions of the IMU which also suggests that there are "few or no career development opportunities for these students" (ibid, p.6). Humble (2015), based on research carried out in Tanzania, suggests that teachers are not good at identifying gifted pupils because they use criteria based on, for example, performance in class, performance in examinations, and even helpful behaviour. They do not look for, or recognise, one of the key characteristics of the truly gifted child – creativity. Humble concludes that "talented creative children can be found living in the slums of sub-Saharan Africa. This research implies that there is a waste of human capital in Africa as typically governments and education officials believe that such children, who are first generation learners with illiterate parents, are not capable of greatness. Also too few development experts believe that part of the solution to poverty can come from the poor themselves. Yet in Dar Es Salaam we found 'Slum Super Stars' waiting to be discovered, their contribution to economic growth of their country wasted as no one believes they exist. All they need is a chance – opportunity" (Humble, 2015, p.1).

Notwithstanding the above, there is evidence as to the positive impact of competitive Olympiads on student attitudes towards mathematics at the highest levels.

Mathematical Olympiads in the Latin America and Caribbean region

The IMU (2014b) suggests that Mathematical Olympiads have proved effective in both identifying highly-talented students and promoting the status of mathematics as a subject. At the highest level, several countries in the Latin American and Caribbean (LAC) region have competed for many years in the International Mathematical Olympiad (IMO). These include: Cuba (since 1971); Colombia (since 1981); Mexico (since 1987); Uruguay (since 1997); and Venezuela (since 1997). The involvement of countries from SSA in IMO has been more recent but in 2014, nine[64] countries from the region took part (IMO, 2015). Olympians from Mexico and Brazil have been particularly successful in recent years with all six members of their teams winning medals in 2015. (Mexico with three bronze, two silver and a much-coveted gold and Brazil with three silver and three bronze.) African teams[65] have not yet reached these levels of success but increased participation and a growing number of 'Honourable Mentions' bode well for the future.

The participation of LAC countries in the IMO has prompted the formation of a number of regional and national competitions. The pyramidal selection process for these ensures that the impact of the competitions is far reaching. For example, the National Mathematical Olympiad of Brazil involves up to 18 million young people (IMU, 2014b). The message that this sends out is that everyone can 'do' mathematics – even if only a few are brilliant enough to win medals.

9.4 Teacher training and support

The serious weakness of initial teacher training programmes and in-service support services for teachers in general and mathematics teachers in particular has long been recognised. A number of initiatives have been developed to address these challenges – some of which are described here. It should be noted that little, if any, objectively verifiable evidence as to the effectiveness of these initiatives in terms of raising the mathematical achievement of students is available. They are included in this study to serve as examples of what is being tried.

1+4 Teacher Development Plan for Mathematics, South Africa

In response to poor student achievement in Mathematics, Science and Technology, the Department of Basic Education in South Africa announced in 2014 that the professional development of mathematics teachers will follow a '1+4 model' (South Africa, 2015). Under this model, one day is used to prepare teachers in delivering the curriculum content to be delivered to senior classes in the remaining four days of the school week. On the training day, the teachers meet in a local school where a designated Lead Teacher presents the content and recommended teaching strategies for the following four days. The training day is highly structured and teachers are to be tested to ensure that they have mastery of the content. Teachers who fail to demonstrate mastery will be identified and supported during the week by a 'support team'.

According to the Minister of Basic Education, this radical approach "translates into a whopping 23 days in a year dedicated to intensive training and discussion on mathematics content and methodology" (ibid). This replaces the previous provision for professional development which amounted to approximately 10 days per year. The 1+4 development model, which was trialled in three[66] of South Africa's nine provinces, has significant implications for the organisation of school timetables. For example, school management teams have to try to arrange teaching programmes so that no senior

64. Benin, Burkina Faso, Gambia, Ghana, Nigeria, Uganda, South Africa, Tanzania, and Zimbabwe.
65. To date, South Africa has won 49 medals and the same number of Honourable Mentions from 24 Olympiads.
66. Mpumalanga, North West and Eastern Cape.

mathematics classes are scheduled for the designated training day – a major constraint for those responsible for drawing up the timetable. However, this model exhibits three of the key characteristics associated with effective in-service training: training sessions are frequent and sustained over time; training forms part of a formal CPD programme; and, peer-to-peer support is a prominent feature.

Intensive In-service Training for Teachers, Democratic Republic of the Congo

The 1+4 Development Plan for Mathematics described above is ambitious, demanding and expensive. It has required, inter alia, the radical restructuring of school timetables, the training of Lead Teachers, and the coordination of regular and frequent teacher development meetings across the country. The scheme is also associated with significant direct and indirect costs. This sophisticated approach may be sustainable in a resilient country like South Africa, but it would be far harder to replicate and maintain in a fragile state like DRC. In DRC, alternative approaches are being implemented with the support of international donors and development banks. A major initiative is the on-going Quality and Relevance of Secondary and Tertiary Education Project, supported by a grant and credit from the International Development Association. This has as one of its aims “to improve the teaching and learning of mathematics and science in general secondary education” (World Bank, 2015, p.8). One component of the project will provide an intensive, six-week training programme for secondary school teachers of mathematics and science. The programme, with newly developed content and materials, will be delivered in and by the Higher Teacher Training Institutes (Institut Supérieur Pédagogique) during the summer recess. This approach has the benefit of focusing efforts on building capacity in a limited number of key institutions. It also ensures that teachers who participate in the one-off training programme receive full exposure. An extended programme involving a series of one- or two-day meetings over a long period would be unlikely to have the same impact and, in a fragile environment, there would be a significant risk of teacher drop-out.

African Institute for Mathematical Sciences School Enrichment Centre, South Africa

“The African Institute for Mathematical Sciences School Enrichment Center (AIMSSEC) has been operating in South Africa since 2004. AIMSSEC is a schools Mathematics enrichment programme offering free learning resources for learners of all ages from 5 to 18+ years together with professional development courses for teachers. AIMSSEC operates a variety of educational programmes for teachers, including:

- Advanced Certificate in Education (ACE) course - an innovative two-year professional development programme involving both residential and distance learning components. The programme uses the internet, interactive TV and cell phone technologies to link teachers in rural areas of South Africa.

- Mathematical Thinking, Problem Solving and Technology in teaching and learning Mathematics - a 10-day residential programme followed by a 3-month distance learning programme” (AIMS, n.d.)

Teacher Education in Sub-Saharan Africa (TESSA) initiative

The Open University, UK working in close collaboration with international partners and supported by funding from philanthropic organisations[67] hosts The Teacher Education in Sub-Saharan Africa (TESSA) initiative. TESSA operates through a network of teacher educators and teachers working to improve the quality of classroom practice across SSA. Its focus is on supporting school-based teacher education through providing unrestricted access, through the internet, to a large bank of Open Educational Resources (OER) including: general teaching resources; subject-specific resources including teaching packs; audio clips; and, handbooks for teachers and teacher educators. The materials, prepared and/or adapted by African authors, are designed to enhance the training of teachers both pre-service and in-service. They are currently available in four languages - English, French, Kiswahili (Tanzania) and Arabic (Sudan)[68]. Some 'pan-Africa' materials are widely applicable whilst others have been modified to match local curricula and contexts. The latter are available through country-specific pages of the TESSA website.

Where possible the OER promote active learning and constructivist approaches to teaching mathematical concepts. Wolfenden et al. (2010) report that within two years of their completion at least some TESSA OER had been formally incorporated into 19 teacher education programmes from the certificate level to B.Ed. level across nine partner countries. They also report that the initiative has a very high degree of visibility amongst teacher educators and, increasingly, teachers. One of the key strengths of the TESSA approach is the flexibility offered by using OER which can be used as they are or modified to meet specific needs and/or country-specific contexts. Ministries of education, Higher Education Institutions, and TTIs can, if they wish, join the TESSA network for support or they can simply 'plunder' the available resources to build or enhance their own teacher training modules. For example, the Mauritius Institute of Education has used OER as the basis of a 'Creative Pedagogy' module and the Ministry of Education in Togo has adapted TESSA's freely available materials to meet local needs. Further examples of the use of TESSA OER are given in Wolfenden et al. (2010). It is reported that the use of TESSA materials results in "a much more diverse set of teaching practices" and "increased teacher preparation" (ibid, p.4). No formal evaluation of the impact on student achievement has, as yet, been conducted.

UNESCO/Nokia Teacher Support through Mobile Technology, Senegal

UNESCO and Nokia have implemented initiatives to build the capacity of primary teachers in Mexico, Nigeria, Pakistan, and Senegal through the use of mobile technologies. In Senegal, the initiative (launched in 2012) focuses on student learning in Mathematics and Science. In particular, the Nokia Mobile Mathematics application (MoMath) has been adapted to match the national curriculum. This allows students "to master mathematical concepts in a dynamic digital environment that can be accessed from any internet-enabled mobile phone" (UNESCO, 2013). Students can therefore practise problems at home or at school at any time. The system also stores information about the progress of students on remote servers making this immediately available to teachers. UNESCO and Nokia worked with local partners

67. To date, TESSA has been largely funded by the Allan and Nesta Ferguson Charitable Trust, and the William and Flora Hewlett Foundation.
68. Materials are available at: http://www.tessafrica.net/.

RESAFAD (Réseau Africain de Formation à Distance - Sénégal) and CRFPE (Centre Régionale de Formation de Personnels de l'Education de Dakar) to train 100 teachers from 50 schools "on using the application to gain deeper insights into the learning needs of their students and constructively respond to these needs" (ibid).

A pilot exercise yielded anecdotal evidence that training in the use of mobile technologies made teachers feel that their content knowledge had improved as a result. However, this finding was not tested empirically (Atchoarena, 2014). In addition, no evidence as to the impact of the intervention on student achievement in mathematics was gathered because "the project didn't target students directly and its duration was too short for teachers to use the improved knowledge for their students" (ibid, p.23).

9.5 Using technology to enhance student learning in mathematics

There is enormous and growing interest in the use of technologies to address the serious learning deficiencies observed in low- and middle-income countries (LMIC). The general situation is well described by the following. "Educational technology programs around the world — and especially in low- and middle-income countries — are taking advantage of rapid increases in internet and mobile connectivity to bolster students' access to and quality of education. As of 2014, more than 30% of households in LMIC had internet access, compared to less than 10% in 2005. Moreover, in 2014, there were about 90 mobile phone subscriptions for every 100 inhabitants in the developing world, as opposed to 23 just 10 years prior. Many educational technology programs utilise this growing prevalence of technology to reach greater audiences; some take advantage of the speed of technology to make learning and teaching faster, easier, and more efficient; and others connect students, teachers, and educators to those not only in their communities but also around the world so they have access to more materials and resources than ever before" (CEI, 2015a). Nowhere is the search for technological solutions more extensive or urgent than in SSA. Of the 130 educational technology projects recorded on the Centre for Education Innovations (CEI) database, more than half target students in SSA (ibid). Whilst national governments are key partners in many of these initiatives most are funded and/or implemented by NGOs often in collaboration with commercial, i.e. for-profit, organisations.

Some technology-based initiatives claim impressive results but caution is required when interpreting these. First, the large gains observed in the short-term may not persist. For example, Banerjee et al. (2007) report that in India a computer-assisted mathematics learning programme increased student test scores by 0.47 standard deviations. However, after one year they found that whilst gains remained significant for targeted children, "they (had) faded to about 0.10 standard deviation" (ibid, p.1). Secondly, the large gains detected in small scale pilots may not be duplicated at scale. For example, the resistance of teachers to adopt new practices may be overcome in small groups where sufficient support is available but this may not be possible when all teachers – including those with little experience of using new technologies - have to be persuaded to engage with the programme and to be trained.

A few examples of initiatives designed to raise the mathematical achievement of learners are described below.

'Academy in a Box', Kenya

Bridge International Academies, an international education innovation for-profit company, targets its services at poor communities most noticeably in Kenya and Uganda. It supports a chain of private, low-cost nursery and primary schools where it tries to maximise efficiency and effectiveness through the use of modern technologies. One initiative is its 'Academy in a Box' model, the essential elements of which are described below.

"The curriculum itself is standardised and transformed into scripted lesson plans, which include step-by-step instructions detailing what teachers should do and say during any given moment of a class. Teacher scripts are delivered through data-enabled tablets, synced to headquarters, enabling Bridge to monitor lesson pacing, record attendance, track assessment scores, and update or add lesson scripts in real time. … Teachers come from the local communities and receive thorough training in delivering the Bridge curriculum. In this way, Bridge seeks to contribute to the local community by driving job creation. Bridge's curriculum is based on government standards, with a greater emphasis on basic literacy, numeracy, and critical thinking skills in the early grades" (CEI, 2015b). Whilst an evaluation of student achievement in Bridge schools is available (Bridge, 2013), the impact of the 'Academy in a Box' element is not estimated separately.

'Digital School in a Box', Uganda

"UNICEF is setting up 60 'Digital Schools in a Box' to reach the most marginalised groups (in Uganda). These digital schools, serving 100 to 200 children each, are set up in schools and health centres in rural communities where children spend most of their time so that they have access to quality educational content 24/7 and are more prone to learning in a collaborative manner. Each digital school is built around a solar-powered laptop with Internet connectivity, a projector, a speaker and a document camera" (UNICEF, 2013). The impact of this initiative is, as yet, unclear.

Text2Teach, Philippines and Elimu kwa Teknolojia, Kenya[69]

The Text2Teach programme emanates from the BridgeIT Project initiated by commercial partners Nokia and Pearson. It was first piloted in the Philippines in 2003 and has since been modified and expanded. The programme allows teachers to download web-based TLM to their mobile phones using the Microsoft Education Delivery (MED) platform[70]. These generally take the form of short instructional videos and teacher guides on mathematics, science, and English Language for Grade 5 and Grade 6 students. Additional materials on 'Values' are currently being added (Text2Teach, n.d.). Text2Teach videos can be used with the whole class by connecting the mobile phone to a projector television. By 2014, Text2Teach had reached 1,433 schools in the Philippines and had trained more than 7,000 teachers in the use of the technology. An external evaluation of the impact of Text2Teach on student achievement found that it "leads to significantly higher learning gains in English, Maths and Science at both grade levels. The gains are very impressive for English and Science but less so in Maths although still highly significant" (Natividad, 2007). From 2015, the Department of Education will lead

69. Both Text2Teach and Elimu kwa Teknolojia emanate from the BridgeIT project from Nokia and Pearson. BridgeIT also operates in Bangladesh, Chile, Colombia, Haiti, India, Indonesia, Vietnam, and in SSA, Nigeria and South Africa.
70. Formerly the Nokia Education Delivery platform.

the rollout of the Text2Teach programme to all 22,000 of the nation's public elementary schools (Text2Teach, n.d.). Its main commercial partners in this will be Microsoft, the Pearson Foundation and the mobile network provider Globe Telecom (ibid).

Since its introduction to the Philippines in 2003, the BridgeIT programme has been introduced in a number of many low-income countries including Tanzania where it is known as Elimu kwa Teknolojia (Education through Technology). The subjects covered include Mathematics, Science and Life Skills. Where existing content was appropriate it was translated into Kiswahili. Additional content was generated to match the national curriculum. An evaluation of the programme's impact on student test scores in mathematics found that those in classes where the technology had been used had made significantly more progress than their peers in the control group (Enge, 2011). The reported differences in mathematics scores for the two groups were relatively modest but nevertheless significant with score improvements ranging from about 8 to 17 percentage points for the two age cohorts (ibid). Similar gains were also detected when the programme was evaluated in Kenya (Bridge, 2013).

Descriptions of other mobile-based applications designed to support learning in Mathematics, including MoMaths, Dr Maths and Maths4Mobile[71], can be found in Strigel and Pouezevara (2012).

Tablet-based mathematics learning, Malawi

Selected schools in Malawi piloted a tablet-based mathematics learning scheme targeted at young learners with little or no previous experience in the subject. The content was based on the national primary curriculum and presented in the official language, Chichewa. Teachers were trained in the use of the hardware and software[72]. Children used the tablets on an individual basis. This meant that groups of up to 25 children were taken from their normal, large classes to work in a dedicated room or 'learning centre'. Each child was given the opportunity to work with a tablet for 30 minutes per day. The software presented the child with a well-defined mathematical concept. They were then given a chance to show what they had learnt through a non-threatening 'test'. If the child was successful on all of the test items she/he was rewarded with an on-screen 'certificate'. If any items were answered incorrectly the child got a chance to try the test again. The software did not allow children to move onto the next topic until they had demonstrated complete mastery (Pitchford, 2015). An evaluation of the Malawi pilot found that groups using the mathematics application significantly outperformed those from normal classes (i.e. without tablets) and a group that used tablets but without the specific software (Pitchford, 2014). Effect sizes varied according to the school grade and the skill being tested. All grades showed a positive impact but this was bigger for students in Grades 2 and 3 than for those in the first grade. Using measures for the knowledge of the primary school curriculum, effect sizes for students in Grade 3 ranged from 0.8 to 1.7 (ibid, p.25). According to Pitchford, this is equivalent to a gain of three months of learning from a one-week intervention (BBC, 2014).

In a follow-up study, the same mathematics app (translated into English) was trialled with a group of young learners in the UK. The results were very similar to those seen in the Malawi pilot - using the tablet-based app for

71. MoMaths was produced by Nokia in partnership with, amongst others, the Meraka Institute and the Department of Basic Education, South Africa. Math4Mobile is an app developed within the University of Haifa, Israel. Dr Maths is an online 'question and answer' service for mathematics learners organised by the Drexel University School of Education, USA.
72. The pilot used commercial software called Masumu developed by EuroTalk. The application is now available through the not-for-profit organisation 'one billion' (https://onebillion.org/about).

30 minutes a day for six weeks led to a learning gain of between 12 and 18 months (BBC, 2014).

Khan Academy Online Learning, Sri Lanka

Khan Academy is a non-profit organisation based in the USA and created in 2006 with a mission "to provide a free, world-class education for anyone, anywhere" (Khan Academy, n.d.). It provides instructional videos through its website and YouTube channels, practice exercises and, for registered users, a dashboard to monitor progress. Materials cover a range of subjects – including mathematics – and are freely available with open access to individual learners, parents, and teachers. Originally, materials were only provided in English. In 2013, the Asian Development Bank (ADB) supported the Khan Academy Localisation Project in Sri Lanka (Pereira, n.d.). This funded the mapping of all Khan Academy materials to the local curriculum for mathematics for Grades 3-13. Suitable videos were dubbed in Sinhala and gaps were filled with the production of additional videos. Additional tools were put in place to help teachers integrate the materials into their work. For schools with little or no internet access, the resource is to be made available in an offline, CD-based version (ibid). The evaluation of the first phase of implementation was, at the time of writing, underway. One of the key features of this approach to e-learning is that the instructional and practice materials are not the preserve of teachers – students can learn independently out of school.

MathCloud e-learning, Sri Lanka

MathCloud is an e-learning platform developed by the for-profit company MPDA[73] in Korea. The software is adaptive in that as a student progresses through a module, the system uses the answers to diagnostic tests to identify strengths and weaknesses and, hence, to deliver a programme tailored to the student's specific needs. Student progress is tracked in the software and the teacher has access to a number of tools designed to make whole-class and personalised teaching more efficient (MPDA, n.d.). The ADB's Testing e-learning as Learning Project funded the customisation of MathCloud materials to match the national curriculum for mathematics, including translation to Sinhala. In the pilot phase, students in selected schools used MathCloud for two hours per week (out of five hours mathematics tuition in total) for a year. An evaluation of the impact of the intervention reported that the treatment group made statistically significant gains when compared with the control group (Chin, 2012). The effect size, estimated from the evaluation data, is approximately 0.25. Whilst this may be considered to be 'small', it is comparable to reported effect sizes for other CAI interventions (Fletcher-Flinn and Gravatt, 1995, and Cheung and Slavin, 2011).

9.6 Promoting STEM through collaboration with business and industry

The challenge of attracting more and better students[74] into the areas of mathematics and other STEM subjects is one faced not only by the poorer countries of SSA and beyond, but also some of the world's most highly developed economies. In any country, the state education system is by far the most important and influential player but, in general, it cannot on its own meet the needs of the highly specialised and fast-changing world of STEM-based commercial sector. In particular, the private sector is uniquely placed to provide:

73. My Personal Data Analysis (MPDA) is the parent company responsible for MathCloud. MPDA Angels is a not-for-profit subsidiary which partners the Sri Lankan Ministry of Education and the Asian Development Bank in the implementation of the Testing e-learning as Learning Project.
74. Attracting students on to advanced study programmes in STEM subjects and into STEM-based careers is an almost universal challenge. However, this problem is particularly acute when it comes to attracting girls. In recognition of this, many countries have public initiative and/or public-private partnerships specifically targeted at encouraging young women into the STEM sector.

additional finance to support schools and universities in the teaching of STEM subjects; sponsored places for students in institutions of further and higher education; opportunities for students to gain exposure to modern STEM environments; and technical expertise in the development of authentic teaching aids for modern technologies. In return for investment, the private sector benefits from an increased flow of applicants who are better prepared in Mathematics and other STEM subjects. For example, The Mastercard Foundation announced in 2015 that it was committing USD 25 million to supporting the work of the African Institute for Mathematical Sciences (MasterCard Foundation, 2015). The investment is to "enable 500 academically talented students from economically disadvantaged communities to pursue their Masters level education in science, technology, engineering and mathematics. It will also support the creation of a teacher training program which will improve the quality of secondary-level math and science teaching in Cameroon" (ibid, p.1).

'Change the Equation' is a particularly interesting example, from the USA, of the way in which industry and commerce can be engaged to support state initiatives in the field of STEM education. 'Change the Equation' is an organisation formed in response to President Obama's Educate to Innovate initiative (United States, 2009). Its members are Chief Executive Officers (CEOs) of forty major, multi-national and US-based companies including BP, DuPont, IBM, Intel, Microsoft, Rolls Royce, Time Warner Cable and Xerox[76]. The consortium's mission is to "work at the intersection of business and education to ensure that all students are STEM literate by collaborating with schools, communities, and states to adopt and implement excellent STEM policies and programs" (Change the Equation, 2016a, p.1.) It does this by identifying educational policies and practices which have been shown to be effective in producing STEM-literate students and then advocating their adoption by schools, communities and states. In addition, member companies invest in a wide range of programmes. These include events designed to engage young learners (e.g. National Science Olympiads, state science fairs, inter-school robotics championships, etc.) and activities to support teachers through the provision of materials and ideas. In some cases, for example the Denver Public Schools CareerConnect program, students are given the opportunity to experience what it is like to work in a STEM environment (Change the Equation, 2016b). It is estimated that the member companies of the consortium invest around USD 750 million per year in STEM initiatives. Further details of the organisation's work and the resources it offers to educational policy makers, businesses, schools and teachers can be found at http://changetheequation.org/resources.

9.7 Summary

Throughout SSA, a large number of diverse and innovative interventions are being tried to tackle the systemic problems that contribute to low levels of student achievement in mathematics. Many focus on supporting in-service teachers by providing them with better training and access to more and better teaching and learning materials through the use of modern technologies. Some effect optimism but, as yet, little objectively verifiable evidence is available as to the returns on investment offered by the various programmes.

[76] For a full list see: http://changetheequation.org/our-members.

Developing and delivering technological solutions for implementation at scale is both technically demanding and expensive. As a result, few such initiatives are solely owned or controlled by national governments. Many rely on external sources of funding from international NGOs and/or philanthropic groups. Governments may also need to form partnerships with for-profit companies including, for example, software developers and the providers of internet services and mobile networks. Such arrangements may in the longer-term raise questions as to intellectual property rights and have implications for sustainability.

The sustainability of technological solutions is of concern especially in the resource-poor and often insecure context of SSA's schools. The problem is generally less serious in e-learning programmes where teachers and/or learners access materials through their own digital devices and in m-learning programmes where TLM's are delivered through a mobile phone (e.g. Elimu kwa Teknolojia). However, sustainability is of major concern in programmes which require schools to be equipped with highly specialised and/or expensive equipment (e.g. Digital School in a Box and Tablet-based Learning). In this case, many fundamental questions have to be asked including: Who within the school is to be responsible for the safe keeping of the equipment? How will the hardware be maintained and what happens if something goes wrong with the software? How will obsolete equipment be replaced and who will pay? The long-term sustainability of programmes designed to enhance learning in SSA through the use of educational technologies is an area worthy of further research.

10 Findings and recommendations

10.1 Summary of findings

There is a consensus that investment in education yields significant returns for individuals, communities, and nations. Returns are maximised when the education system promotes the acquisition of critical cognitive skills - linguistic literacy, numeracy, and problem solving skills. Of these, research suggests that, in an increasingly technological world, mathematical literacy is the most important. Unfortunately, a large body of evidence supports the view that mathematics education in SSA is in a precarious state. The learning deficit between countries in the region and international norms is so large that, without extensive and sustained interventions across all phases of education, the gap may never be narrowed let alone closed.

The factors that contribute to low levels of student achievement in mathematics in SSA are numerous, varied, and interconnected in complex ways. There is no panacea; there is no magic bullet. Any solution will require simultaneous actions on many fronts. Mounting a comprehensive and coherent campaign to raise the quality of mathematical education will require careful strategic planning and significant investment. Even with a suitable plan in place it will be difficult to overcome the inertia associated with large education systems, so governments and other stakeholders should be prepared to sustain their efforts over the long term. There are no quick fixes.

Mathematics education is not an island in the ocean: it is inextricably linked to the quality of schooling experienced by learners. Providing access to high quality schooling for all would inevitably raise achievement levels in mathematics along with those in all other subjects. The umbrella term ‘quality of schooling’ covers many factors: adequate financial resources; good physical structures; access to utilities and services (e.g., potable water, electricity, and internet services); availability of TLMs and educational technologies; effective school managers; and, above all else, well trained and highly motivated teachers. Financial investment in schools serving poor and disadvantaged communities is of particular importance as highlighted by Spaull (2011) who shows that the socio-economic status (SES) of the school is a significantly more important factor in determining outcomes than the SES of the student.

Notwithstanding the above, mathematics education in SSA requires special attention for three reasons. First, it is a priority because the economic well-being of a nation depends on the capacity of its education system to produce workers and consumers who are mathematically literate. Secondly, the learning deficit in mathematics for most countries in the region is huge and shows no sign of diminishing. Thirdly, widely-held negative attitudes towards mathematics and an acceptance of failure increase resistance to change and hamper progress.

Whilst the need to address poor outcomes in mathematics is urgent, many of the most important interventions will only be effective in the longer-term. However, there are areas where interventions could be implemented in the short- to medium-term. Some of these require little investment and whilst they may not on their own make a significant impact, they would send an important message at the start of what is likely to be a protracted campaign. Suggested interventions are presented below. It should be noted that the order in which they appear is not intended to suggest a hierarchy of priorities. All will need to be included in any comprehensive action plan.

10.2 Suggested interventions

Raising the status of education in mathematics to that of a national priority

This study has shown that raising mathematical achievement from the current low levels found throughout SSA is now a critically important issue. This should be recognised by governments in their strategic plans where improving standards in mathematics should be explicitly classified as a national priority. The difficulty in achieving ambitious strategic objectives related to the numbers pursuing and succeeding in mathematics and other STEM-related courses should not be underestimated. For example, in 1970 the Government of Malaysia implemented a '60:40 Policy' aimed at having 60% of students at the upper secondary level enrolled in a STEM stream (with 40% in the Arts and Humanities stream). Four decades later, this target has not been reached – currently 42% are in the STEM stream – but significant progress from a low baseline has been made and the explicit policy objective continues to guide the actions of the Ministry of Education[76] and to serve as a signpost as to the desired direction of travel (MOE, Malaysia, 2016).

Budgets for education in SSA tend to be severely constrained but the evidence is that increased per student expenditure is associated with better mathematical outcomes. Therefore, additional funding, over and above that for general education, should be allocated to interventions specifically targeted at improving mathematical outcomes at the primary, secondary and tertiary levels as a matter of priority.

This shift in priorities should be reflected in the policies and actions of the many international banks, donor agencies, NGOs and philanthropic organisations that play a vital role in supporting governments in the implementation of educational reforms. For example, those preparing any programme and/or project to be supported by an international development bank should be required to describe if/how proposed actions will address the acute issue of promoting increased engagement with, and achievement in, STEM subjects[77].

Changing attitudes towards mathematics

It has been suggested that one of the key factors contributing to the success of the countries of East Asia which consistently top the TIMSS and PISA rank orders for mathematics is the prevailing 'culture'. This manifests itself in three ways which are relevant here. First, education is highly prized and teaching is a respected profession. Secondly, hard work is recognised as the means by which educational success is achieved. Thirdly, mathematics is no exception to the rule; as in any other subject success in mathematics can be achieved with hard work and does not depend upon a special 'natural ability'. Therefore, as a first step in tackling underachievement in mathematics in SSA, governments and their ministries of education should implement a public relations campaign

76. Under the 60:40 policy students who achieve the highest grades in mathematics and science in the examinations administered at the end of the lower secondary phase are automatically placed in the STEM stream unless they or their parents object. One consequence of this is that a disproportion number of girls are placed in the STEM stream because they outperform boys in both mathematics and science in the lower secondary phase. In addition, a study conducted in 2015 found that the arrangement had "raised the girls' self esteem and confidence (MOE, Malaysia, 2016, p.19).
77. This requirement to reflect on a programme's likely impact on a critical issue is akin to the World Bank's approach to the vitally important issues of, for example, gender equality and HIV-AIDS.

incorporating three key messages: (a) It pays to invest in the mathematical education of your children because, amongst other benefits, success in mathematics is linked to greater economic returns; (b) Everyone can be successful in mathematics - you don't need to be born with a special ability; (c) Hard work will bring better results in mathematics.

Other countries are already trying to change attitudes towards the subject in this way. In 2015, the UK Education Secretary said in an interview, "there is no such thing as having a 'Maths brain'. With the right support we can all get better at Maths. For too long, being bad with numbers has been something to brag about" (McTague, 2015). Similarly, the Minister of Education in Jamaica in launching a campaign to tackle low standards in mathematics has warned teachers that "phrases such as "Mathematics is hard" or "Mathematics is boring" should not be encouraged around students" (Linton, 2014).

When addressing attitudes towards mathematics, special attention should be paid to changing the view that this (along with the natural sciences) is predominantly a subject for boys. Schools, institutions of further and higher education, and potential employers should reinforce the message that careers in STEM-related fields offer valuable opportunities to all regardless of gender. Highlighting good female role models, using gender-appropriate learning materials, and adopting interactive teaching methods will improve the confidence (i.e. self-efficacy) of girls and, hence, their achievement. The countries of SSA cannot afford to continue to ignore the valuable human capital represented by girls and young women.

Improving initial teacher training

Improving the quality of teaching is the most important challenge facing those attempting to improve the outcomes of mathematical education. Whilst some advantage can be achieved through training teachers who are already in service, it is vital that new entrants to the profession are properly prepared through the pre-service courses offered by teacher training institutions. Unfortunately, in many countries of SSA such colleges have not risen to the challenge and perpetuate an unacceptable status quo by preparing graduates who, as evidenced by the poor outcomes of their students, are not effective teachers of mathematics. TTIs which currently serve as a block against progress must be transformed so that they fulfil their potential and become a significant part of the solution.

Currently, the general impression is that the curricula and instructional practices of TTIs are primarily designed to produce teachers who know how to do the mathematics required by school curricula and, hence, can demonstrate to their students the right way (sic) to solve mathematical problems. This is at odds with current thinking about the skills and deep knowledge required by good mathematics teachers. In addition, it does not reflect the constructivist/child-centred approaches to teaching mathematics incorporated in many of the revised school curricula of SSA. Generating a new vision of the type of graduate that TTIs should produce is essential, but there is likely to be much resistance to change. Four key areas in need of reform are: revising curricula of TTIs; revising the way in which curricula are delivered; making better use of new educational technologies; and, crucially, changing the profile of TTI tutors – especially those who are preparing teachers for the primary phase of education.

A number of observers have commented that much of the pre-service curriculum is currently dedicated to teaching trainees how to do the mathematics that they should have learned in school, i.e. strengthening their subject content knowledge. Instruction as to how to teach mathematics to young learners (e.g. through the effective use of alternative methods, TLM, and formative assessment) often receives less attention. This means that trained teachers lack the knowledge and skills necessary "to build bridges between the meaning of the subject content and the construction students make of that meaning" (Moreno, 2005, p.12). Akyeampong et al. (2011) suggest that what is lacking in initial teacher training is a comprehensive treatment of theory so that trainees can make sense of practice. The importance of stressing the complementary nature of theory and practice in training mathematics teachers is further explored in Ogwel (n.d.).

In terms of mathematical content, trainees should be helped to develop a far deeper understanding of the mathematical concepts they will teach even though this may mean sacrificing the breadth of the content somewhat. At the same time, trainees must be provided with a range of strategies for helping learners who when presented with a mathematical problem may choose to tackle it in different ways because they conceptualise it differently. In short, the curricula of TTIs and the way in which they are delivered should reflect best practice in the classroom.

Revising curricula and teaching programmes for TTIs does not require great investment and could begin immediately. However, it is not clear that the current management and tutors of TTIs are in a position to deliver a radically different approach to preparing new teachers. A key deficiency is that TTI tutors receive little or no training in how to teach primary and secondary level teachers. An additional concern is the lack of tutors who have experience of teaching in primary grades. It is difficult to see how a teacher trainer who does not have first-hand experience of how young learners think about mathematics can advise trainees on effective teaching strategies. Correcting this will be neither easy nor quick. First, the rights of teacher trainers currently in post will need to be respected. Secondly, there is no obvious supply of potential tutors who are both well qualified and have experience of primary school teaching.

It should be possible to retrain selected TTI tutors through a suitable professional development programme - including a practicum. If necessary, financial incentives could be offered to those who successfully complete a certified course in, for example, 'the teaching of mathematics in primary schools'. Appointing new teacher trainers from the primary sector is likely to require the formal recognition of a new career path and the amendment of the selection criteria currently applied by TTIs. One strategy would be to identify outstanding primary school teachers and/or school principals and to encourage them to join TTIs in order to better prepare the next generation of teachers[78].

Whilst the structural changes advocated above may only be effective in the medium- to longer-term, there is an immediate opportunity to strengthen teacher training through the use of educational technologies. Unfortunately, many TTIs do not seem well-placed to take advantage of this in that they are under

78. In some countries, e.g. Ghana, there are plans to give good primary and secondary school teachers incentives to stay in their classroom rather than seeking promotion to non-teaching administrative roles.

resourced (in terms of hardware and software) and have not yet developed sufficient technical capacity. As ministries of education increasingly explore the opportunities offered by technology in partnership with NGOs and commercial partners, there is a danger that TTIs will fall further behind and will not be able to prepare their trainees to make best use of e-learning and m-learning (mobile learning) tools. Fortunately, examples of good practice are emerging in SSA. For example, in some countries TTIs are already incorporating open educational resources freely available from, for example, the TESSA initiative in their taught programmes. Harnessing the potential benefits of e-based TLM and helping trainees to appreciate that they can use such technologies in their own work should be a priority for all TTIs.

The natural inertia of large organisations such as TTIs may make it difficult to achieve significant progress over a short period. In particular, it may be some time before reforms of formal study programmes yield positive results. Individual trainees, however, can respond far more quickly if they are encouraged to take greater responsibility for their own professional development. Therefore, TTIs should be advocating and facilitating self-development as an adjunct to their taught courses. Most importantly, trainees should be exposed to current ideas about teaching mathematics effectively by being given free access to a wide range of materials and resources. These should include both traditional TLM[79] including textbooks, teachers' guides, exemplar worksheets, etc and e-based learning materials for both teachers and students. Free (i.e. unfettered and free of charge) internet access is the key to this since it allows trainees to see, for example, video clips of model lessons and to download materials for their own education and for use in their practicum.

Supporting practising teachers

Whilst the reform of initial teacher training is of paramount importance the needs of the majority of teachers who are currently in service must not be neglected. Research from both SSA and beyond shows that in-service training can be effective if it has the right characteristics. Walter and Briggs (2012) suggest that "The professional development that makes the most difference to teachers: (1) is concrete and classroom-based; (2) brings in expertise from outside the school; (3) involves teachers in the choice of areas to develop and activities to undertake; (4) enables teachers to work collaboratively with peers; (5) provides opportunities for mentoring and coaching; (6) is sustained over time; and (7) is supported by effective school leadership" (Walter and Briggs, 2012, p1.). In mathematics education, peer support and collaboration between teachers appears to be of particular importance. Evidence suggests that high levels of achievement in China are due, at least in part, to the fact that teachers of mathematics collaborate routinely – something which does not seem to be the norm in, for example, North America and Europe (Cai, Lin, & Fan, 2004). It is interesting to note that the 1+4 teacher development plan for South Africa discussed in the previous chapter provides, within its design, the opportunity for teachers to meet regularly in order to discuss teaching and learning strategies. It will be interesting to see whether this initiative translates into significantly better teaching and learning.

79. Akyeampong et al (2011) report that "Another factor contributing to the misalignment of school and college curricula is that neither college tutors nor trainees are likely have access to the materials, such as teacher guides and textbooks used in schools. Access to the primary curriculum documents and guides was also not always guaranteed" (Akyeampong et al, 2011, p.18).

Providing more and better mathematics textbooks

In countries where, especially in the primary phase, the student:textbook ratio for mathematics is greater than 2:1, there is probably benefit in investing in the provision of more books (Fehrler, Michaelowa and Wechtler, 2007). Fredriksen and Brar (2015) suggest strategies for meeting the demand for textbooks in SSA.

Whilst there is currently a great need for physical textbooks in many countries of SSA, the internet offers a parallel route for allowing teachers, students and parents free access to the books. For example, The National Council for Educational Research and Training (NCERT) in India commissions physical textbooks for use in schools on a commercial basis. However, it also makes e-versions freely available to individuals provided that these are not offered for resale. The books, and supplementary learning materials, are available through an e-portal[80]. They are available in formats suitable for download to mobile devices and PCs. There is, as yet, little data on the use of these resources but the principle of allowing free access to TLMs produced with the support of the state is sound. The potential advantages of such a system in the countries of SSA context are significant. For example, tutors in TTIs and their trainees would have access to the curricula and textbooks being used in schools; serving teachers would have free access to textbooks in multiple languages[81] when preparing their lessons; and students fortunate enough to have access to the internet would have free access to textbooks and other materials for self-tuition.

Notwithstanding the above, research shows that simply supplying more textbooks will not, on its own, raise mathematical achievement significantly. The textbook has to be the right textbook and determining whether this is the case or not requires systematic evaluation. Currently the pre-publication evaluation of new textbooks tends to focus on alignment with the content of the curriculum, attractiveness to learners, physical quality and, of course, cost of production. However, there is little evidence that new textbooks in SSA are systematically evaluated as to their effectiveness as aids to learning i.e. that they are closely aligned with instructional objectives. A description of a model used in the USA to evaluate textbooks in mathematics and science is given by Kulm, Roseman, and Treistman (1999). This involved training a cadre of reviewers (school teachers and university mathematics specialists) in the application of a structured evaluation procedure. The first step in the process was to identify from the national standards the specific learning goal or goals to be analysed. Then the relevant section in the textbook was analysed to ascertain the degree of alignment between the textbook's content and the selected learning goal(s). Then, and most importantly, the material was analysed for alignment between the book's mode of instruction and the selected learning goal(s). Evaluators were required "to estimate how well each activity addresses the targeted learning goal from the perspective of what is known about student learning and effective teaching" (Kulm, Roseman, and Treistman, 1999, p1.).

Systematically investigating the effectiveness of a textbook before publication may add to the initial costs of production, but this may be a small price to pay for greater returns in terms of educational outcomes.

80. Materials are available at: http://epathshala.nic.in/e-pathshala-4/.
81. For example, the Indian NCERT website gives teachers free access to Hindi, Urdu and English versions of the textbook for Grade 3 Mathematics – extremely useful, for example, for teachers presenting lessons in English rather than their Mother Tongue.

Supporting mathematics teachers through technology

As described in Chapter 9, many initiatives have been launched in recent years to try to turn the potential of digital technologies into improved teaching and learning. It is not yet clear which, if any, of these should be taken to scale in any particular country. It is also unclear which will be sustainable in the long run. However, it is clear that technological tools are emerging that individual teachers can, with support, use to enhance their teaching of mathematics. Typically these teaching tools and materials are not being created by government agencies: they are being generated by not-for-profit organisations, academic institutions, and commercial entities. Commercial and professional competition tends to ensure that they are, in general, of high quality. Given the fact that the available pool of resources is constantly growing and changing, perhaps the best short-term strategy is not to be too directive and simply to facilitate teachers' access to ideas, models, materials and tools. For example, ministries of education may wish to guide teachers towards particular resources through, for example, a national education portal. In addition, online communities of mathematics teachers should be encouraged in order to facilitate the sharing of resources that have been found, by teachers, to work in the classroom. A good example of this is the resource-sharing website hosted by the Times Educational Supplement[82] in the UK. Teachers from all phases of education and in all subjects upload resources they have made and used. These can be accessed and used, many without charge, by teachers from anywhere in the world.

The informal, decentralised, and uncontrolled approach advocated here may not sit well with more conservative policy makers. However, it reflects the reality of a digital universe where teaching communities are not limited by national borders and where the best teaching/learning materials emerge through a process akin to natural selection: the best survive and are used by teachers whilst the worst simply fade from view.

Harnessing the power of assessment: regional and national assessments

Participating in international large-scale assessments may bring benefits but for countries in SSA where it is known that achievement in mathematics currently lies far, far below international norms it is not clear that the potential benefits outweigh the costs. In the longer-term, new initiatives such as PISA for Development may make the proposition more attractive. In the shorter-term, alternatives include the development of national assessments and participation in regional assessments. The advantage of joining an existing regional assessment is that individual countries do not have to develop capacity in the highly technical fields associated with such assessments – especially the capacity to apply IRT to student responses. Over recent years, the two regional assessments currently available – SACMEQ and PASEC – have become increasingly sophisticated and potentially more powerful. Collaboration between SACMEQ and PASEC should be strengthened through formal agreements to work towards common operational standards, and the use of a common reporting scale. At the same time, more countries should be encouraged to join the consortia. Co-operation and expansion would move SSA towards a pan-African

82. The Times Educational Supplement is a newspaper/magazine specifically aimed at schools and teachers. Its resources for teachers are available at: https://www.tes.com/teaching-resources/ [Accessed 5 February 2016]. As at February 2016, there were 35,000 Mathematics TLMs available, suitable for learners from 3-11 years old.

comparative assessment programme capable of measuring student achievement and, of paramount importance, monitoring trends over time.

Notwithstanding the above, a significant number of countries in SSA have attempted to conduct national assessment programmes, and in some cases succeeded in doing so. However, in many cases it is not clear that these yield the information that policymakers require and there is little evidence that they are providing schools and mathematics teachers with sound and practical advice that can be used to improve learning. All countries that are currently investing in national assessments should immediately review these to ensure that they are providing value for money. In particular, steps should be taken to ensure that all national assessments provide mathematics teachers with concrete examples of student performance at different achievement levels. Examples of test items, descriptions of alternative solutions and popular misconceptions, and supporting statistical data are all necessary if national assessments are to have a positive impact on classroom practices.

Allowing access to materials and data related to high-stake examinations

In many countries of SSA, high-stake examinations act as gatekeepers at the transition points of the education system. The agencies responsible for them are under great pressure to maintain the security of their systems and to ensure that individual students receive the correct result in a timely fashion. In focusing on this they tend to neglect their role in enhancing education by providing materials and information to teachers and students. Governments and their ministries of education should instruct national examination boards and other assessment agencies to put in place, without delay, comprehensive feedback systems to supply teachers and other practitioners with both qualitative and quantitative information as to student performance in mathematics (and all other subjects). Anonymised datasets should also be made freely available to bona fide researchers wishing to conduct secondary analysis since, as Fehrler, Michaelowa and Wechtler (2009) conclude “any kind of measures to enhance transparency about… learning outcomes appears to be valuable” (Fehrler, Michaelowa and Wechtler 2009, p.27).

Where they do not already do so, examination boards should be instructed to make materials which would help teachers and students prepare for examinations in mathematics (and all other subjects) freely available via the internet. These should include examination programmes (syllabuses), reports of examiners and, most importantly, past papers[83] (with their marking schemes).

Supporting student self-learning through technology

When it comes to knowledge and education, the advent of the internet has begun to undermine the hegemony of schools, teachers, ministry-approved textbooks, etc. Students who have access to the internet can now easily supplement their formal education with information and resources from elsewhere. This should not be seen as a threat but as an opportunity to raise levels of achievement (at least for some) without significant additional investment from the state. This is particularly true in SSA where many students are currently being taught by teachers who lack confidence and/or competence in mathematics. Three

83. Examination boards that currently charge for past papers (hard copy) should be encouraged to accept a small loss in income for the greater national good.

initial steps are recommended. First, students, parents and local communities should be made aware of the possibilities for self-learning. They should be encouraged to access suitable learning materials – possibly through a user-friendly, national education portal. Secondly, key players in education, both government agencies and NGOs, should be encouraged to provide free access to existing open educational resources. Thirdly, NGOs and commercial partners should be encouraged to collaborate with, for example, ministries of education in the generation of age-appropriate learning materials compatible with the content and philosophy of national curricula for mathematics[84].

10.3 Challenges associated with implementation in fragile states

As mentioned previously, the OECD (2015a) classifies 28 states in SSA as being 'fragile'. Gelbard et al (2015) define a fragile state as one "in which the government is unable to deliver basic services and security to the population" and suggest that such states "display an elevated risk of both political instability (including civil conflict), and economic instability" (Gelbard et al, 2015, p.7). In such states, the implementation of complex, long-term educational reforms, as advocated in this report, is extremely problematic. The probability of success is enhanced by addressing three key issues: poor governance in the education sector; failure to allocate adequate and sustainable resources to education; weakness of key educational institutions. A detailed analysis of these issues and evaluation of possible solutions is beyond the scope of this report. However, the importance of strengthening institutional capacity is worth highlighting. Gelbard et al (ibid) note that, in general, "institutions and their transformation are driven by long-term processes that involve several actors and often impersonal factors and large social groups, leading to a slow pace of change subject to various forces, some of which cannot be easily controlled even by a benevolent national authority" (ibid, p.16). Therefore, they suggest that fragile states wishing to build resilience should "focus in the near term on more 'narrowly defined' institutions that can be reformed within a decade or so through the action of a well-identified authority" (ibid, p.16). The evidence presented in this report suggests that two categories of institution are of critical importance in raising educational outcomes in mathematics: institutions responsible for the pre-service and in-service training of teachers; and, institutions responsible for examinations and other forms of educational assessment.

Chapter 7 highlights the fact that the majority of TTIs are currently so weak that they represent a significant barrier to progress. Therefore, in any development strategy, these should be radically reformed and strengthened - as a matter of priority - so that they are capable of preparing competent and confident teachers of mathematics who, in turn, are capable of inspiring learners and inculcating a deeper understanding of mathematics.

Chapters 5 and 8 reveal the important roles played by examination boards and national assessment agencies. Examination boards and the agencies responsible for the conduct of national and regional assessments have the potential to provide valuable information to policy makers and practitioners on standards of achievement and on the factors which contribute to better outcomes. Unfortunately, this potential is rarely fulfilled. Therefore, strengthening the professionalism and

84. A relevant example is the long-standing collaboration between South Africa's Department of Basic Education, Sesameworkshop ®, and the South African Broad casting Corporation in producing child-friendly TV programmes, on-line video clips, and workbooks to support early childhood development in a number of areas – including numeracy. (See http://www.takalanisesame.co.za/)

technical capacity of these institutions should be a priority. In countries where there is currently no capacity to conduct regional assessment programmes and/or design and conduct national assessments, developing a new institution for these purposes should be considered from the outset.

10.4 Areas worthy of further research

The issue of low levels of achievement in numeracy and mathematics in SSA has been widely acknowledged for some time and, as a result, the underlying factors have been the subject of much research. There remain, however, areas where further research could make a positive contribution to the formulation of strategies for remedial action. Some of the research questions which, during the preparation of this report, have emerged as being worthy of study are described below.

How can countries monitor trends in mathematical achievement?

As countries invest in reforms designed to significantly raise levels of mathematical achievement they will need to know whether progress is being made or not. It is our contention that, to date, national and regional assessments in SSA have not been able to provide sufficiently precise and reliable data on trends in student achievement. The question is: 'How can education systems establish quick and effective mechanisms for monitoring mathematical achievement over time?' What will be necessary to establish sufficiently precise baseline measurements and how can subsequent measurements be systematically linked with those baselines?

How do learners understand mathematical concepts as demonstrated by their teachers? How do they approach mathematical problems?

A recurring theme in this study has been the mismatch between teaching practice and the constructivist approach advocated by modern curricula. Some examples of alternative ways in which students may view particular mathematical concepts are given in academic papers. However, there appears to be little evidence, and few examples, gathered in the context of typical classrooms in SSA. In addition, Akyeampong et al. (2011) point out that the use of TLMs has been "ritualised to the point where how they communicate conceptual understanding is lost" (Akyeampong et al., 2011, p.39). Both of these issues should be subject to action research.

How effective are the textbooks currently being used to teach basic mathematics in SSA?

Whilst many argue that the availability of mathematics textbooks is an important factor in raising student achievement, quantitative research repeatedly suggests that the direct benefits are, at best, small. One hypothesis is that investing in textbooks is of value only if the prescribed textbook is effective. There are, however, few rigorous evaluations of textbook effectiveness. This is an area where further study would be of value.

How can national assessments of student achievement in mathematics be improved so that they provide policy makers and teachers with the information needed to improve outcomes in mathematics?

Whilst commentators such as Kellaghan and Greaney (2004) highlight the potential benefits of conducting national assessments and UNESCO (2015) applauds the fact that a significant number of countries across SSA have carried out such assessments, there is little evidence as to the technical quality of these. Few governments appear to be asking these fundamental questions: Do our national assessments serve their intended purposes? Do they offer value for money? Have they had a discernible impact on educational policy and/or practice? Answering these questions will require both qualitative and quantitative research.

Where OER have been used as the basis of, or to supplement, formal teacher education development programmes, have they been effective?

Open Educational Resources produced by international development partners have been used in some TTIs as the basis of new initial teacher training programmes or to supplement existing programmes. In other cases, OER have been built into in-service professional development programmes for teachers. Independent evaluations of these initiatives are required to determine whether they have contributed to the production of better graduates or not. If such programmes can be shown to be effective and offer good value for money then the approach is more likely to be adopted by other countries and other TTIs.

Which of the e-learning and m-learning technologies in the classroom have the greatest potential to raise levels of numeracy and mathematical competence? What are the challenges of introducing e- and m-learning technologies - especially in fragile states?

Over recent years, a significant number of initiatives to raise levels of numeracy and student achievement in basic Mathematics through the use of digital technologies have been piloted across SSA. Few of these have been subjected to fully independent scrutiny. There is a need to evaluate any such initiative before investing in implementing it at scale. Evaluative studies should not only investigate the returns to learning but also the costs and risks associated with adoption on a large-scale. These are the key questions: Which technologies/approaches yield the greatest benefits in terms of improved outcomes? What are the costs associated with implementing the proposed technological solution at the regional and/or national levels? Given the prevailing context, is the proposed technological solution viable and sustainable? In 'fragile states' which technologies/ approaches are likely to be effective and sustainable?

Appendix A. Case studies for six countries

A.1 Overview

The case studies documented here were carried out in 2015 to gather evidence to supplement that available in the many research reports and other documents reviewed in the preparation of the main study. The six countries – Cameroon, Democratic Republic of the Congo, Ethiopia, Nigeria, Rwanda, and Uganda – were selected to represent some of the diversity which can be found across SSA. In particular, countries nominally designated as anglophone and francophone were chosen although, as shown in Table A.1, policies with regards to the use of language in education are more complicated.

Table A.1: Overview of the locations and educational language policies of the study's six focus countries

Location		Language policy for education
Cameroon	Central Africa	Government policy is to promote bilingualism (French and English) for all official functions including education. According to Rosendal (2008), "The law guarantees education in either English or French, depending on the linguistic zone, from first grade throughout secondary school. Teaching the second official language starts in Grade 6. The teachers, as state employees, must use the official languages in communication with the learners. Pupils are prohibited from speaking to teachers in a national language" (Rosendal, 2008, p.37).
DRC	Central Africa	There appears to be no official policy with regard to the language of instruction. In general, however, in the first two years of primary school, one of the national languages (Kikongo, Lingala, Luba-Kasai, and Congo Swahili) is used with the official language, French, being introduced from Grade 3. French is the language of instruction for secondary and higher education. (Language Education Policy Studies, n.d.)
Ethiopia	East Africa (Horn of Africa)	National languages at primary level (to Grade 4 at least but with some variation thereafter by administrative area). English is the language of instruction for secondary and higher levels (Vujcich, 2013).
Nigeria	West Africa	Mother Tongue or local language at the pre-primary and in the early stages of primary education. Thereafter transitioning to English which is the language of instruction for secondary and higher levels (Orekan, 2010).
Rwanda	East Africa (Great Lakes Region)	From 2008, English has been designated the official language of instruction for education beyond the lower primary phase replacing earlier French or French/English bilingual practices. In the early years of primary education, Kinyarwanda is used as the language of instruction but English is studied as a subject from Grade 1. (Samuelson and Freedman, 2010).
Uganda	East Africa (Great Lakes Region)	From 2007, rural primary schools have been required to teach pupils in the first three grades in the dominant local language. During the fourth year, English is introduced as one of the languages of instruction and from Grade 5 it is the sole language of instruction. Urban primary schools are exempt and many choose to teach in English from Grade 1.

In each country the survey focused on classroom practices and teacher attitudes towards mathematics and the teaching of mathematics. Each case study is based on observations made in a sample of schools and on questionnaires completed by teachers. The samples were not drawn using probabilistic methods and we do not claim that they are representative. National co-ordinators used their local knowledge to select schools operating in a range of geo-social contexts taking into account the limited time and resources available. We do not claim that the findings are generalisable with any great degree of precision, but they do allow us to check whether the general claims made by researchers and agencies involved in the implementation of educational reforms are confirmed by observations made in the field.

Three mechanisms were used to collect data: classroom observations; teacher questionnaires; and a questionnaire for institutions providing initial teacher training. Classroom observations and teacher interviews were conducted in public schools only. The target within each country was to observe 50 mathematics lessons in the primary phase and 20 mathematics lessons in the upper secondary phase. The classroom observations were structured to focus on the question: "What actually happens in classrooms where mathematics is being taught?" Following each observed lesson the teacher responsible was invited to complete the teacher questionnaire. In each country, three institutions responsible for delivering pre-in-service training for teachers were invited to complete questionnaires. We do not suggest that this small sample is representative of the country, but we were able to check whether their responses were consistent with the findings of more extensive studies – especially the influential report 'Teacher Preparation and Continuing Professional Development in Africa' prepared by Akyeampong et al (2011).

Each country-specific profile starts with a table containing contextual information. This is followed by a description of "lesson signatures" following the model used in the 1999 TIMSS video study (Hiebert, et al, 2003). Statements made within the lesson signatures are, where appropriate, supported by statistics from the classroom observations in order to give some indication of the frequency of the described behaviour. Information from the attitudinal questionnaires completed by teachers is then summarised. Finally, responses from teacher training institutions are summarised.

Table A.2: Cameroon: Country key facts

Indicator	Value	Year
Size (area):	472,710 km2	
Population:	22.77 million	2014
Urban population growth (annual %)	3.6%	2014
GDP (current USD):	USD 32.55 billion	2014
GDP growth (annual %)	5.9%	2014
GDP per capita (current USD)	USD 1,429.3	2014
Expenditure on education as a % of GDP	3%	2012
Expenditure on education as a % of total government expenditure	15.2%	2012
Government expenditure per primary pupil (USD)	USD 73.8	2012
Mobile cellular subscriptions (per 100 people)	76	2014
Internet users (per 100 people)	11	2014
Structure of education system (years primary + lower secondary + upper secondary)	6 + 4 + 3 (Fr) 6 + 5 + 2 (En)	
School enrolment, pre-primary (% gross)	34%	2014
School enrolment, primary (% gross)	113%	2014
Primary completion rate, total (% of relevant age group)	72%	2014
School enrolment, secondary (% gross)	52%	2013
Ratio of girls to boys in primary and secondary education (%)	87%	2012
Pupil:teacher ratio in primary education (headcount)	44.2	2014
Pupil:teacher ratio in secondary education (headcount)	21.4	2012
Average number of pupils per mathematics textbook in primary education	13.9	2012

A.2 Case study: Cameroon

A.2.1 Primary mathematics ‘lesson signature’ (Grades 3 and 6)

This description is based on 50 classroom observations made in 25 schools.

Typically, the mathematics lessons observed lasted for about 40 minutes. On average, 42 students were on the class register but there was a great degree of variation and the maximum number observed in one class was 90. In nearly all cases (>90%) children had chairs or benches to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were adequate and the majority of classrooms (72%) were described as “cheerful and bright environments decorated with wall charts etc“. Chalkboards were available and used in all classrooms (100%) and the majority of teachers (90%) had their own copy of the textbook. In about a half of cases (52%) measuring instruments and concrete teaching aids for mathematics were available. None of the classrooms visited was equipped with any form of educational technology. Nearly all pupils (-95%) had a pencil/pen and an exercise book. In two-thirds of cases (68%) most or all of the pupils had a mathematics textbook.

The start of each lesson was orderly and well structured. About three-quarters of teachers (78%) referred back to the previous lesson with a significant number (60%) handing back, or talking about, pupils’ homework. The majority of teachers (-80%) started by giving a clear description of what the lesson was to be about.

About 15 minutes into the lesson nearly all teachers were explaining the mathematical concept of interest by lecturing (98%) and by writing on the chalkboard (86%). Pupils were being questioned and asked to respond (90%). A minority (40%) used some form of TLM to aid their explanation. At this time, the majority of pupils (86% of cases) were orally answering questions asked by the teacher and, in about two-thirds of cases (68%), reciting their answers in unison. It was relatively rare (-20% of cases) to find pupils working in pairs or groups.

About halfway through the lesson, little had changed with nearly all teachers (90%) still using the chalkboard, lecturing and questioning pupils. Most students (-85% of cases) were involved in answering questions and/or doing mathematics problems in their exercise books. Pair and group work was not frequently observed (20%). Throughout the lesson, very few incidents of pupil indiscipline were observed.

At the end of the lesson, the majority of teachers summarised the contents of the lesson (84%) and the majority (72%) set a homework task. In general, the end of the lesson was as orderly as the beginning with, according to observers, 76% having “a clear and orderly end”.

The overall impression was generally favourable. The vast majority of teachers (96%) appeared to understand the concept they were teaching and were able to explain it to their classes. Compared with the results seen in other countries, a relatively high proportion of teachers (76%) incorporated at least one ‘real life’ example in their explanations. Our observers considered that in about three-quarters of the lessons the majority of students not only understood what had been taught (80%) but had also enjoyed the lesson (72%).

A.2.2 Secondary mathematics ‘lesson signature’ (Grades 9, 10 and 11)

This description is based on 20 classroom observations made in 10 schools.

On average, the observed mathematics lessons lasted for about 60 minutes. Relative to other countries in this study, classes were relatively large with an average of 57 students attending the lesson. However, class sizes varied and in one case 130 students were present! Notwithstanding the large numbers of students present, there was generally enough seating available and students had a hard surface on which to write. However, few classrooms (15%) were described as being “bright and cheerful learning environments”. Apart from the omnipresent chalkboard, teachers had few TLM available to them save for drawing equipment for the chalkboard which was available in about half the classrooms (55%). Only 40% of teachers appeared to have their own copy of the textbook. Not surprisingly, none (0%) of classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. Compared with the teachers, the students appeared relatively equipped with all, or nearly all, having writing materials and textbooks. In addition, in all of the classrooms observed, all or nearly all students had calculators.

The start of each lesson was, in general, orderly with all (100%) teachers giving a clear description of what the lesson was to be about. Nearly all teachers (95%) explicitly referred back to the previous lesson and a large number (65%) handed back, or talked about, pupils’ homework.

About 15 minutes into the lesson the vast majority (>90%) of teachers were explaining the mathematical concept of interest by writing on the chalkboard and lecturing to their pupils. In addition, they were asking pupils questions and listening to their oral responses. In about three-quarters of the classrooms, students were also set problems to solve. At this time, the majority of pupils (85% of cases) were orally answering questions asked by the teacher. Answering in chorus was a very frequent activity and was observed in nearly all (95%) lessons. It was relatively rare (-20% of cases) to find pupils working in pairs or groups and even rarer (10%) to see them handling/using teaching and learning materials.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (85%) still using the chalkboard to explain the concept of interest and questioning pupils to judge their understanding. The majority of pupils were copying from the chalkboard (90% of cases) and/or attempting to solve problems in their exercise books (90%). At this stage of the lesson pair or group work was not observed.

Without exception, the lessons observed were brought to “a clear and orderly end”. Nearly all (95%) of teachers summarised the contents of the lesson and about three-quarters (70%) set a homework task.

The overall impression was that the teachers were technically competent in that they all appeared to understand the concept they were teaching and they rarely, if ever, made mathematical mistakes. However, in only two cases were teachers observed using ‘real life’ examples in their teaching.

A.2.3 Teacher characteristics and attitudes

In Cameroon, attitudinal questionnaires were completed by 50 teachers teaching at the primary level and 20 teaching mathematics at the secondary level. Most (86%) of the teachers interviewed were between 30 and 59 years old. They were also relatively experienced with the majority (72%) having at least five years' teaching experience. Prior to embarking on their pre-service training, 28% had graduated from senior secondary school, 46% had completed A-levels or the equivalent, and 21% had gained a first degree. Of the secondary school teachers nearly two-thirds (63%) had gained a degree level qualification.

At the primary level nearly all of our teachers (96%) reported that whilst they are fluent in the language of instruction, they are not teaching in their mother tongue. The vast majority (86%) claim that their students do not face any significant problems because they all understand the language of instruction. A similar pattern was found amongst secondary school teachers.

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. All reported having a mobile phone and, of these, almost 50% have smart phones with internet access. In contrast with some of the other countries in our study, PC ownership amongst teachers appears to be relatively high. 61% reported owning a PC, laptop or tablet computer and half of these have internet access. Only a small number (9%) classed themselves as non-users but a relatively large proportion (62%) considered themselves to be beginners with limited skills. However, more than a quarter (29%) claimed to be confident or expert users.

The primary school teachers in the survey reported, with very few exceptions, that they were very well prepared, or at least partially prepared, to teach the required concepts of the basic mathematics curriculum. Not surprisingly, the vast majority (>85%) of mathematics specialists teaching at the secondary level reported that they were very well prepared to teach any of the concepts required by the curriculum.

When asked about the value of group work and/or pair work in the classroom, there was almost unanimous agreement that this was "somewhat important" or "very important". Similarly, the use of concrete practical equipment in the teaching/learning of Mathematics was considered to be very important by 97% of teachers. It is interesting to contrast what teachers say is important with what they do in practice as described in the lesson signatures above.

Prior to teaching, a significant minority of our primary teachers (19%) had received no formal teacher training and another 15% had been trained through short courses amounting to less than one-year. About one-third (36%) had completed a one-year programme and a further 23% a two-year pre-service training course. Our small sample of secondary level teachers displayed a remarkably wide range of pre-service experience. 40% said they had not been trained (sic) or had followed short courses only, 20% reported two years of training and 40% had received three or more years of training.

The primary school teachers who had been trained generally displayed positive attitudes towards their pre-service training with the majority agreeing or strongly agreeing with statements such as: "My own mathematical skills improved a lot as a result of my training"

(56%); “My pre-service training left me well prepared to teach mathematics” (68%); and, “I enjoyed my pre-service training”(87%). There was less agreement on the content of training courses. For example, whilst 36% of our primary teachers agreed with the statement “nearly all my pre-service training was about improving my mathematical skills”, 26% disagreed. Similarly, the statement “We did not get enough practice teaching mathematics in the classroom” split the group with 28% agreeing and 34% disagreeing.

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, there is a general consensus that all students have the potential to be good at mathematics and that this does not require a special sort of brain. Secondly, whilst teachers are very positive about their students’ attitude towards mathematics and their progress, the vast majority (80%) agree that “most pupils need additional tutoring”. Thirdly, most (74%) teachers obviously feel under pressure to cover the syllabus and nearly half feel that they do not have enough time to cover the curriculum and sometimes have to move on before their pupils have mastered the current topic. Fourthly, nearly all mathematics teachers (91%) believe that more in-service support is required if student achievement is to be enhanced. At present, peer-support looks to be very important with nearly all (94%) of teachers reporting that they regularly exchange ideas related to the teaching of mathematics. Finally, most (64%) of the teachers in our sample are confident that computers and other educational technologies will help to improve results in mathematics.

Table A.3: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	44 (62.9%)	22 (31.4%)	1 (1.4%)	0 (0.0%)	2 (2.9%)
Everyone has the potential to be good at mathematics.	19 (27.1%)	31 (44.3%)	8 (11.4%)	7 (10.0%)	3 (4.3%)
You have to have the right sort of brain to be good at mathematics.	1 (1.4%)	7 (10.0%)	8 (11.4%)	32 (45.7%)	19 (27.1%)
Very few pupils are naturally good at mathematics.	7 (10.0%)	40 (57.1%)	10 (14.3%)	8 (11.4%)	1 (1.4%)
The current curriculum for Mathematics is too difficult for my students.	3 (4.3%)	16 (22.9%)	15 (21.4%)	22 31.4%)	8 (11.4%)
My pupils are making good progress in mathematics.	6 (8.6%)	47 (67.1%)	7 (10.0%)	5 (7.1%)	1 (1.4%)
Students seem to be interested in learning mathematics.	12 (17.1%)	29 (41.4%)	10 (14.3%)	10 (14.3%)	1 (1.4%)
Most pupils need additional tutoring in mathematics.	19 (27.1%)	37 (52.9%)	6 (8.6%)	5 (7.1%)	0 (0.0%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	12 (17.1%)	40 (57.1%)	3 (4.3%)	9 (12.9%)	2 (2.9%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	4 (5.7%)	29 (41.4%)	7 (10.0%)	19 (27.1%)	9 (12.9%)
I have enough time to teach everything in the mathematics curriculum.	12 (17.1%)	25 (35.7%)	3 (4.3%)	20 (28.6%)	4 (5.7%)
Teachers need more in-service support to improve the teaching of mathematics in our schools.	36 (51.4%)	28 (40.0%)	1 (1.4%)	2 (2.9%)	0 (0.0%)
I regularly exchange ideas on how to teach mathematics with my fellow teachers.	37 (52.9%)	29 (41.4%)	2 (2.9%)	1 (1.4%)	0 (0.0%)
Using computers and other new technologies in the classroom will improve results in mathematics	22 (31.4%)	23 (32.9%)	11 (15.7%)	8 (11.4%)	3 (4.3%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. ‘missing’ responses).

A.2.4 Teacher Training Institutions

In Cameroon, questionnaires were completed by representatives of three institutions for initial teacher training – two for the basic phase and one for the secondary phase. Compared with the TTIs questioned in other countries, the TTIs in Cameroon were very small with between 106 and 320 trainees in total with an average annual intake of just 80 trainees. They employ, on average, 25 tutors but none of the three reported having more than one or two mathematics specialists. The minimum qualification required for tutors is a first degree and some previous teaching experience. No college requires its tutors to periodically refresh their skills in a school environment or to undergo formal appraisals to check that their knowledge is up-to-date.

The minimum entry requirement for prospective primary school teachers is a qualification gained after four years of secondary education (i.e. equivalent to O-level). Somewhat surprisingly, it was reported that a pass in mathematics at this level is not a requirement. Both colleges for the preparation of primary teachers reported that in the current academic year they were "undersubscribed and many places were left unfilled". All respondents agreed with the statement "we face problems attracting high quality applicants to train as teachers".

During the initial three-year teacher training programme for primary school teachers, the colleges reported that just one to two hours per week are dedicated to the subject of mathematics. This is far fewer than the level reported in other countries in our study. Trainees are required to undergo a practicum of between six to nine weeks in each year of their training. In all colleges, trainees are required to pass examinations at the end of their first year.

The colleges in our study reported significant deficiencies in terms of educational technologies. They do not have libraries of video material for teaching/learning mathematics for use by trainees and none reported having computers with internet access available for use by trainees. The colleges in our sample volunteered that they do not have adequate technical resources to teach their trainees how to use educational software in the classroom.

A.3 Case study: Democratic Republic of the Congo (DRC)

Table A.4: Democratic Republic of the Congo: Country key facts

Indicator	Value	Year
Size (area):	341,500 km2	
Population:	4.50 million	2014
Urban population growth (annual %)	3.1%	2014
GDP (current USD):	USD 14.14 billion	2014
GDP growth (annual %)	6.5%	2014
GDP per capita (current USD)	USD 3,137.7	2014
Expenditure on education as a % of GDP	6.2%	2010
Expenditure on education as a % of total government expenditure	29%	2010
Government expenditure per primary pupil (USD)	USD 10.4	2010
Mobile cellular subscriptions (per 100 people)	108	2014
Internet users (per 100 people)	7	2014
Structure of education system (years primary + lower secondary + upper secondary)	6 + 4 + 3	
School enrolment, pre-primary (% gross)	14%	2012
School enrolment, primary (% gross)	109%	2012
Primary completion rate, total (% of relevant age group)	73%	2012
School enrolment, secondary (% gross)	54%	2012
Ratio of girls to boys in primary and secondary education (%)	100%	2012
Pupil:teacher ratio in primary education (headcount)	37.1	2013
Pupil:teacher ratio in secondary education (headcount)	14.2	2013
Average number of pupils per mathematics textbook in primary education	1.65	2013
PASEC: 5th Grade mathematics – median score (100 scale)	46.9	2010

A.3.1 Primary mathematics 'lesson signature' (Grades 3 and 6)

This description is based on 50 classroom observations made in 25 schools.

Typically, the mathematics lessons observed lasted for about 40 minutes. On average, 38 students were present but the number varied dramatically from a class where just five children attended to one in which there were 90 pupils. In only 70% of cases did all the children have a chair or bench to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were considered "adequate" but only one in five (20%) of classrooms were described as being "cheerful and bright environments decorated with wall charts, etc". Chalkboards were available and used in all classrooms (100%) and the majority of teachers (80%) had their own copy of the textbook. In about one-quarter of classrooms (26%) measuring instruments such as rulers, scales and measuring jugs were present but other forms of mathematical teaching aid (e.g. models, Cuisenaire rods, etc.) were less frequently available (16%). It was very rare (<5%) to see a classroom equipped with any form of educational technology. In the majority of classrooms (-95%) all or most pupils were equipped with writing materials. However, our observers did see two lessons in which it appeared that none of the children had pen or paper. In about one-third of classrooms (34%) at least some of the pupils were seen to have a mathematics textbook. At the same time, in 34% of classrooms no child appeared to have a textbook[85].

The start of each lesson was orderly and well structured. Nearly all teachers referred back to the previous lesson (90%) and gave a clear description of what the lesson was to be about (94%). In only about a quarter of lessons observed (24%) was homework returned or discussed – a lower proportion than observed in the other five countries covered by our survey.

About 15 minutes into the lesson nearly all teachers (99%) were explaining the mathematical concept by writing on the chalkboard and talking to their pupils. About a half (52%) were using some form of TLM to aid their explanation. In addition, all teachers (100%) were asking pupils questions and listening to their oral responses. At this time, the majority of pupils were engaged in teacher-led question/answer activities. Individual answering (92% of cases) coupled with whole-class answering in chorus (78%) were prevalent but it was also very common (72% of cases) for pupils to be invited to the board to answer a question whilst the rest of the class watched. Pair or group work was never observed and even individual work on problem solving was relatively rare (36%). Our observers reported that nearly all teachers (92%) were involved in "disciplining" pupils but given that pupil misbehaviour was, to all intents and purposes, never observed this probably refers to 'strict control' rather than punitive action.

About halfway through the lesson, most teachers (-90%) were still using the chalkboard and questioning their pupils. However, about three-quarters (74%) were also setting tasks for their pupils to solve. Once again "disciplining students" was reported in nearly all classrooms suggesting that teachers in DRC adopt an authoritative approach to classroom control.

At the end of the lesson, nearly all teachers (96%) summarised the contents of the lesson. About a half (56%) set their pupils a task to be done as homework. According to our observers, the vast majority of lessons (-80%) had "a clear and orderly end".

The overall impression was generally favourable. The vast majority of teachers (96%) appeared to understand the concept they were teaching and were able to explain it to their classes with a significant number (50%) incorporating at least one 'real life' example. However, our observers believe that they detected mathematical errors or points which the teacher could not explain adequately in about a quarter of the lessons observed (24%). Notwithstanding this, observers considered that in nearly all lessons (-90%) the majority of students not only appeared to understand what had been taught but had also enjoyed the lesson.

85. In the remaining classrooms, observers could not be sure whether children had access to textbooks or not.

A.3.2 Secondary mathematics 'lesson signature' (grades 9 and 11)

This description is based on 20 classroom observations made in 10 schools.

Typically, a single mathematics lessons lasted for between 45 and 50 minutes. On average, 34 students were present but the number varied significantly from a class where just seven children attended to one in which there were 68 pupils. Somewhat surprisingly for secondary phase classes, the physical conditions for pupils were not good. In only about 60% of cases did all pupils have chairs or benches to sit on and a hard surface on which to write. In about three-quarters of classrooms, the lighting, temperature and ventilation were considered as adequate but only 25% of classrooms were described as being bright and cheerful learning environments. Chalkboards were available in all classrooms (100%) and 75% of teachers had their own copy of the textbook. Basic TLMs were available in a minority of classrooms (15%-30%) but none (0%) of the classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. Nearly all pupils had writing materials but in 80% of classrooms textbooks were either not available or in short supply. In only 10% of classrooms did all students have a textbook. The majority of teachers (75%) did have a copy of the textbook.

The start of each lesson was orderly and well structured. All teachers referred back to the previous lesson and nearly all (90%) gave a clear description of what the lesson was to be about. In half the lessons (50%) homework was returned to pupils and/or discussed.
About 15 minutes into the lesson the vast majority of teachers (95%) were explaining the mathematical concept of interest by writing on the chalkboard and lecturing to their pupils. In addition, they were asking pupils questions and listening to their oral responses. As in the primary lessons, our observers noted the strict approach of teachers with "disciplining students" being recorded in 85% of cases even though student misbehaviour was extremely rare. At this time, the majority of pupils (85% of cases) were orally answering questions asked by the teacher and/or attempting to solve mathematical problems in their exercise books (50% of cases). Pair or group work was never observed.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (95%) still using the chalkboard to explain the concept of interest and questioning pupils to judge their understanding. The pupils were copying from the chalkboard (100% of cases) and/or answering questions orally (85%). Somewhat surprisingly, "answering in unison" was observed in a significant number of classes (40%). On only one occasion were students seen to be working in pairs or groups.

At the end of the lesson, about three-quarters of the teachers summarised the contents of the lesson (80%) and set a homework task (75%). In about two-thirds of cases (65%) the lesson had, according to observers, "a clear and orderly end".

The overall impression was relatively good. Nearly all teachers (95%) appeared to understand the concept they were teaching and our observers detected very few mathematical errors or problems in the teacher's explanation. In addition, they judged that students appeared to understand what had been taught in more than three-quarters (80%) of the lessons observed.

A.3.3 Teacher characteristics and attitudes

In DRC, attitudinal questionnaires were completed by 52 teachers teaching at the primary level and 18 teaching mathematics at the secondary level. The vast majority (84%) of the teachers in our survey fell into the age range 30-59 years old. They were also relatively experienced with the majority (97%) having at least three years' teaching experience. However, their educational experience prior to taking up training was, by the standards observed in other countries in our study, extremely limited. More than half (57%) reported having completed primary school only with a further 20% not studying beyond the junior secondary level or its equivalent. Only a small minority (7%) had a post-secondary qualification before training to become teachers.

At the primary level only a very small minority of our teachers (6%) are teaching in their mother tongue. However, nearly all (92%) claim to be fluent in the language of instruction. About 40% of primary teachers report that their pupils face some difficulties due to the language of instruction with almost one in five (17%) teaching in more than one language to help their pupils. At the secondary level, 94% of teachers in our sample are teaching in a language which is not their mother tongue but all claim to be fluent in the language of instruction.

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. Nearly one-fifth (19%) do not have a mobile phone – a larger proportion than reported in the other countries in our survey. Just over half (51%) of our teachers have phones without internet access with the remainder (30%) having smart phone with internet. Ownership of a PC, laptop or tablet computer was extremely rare (~9%) with only four of our teachers having a computer with internet access. The vast majority (79%) admitted that they could not use a computer with a further 16% operating at the level of a beginner with limited skills.

The primary school teachers in the survey reported, with very few exceptions, that they were very well prepared, or at least partially prepared, to teach all the required concepts of the basic mathematics curriculum. Not surprisingly, the vast majority (~90%) of mathematics specialists teaching at the secondary level reported that they were very well prepared to teach any of the concepts required by the curriculum.

When asked about the value of group work and/or pair work in the classroom, 81% of teachers agreed that this was "very important". This is in stark contrast to the practices observed in the classroom where any form of collaborative learning was extremely rare. Of all the teaching practices included in the teacher questionnaire the two that were considered most important were "homework assignments" and "doing quizzes, tests and examinations in school" with 96% of teachers rating these as being "very important".

Prior to teaching, the majority of our primary teachers (65%) had completed a three-year teacher training programme. However, a sizeable minority (23%) reported that they had received no pre-service training. A similar pattern emerged amongst secondary teachers with 56% having had three or more years of initial teacher training and 33% having had none.

In general, the teachers in our sample who had received formal training displayed positive attitudes towards their pre-service training with

60% agreeing or strongly agreeing with statements such as: “My own mathematical skills improved a lot as a result of my training”; “My pre-service training left me well prepared to teach mathematics”; and, “I enjoyed my pre-service training”. In terms of content, 43% agreed with the statement “nearly all my pre-service training was about improving my mathematical skills”. In addition, a third (31%) agreed that in their pre-service training they “did not get enough practice teaching mathematics in the classroom”.

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, whilst there is consensus that “mathematical skills are useful for everyone” there is a divergence of opinion over what it takes to be successful in mathematics. For example, 45% of teachers do not agree that “everyone has the potential to be good at mathematics” and a staggering 91% agree that “you have to have the right sort of brain to be good at mathematics”. Secondly, whilst teachers are very positive about their students’ attitude towards mathematics and their progress, nearly three-quarters (71%) agree that “most pupils need additional tutoring”. This may be because a similar proportion (74%) feels that the mathematics curriculum is too difficult for their pupils. Thirdly, 78% believe that more in-service support is required if student achievement is to be enhanced. Finally, in DRC opinion appears to be divided on the likely impact on mathematics achievement of introducing new educational technologies. This may well reflect our teachers’ lack of confidence in their own computing skills.

Table A.5: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	35 (43.8%)	26 (32.5%)	4 (5.0%)	5 (6.3%)	0 (0.0%)
Everyone has the potential to be good at mathematics.	15 (18.8%)	15 (18.8%)	4 (5.0%)	25 (31.3%)	11 (13.8%)
You have to have the right sort of brain to be good at mathematics.	29 (36.3%)	36 (45.0%)	0 (0.0%)	3 (3.8%)	2 (2.5%)
Very few pupils are naturally good at mathematics.	6 (7.5%)	33 (41.3%)	3 (3.8%)	27 (33.8%)	1 (1.3%)
The current curriculum for mathematics is too difficult for my students.	19 (23.8%)	40 (50.0%)	7 (8.8%)	4 (5.0%)	0 (0.0%)
My pupils are making good progress in mathematics.	21 (26.3%)	46 (57.5%)	1 (1.3%)	2 (2.5%)	0 (0.0%)
Students seem to be interested in learning mathematics.	17 (21.3%)	44 (55.0%)	3 (3.8%)	5 (6.3%)	0 (0.0%)
Most pupils need additional tutoring in mathematics.	24 (30.0%)	33 (41.3%)	2 (2.5%)	11 (13.8%)	0 (0.0%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	8 (10.0%)	15 (18.8%)	2 (2.5%)	33 (41.3%)	12 (15.0%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	1 (1.3%)	5 (6.3%)	2 (2.5%)	45 (56.3%)	17 (21.3%)
I have enough time to teach everything in the mathematics curriculum.	23 (28.8%)	33 (41.3%)	1 (1.3%)	13 (16.3%)	0 (0.0%)
Teachers need more in-service support to improve the teaching of mathematics in our schools.	33 (41.3%)	29 (36.3%)	2 (2.5%)	5 (6.3%)	1 (1.3%)
I regularly exchange ideas on how to teach mathematics with my fellow teachers.	46 (57.5%)	21 (26.3%)	1 (1.3%)	1 (1.3%)	0 (0.0%)
Using computers and other new technologies in the classroom will improve results in mathematics	26 (32.5%)	9 (11.3%)	9 (11.3%)	3 (3.8%)	23 (28.8%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree.
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. ‘missing’ responses).

A.3.4 Teacher Training Institutions

In DRC, questionnaires were completed by representatives of three institutions for teacher training all of which are government institutions subordinated to the Ministry of Education. Of these, two prepare teachers for the primary/ junior secondary phase only, and one prepares teachers for the secondary phase. The institutions offer training for, on average, 1,200 trainees per year. The minimum qualification required for tutors is a first degree. Two colleges reported that their tutors are required to have some prior teaching experience but one allows for the appointment of tutors from a non-teaching route.

The colleges reported that trainee primary school teachers are typically aged 20-23 on admission. The minimum entry requirement is a qualification gained after 13 years of education (i.e. equivalent to A-level). In all cases a pass in mathematics is said to be required. Two colleges said that they were undersubscribed for the current academic year and that it was difficult to attract sufficient applicants. The other college said that supply and demand were roughly balanced. All colleges agreed with the statement "we face problems attracting high quality applicants to train as teachers".

During the initial three-year teacher training programme for primary school teachers, up to four hours per week only are dedicated to the subject of mathematics. Trainees undergo a short practicum (between two to four weeks) in each of the first two years and a longer practicum (between 8-12 weeks) in the third year. In all colleges, trainees are required to pass examinations at the end of their first year. The reported failure rate at this point was between 10-16%. All respondents agreed with the statement "ideally our trainees should spend more time practising in schools before they qualify".

The colleges in our study reported significant deficiencies in terms of educational technologies. Two stated that video material for teaching/learning mathematics, computers and teaching/learning software are simply not available. The other reported having some resources but that these were not for use by trainees. All colleges in our sample volunteered that they do not have adequate technical resources to teach their trainees how to use educational software in the classroom and that they do not use technology to a significant extent in their training.

A.4 Case study: Ethiopia

Table A.6: Ethiopia: Country key facts

Indicator	Value	Year
Size (area):	1,000,000 km2	
Population:	96.96 million	2014
Urban population growth (annual %)	4.8%	2014
GDP (current USD):	USD 54.80 billion	2014
GDP growth (annual %)	9.9%	2014
GDP per capita (current USD)	USD 565.2	2014
Expenditure on education as a % of GDP	4.7%	2010
Expenditure on education as a % of total government expenditure	22%	2010
Government expenditure per primary pupil (USD)	USD 72.0	2010
Mobile cellular subscriptions (per 100 people)	32	2014
Internet users (per 100 people)	3	2014
Structure of education system (years primary + lower secondary + upper secondary)	8 + 2 +2	
School enrolment, pre-primary (% gross)	2%	2006
School enrolment, primary (% gross)	84%	2006
Primary completion rate, total (% of relevant age group)	47%	2006
School enrolment, secondary (% gross)	29%	2006
Ratio of girls to boys in primary and secondary education (%)	81%	2006
Pupil:teacher ratio in primary education (headcount)	53.7	2012
Pupil:teacher ratio in secondary education (headcount)	38.8	2012
Average number of pupils per mathematics textbook in primary education	1	2012

A.4.1 Primary mathematics 'lesson signature' (Grades 3 and 6)

This description is based on 50 classroom observations made in 25 schools.

Typically, the mathematics lessons observed lasted for between 35 and 40 minutes. On average, 43 students were in attendance but the number varied dramatically from just 8 to 78! In the vast majority of cases (>90%) children had chairs or benches to sit on and a hard surface on which to write. In general the lighting and temperature were described as satisfactory but ventilation was inadequate in one-third of classrooms and less than half

(42%) were described as "cheerful and bright environments decorated with wall charts etc". Compared with some of the other countries in this study the physical equipment in classrooms was relatively poor. For example one third of classrooms observed did not have a chalkboard or its equivalent, drawing instruments for the board were not seen, and concrete teaching aids and models were not available for teachers to use. About half (52%) of teachers had their own textbook. None of the primary classrooms observed was equipped with any form of educational technology. The vast majority of students (-90%) had a pencil/pen and an exercise book and in 60% of classrooms all, or nearly all, of the students had a mathematics textbook.

The start of each lesson was, in general, orderly and well structured. Nearly all teachers (- 90%) made some reference back to a previous lesson and/or handed back, or talked about, pupils' homework (54%). The vast majority of teachers (96%) started by giving a clear description of what the lesson was to be about.

About 15 minutes into the lesson the majority of teachers (>90%) were at the chalkboard, explaining the mathematical concept of interest by talking to their pupils (i.e. lecturing) and asking pupils questions and listening to their oral responses (94%). At this time, nearly all pupils (92% of cases) were orally answering questions asked by the teacher and, in about two-thirds of cases (66%), reciting their answers in unison. There was, however, some variation and in about half of classrooms there was some evidence of collaborative work between pairs or small groups of pupils.

About halfway through the lesson, the pattern of teaching remained largely unchanged with most teachers still using the chalkboard (86%) and lecturing (78%). Pupils were still answering teachers' questions (86%) and our observers reported seeing 'rote' responses in nearly two-thirds (64%) of cases. However, around this time pupils were also solving mathematical problems in their exercise books. It was extremely rare (6%) to see students handling any form of physical teacher/learning material.

In contrast with some of the other countries in this study, our observers considered that teachers spent considerable time "disciplining students". However, it is not clear what this means because significant misbehaviour was seen rarely. It is possible that teachers in Ethiopia adopt a more authoritative stance than their counterparts in other countries.

At the end of the lesson, the majority of teachers (> 80%) ensure a quiet and orderly end to the lesson. However, only half (54%) explicitly summarised the contents of the lesson.

The overall impression was that the vast majority of teachers (92%) appeared to understand the concept they were teaching and were able to explain it to their classes. However, most relied on the textbook as their main teaching aid and only a quarter (28%) used real-life examples when explaining the topic. The observers considered that in about three-quarters of the lessons (80%) the majority of students appear to understand what had been taught. Notwithstanding the apparently strict control exercised by teachers, the majority of students also appeared to have enjoyed the lesson.

A.4.2 Secondary mathematics 'lesson signature' (Grades 9, 10 and 11)

This description is based on 20 classroom observations made in 10 schools.

Typically, a single mathematics lesson lasted for about 40 minutes. On average, 43 students attended the lesson. In all cases pupils had chairs or benches to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were adequate and the majority of classrooms (70%) were described by observers as being bright and cheerful learning environments. As in the primary phase classrooms, physical equipment was relatively limited. For example 25% of classrooms observed did not have a chalkboard or its equivalent, drawing instruments for the board were not seen, and concrete teaching aids and models were not available for teachers to use. The textbook was, to all intents and purposes, the only TLM available to teachers and pupils. About half (55%) of teachers used the textbook as a teaching aid and in 50% of classrooms all, or nearly all, of the students had a mathematics textbook. Televisions were available in a significant number of classrooms but other forms of educational technology were extremely rare. On the positive side, the only overhead projector seen by observers was used by the teacher!

The start of each lesson was, in general, orderly with nearly all (95%) teachers giving a clear description of what the lesson was to be about. The majority (80%) of teachers explicitly referred back to the previous lesson and a third (35%) handed back, or talked about, pupils' homework.

About 15 minutes into the lesson the vast majority of teachers were explaining the mathematical concept of interest by writing on the chalkboard and lecturing to their pupils. Very few (15%) used a concrete model or other TLM to support their explanation. In addition, they were asking pupils questions and listening to their oral responses. In addition, it was common (80%) to see teachers setting a mathematical problem for pupils to solve. At this time, the majority of pupils (85% of cases) were orally answering questions asked by the teacher with a significant incidence of 'rote' responses (60%). However, it was also common to see pupils "doing mathematics items in their exercise books" (80% of cases) with pair or small group working seen in about half of the observed lessons.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (>90%) still lecturing from the front of the class and questioning pupils to judge their understanding. Copying from the board, responding to the teacher's questions and attempting to solve problems in their exercise books were the most common pupil activities observed.

At the end of the lesson, two-thirds of the teachers (65%) summarised the contents of the lesson and a similar proportion set a homework task. In general, the vast majority of teachers (90%) ensured that the lesson came to "a clear and orderly end".

According to our observers, nearly all teachers (-90%) appeared to understand fully the concept they were teaching and in only one case was a possible mathematical error or a problem in the teacher's explanation detected.

A.4.3 Teacher characteristics and attitudes

In Ethiopia, attitudinal questionnaires were completed by 48 teachers teaching at the primary level and 20 teaching mathematics at the secondary level. The group displayed a very wide range of ages with teachers distributed in age groups of under 25 years to more than 60. Nearly two-thirds (65%) of our teachers reported having at least six years' teaching experience. Prior to embarking on their pre-service training, 31% had studied only up to the end of junior secondary school. The largest group (41%) had completed senior secondary school before training. Of the secondary school teachers nearly half (44%) had gained a degree level qualification.

At the primary level nearly three-quarters (71%) of our teachers are teaching in their mother tongue and nearly all (96%) claim to be fluent in the language of instruction. Unlike the findings in other countries, the vast majority of primary teachers in our sample (84%) claim that students have no or few problems understanding the language in which lessons are presented. At the secondary level, the picture is markedly different. Only 10% of teachers in our sample are teaching in their mother tongue with a significant number (30%) admitting that they have at least some difficulty in the language of instruction. When it comes to their pupils, 70% suggest that their students encounter at least some difficulties in understanding the language of instruction with half of these using code switching to help their students. This reflects the educational language policy of Ethiopia where after Grade 6 the language of instruction in many administrative areas switches to English (Vujchic, 2013).

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. Nearly all (91%) reported having a mobile phone and, of these, 62% have phones with internet access. None of our teachers reported owning a PC, laptop or tablet computer with internet access. A large majority (82%) admitted that they either could not use a computer or that they considered themselves to be beginners with limited skills.

The primary school teachers in the survey reported, with very few exceptions, that they were very well prepared, or at least somewhat prepared, to teach the required concepts of the basic mathematics curriculum. Not surprisingly, the majority (>75%) of mathematics specialists teaching at the secondary level reported that they were 'very well prepared' to teach any of the concepts required by the curriculum.

When asked about the value of group work and/or pair work in the classroom, there was almost unanimous agreement (97%) that this was "very important". Similarly, the use of concrete practical equipment in the teaching/learning of mathematics was considered to be very important by 76% of teachers. It is interesting to contrast what teachers say is important with what they do in practice as described in the lesson signatures above. There was also near unanimous support for assigning homework and "doing quizzes, tests and examinations in schools".

The majority (61%) of our secondary teachers had at least three years of pre-service training but, somewhat surprisingly, the rest (39%) reported having received initial training amounting to less than one year.

Both primary and secondary school teachers in our sample displayed very positive attitudes towards their pre-service training with about three-quarters (70 - 74%) agreeing or strongly agreeing with statements such as: "My own mathematical skills improved a lot as a result of my training" and "My pre-service training left me well prepared to teach mathematics". However, 71% also agreed with the statement "nearly all my pre-service training was about improving my mathematical skills". There was slightly less agreement when it came to practice in the classroom with 41% of our teachers agreeing they "did not get enough practice teaching mathematics in the classroom" in their pre-service training.

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, and unsurprisingly, there is a great deal of consensus that "mathematical skills are useful for everyone". However, opinion is divided when it comes to students' capacities to be successful in mathematics. For example, nearly one-quarter (24%) disagree to some extent with the statement "everyone has the potential to be good at mathematics". Similarly, 80% think that "you have to have the right sort of brain to be good at mathematics" and 72% agree that "very few pupils are naturally good at mathematics". Secondly, whilst most teachers are positive about their students' attitude towards mathematics and their progress, nearly everyone (94%) agrees that "most pupils need additional tutoring". Thirdly, nearly all mathematics teachers (94%) believe that more in-service support is required if student achievement is to be enhanced. Finally, these teachers in Ethiopia are convinced that computers and other educational technologies will help to improve results in mathematics. However, it should be remembered that this particular group of teachers admit to having weak technological skill so this begs the question 'who will be able to use these new technologies?'

Table A.7: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	53 (75.7%)	13 (18.6%)	2 (2.9%)	1 (1.4%)	0 (0.0%)
Everyone has the potential to be good at mathematics.	18 (25.7%)	26 (37.1%)	8 (11.4%)	13 (18.6%)	4 (5.7%)
You have to have the right sort of brain to be good at mathematics.	41 (58.6%)	15 (21.4%)	4 (5.7%)	6 (8.6%)	4 (5.7%)
Very few pupils are naturally good at mathematics.	20 (28.6%)	30 (42.9%)	3 (4.3%)	10 (14.3%)	3 (4.3%)
The current curriculum for mathematics is too difficult for my students.	9 (12.9%)	16 (22.9%)	4 (5.7%)	26 (37.1%)	12 (17.1%)
My pupils are making good progress in mathematics.	12 (17.1%)	34 (48.6%)	9 (12.9%)	10 (14.3%)	2 (2.9%)
Students seem to be interested in learning mathematics.	23 (32.9%)	25 (35.7%)	4 (5.7%)	12 (17.1%)	6 (8.6%)
Most pupils need additional tutoring in mathematics.	34 (48.6%)	32 (45.7%)	3 (4.3%)	1 (1.4%)	0 (0.0%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	14 (20.0%)	18 (25.7%)	4 (5.7%)	22 (31.4%)	10 (14.3%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	4 (5.7%)	19 (27.1%)	5 (7.1%)	27 (38.6%)	14 (20.0%)
I have enough time to teach everything in the mathematics curriculum.	19 (27.1%)	22 (31.4%)	1 (1.4%)	22 (31.4%)	4 (5.7%)
Teachers need more in-service support to improve the teaching of mathematics in our schools.	44 (62.9%)	22 (31.4%)	3 (4.3%)	1 (1.4%)	0 (0.0%)
I regularly exchange ideas on how to teach mathematics with my fellow teachers.	27 (38.6%)	34 (48.6%)	2 (2.9%)	3 (4.3%)	4 (5.7%)
Using computers and other new technologies in the classroom will improve results in mathematics	36 (51.4%)	23 (32.9%)	2 (2.9%)	4 (5.7%)	5 (7.1%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree.
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. 'missing' responses).

A.4.4 Teacher Training Institutions

In Ethiopia, questionnaires were completed by representatives of three institutions for teacher training – two preparing teachers for the primary/junior secondary phase only, and the smallest one preparing teachers for the senior secondary phase. In addition, all three institutions offer in-service courses. The institutions offer training for between 820 and 4500 trainees in total with an average of 1100 trainees in their first year. The largest of them employs about 185 tutors. Relatively few (up to 12) of these are specialists in mathematics and/or mathematics education. The minimum qualification required for tutors is a first degree. The colleges preparing primary teachers require their tutors to have some teaching experience at the primary level. The other college also requires its tutors to have prior teaching experience. All three colleges said that their tutors are required to participate in some form of continuous professional development but none requires its tutors to periodically refresh their skills in a school environment or to undergo any form of periodic appraisal.

During the initial three-year teacher training programme for primary school teachers, three to four hours per week are dedicated to the subject of mathematics. In all colleges, trainees are required to pass examinations at the end of their first year but the reported failure rates were extremely low (-3%). Whilst acknowledging that our sample is small and probably not representative, the responses to the attitudinal part of the questionnaire were not encouraging. None agreed that "teaching in primary schools is a highly respected profession" and all agreed that they faced difficulties in "attracting high quality applicants to train as teachers".

The three colleges in our study reported significant deficiencies in terms of educational technologies. They all admitted that they do not use technological aids (video, broadcast material, etc) extensively in their training. Only one reported having a library of video material for teaching/learning mathematics for use by trainees. All said that they have at least some computers with internet access but that these are rarely used by trainees. None reported having any specialist software available for teaching mathematics.

A.5 Case study: Nigeria

Table A.8: Nigeria: Country key facts

Indicator	Value	Year
Size (area):	910,770 km2	
Population:	177.48 million	2014
Urban population growth (annual %)	4.5%	2014
GDP (current USD):	USD 568.5 billion	2014
GDP growth (annual %)	6.3%	2014
GDP per capita (current USD)	USD 3,203.3	2014
Expenditure on education as a % of GDP	n.a.	
Expenditure on education as a % of total government expenditure	n.a.	
Government expenditure per primary pupil (USD)	n.a.	
Mobile cellular subscriptions (per 100 people)	78	2014
Internet users (per 100 people)	43	2014
Structure of education system (years primary + lower secondary + upper secondary)	6 + 3 + 3	
School enrolment, pre-primary (% gross)	13%	2010
School enrolment, primary (% gross)	85%	2010
Primary completion rate, total (% of relevant age group)	76%	2010
School enrolment, secondary (% gross)	44%	2010
Ratio of girls to boys in primary and secondary education (%)	91%	2010
Pupil:teacher ratio in primary education (headcount)	37.6	2010
Pupil:teacher ratio in secondary education (headcount)	33.1	2010
Average number of pupils per mathematics textbook in primary education	n.a.	

A.5.1 Primary mathematics 'lesson signature' (Grades 3 and 6)

This description is based on 50 classroom observations made in 25 schools.

Typically, the mathematics lessons observed lasted for between 35 and 40 minutes. On average, 39 students were on the class register.

In nearly all cases (96%) children had chairs or benches to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were adequate and the vast majority of classrooms (84%) were described as "cheerful and bright environments decorated with wall charts, etc". Chalkboards were available and used in nearly all classrooms (98%) and the majority of teachers (82%) had their own copy of the textbook. In about a third of cases (34-40%) measuring instruments and concrete teaching aids for mathematics were available. Very few classrooms (-5%) were equipped with any form of educational technology. However, in the rare cases where an overhead projector or computer with projector were available, the teachers used them! Nearly all pupils (-95%) had a pencil/pen and an exercise book. In nearly all cases, at least some of the pupils had a mathematics textbook. In more than half (54%) most, if not all, had a textbook.

The start of each lesson was orderly and well structured. Nearly all teachers (> 94%) referred back to the previous lesson with a significant number (48%) handing back, or talking about, pupils' homework. The vast majority of teachers (-90%) started by giving a clear description of what the lesson was to be about.

About 15 minutes into the lesson the majority of teachers (-90%) were explaining the mathematical concept of interest by talking to their pupils (i.e. lecturing) and by writing on the chalkboard. 40% were using some form of TLM to aid their explanation. In addition, they were asking pupils questions and listening to their oral responses (76%). At this time, the majority of pupils (86% of cases) were orally answering questions asked by the teacher and, in about half of cases (48%), reciting their answers in unison. It was also very common (-80% of cases) for pupils to be invited to the board to answer a question whilst the rest of the class watched. It was rare (<15% of cases) to find pupils working in pairs or groups. At this stage of the lesson, we observed very few cases where students were disrupting the lesson to any significant extent.

About halfway through the lesson, most teachers (-80%) were still using the chalkboard and lecturing. However, most students (-80 of cases) were copying problems from the chalkboard and solving them in their exercise books. Pair and group work was still rare. Once again, we observed no significant bad behaviour or inattention.

At the end of the lesson, two-thirds of the teachers (68%) summarised the contents of the lesson and the majority (82%) set a homework task. In general, the end of the lesson was as orderly as the beginning with, according to observers, 88% having "a clear and orderly end".

The overall impression was generally favourable. The vast majority of teachers (92%) appeared to understand the concept they were teaching and were able to explain it to their classes with a significant number (42%) incorporating at least one 'real life' example. However, our observers believe that they detected mathematical errors or points which the teacher could not explain adequately in about a quarter of the lessons observed (24%). Notwithstanding this, observers considered that in about three-quarters of the lessons the majority of students not only understood what had been taught but had also enjoyed the lesson.

A.5.2 Secondary mathematics 'lesson signature' (Grades 9, 10 and 11)

This description is based on 20 classroom observations made in 10 schools.

Typically, a single mathematics lessons lasted for about 40 minutes. On average, 45 students were on the class register with 42 attending the lesson. In all cases pupils had chairs or benches to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were adequate and the majority of classrooms (85%) were described by observers as being bright and cheerful learning environments. Chalkboards together with suitable drawing instruments were available in all classrooms (100%). 80% of teachers had their own copy of the textbook even though only half used them during the lesson. In more than 60% of classrooms, concrete teaching aids and other TLMs for Mathematics were available (note, however, that only one-third of teachers used them). However, no (0%) classroom was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. All, or nearly all, pupils had writing materials. In all of the classrooms observed, at least some pupils had a Mathematics textbook and in 70% of cases all, or nearly all, had a textbook. In three-quarters of classrooms at least some pupils had calculators.

The start of each lesson was, in general, orderly with all (100%) teachers giving a clear description of what the lesson was to be about. All teachers explicitly referred back to the previous lesson and a large number (70%) handed back, or talked about, pupils' homework.

About 15 minutes into the lesson the vast majority of teachers were explaining the mathematical concept of interest by writing on the chalkboard and lecturing to their pupils. About half (55%) used a concrete model or other TLM to support their explanation. In addition, they were asking pupils questions and listening to their oral responses. At this time, the majority of pupils (95% of cases) were orally answering questions asked by the teacher and/or watching as others answered at the blackboard (80%). Answering in chorus was rarely observed during lessons at the secondary level. It was rare (-15% of cases) to find pupils working in pairs or groups, or handling/using teaching and learning materials.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (-90%) still using the chalkboard to explain the concept of interest and questioning pupils to judge their understanding. The vast majority of pupils were copying from the chalkboard (95% of cases) and/or attempting to solve problems in their exercise books (95%). It was rare (10% of cases) to find students working in pairs or groups.

At the end of the lesson, nearly three-quarters of the teachers (70%) summarised the contents of the lesson and all (100%) set a homework task. In general, the end of the lesson was orderly with 85% having, according to observers, "a clear and orderly end".

The overall impression was somewhat mixed. Nearly all teachers (95%) appeared to understand the concept they were teaching but, in about one-third of cases (35%-45%), our observers believed that they detected a mathematical error or a problem in the teacher's explanation. In addition, they judged that students appeared to understand what had been taught only in half (55%) of the lessons observed.

A.5.3 Teacher characteristics and attitudes

In Nigeria, attitudinal questionnaires were completed by 40 teachers teaching at the primary level and 30 teaching mathematics at the senior secondary level. Most of the teachers interviewed were more than 30 years old and were relatively experienced with the majority

(96%) having at least five years' teaching experience. Prior to embarking on their pre-service training, 38% had studied up to the end of senior secondary school, 28% had completed A-levels and 30% had gained a first degree. Of the secondary school teachers nearly half (47%) had gained a degree level qualification.

At the primary level only a very small minority of our teachers (8%) are teaching in their mother tongue. Most (80%) claim to be fluent in the language of instruction but a significant minority (12%) report that they themselves have some difficulty in the language in which they have to teach. About 40% of primary teachers report that their pupils face difficulties due to the language of instruction. At the secondary level, 86% of teachers in our sample are teaching in a language which is not their mother tongue but, with few exceptions, they claim to be fluent in the language of instruction.

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. All reported having a mobile phone and, of these, 60% have smart phones with internet access. One-fifth (21%) reported owning a PC, laptop or tablet computer with internet access. Perhaps surprisingly, a large majority (80%) admitted that they either could not use a computer or that they considered themselves to be beginners with limited skills.

The primary school teachers in the survey reported, with very few exceptions, that they were very well prepared, or at least partially prepared, to teach the required concepts of the basic mathematics curriculum. Not surprisingly, the vast majority (-90%) of mathematics specialists teaching at the secondary level reported that they were very well prepared to teach any of the concepts required by the curriculum.

When asked about the value of group work and/or pair work in the classroom, there was almost unanimous agreement that this was "very important". Similarly, the use of concrete practical equipment in the teaching/learning of mathematics was considered to be very important by 96% of teachers. It is interesting to contrast what teachers say is important with what they do in practice as described in the lesson signatures above.

Prior to teaching, the majority of our primary teachers (66%) completed a three-year teacher training programme with a further 18% having followed a two-year course. The vast majority (80%) of our secondary teachers had three or more years of initial teacher training.

Both primary and secondary school teachers in our sample displayed very positive attitudes towards their pre-service training with typically -90% agreeing or strongly agreeing with statements such as: "My own mathematical skills improved a lot as a result of my training"; "My pre-service training left me well prepared to teach mathematics"; and, "I enjoyed my pre-service training". However, 80% also agreed with the statement "nearly all my pre-service training was about improving my mathematical skills". There was slightly less agreement when it came to practice in the classroom. More than a third of our teachers (39%) agreed that in their pre-service training they "did not get enough practice teaching mathematics in the classroom".

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, it is interesting to note that whilst there is a great deal of consensus that, for example, "everyone has the potential to be good at mathematics", there is an equally strong feeling that "very few pupils are naturally good at mathematics". Secondly, whilst teachers are very positive about their students' attitude towards mathematics and their progress, nearly everyone agrees that "most pupils need additional tutoring". Thirdly, most teachers obviously feel under pressure to cover the syllabus and a significant minority (34%) feel that they do not have enough time to cover the curriculum and sometimes have to move on before their pupils have mastered the current topic. Fourthly, nearly all mathematics teachers (96%) believe that more in-service support is required if student achievement is to be enhanced. Finally, these teachers in Nigeria are confident that computers and other educational technologies will help to improve results in mathematics. This feeling appears to be stronger than in other, perhaps poorer, countries where teachers have less faith in technology.

Table A.9: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	49 (70%)	19 (27.1%)	1 (1.4%)	0 (0%)	0 (0%)
Everyone has the potential to be good at mathematics.	22 (31.4%)	29 (41.4%)	11 (15.7%)	8 (11.4%)	0 (0%)
You have to have the right sort of brain to be good at mathematics.	22 (31.4%)	27 (38.6%)	10 (14.3%)	7 (10%)	4 (5.7%)
Very few pupils are naturally good at mathematics.	22 (31.4%)	32 (45.7%)	4 (5.7%)	10 (14.3%)	2 (2.9%)
The current curriculum for mathematics is too difficult for my students.	2 (2.9%)	10 (14.3%)	9 (12.9%)	32 (45.7%)	17 (24.3%)
My pupils are making good progress in mathematics.	20 (28.6%)	44 (62.9%)	6 (8.6%)	0 (0%)	0 (0%)
Students seem to be interested in learning mathematics.	6 (8.6%)	27 (38.6%)	20 (28.6%)	17 (24.3%)	0 (0%)
Most pupils need additional tutoring in mathematics.	31 (44.3%)	34 (48.6%)	1 (1.4%)	1 (1.4%)	1 (1.4%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	20 (28.6%)	29 (41.4%)	10 (14.3%)	9 (12.9%)	2 (2.9%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	5 (7.1%)	19 (27.1%)	11 (15.7%)	24 (34.3%)	11 (15.7%)
I have enough time to teach everything in the mathematics curriculum.	3 (4.3%)	14 (20%)	15 (21.4%)	29 (41.4%)	7 (10%)
Teachers need more in-service support to improve the teaching of mathematics in our schools.	46 (65.7%)	21 (30%)	2 (2.9%)	0 (0%)	0 (0%)
I regularly exchange ideas on how to teach mathematics with my fellow teachers.	27 (38.6%)	32 (45.7%)	8 (11.4%)	2 (2.9%)	1 (1.4%)
Using computers and other new technologies in the classroom will improve results in mathematics	37 (52.9%)	22 (31.4%)	5 (7.1%)	3 (4.3%)	3 (4.3%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree.
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. 'missing' responses).

A.5.4 Teacher Training Institutions

In Nigeria, questionnaires were completed by representatives of three institutions for teacher training – two preparing teachers for the primary/junior secondary phase only, and one preparing teachers for the secondary phase. In addition, all three institutions offer in-service courses. The institutions offer training for between 2,200 and 3,700 trainees in total with between 1,400 and 1,800 trainees in their first year. They employ between 115 and 380 tutors. Relatively few (between 8 and 15) of these are specialists in mathematics and/or mathematics education. The minimum qualification required for tutors is a first degree. The colleges preparing primary teachers require their tutors to have some teaching experience at the primary level. The other college also requires its tutors to have prior teaching experience. All three colleges said that their tutors are required to participate in some form of continuous professional development. No college requires its tutors to periodically refresh their skills in a school environment.

All colleges reported that trainee primary school teachers are typically aged 16-17 on admission. The minimum entry requirement is a qualification gained after four years of secondary education (i.e. equivalent to O-level). In all cases a pass in mathematics is required. All colleges reported being heavily oversubscribed in the current academic year with one saying that entry requirements have been raised in recent years.

During the initial three-year teacher training programme for primary school teachers, at least five hours per week are dedicated to the subject of mathematics. Two colleges admitted that the majority of this time (>66%) is dedicated to mathematical content rather than pedagogical methods whilst the other claimed that content and methodology were given equal weight. In all colleges, trainees are required to pass examinations at the end of their first year. Two colleges reported that at this point around 20% of students fail. All respondents agreed with the statement "when they start their courses most of our trainees have inadequate knowledge of the school mathematics curriculum".

The colleges in our study reported significant deficiencies in terms of educational technologies. None has a library of video material for teaching/learning Mathematics for use by trainees. Only one of the three reported having computers with internet access available for use by trainees. All colleges in our sample volunteered that they do not have adequate technical resources to teach their trainees how to use educational software in the classroom but that they do not use technology to a significant extent in their training.

A.6 Case study: Rwanda

Table A.10: Rwanda: Country key facts

Indicator	Value	Year
Size (area):	24,670 km2	
Population:	11.34 million	2014
Urban population growth (annual %)	5.9%	2014
GDP (current USD):	USD 7.89 billion	2014
GDP growth (annual %)	7%	2014
GDP per capita (current USD)	USD 695.7	2014
Expenditure on education as a % of GDP	5%	2014
Expenditure on education as a % of total government expenditure	16.6%	2013
Government expenditure per primary pupil (USD)	USD 45.5	2013
Mobile cellular subscriptions (per 100 people)	64	2014
Internet users (per 100 people)	11	2014
Structure of education system (years primary + lower secondary + upper secondary)	6 + 3 + 3	
School enrolment, pre-primary (% gross)	14%	2013
School enrolment, primary (% gross)	134%	2013
Primary completion rate, total (% of relevant age group)	59%	2013
School enrolment, secondary (% gross)	33%	2013
Ratio of girls to boys in primary and secondary education (%)	103%	2013
Pupil:teacher ratio in primary education (headcount)	59.8	2013
Pupil:teacher ratio in secondary education (headcount)	22.8	2013
Average number of pupils per mathematics textbook in primary education	1.4	2012

A.6.1 Primary mathematics 'lesson signature' (Grades 3 and 6)

This description is based on 53 classroom observations made in 25 schools.

Typically, the mathematics lessons observed lasted for 40 minutes. On average, 44 students were on the class register with 40 attending the lesson. In all cases (100%) children had chairs or benches to sit on and a hard surface on which to write. In general the lighting, temperature and ventilation were adequate but a quarter of classrooms (25%) were too crowded to allow easy movement. In addition only two-thirds (68%) were described as "cheerful and bright environments decorated with wall charts, etc". Chalkboards were available in all classrooms (100%) and nearly all teachers (93%) had their own copy of the textbook. In the majority of classrooms (>66%) concrete teaching aids for mathematics were not visible. To all intents and purposes, none of classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. In only one classroom was an overhead projector available but in that case the teacher did use it! All pupils (100%) had a pencil/pen and an exercise book. In the majority of classrooms (53%) all or most of the students had a mathematics textbook.

The start of each lesson was orderly and well structured. All teachers referred back to the previous lesson and the vast majority (> 94%) started by giving a clear description of what the lesson was to be about. In only 15% of cases did teachers hand back pupils' homework or talk about a homework task.

About 15 minutes into the lesson our observers noted a wide range of teacher and pupil activities (in sharp contrast with the observations made in, for example, Uganda). Whilst a majority of teachers were lecturing their pupils (53%) and writing on the chalkboard (66%), they were also setting tasks and moving around the classroom observing and/or helping pupils (55%). At this time, pupils (>53% of cases) were engaged in answering questions asked by the teacher and in many cases watching while a classmate answered a question on the board. Reciting answers in unison was not very common (21% of cases). It was rare (<20% of cases) to find pupils working in pairs or groups or handling/using teaching and learning materials. Pupil behaviour was good with no significant disruption of the lesson.

About halfway through the lesson, the teaching pattern in many cases was largely unchanged but there were exceptions. More cases of students solving problems in their exercise books were noted (55%) and in 38% of lessons students were working in pairs or groups. Once again, we observed no significant bad behaviour.

At the end of the lesson, three-quarters (75%) of the teachers summarised the contents of the lesson and 42% set a homework task. According to observers, the vast majority of lessons (85%) had "a clear and orderly end".

The overall impression was generally favourable. All teachers (100%) appeared to understand the concept they were teaching and were able to explain it to their classes. However, fewer than a half (40%) incorporated 'real life' examples in their teaching. Whilst these things are difficult to judge, observers considered that in nearly all lessons (>85%) the majority of students not only understood what had been taught but had also enjoyed the lesson.

A.6.2 Secondary mathematics 'lesson signature' (Grades 9 and 11)

This description is based on 19 classroom observations made in 10 schools.

Typically, the mathematics lessons observed lasted for 40 minutes but with some "double lessons" lasting for up to 100 minutes. On average, 34 students were on the class register with 31 attending the lesson. In practically all cases the learning environment was good with sufficient space, chairs and desks, lighting and ventilation. Three-quarters (74%) of classrooms were described by observers as being bright and cheerful learning environments. Chalkboards were universally available and almost all teachers (95%) had their own copy of the textbook. In a minority of classrooms (26% to 32%) some concrete teaching aids were visible. None (0%) of the classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. All pupils (100%) had writing materials. In almost half (47%) of the classrooms observed, all or most of the students present had a mathematics textbook. In over 40% of classrooms at least some pupils had calculators.

The start of each lesson was, in general, orderly with all (100%) teachers giving a clear description of what the lesson was to be about. The vast majority (79%) also referred back to the previous lesson or an earlier associated topic. It was relatively rare (16%) for teachers to be seen handing back homework or talking about it.

About 15 minutes into the lesson the vast majority of teachers were explaining the mathematical concept of interest by writing on the chalkboard (79%) and lecturing to their pupils (63%). In addition, they were asking pupils questions and listening to their oral responses. At this time, the majority of pupils (58% of cases) were copying from the chalkboard and/or orally answering questions asked by the teacher (63%). Answering by rote was rarely observed during lessons at the secondary level. In about a quarter (26%) of the cases observed there was some evidence of students working in pairs or small groups.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (68%) still using the chalkboard and lecturing to explain the concept of interest and/or set of problems for their pupils. Many pupils were still copying from the chalkboard (53% of cases) and/or attempting to solve problems in their exercise books (58% of cases). Pair or group work was observed in a significant number of classrooms (42% of cases).

At the end of the lesson, about three-quarters of the teachers (74%) summarised the contents of the lesson with about half (53%) setting a homework task. With very few exceptions, all lessons had, according to observers, "a clear and orderly end".

The overall impression was generally favourable. Nearly all teachers (90%) appeared to understand the concept they were teaching and were, in general, able to present it to their classes without any discernible errors. Only a minority (16%) used 'real life' examples in their teaching. Observers judged that in about 80% of lessons the majority of students not only appeared to understand what had been taught but also seemed to enjoy the lesson.

A.6.3 Teacher characteristics and attitudes

In Rwanda, attitudinal questionnaires were completed by 52 teachers teaching at the primary level and 18 teaching mathematics at the senior secondary level. Of the primary teachers, 39 (75%) were male and 13 (25%) were female. Of the secondary teachers, nine (50%) were male and nine (50%) were female. In both cases, there was a wide range of ages from under 25 to 59. In the case of primary teachers there was also a wide range in their pre-service educational experience. 13% had only completed primary education; 35% had completed junior secondary; 37% had completed senior secondary education. Somewhat surprisingly, the secondary school teachers in our sample also displayed a wide range of pre-service educational experience. Nine teachers (53%) reported that they had not gone beyond the junior secondary level. The teachers in our sample were relatively experienced with the majority (93%) having at least three years' teaching experience and 33% having more than 10 years.

At the primary level about a fifth (21%) of our teachers are teaching in their mother tongue. Most (65%) claim to be fluent in the language of instruction but a significant minority (35%) report that they themselves have some difficulty in the language in which they have to teach. About 40% of primary teachers report that their pupils face difficulties due to the language of instruction. At the secondary level, only a minority (17%) are teaching in their mother tongue. Of the rest, half claimed to be fluent in the language of instruction. However, 40% of teachers admitted that their command of the language of instruction presents them with some difficulties.

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. 99% reported having a mobile phone and 61% have smart phones with internet access. One-fifth (20%) said that they own a PC, laptop or tablet computer with internet access. A significant majority (67%) admitted that they either could not use a computer or that they considered themselves to be beginners with limited skills.

The primary school teachers in the survey, with very few exceptions, reported that they were very well prepared, or at least partially prepared, to teach the required concepts of the basic mathematics curriculum. Not surprisingly, the vast majority (-80%) of mathematics specialists teaching at the secondary level reported that they were very well prepared to teach any of the concepts required by the curriculum.

When asked about the value of group/pair work, and the use of practical equipment in the teaching/learning of mathematics, there was almost unanimous agreement that these aspects are "very important". Fewer teachers (39%) felt that pupils working alone to solve mathematical problems is "very important" with 15% suggesting that it is "not important". It is interesting to contrast what teachers say is important with what they do in practice as described in the lesson signatures above.

Prior to teaching, the majority of our primary teachers (75%) hsd completed a three-year teacher training programme. 78% of our secondary teachers had also followed a three-year programme.

Both primary and secondary school teachers in our sample displayed very positive attitudes towards their pre-service training with typically 80% agreeing or strongly agreeing with statements such as: "My own mathematical skills improved a lot as a result of my training"; "My pre-service training left me well prepared to teach mathematics"; and, "I enjoyed my pre-service training". However, about 70% also agreed with the statement "nearly all my pre-service training was about improving my mathematical skills". There was slightly less agreement when it came to practice in the classroom. About a quarter of our teachers (23%) agreed that in their pre-service training they "did not get enough practice teaching mathematics in the classroom".

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, it is interesting to note that whilst there is a great deal of consensus that "mathematical skills are useful for everyone" there is less agreement when it comes to questions concerning the potential/aptitude of learners. For example, 27% of the teachers in our sample do not agree with the statement "Everyone has the potential to be good at mathematics" and 69% seem to think that you need a special sort of brain to be good at mathematics. Secondly, whilst teachers are very positive about their students' attitude towards Mathematics and their progress, the majority (79%) agree that "most pupils need additional tutoring". Thirdly, most teachers obviously feel under pressure to cover the syllabus and nearly half (47%) say that they sometimes have to move on before their pupils have mastered the current topic. Fourthly, nearly all mathematics teachers (87%) believe that more in-service support is required if student achievement is to be enhanced.

Table A.11: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	46 (65.7%)	20 (28.6%)	1 (1.4%)	3 (4.3%)	0 (0%)
Everyone has the potential to be good at mathematics.	19 (27.1%)	19 (27.1%)	13 (18.6%)	19 (27.1%)	0 (0%)
You have to have the right sort of brain to be good at mathematics.	24 (34.3%)	24 (34.3%)	5 (7.1%)	8 (11.4%)	5 (7.1%)
Very few pupils are naturally good at mathematics.	19 (27.1%)	28 (40%)	4 (5.7%)	16 (22.9%)	2 (2.9%)
The current curriculum for mathematics is too difficult for my students.	7 (10%)	15 (21.4%)	16 (22.9%)	25 (35.7%)	7 (10%)
My pupils are making good progress in mathematics.	18 (25.7%)	48 (68.6%)	3 (4.3%)	0 (0%)	0 (0%)
Students seem to be interested in learning mathematics.	20 (28.6%)	40 (57.1%)	8 (11.4%)	2 (2.9%)	0 (0%)
Most pupils need additional tutoring in mathematics.	21 (30%)	34 (48.6%)	5 (7.1%)	7 (10%)	1 (1.4%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	22 (31.4%)	28 (40%)	4 (5.7%)	11 (15.7%)	4 (5.7%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	6 (8.6%)	27 (38.6%)	5 (7.1%)	21 (30%)	10 (14.3%)
I have enough time to teach everything in the mathematics curriculum.	8 (11.4%)	31 (44.3%)	5 (7.1%)	23 (32.9%)	2 (2.9%)
Teachers need more in-service support to improve the teaching of mathematics in our schools.	41 (58.6%)	25 (35.7%)	2 (2.9%)	1 (1.4%)	0 (0%)
I regularly exchange ideas on how to teach mathematics with my fellow teachers.	31 (44.3%)	37 (52.9%)	1 (1.4%)	0 (0%)	0 (0%)
Using computers and other new technologies in the classroom will improve results in mathematics	30 (42.9%)	16 (22.9%)	11 (15.7%)	8 (11.4%)	4 (5.7%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree.
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. 'missing' responses).

A.6.4 Teacher Training Institutions

Questionnaires were completed by representatives of three institutions for teacher training – two preparing teachers for the primary phase only, and one preparing teachers for both the primary and secondary phases. In addition, all three institutions offer in-service courses. The institutions varied in size offering training for between 670 and 5400 trainees in total with between 215 and 900 trainees in their first year. They employ between 19 and 170 tutors but relatively few of these are specialists in mathematics and/or mathematics education. Indeed the largest college reported having just nine mathematics specialists on its staff. The minimum qualification required for tutors is a first degree. Somewhat surprisingly, none of the responding colleges said that their tutors are required to have prior teaching experience. Equally surprisingly, two colleges said that their tutors are not required to participate in some form of continuous professional development. No college requires its tutors to periodically refresh their skills in a school environment.

All colleges reported that trainee primary school teachers are typically aged 16 on admission. The minimum entry requirement is a qualification gained after four years of secondary education (i.e. equivalent to O-level). In two cases a pass in mathematics is required. One college reported being heavily oversubscribed in the current academic year with the others saying that the numbers of applicants was approximately equal to the number of available places.

During the initial three-year teacher training programme for primary school teachers, between five and six hours per week are dedicated to the subject of mathematics. All colleges admitted that the majority of this time (>66%) is dedicated to mathematical content rather than pedagogical methods and strategies. Trainees are required to spend time in schools observing and/or practising in each year of their training. The length of this practicum varies but in the final year of the course, trainees spend between 10-14 weeks in schools. In all colleges, trainees are required to pass examinations at the end of their first year in order to continue their studies.

The colleges in our study reported significant deficiencies in terms of educational technologies. None had a library of video material for teaching/learning mathematics for use by trainees and none had specialist software for mathematics instruction for use by tutors or trainees. Computers with internet access were said to be available for use by trainees. Two colleges volunteered that they do not have adequate technical resources to teach their trainees how to use educational software in the classroom and that they do not use technology (i.e. video, low-cost material, computer software applications, etc) to any great extent in their training.

A.7 Case study: Uganda

Table A.12: Uganda: Country key facts

Indicator	Value	Year
Size (area):	241,550km2	
Population:	38.84 million	2014
Urban population growth (annual %)	5%	2014
GDP (current USD):	USD 26.31 billion	2014
GDP growth (annual %)	5%	2014
GDP per capita (current USD)	USD 677.4	2014
Expenditure on education as a % of GDP	2.2%	2013
Expenditure on education as a % of total government expenditure	12.9%	2013
Government expenditure per primary pupil (USD)	USD 33.7	2012
Mobile cellular subscriptions (per 100 people)	52	2014
Internet users (per 100 people)	18	2014
Structure of education system (years primary + lower secondary + upper secondary)	7 + 4 + 2	
School enrolment, pre-primary (% gross)	11%	2013
School enrolment, primary (% gross)	107%	2013
Primary completion rate, total (% of relevant age group)	54%	2013
School enrolment, secondary (% gross)	27%	2013
Ratio of girls to boys in primary and secondary education (%)	99%	2013
Pupil:teacher ratio in primary education (headcount)	45.6	2013
Pupil:teacher ratio in secondary education (headcount)	21.3	2013
Average number of pupils per mathematics textbook in primary education	3.1	2011
SACMEQ III mean performance on the mathematics scale	481.9	2007
SACMEQ III proportion functionally innumerate (level 1 + level 2)	38.8%	2007

A.7.1 Primary mathematics 'lesson signature' (Grade 3 and 6)

This description is based on 48 classroom observations made in 24 schools.

Typically, the mathematics lessons observed lasted for 40 minutes. On average, 77 students were on the class register with 66 attending the lesson. In nearly all cases (92%) children had chairs or benches to sit on and a hard surface on which to write. In contrast, nearly a quarter of teachers (23%) did not have their own chair and table. In general the lighting, temperature and ventilation were adequate but only three-quarters of classrooms (77%) were described as "cheerful and bright environments decorated with wall charts, etc". Chalkboards were available and used in all classrooms (100%) but teachers had few other resources at their disposal. Most (63%) had their own copy of the textbook but in the majority of classrooms (>75%) concrete teaching aids for mathematics were not visible. None (0%) of the classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. Nearly all pupils (-85%) had a pencil/pen and an exercise book. In over three-quarters (77%) of the classrooms observed, none of the students had a mathematics textbook.

The start of each lesson was orderly and well structured. Nearly all teachers (> 85%) referred back to the previous lesson with a significant number (38%) handing back, or talking about, pupils' homework. The vast majority of teachers (> 90%) started by giving a clear description of what the lesson was to be about.

About 15 minutes into the lesson the majority of teachers (-90%) were explaining the mathematical concept of interest by talking to their pupils (i.e. lecturing) and by writing on the chalkboard. In addition, they were asking pupils questions and listening to their oral responses. Without exception, the teachers were standing up and interacting with their pupils. At this time, the majority of pupils (88% of cases) were orally answering questions asked by the teacher and, in three-quarters of cases, reciting their answers in unison. It was also common (-50% of cases) for pupils to be invited to the board to answer a question whilst the rest of the class watched. It was rare (<20% of cases) to find pupils working in pairs or groups or handling/using teaching and learning materials. At this stage of the lesson, we observed no cases where students were misbehaving and disrupting the lesson to any significant extent.

About halfway through the lesson, the teaching pattern was largely unchanged with most teachers (-90%) still using the chalkboard and oral questioning to explain the concept of interest and judge the understanding of pupils. However, in 30% of lessons students were at this stage working in pairs or groups and/or using some form of learning aid. Once again, we observed no significant bad behaviour.

At the end of the lesson, fewer than half of the teachers (42%) summarised the contents of the lesson but the majority (63%) did set a homework task. In general, the end of the lesson was somewhat less orderly than the beginning with just about half (46%) having, according to observers, "a clear and orderly end".

The overall impression was generally favourable. The vast majority of teachers (96%) appeared to understand the concept they were teaching and were able to explain it to their classes with about half (54%) incorporating at least one 'real life' example. Whilst these things are difficult to judge, observers considered that in about three-quarters of the lessons the majority of students not only understood what had been taught but had also enjoyed the lesson.

A.7.2 Secondary mathematics 'lesson signature' (Grades 9 and 10)

This description is based on 20 classroom observations made in 10 schools.

Typically, the mathematics lessons observed lasted for 40 minutes but with some "double lessons" lasting for 80 minutes. On average, 74 students were on the class register with 63 attending the lesson. In all cases pupils had chairs or benches to sit on and a hard surface on which to write. In contrast, nearly a half of teachers (45%) did not have their own chair and table. In general the lighting, temperature and ventilation were adequate but none of the classrooms (0%) was described by observers as being bright and cheerful learning environments. Chalkboards were available and used in all classrooms (100%) but teachers had few other resources at their disposal. About a half (45%) had their own copy of the textbook but in the vast majority of classrooms (95%) concrete teaching aids for mathematics were not visible. None (0%) of classrooms was equipped with any form of educational technology i.e. overhead projectors, televisions, and computer projection equipment were not available. All pupils (100%) had writing materials. In almost half (45%) of the classrooms observed, none of the students had a mathematics textbook. In nearly three-quarters of classrooms at least some pupils had calculators.

The start of each lesson was, in general, orderly but perhaps less well-structured than those observed in the primary grades. Only 60% of teachers explicitly referred back to the previous lesson and only a minority (30%) handed back, or talked about, pupils' homework. However, the vast majority of teachers (> 95%) started by giving a clear description of what the lesson was to be about.

About 15 minutes into the lesson the vast majority of teachers were explaining the mathematical concept of interest by writing on the chalkboard and lecturing to their pupils. In addition, they were asking pupils questions and listening to their oral responses. At this time, the majority of pupils (>60% of cases) were orally answering questions asked by the teacher and/or solving problems in their exercise books or on paper. Answering by rote was rarely observed during lessons at the secondary level. It was rare (<10% of cases) to find pupils working in pairs or groups, or handling/using teaching and learning materials.

About halfway through the lesson, the observed teaching pattern was largely unchanged with most teachers (-90%) still using the chalkboard to explain the concept of interest and questioning pupils to judge their understanding. The majority of pupils were copying from the chalkboard (80% of cases) and/or attempting to solve problems in their exercise books (95%). It was rare (10% of cases) to find students working in pairs or groups.

At the end of the lesson, about half of the teachers (55%) summarised the contents of the lesson and the majority (70%) set a homework task. In general, the end of the lesson was somewhat less orderly than the beginning with just about half (55%) having, according to observers, "a clear and orderly end".

The overall impression was generally favourable. All teachers (100%) appeared to understand the concept they were teaching and were, in general, able to explain it to their classes. Only a minority (30%) used 'real life' examples in their teaching. All teaching appeared to be directed at the whole class with no evidence of teachers working with individual pupils. Observers judged that in about 80% of lessons the majority of students not only appeared to understand what had been taught but also seemed to enjoy the lesson.

A.7.3 Teacher characteristics and attitudes

In Uganda, attitudinal questionnaires were completed by 50 teachers teaching at the primary level and 20 teaching mathematics at the senior secondary level. Of the primary teachers, 34 (68%) were male and 16 (32%) were female. Of the secondary teachers, 18 (90%) were male and only two (10%) were female. In both cases, most of the teachers interviewed were aged 30 to 39 years. Prior to embarking on their pre-service training, the a majority of primary school teachers (78%) had completed senior secondary education. Of the secondary school teachers 65% had completed A-levels or some other post-secondary study and a further 25% had gained a degree level qualification. The teachers in our sample were relatively experienced with the majority (93%) having at least three years' teaching experience and 39% having more than 10 years.

At the primary level only a small minority of teachers (16%) are teaching in their mother tongue. Most (72%) claim to be fluent in the language of instruction but a significant minority (12%) report that they themselves have some difficulty in the language in which they have to teach. About half of primary teachers (52%) report that their pupils face difficulties due to the language of instruction. At the secondary level, 95% of teachers are teaching in a language which is not their mother tongue but, almost without exception, they claim to be fluent in the language of instruction.

In order to judge the readiness of our teachers to use educational technologies they were asked about their ownership of mobile phones and the way they saw their own computer skills. 99% reported having a mobile phone but only 50% have smart phones with internet access. Only 13% said that they own a PC, laptop or tablet computer with internet access. A large majority (81%) admitted that they either could not use a computer or that they considered themselves to be beginners with limited skills.

The primary school teachers in the survey, with very few exceptions, reported that they were very well prepared, or at least partially prepared, to teach the required concepts of the basic mathematics curriculum. Not surprisingly, the vast majority (-80%) of mathematics specialists teaching at the secondary level reported that they were very well prepared to teach any of the concepts required by the curriculum.

When asked about the value of group work and/or pair work in the classroom, there was almost unanimous agreement that this was "very important". Similarly, the use of concrete practical equipment in the teaching/learning of mathematics was considered to be very important by 90% of teachers. Fewer teachers (21%) felt that pupils working alone to solve mathematical problems was "very important". It is interesting to contrast what teachers say is important with what they do in practice as described in the lesson signatures above.

Prior to teaching, the majority of our primary teachers (78%) completed a two-year teacher training programme. 35% of our secondary teachers also followed a two-year programme, but the majority (55%) had three or more years of initial teacher training.

Both primary and secondary school teachers in our sample displayed very positive attitudes towards their pre-service training with typically 80% agreeing or strongly agreeing with statements such as: "My own mathematical skills improved a lot as a result of my training"; "My pre-service training left me well prepared to teach mathematics"; and, "I enjoyed my pre-service training". However, about three-quarters (78%) also agreed with the statement "nearly all my pre-service training was about improving my mathematical skills". There was slightly less agreement when it came to practice in the classroom. About a quarter of our teachers (27%) agreed that in their pre-service training they "did not get enough practice teaching mathematics in the classroom".

The table below summarises how the 70 teachers in our survey responded to selected statements in our attitudinal questionnaire. This raises several points of interest. First, it is interesting to note that whilst there is a great deal of consensus that, for example, "everyone has the potential to be good at mathematics", there is less agreement when it comes to the statement "very few pupils are naturally good at mathematics". Secondly, whilst teachers are very positive about their students' attitude towards mathematics and their progress, the majority (66%) agree that "most pupils need additional tutoring". Thirdly, most teachers obviously feel under pressure to cover the syllabus and a significant minority (>35%) feel that they do not have enough time to cover the curriculum and sometimes have to move on before their pupils have mastered the current topic. Fourthly, nearly all mathematics teachers (87%) believe that more in-service support is required if student achievement is to be enhanced.

Table A.13: Teacher responses to selected statements using a five-point Likert scale

Indicator	SA	A	N	D	SD
Mathematical skills are useful for everyone.	63 (90%)	7 (10%)	0 (0%)	0 (0%)	0 (0%)
Everyone has the potential to be good at Mathematics.	21 (30%)	32 (45.7%)	7 (10%)	9 (12.9%)	1 (1.4%)
You have to have the right sort of brain to be good at Mathematics.	23 (32.9%)	19 (27.1%)	6 (8.6%)	17 (24.3%)	5 (7.1%)
Very few pupils are naturally good at Mathematics.	14 (20%)	22 (31.4%)	6 (8.6%)	20 (28.6%)	7 (10%)
The current curriculum for Mathematics is too difficult for my students.	4 (5.7%)	7 (10%)	10 (14.3%)	38 (54.3%)	11 (15.7%)
My pupils are making good progress in Mathematics.	17 (24.3%)	46 (65.7%)	3 (4.3%)	4 (5.7%)	0 (0%)
Students seem to be interested in learning Mathematics.	8 (11.4%)	47 (67.1%)	12 (17.1%)	2 (2.9%)	0 (0%)
Most pupils need additional tutoring in Mathematics.	12 (13.1%)	37 (52.9%)	9 (12.9%)	11 (15.7%)	1 (1.4%)
We are under a lot of pressure to cover the syllabus so that pupils are ready for examinations.	13 (18.6%)	36 (51.4%)	5 (7.1%)	10 (14.3%)	6 (8.6%)
Sometimes you have to move onto the next topic even if some pupils do not understand the current topic.	5 (7.1%)	24 (34.3%)	6 (8.6%)	23 (32.9%)	12 (17.1%)
I have enough time to teach everything in the Mathematics curriculum.	4 (5.7%)	29 (41.4%)	12 (17.1%)	21 (30%)	4 (5.7%)
Teachers need more in-service support to improve the teaching of Mathematics in our schools.	28 (40%)	33 (47.1%)	7 (10%)	2 (2.9%)	0 (0%)
I regularly exchange ideas on how to teach Mathematics with my fellow teachers.	41 (58.6%)	24 (34.3%)	1 (1.4%)	2 (2.9%)	2 (2.9%)
Using computers and other new technologies in the classroom will improve results in Mathematics	20 (28.6%)	30 (42.9%)	10 (14.3%)	7 (10%)	3 (4.3%)

SA = strongly agree; A = agree; N = neither agree nor disagree; D = disagree; SD = strongly disagree.
Note: Percentages may not add to 100% due to teachers who chose not to respond to a particular statement (i.e. 'missing' responses).

A.7.4 Teacher Training Institutions

In Uganda, questionnaires were completed by representatives of three government institutions for teacher training – two preparing teachers for the primary phase and one preparing mathematics teachers for the secondary phase. In addition, all three institutions offer in-service courses. The institutions varied in size offering training for between 400 and 1,000 trainees in total with between 160 and 530 trainees in their first year. They employ between 22 and 62 tutors but relatively few are specialists in mathematics and/or mathematics education. Indeed the smallest college reported having just one mathematics specialist on its staff. The minimum qualification required for tutors is a first degree. In addition, tutors are required to have some teaching experience but not necessarily at the primary level. Tutors in all the colleges in our sample are required to participate in professional development courses, but no college requires its tutors to periodically refresh their skills in a school environment.

Colleges reported that their trainees are aged between 18 and 21 on admission. One college preparing primary teachers required a minimum of O-level (i.e. a qualification gained after four years of secondary education) while the other had raised its entry requirement to a minimum of A-level (i.e. the qualification gained after six years of secondary education). In all cases a pass in mathematics is required. All three colleges reported that in the current academic year they were heavily oversubscribed and so had to reject many applicants. That having been said, they also reported that they face problems attracting high quality applicants to train as teachers.

During the initial teacher training programme (two years for primary school teachers and three for secondary school mathematics specialists) a significant amount of time is dedicated to the subject of mathematics - at least five hours per week for the duration of the course. Two colleges admitted that the majority of this time (>66%) is dedicated to mathematical content rather than pedagogical methods and strategies. One college said that their programme struck a balance between content and methodology. Trainees are required to spend time in schools observing and/or practising in each year of their training. The length of this practicum varies from four to nine weeks per year. In two colleges, trainees are required to pass examinations at the end of their first year in order to continue their studies. However reported failure rates are low (<5%).

The colleges in our study reported significant deficiencies in terms of educational technologies. None had a library of video material for teaching/learning mathematics which could be used by trainees. Computers with internet access were available and regularly used by trainees, but specialist software for mathematics instruction was not available. All colleges volunteered that they did not have adequate technical resources to teach their trainees how to use educational software in the classroom. They also admitted that they did not use technology (i.e. video, low-cost material, computer software applications, etc) to any great extent in their training.

Appendix B. References

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This report and the corresponding overview were prepared by Cambridge Education for the World Bank, with George Bethell as the author. It was commissioned by Sukhdeep Brar and supervised by Ryoko Tomita (World Bank)

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