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

Overview Report

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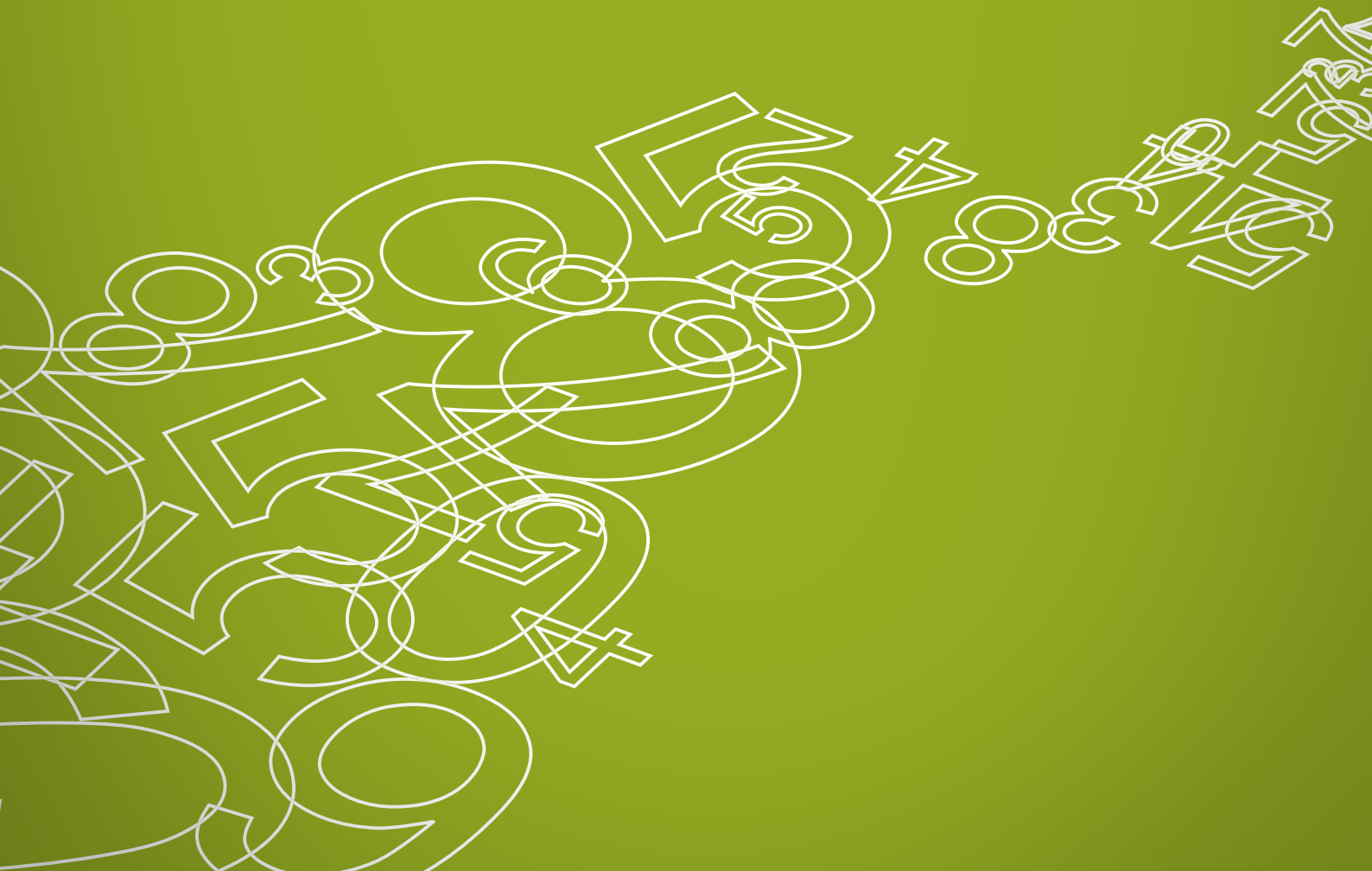
This overview report summarises the findings of the study Mathematics Education in Sub-Saharan Africa: Status, Challenges, and Opportunities.

The study was commissioned by the World Bank in response to a growing recognition that countries in the region will need to boost performance significantly in the Science, Technology, Engineering and Mathematics subjects if they are to realise their full potential in a competitive global market increasingly shaped by the use of new technologies. The findings of the study will be used to support the efforts of the World Bank, and its partners, to improve mathematics education across Sub-Saharan Africa (SSA) and in other developing economies where similar challenges are faced.



Mathematics Education in Sub-Saharan Africa: Main Messages

Overview Report

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 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).

"The pace of progress is very slow. At 'business as usual' progress, it would take a century or more for developing countries to reach current OECD assessment levels."

(Beatty and Pritchett, 2012, p.1.)

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 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. 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.

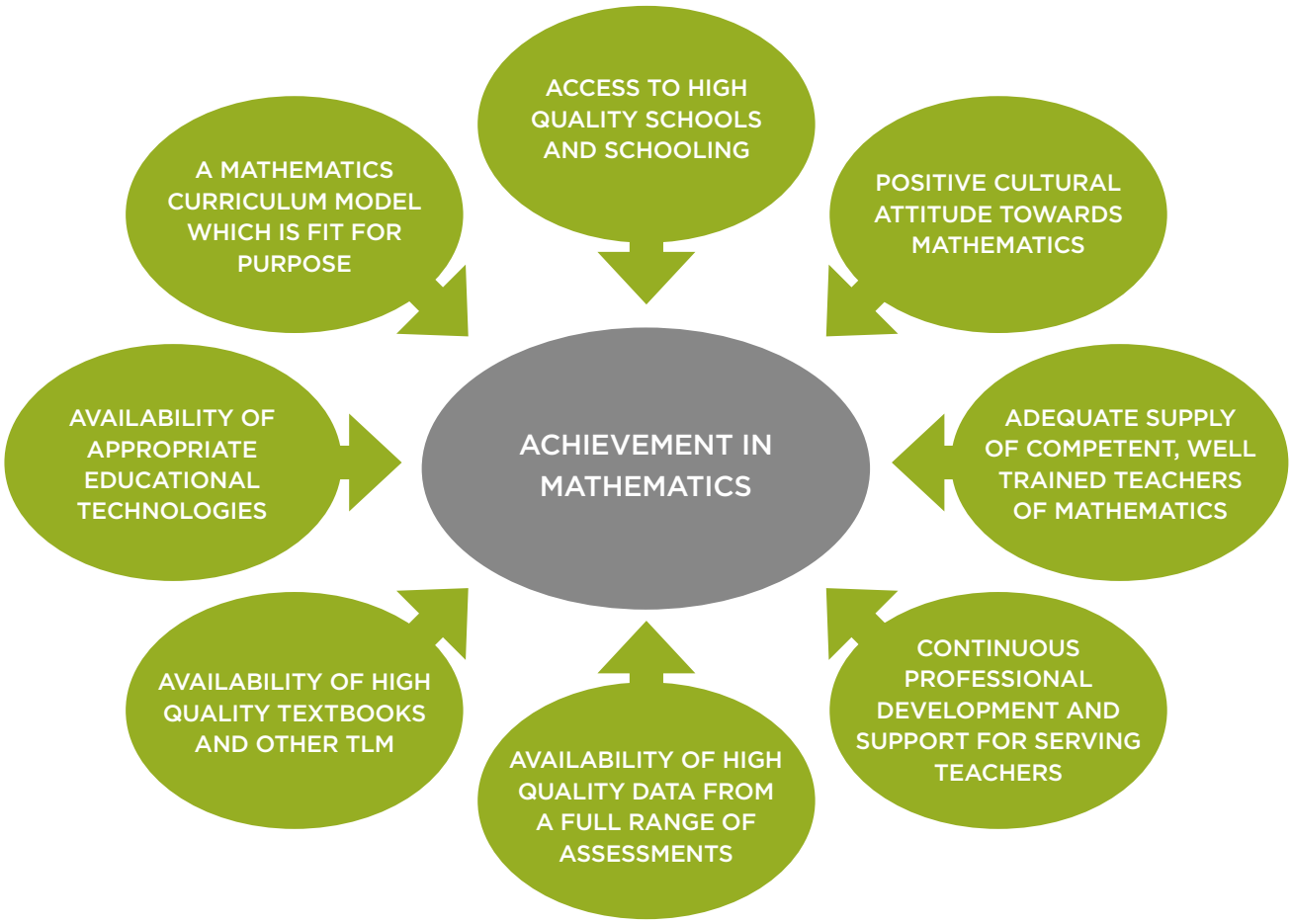
"Placing a poor child in a wealthy school is likely to more than compensate for any negative effects of a poor home background."

(Spaull, 2011, p.16)

Whilst raising the general quality of education is an important factor in improving outcomes in mathematics, it is not a sufficient response to the current situation 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 little sign 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.

Fig 1 **Factors associated positively with achievement in, and engagement with, mathematics.**



Whilst many problems need to be addressed simultaneously, 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, the inadequate initial teacher training so frequently observed in SSA will remain part of the problem and poorly prepared teachers will continue to serve as a brake on progress.

Increasingly, new technologies seem to offer possible solutions for many of the problems associated with raising educational quality in general and mathematical standards in particular. However, it is not yet clear which approach will deliver the greatest returns. Cost effectiveness and long-term sustainability are major concerns. In particular, investing heavily in inflexible hardware configurations and/or committing to single-source commercial software packages would appear to be risky strategies. On the other hand, harnessing the internet to deliver a wide range of resources to educational institutions, teachers, students and their parents is relatively cheap and has the potential to bring benefits with few attendant risks. Good examples of national educational e-portals are starting to emerge but, as yet, there is little reliable evidence as to their penetration and impact.

Mathematics Education in Sub-Saharan Africa: 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 should be made clear in all national strategic plans and be reflected in all ministerial development plans. As a priority, 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.

International agencies (e.g. development banks, donors, NGOs, and philanthropic organisations) that support governments in the implementation of educational reforms should reflect this shift in priorities in their policies and actions. For example, the World Bank and its development partners should require those preparing any support programme to state explicitly if/how proposed interventions will promote 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:

- It pays to invest in the mathematical education of children because, amongst other benefits, success in mathematics is linked to greater economic returns.
- Hard work in and out of school will bring better results in mathematics.
- Everyone can be successful in mathematics - you don't need to be born with a special ability.

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 improve the confidence (i.e. self-efficacy) of girls in mathematics and, hence, their achievement.

"Gender gaps in academic performance are not determined by innate differences in ability. A concerted effort by parents, teachers, policy makers and opinion leaders is needed if both boys and girls are to be able to realise their full potential and contribute to the economic growth and well-being of their societies."

(OECD, 2015, p.4)

3. Improving initial teacher training

It is vital that new entrants to the teaching profession are properly prepared. Unfortunately, many Teacher Training Institutions (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 brake against progress. These must be radically 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 (a) they include a comprehensive treatment of theory so that trainees can make sense of practice, (b) they 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, and (c) they provide trainees with 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 teacher trainers of TTI are in a position to deliver a radically different approach to preparing new teachers. The most serious deficiency appears to be a lack of teacher trainers having first-hand experience of teaching in primary school classrooms. Correcting this will be neither easy nor quick. Selected teacher trainers 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, a new, recognised career path should be established, with incentives, to encourage outstanding teachers and/or principals from the primary sector to become specialist teacher trainers in TTI.

There is an immediate opportunity to strengthen teacher training through the use of educational technologies but many TTI are not 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 e.g. see Box 1.

Box 1 **Strengthening initial teacher training through use of open educational resources**

The Open University, UK working in close collaboration with international and national partners, guides The Teacher Education in Sub-Saharan Africa (TESSA) initiative - 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 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) – and can be accessed at: **http://www.tessafrica.net/.**

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, Institutions of Higher Education, 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.

Following the success of the TESSA initiative in SSA, the model has now been adapted for India (see http://www.open.ac.uk/about/international-development/ido-asia/TESS-India).

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 TLM including textbooks, teachers' guides, 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).

Peer support and collaboration between mathematics teachers appears 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 subject teachers meet regularly to discuss effective teaching strategies (see Box 2). If this initiative is shown to yield significant improvements in learner achievement, other countries should consider ways of promoting collaboration among subject teachers.

Box 2 **In-service support for mathematics teachers**

In 2014, the Department of Basic Education in South Africa announced that the professional development of mathematics teachers will follow a '1+4 model'. 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 tested to ensure that they have mastered the content. Teachers who fail to demonstrate mastery will be supported during the week by a 'support team'. This radical approach provides each mathematics teacher with 23 days per year of intensive training and regular opportunities to discuss mathematics content and methodology. The 1+4 development model clearly has significant implications for the organisation of school timetables but it 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.

5. Providing more and better mathematics textbooks

In the many countries of SSA where the ratio of mathematics textbooks to students is significantly worse than 1:2 there is probably benefit in investing in the supply of more books. 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 effective in the teaching of mathematics requires systematic evaluation in advance of publication. Currently the evaluation of textbooks tends to focus on correspondence with the content of the curriculum, attractiveness to learners, physical quality and cost of production. However, there is little evidence that new textbooks are subjected to rigorous trials of their effectiveness as aids to learning. Ministries of education should subject all proposed textbooks to a comprehensive evaluation by trained reviewers - including practising teachers of mathematics.
The 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 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 publishes physical books but also provides e-copies for personal, i.e. non-commercial use, through its e-portal (see Box 3). In SSA, governments should, through their key agencies, establish 'education portals' allowing free access to textbooks and supplementary teaching and learning materials.

Box 3 **Making e-textbooks freely available to all**

The National Council for Educational Research and Training (NCERT) in India commissions and publishes 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 the e-portal at: http://epathshala.nic.in/e-pathshala-4/. They are available in Hindi, English and, in some cases, Urdu. 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 context of SSA 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 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.

Fig 2 **Indian e-portal**

6. Supporting mathematics teachers through technology

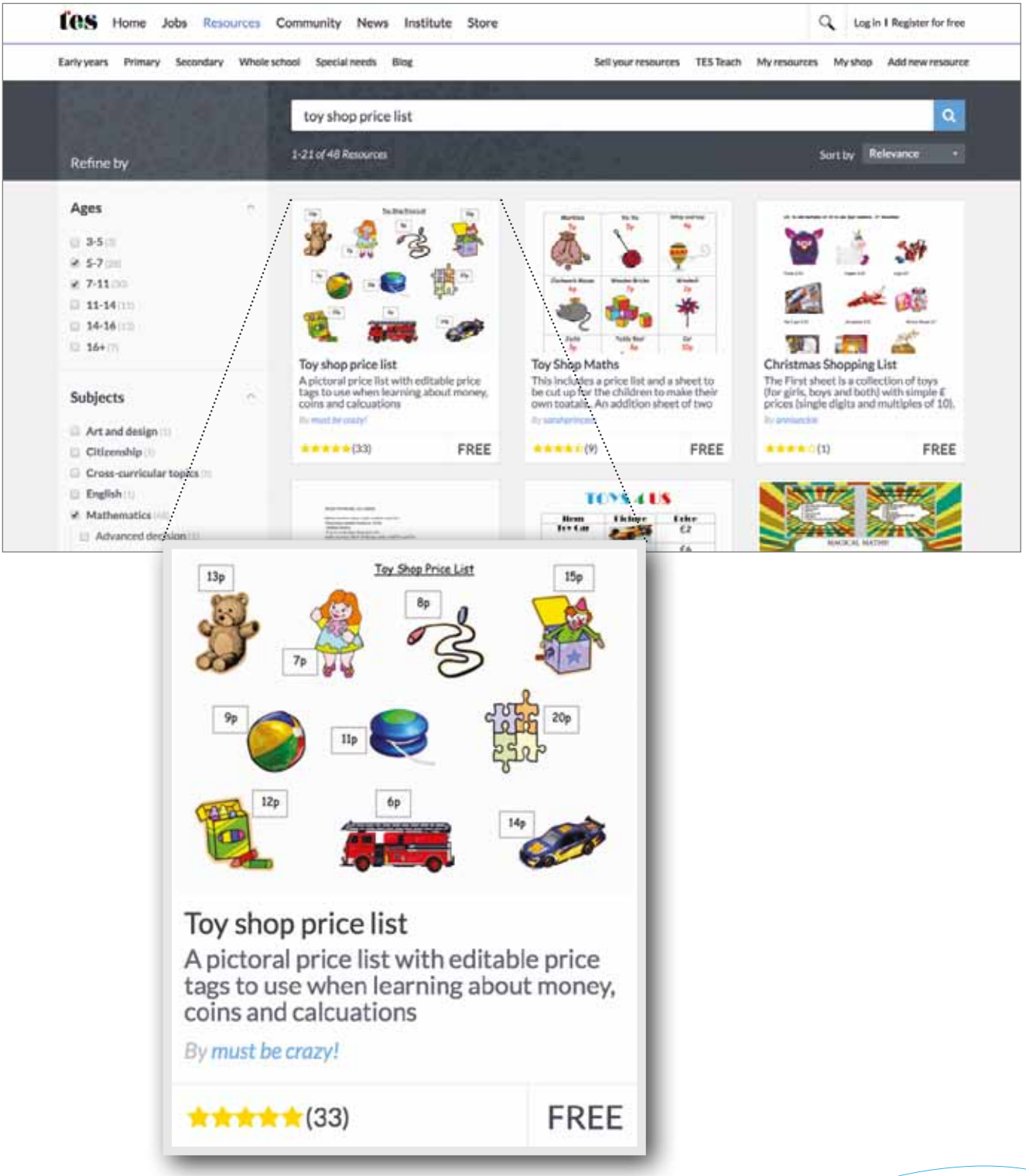
Whilst many initiatives to turn the potential of digital technologies into improved teaching and learning have been launched in recent years, it is not yet clear which, if any, of these will be most effective and/or sustainable in the long-term. However, technological tools are emerging that individual teachers can, with support, use to enhance their teaching of mathematics (see Box 4). Typically these 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 through national education portals.

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 (https://www.tes.com/teaching-resources). Teachers from all phases of education and in all subjects upload resources they have made and used successfully. These can be accessed 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 use.

Box 4 Text2Teach, Philippines and Elimu kwa Teknolojia, Tanzania

In the Philippines, the Text2Teach programme allows teachers to download web-based TLM to their mobile phones. 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. Videos can be used with the whole class by connecting the mobile phone to a projector television. Following successful large-scale trials and positive evaluation results, the Department of Education (in collaboration with its commercial partners, Microsoft, the Pearson Foundation and the mobile network provider Globe Telecom) is rolling out the Text2Teach programme to all 22,000 of the nation's elementary schools from 2015. Text2Teach emanates from the BridgeIT Project initiated by commercial partners Nokia and Pearson. BridgeIT operates in many low-income countries including Tanzania where the programme is known as Elimu kwa Teknolojia (Education through Technology). The subjects covered include Mathematics, Science, and Life Skills. Existing content was translated into Kiswahili and additional content was generated to ensure coverage of the national curricula. 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 more progress than their peers in the control group. The reported differences were relatively modest but nevertheless significant with score improvements ranging from about 8 to 17 percentage points for the two age groups studied (Enge, 2011).

Fig 3 **Example of a shared resource freely available from the Times Educational Supplement teaching resource bank. Note the five star approval rating given to this resource by teachers who have used it.**

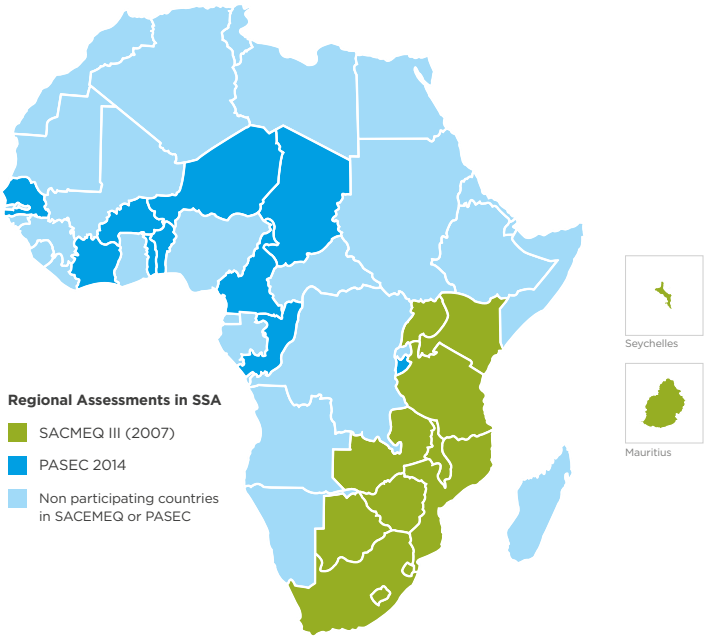


7. Harnessing the power of assessment: regional and national assessments

Participating in international large-scale assessments such as PISA and TIMSS may bring benefits. However, 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, more promising alternatives include participation in regional assessments and the development of national assessments.

The two regional assessments - SACMEQ and PASEC - have over the years become increasingly sophisticated and have aligned to a significant extent the technical procedures and standards they use. This convergence has made them potentially more powerful both independently and in collaboration. SACMEQ and PASEC should strengthen their existing links through formal agreements, the adoption of common operating standards, and the use of a common (linked) 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.

Fig 4 **PASEC and SACMEQ coverage**



A significant 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 that are currently investing in conducting national assessments should immediately review these to ensure that they are providing value for money. Where countries do not have the necessary technical expertise to evaluate and/or 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.
In order to address this, 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 schools, teachers and other practitioners with both qualitative and quantitative information as to student performance in mathematics (and all other subjects).

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. These should include examination programmes (syllabuses), reports of examiners and, most importantly, past papers (with their marking schemes). This could be implemented immediately and with 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.

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 therefore anonymised datasets should be made freely available to bona fide researchers wishing to conduct secondary analysis. The potential benefits can be judged by the important work carried out by independent researchers given open access to the datasets of SACMEQ assessments.

"... any kind of measures to enhance transparency about resource flows and 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 (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 initial steps are recommended.

- Students, parents and 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.
- Key players in education including government agencies, NGOs, and commercial entities should be encouraged to provide free access to existing open educational resources.
- NGOs and commercial partners should be encouraged to collaborate with, for example, ministries of education in the generation of age-appropriate m-learning materials compatible with the content and philosophy of national curricula for mathematics.

10. Promoting further research

During the conduct of the study, many areas worthy of further investigation and research have emerged. These include, but are not limited to, the following research questions.

Have initial teacher training programmes which have been designed around OER been effective? Where OER have been built into continuous development programmes for serving teachers, have they been effective?

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

How effective are the textbooks currently being used to teach basic mathematics? What makes a textbook effective in SSA?

How can countries monitor trends in mathematical achievement? Does participation in a regional large-scale assessment offer a solution? Can national assessments be designed/modified so that they can detect small changes over short periods?

Which of the initiatives using e-learning and m-learning technologies in the classroom have the greatest potential to raise levels of numeracy and mathematical competence?

Given the prevailing conditions, which of the proposed technological solutions are most likely to be viable and sustainable?

References and Links

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Links

Mauritius Examinations Syndicate
http://mes.intnet.mu/portal/sites/mesweb/index.htm

National Centre for Educational Research and Training, India: e-learning materials
http://epathshala.nic.in/e-pathshala-4/

Teacher Education in Sub-Saharan Africa (TESSA)
http://www.tessafrica.net/

Teacher Education through School-based Support in India (TESS India)
http://www.open.ac.uk/about/international-development/ido-asia/TESS-India

Times Educational Supplement teacher resources
https://www.tes.com/teaching-resources

West African Examinations Council e-learning portal
http://waeconline.org.ng/e-learning/index.htm

CAMBRIDGE EDUCATION

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