K4D | Knowledge, evidence and learning for development

Foundational mathematics education in developing countries

Laura Bolton
Institute of Development Studies
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Questions

1. What does the evidence say on the current status of progress in foundational maths in developing countries?

- *What does the data say about progress in foundational numeracy in comparison to foundation literacy?*
- *Are there examples of countries that have made fast progress in numeracy?*

2. What does the evidence tell us about key bottlenecks and opportunities for accelerating progress in the teaching of foundational mathematics?

- *What are the big challenges and opportunities for the teaching of maths in developing countries, including through technology?*
- *What are the evidence gaps?*

Contents

1. Overview

There is concern that children in developing countries are not learning sufficient mathematics skills. Focus on enrolment and literacy may have led to neglect of mathematics learning and less is known about the status in this area. According to a UNESCO study in 2014 fewer than 50 per cent of grade 6 students have achieved a minimum level in mathematics in three quarters of eastern and southern African countries (UNESCO, 2014). In the remaining quarter of countries, between 56 and 62 per cent of students had learned basic mathematics skills.

To obtain information on mathematics progress this report extracts data from the World Bank database. Section 2 describes the different data scales and section 3 reports results. Section 4 includes some case studies from further research into different countries.

The following sections 5 to 9 discuss findings on teacher capacity, barriers, curricula, and technology. Section 10 outlines recommendations and research gaps.

It is difficult to assess the current status of progress in mathematics in developing countries with the assessment data that are available. Data that exist in the World Bank database and from the Education Policy and Data Center are not available for recent years, not available for all countries and often not available for different time periods to analyse trends.

Key country-level findings around mathematics achievement include:

- Mathematics achievement data from the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) scale are available from 2000 to 2007 for Kenya, Malawi, Mauritius, Namibia, and Zambia. Mean performance in 2007 is highest in Mauritius, followed by Kenya and then Zimbabwe. Zambia scores the lowest. Malawi and Namibia also fall below average. Crude comparison with average scores from 2000 and 2007 show a reasonable improvement for Namibia and some improvement for Malawi. Kenya show a slight decline in performance. The direction and magnitude of temporal differences are similar for average scores on the reading scale as for mathematics in each country. In most countries, boys appear to be outperforming girls (with the exception of Mauritius).

- Data from Program for the Analysis of CONFEMEN[1] Education Systems (PASEC) are available for 10 francophone African countries for 2014 only, so trends over time are not available as an indicator of progress. Burundi, The Republic of Congo and Burkina Faso consistently rank higher across the different mathematical attainment measures. Niger and Chad tend to rank lowest. Rankings for mathematics and English performance scales are similar. Boys have higher averages scores than girls in most countries except Benin and Burundi.

- Young Lives[2] survey data from Ethiopia suggest a decline in mathematics performance between 2006 and 2013. This may be due to the enrolment of new students who are not

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[1] Conférence des Ministres de l'Education des États et gouvernements de la Francophonie

[2] https://www.younglives.org.uk

yet reaching foundational learning levels. Data on national primary school-level mathematics are not available for Ghana but attainment for grade 8 students show an upward trend.

The data suggest that numeracy and literacy progress are similar within countries. This rapid review was unable to identify countries which have made fast progress in numeracy although some examples of successful programmes are described. Some individual studies are described from a number of African countries where DFID have a major investment. Teachers surveyed in Cameroon, Democratic Republic of Congo, Ethiopia, Nigeria, Rwanda, and Uganda are positive about the progress their students are making in mathematics. There seems to be a dearth of data on foundational level mathematics in developing Asian countries.

A World Bank commissioned study on mathematics education in Sub-Saharan Africa suggests prioritisation of teacher capacity for progress in mathematics attainment (Bethall, 2016). Teacher capacity building needs to focus on how mathematics is taught and not just on improving teacher subject knowledge. Teachers should increase classroom interaction and make conceptual learning more meaningful. Negative attitudes towards new methods from senior teaching staff need to be addressed. Teachers learning to teach using standardised approaches may have misplaced confidence that learning is taking place amongst their students.

Factors affecting mathematics progress tend to mirror issues affecting educational attainment in general. Studies identify socio-economic factors as commonly associated with learning in mathematics. There is a consensus that making improvements in overall school quality will likely improve mathematics attainment. One problem specific to mathematics is cultural attitude. Some cultures do not value mathematics and have expectations of failure. Attitudes need to be changed within the public and education sector highlighting the benefits, accessibility and achievability of mathematics for everyone.

Some evidence is found that teaching mathematics in English or French rather than local languages may impede learning. Translating shared materials into local languages may be resource intensive. Some teachers do not know the local language where they are teaching.

Some case studies are found where technologies have been shown to improve mathematics results. Technologies are particularly cost-effective as they can be shared more easily but language of instruction would not be mother-tongue.

Early childhood development interventions are a good place to start to improve foundational numeracy learning. Positive examples are identified in Botswana, South Africa, and Rwanda.

Further suggestions include:

- Making mathematics improvement a national priority.
- Improving initial teacher training.
- Improving teaching practices so that they are less rigid and involve more collaborative exploration.
- Peer-support among teachers.
- More text books of better quality.
- Consideration of appropriate testing.
- Self-learning technologies where access to schooling is a problem.

There was little identified in the literature linking curriculum content and effective learning within the scope of this report. Information on curriculum change in Ghana described a change from reducing the amount of topics covered to learning about topics more in-depth.

Identified evidence gaps include:

- Investigation of curriculum appropriateness for foundational mathematics learning.
- More is needed to evaluate the effectiveness of learning materials including textbooks and technologies.
- Putting in place assessments generating attainment data which is appropriate for students and useful for measuring progress.
- Looking into how students approach problems and learn.

2. Assessment data introduction

International, regional and national data on foundational mathematics achievement are often not available for developing countries. Bethall (2016, p62) states "to date, national assessments offer little reliable data to prove conclusively that mathematical standards are rising, falling, or remaining static in the countries of Sub-Saharan Africa." This may be an area to improve upon but it should also be recognised that individual countries may have different needs which do not suit focus on international assessment. National assessments may be more useful within country. An example is given from Zimbabwe in section 4 of this review.

Where high level data are available in the World Bank database, they are often not available over a series of years, so it is not really possible to assess progress.

The focus of this report is foundational mathematics. Two sources of regional assessment data for mathematics achievement were identified for Africa: 1) Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ), and 2) Program for the Analysis of CONFEMEN[3] Education Systems (PASEC). Some Trends in International Mathematics and Science Studies (TIMSS) data is included here in the absence of any other data, but scores on this scale were only available from Grade 8. Primary school-level data for Asian countries were not available.

SACMEQ consists of scaled test scores (so that the average for participating countries is equal to 500 with a standard deviation of 100) and competency level scores. This style of data is useful for comparison across countries. This scale is not recommended for comparisons over time; however, the second round of SACMEQ scoring (2007) used the same scale as for the first round (2000) so gives some reflection of change.[4] Change relative to other countries is certainly evident. Different countries have been included in different rounds of SACMEQ for which data are available and reported in section 3.

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[3] Conférence des Ministres de l'Education des États et gouvernements de la Francophonie

[4] http://www.sacmeq.org/?q=sacmeq-projects/sacmeq-ii

PASEC data were identified for the Sahel region and other francophone African countries. Scores are scaled as with SACMEQ data, averaged to 500 with a standard deviation of 100. Data are also provided for the per cent of students who have reached a certain PASEC level within their grade. Data for grade 2 and grade 6 are reported. Data are available for only one year in the World Bank database so trends over time could not be identified.

TIMSS[5] scores are also scaled so that data have an average of 500 across countries with 1 standard deviation of 100. The average is taken across developed and developing countries.

3. Comparable evidence on foundational mathematics progress

SACMEQ data

Table 1: Grade 6 SACMEQ results 2007

Country	% students reaching proficiency level 3[6]	Mean performance on the mathematics scale	Difference from year 2000 mean performance	Mean performance on the reading scale	Difference from year 2000 on the reading scale
Kenya	27.1	557 (Male 567.6, Female 546)	-6.1	543.1	-3.4
Malawi	31.8	447 (M 452.7, F 441.1)	14.1	433.5	4.6
Mauritius	15.5	623.3 (M 616.1, F 630.7)	38.7	573.5	37.1

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[5] https://timssandpirls.bc.edu

[6] At this level, students can translate verbal information presented in a sentence, simple graph or table, using one arithmetic operation in several repeated steps. They can translate graphical information into fractions, interpret place value of whole numbers up to thousands, and interpret simple common everyday units of measurement. http://www.sacmeq.org

Namibia	34.0	471 (M 472, F 470.1)	40.1	496.9	48.1
Zambia	24.5	435.2 (M 440.8, F 429.2)	0.2	434.4	-5.8
Zimbabwe	30.7	519.8 (M 520.8, F 519)	data not available	507.7	data not available

Looking at the data for the per cent of 6th grade students reaching proficiency level 3, Namibia is highest at 34 per cent. Malawi and Zimbabwe are second and third highest. Mauritius scores the lowest, 15.5 per cent, however Mauritius mean performance on the mathematics scale is markedly higher than other countries, 623.3 compared to the second highest, Kenya, 557. Zimbabwe are also above average, 519.8. Zambia scores the lowest, 435.2 and Malawi the next lowest. There are some inconsistencies between rankings of countries based on proportion of students reaching proficiency level 3 and mean performance on the mathematics scale which raises questions about drawing strong conclusions from the data.

Differences on the mathematics scale between 2000 and 2007 are mostly small and unlikely to be a reliable measure of progress. Namibia and Mauritius appear to have made more progress with an increase of 40.1, and 38.7 respectively. They were also the two countries to have shown greatest improvement in their mean reading scale performance, similar increases of 48.1 and 37.1 respectively. The countries with a small difference between performance measures on the mathematics scale showed similar differences with their performances in the reading scale suggesting that improvements or declines are similar for mathematics and reading.

Zimbabwe and Namibia show very small difference in overall mathematics performance scores between boys and girls. In Kenya, Malawi and Zambia boys scores are higher than girls scores. In Mauritius, the data show girls outperforming boys.

PASEC data

Data for the Sahel region were recorded on PASEC[7] performance scales along with a number of other countries (see Table 2 below). Information on the same variables over time were not available for analysing progress.

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[7] Programme d'Analyse des Systèmes Educatifs de la CONFEMEN/Program for the Analysis of CONFEMEN Education Systems (PASEC): http://www.pasec.confemen.org/

Table 2: PASEC data from 2014

Country	% 2nd grade students at PASEC level 2 for their grade[8]	% 6th grade students at PASEC level 2 for their grade[9]	Mean performance on mathematics scale for 2nd grade students	Mean performance on language[10] scale for 2nd grade students	Mean performance on mathematics scale for 6th grade students	Mean performance on the reading scale for 6th grade students
Benin	25.1	29	454.7 (M 452.1, F 457.4)	458.3	496.9 (M 494, F 499.5)	523.4
Burkina Faso	40.9	36.9	505.8 (M 510.3, F 501.5)	513.8	539.5 (M 546.2, F 533)	531.6
Burundi	28.9	46.8	605.1 (M 600.5, F 609.2)	627.7	593.6 (M 578.6, F 611.8)	525.4
Cameroon	37.1	23.7	502.7 (M 512.3, F 493.4)	502.4	489.5 (M 488.5, F 490.7)	517.5

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[8] Students at 2nd grade Level 2 have passed the Sufficient Competency Threshold. Pupils can recognise numbers up to one hundred, compare them, complete logical series and perform operations (sums and subtractions) with numbers under fifty. They have developed awareness of spatial orientation (below, above, beside). They have begun to develop an ability to solve basic problems with numbers under twenty using reasoning skills. http://www.pasec.confemen.org/wp-content/uploads/2016/09/PASEC2014_plaquette_ENG.pdf

[9] Students at Level 2 in year 6 have reached the Sufficient Competency Threshold, and are able to answer brief arithmetic, measurement and geometry questions by resorting to the three assessed processes: knowing, applying and reasoning. Some questions call on factual knowledge or a scientific approach; others require analysis of a situation prior to determining the appropriate approach. In arithmetic, students can perform operations with decimal numbers and can also solve familiar problems by analysing the wording of the question or extracting data from a double-entry table. They know how to complete logical series with decimal numbers or fractions. In measurement, pupils can tell the time and convert units of measurement with or without a conversion table. They are also able to solve arithmetic problems involving operations with units of length or days, hours and minutes. In geometry, pupils know the names of certain solids, basic geometric shapes and some characteristic lines (diagonal, median). http://www.pasec.confemen.org/wp-content/uploads/2016/09/PASEC2014_plaquette_ENG.pdf

[10] Data for 2nd grade students were available for a language scale and not a reading scale on the World Bank database. For 6th grade students, data were available for reading scale and not a language scale.

Chad	27.8	16.1	491.3 (M 513.9, F 466.6)	480.4	450.9 (M 458.5, F 436.6)	432.5
Congo (Republic)	37.7	23.1	541.2 (M 543.2, F 539.2)	522.7	481.4 (M 488.9, F 473.8)	503.4
Cote d'Ivoire	24.2	23.7	465.9 (M 478.6, F 452.4)	484.1	475.7 (M 482, F 468.2)	517
Niger	17.2	6.3	437.4 (M 445, F 427.5)	435.2	405.8 (M 408.9, F 401.7)	403.5
Senegal	32.2	29.7	521.4 (males 528.6, females 513.6)	501.9	546.6 (males 556.5, females 537.7)	548.4
Togo	25.9	27.9	474.5 (M 478.3, F 470.3)	473.6	520.2 (M 523.9, F 515.8)	497.3

Looking at the proportion of grade 2 students at PASEC level 2 for their grade in 2014, Burkina Faso ranks the highest (40.9 per cent) and Congo second highest (37.7 per cent). Niger has the lowest proportion (17.2 per cent) followed by Cote d'Ivoire (24.2 per cent). The greatest percentage of students at PASEC grade 6, level 2 was in Burundi (46.8), followed by Burkina Faso (36.9). Countries with the lowest proportion of students at this level were Niger (6.3) and Chad (16.1). Mean 2nd grade scores were highest in Burundi (605), followed by Congo (541). They were lowest in Niger (437) and Benin (455). Mean 6th grade scores were highest in Burundi (593.6) and Senegal (546.6) and lowest in Niger (405.8) and Chad (450.9).

Consistently ranking higher are Burundi, Congo and Burkina Faso. Consistently ranking lower are Niger and Chad.

Country rankings are very similar for performance on the mathematics scale and performance on the English scale.

Males outperformed females in the 2nd and 6th grade mean mathematics performance in Senegal, Burkina Faso, Niger, Chad, Cote d'Ivoire, Togo, and Congo. And girls outperformed boys in Benin and Burundi. In Cameroon males outperformed females in grade 2 but in grade 6 females outperformed males.

Findings from a comparable data study

A Center for Global Development Working Paper notes the difficulties in comparing countries when different scales are used (Sandefur, 2016). The author constructs metrics using Trends in International Mathematics and Science Study (TIMSS) and SACMEQ data enabling the comparison of a number of African countries. 14 countries are ranked using an item response theory linking model[11] on a TIMSS grade 4 scale. The ranking is: Kenya (highest), Mozambique, Tanzania, Swaziland, Botswana, Uganda, South Africa, Zanzibar, Lesotho, Zambia, Malawi, and Namibia (lowest).

4. Country-level evidence on foundational mathematics progress

Some more in-depth research and discussion is recorded below for individual African countries where DFID have major investments.

Ethiopia

No data for Ethiopia were available on the World Bank database or the Education and Policy Data Centre site.

A Young Lives Survey measures attainment for a cohort of 12-year-old children in 2006 and a cohort of 12-year-olds in 2013 (Woldehanna et al., 2016). Reading and mathematics competencies fell over the 7-year period, with a higher rate of decline among girls than boys. Average raw percentage scores in mathematics were 54.42 for 12-year olds in 2006 and 37.17 in 2013, a 31.7 percentage point decline. The percentage of 12-year olds who could not read anything went up from 10.00 to 13.87. The researchers propose further research to identify why this decline has occurred. It may be that substantially increased enrolment rates[12] have led to a decline in average attainment as those with less previous schooling are included in the second cohort.

Another Young Lives Survey measured Grade 7 and 8 students learning levels at the beginning and end of the school year 2016/17 (Rossiter et al., 2017). Application of mathematics curriculum

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[11] See the paper for methodology https://www.cgdev.org/sites/default/files/math-scores-fourteen-african-countries0.pdf

[12] The enrolment rate in 2006 was 65 per cent. Data are missing for 2013 but are recorded 78.7 per cent in 2012 and 85.7 per cent in 2013. https://data.worldbank.org/indicator/SE.PRM.NENR?locations=ET

knowledge was tested. Mathematics teachers were also tested on their specialised content knowledge. Over 10,000 students were tested with TIMSS assessments. The mean hours of teaching mathematics was the same as for English at 3.5 hours per week. Females scored slightly lower than males (40 per cent average compared to males average of 42 per cent). The average gain over the school year was just over 1/3 of a standard deviation. Response scores went from average 506 to 538, a 32 point increase. Average student achievement in English increased by less,19 points (504 to 523).

Ghana

TIMSS 8th grade data are available for Ghana for 2003, 2007, and 2011.[13] This report is interested in data for lower grades but 4th grade TIMSS data were not available for Ghana. The 10th percentile score (score for the lowest 10 per cent) was 159 in 2003, 192 in 2007, and 222 in 2011 suggesting an upward trend. Also reflected in the percentage of students reaching international benchmarks. 10.5 per cent of children reached the low international benchmark in 2003, 18.9 per cent in 2007 and 25.1 per cent in 2011 (boys outperformed girls in these measures). Mean performance on the mathematics scale for 8th grade students went from 275.7 in 2003 to 309.4 in 2007, and upwards again to 330.8 in 2011. The girls score in 2011 was 318.5 and the boys score was 342.0.

A paper analysing Ghana's TIMSS results finds that they rank 47th out of the 48 TIMSS participating countries (Mereku & Anumel, (2011). The authors suggest one of the differences between Ghana and high achieving countries is not enough emphasis on communicating mathematically, reasoning mathematically, and deriving formal proofs. These are higher level skills than foundational skills which is the focus of this helpdesk report. The authors identify streaming students as a strategy which may improve results. They also suggest that the curriculum tries to cover too much and lacks focus and coherence. Improvement in 2007 from 2003 is suggested as possibly linked to teachers being better at preparing students for tests.

A USAID Early Grade Math Pilot program, implemented in Ghana, aimed to improve topic depth and mathematical reasoning skills (Social Impact Inc., 2019). It aims to improve learners ability to engage in mathematical communication. Syllabi for grade 1-3 were revised reducing the number of concepts taught but improving the depth of learning. Teacher resource guides were developed and mathematics coaches were trained to deliver in-service teacher training. Evaluation after one year found significant improvements in students' conceptual understanding and modest improvements in ability to improve mathematics functions. Teaching was found to be more interactive with pupil-centred learning and improvement in mathematics communication. Programme implementation was suggested to benefit from stronger accountability measures to ensure fidelity but overall, results were promising.

A 2014 Ministry of Education Report states that National Education Assessment results indicate that less than 20 per cent of grade 3 and grade 6 students attained proficiency in mathematics (Ministry of Education, 2014). An over-emphasis on memorisation of facts and rules was apparent.

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[13] https://databank.worldbank.org/source/education-statistics:-learning-outcomes#

Malawi

SACMEQ data are available[14] for grade 6 students in Malawi from 2000 and 2007. The average mathematics score was 433 in 2000, considerably under the 500 international average, and 447 in 2007. There are some signs of improvement compared to other countries but still some way below average. Boys outperformed girls in both years. The average reading assessment scores were lower but showed similar signs of improvement, 429 in 2000 and 434 in 2007.

Nigeria

National data on mathematics achievements in Nigeria was not identified. Nigeria are not present in the World Bank Education Statistics.

Two small scale studies were found which included mathematics testing to investigate relationships between different variables and learning outcomes in Nigeria. A journal paper from 2009 looked at the effects of parental involvement on mathematics and science scores (Olatoye & Agbatogun, 2009). The researchers use a Mathematics Achievement Test. No wider records from this test were found. Parental involvement was found to significantly improve student scores. Another study looked at the impact of motivation on learning outcomes in Nigeria (Tella, 2007). The researcher constructed their own achievement test. More highly motivated students were found to achieve higher test scores.

Rwanda

The USAID Literacy, Language and Learning Initiative (L3) gathered information on learner achievement to support the Rwandan Education Board to establish a regular system (Education Development Centre, 2017). L3 was designed to improve early grade reading and mathematics skills. Assessments were conducted on grade level standards in literacy and mathematics at baseline (2014) and endline (2016). Evidence of impact was mixed. Grade 1 mathematics results improved significantly over the two years. Grades 2 to 4 performance were not significantly different. Grade 1 and grade 3 pupils showed significant decreases in zero scores. Grades 1 to 3 improved in reading performance, fluency and comprehension. Grade 4 learners improved reading only in Kinyarwanda.[15] Comparisons by gender showed no significant difference between girls and boys and baseline but boys outperformed girls at endline in grade 2. In grades 1, 3 and 4 the gender gap decreased over time.

The Early Grade Mathematics Assessment (EGMA) instrument was used in a USAID assessment in 2011 to record how well students were learning in literacy and mathematics in grades 4 and 6 (DeStefano et al., 2012). There were few zero scores. Students demonstrated some automaticity in addition and subtraction, but more skill is needed in this area. Students performed better on quantity discrimination and word problems than they did on timed subtasks. No student represented full mastery of basic mathematics skills. Boys outperformed girls in most tasks.

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[14] https://databank.worldbank.org/source/education-statistics:-learning-outcomes#

[15] The official language of Rwanda

A study recording learning at the beginning and end of grade 6 in Rwanda is used to compare results of mathematics understanding in Botswana and South Africa (Maniraho & Mugabo, 2019). 20 primary schools were included across 7 districts, sampling 713 students. The test in Rwanda was the same as in the comparative Botswana and South Africa study. Rwandan test results were higher than the results from South Africa and Botswana taken in 2012 (Carnoy et al., 2012). Comparing results for different questions shows Rwanda to have a stronger foundational understanding of basic numeracy. The authors (Maniraho & Mugabo, 2019) pose that this may be due to different colonial influences particularly in attitude to education. However, the strength of the evidence comparing country data when measurement was six years apart may be questioned.

South Africa

South Africa is included here as national assessment data over time were available and show increasing percentage scores for most grades 1 to 6 with recorded scores for 2012, 2013, and 2014 (Bethell, 2016). Formal statistical tests for trend analysis are not possible. Controls, and therefore test comparability, are questioned.

Uganda

Attainment data are available for Uganda for 2000 and 2007 from the World Bank database.[16] Data are measured with the SACMEQ survey. The 6th grade, level 3 (basic numeracy) average score went from 31.6 in 2000 and to 36.1 in 2007 suggesting some progress. Girls scores went from 28.2 to 37.1 and boys from 33.9 to 35.2, so a much larger improvement for girls. The score for mean performance *across levels* (from level 1: pre-numeracy to level 8: abstract problem solving) went from 506.3 in 2000 to 481.9 in 2007, suggesting a decline in overall progress.[17]

A study on factors affecting mathematics test scores in Uganda used tests developed by the authors on 316 grade 3 students and 329 grade 6 students from 10 different schools in 2012 (Taniguchi et al., 2013). Student results varied across different areas of the curriculum. Grade 3 students scored highest on 'operations in numbers', 'set concepts', and 'measures'. They scored lowest on 'algebra', 'geometry', and 'fractions'. Grade 6 students scored highest on 'numeration systems and place value', 'operations on numbers', and 'algebra'. They scored lowest on 'integers', 'measures', and 'set concepts'. The results of the same test items were significantly improved from grade 3 to grade 6 students. Significant factors affecting attainment identified were: number of meals, living with mother, and socio-economic status.

Zimbabwe

SACMEQ data are available for Zimbabwe for 2007.[18] 6th grade, level 3 (basic numeracy) average score recorded in the World Bank database is 30.7 (compared to 36.1 for the same year in Uganda). The average score was 32.8 for girls and 28.0 for boys. The average score across

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[16] https://databank.worldbank.org/source/education-statistics:-learning-outcomes

[17] The SACMEQ scale remained the same as in 2000 to allow comparison over time.

[18] https://databank.worldbank.org/source/education-statistics:-learning-outcomes#

levels is 519.8. Comparisons are not necessarily consistent for different measures, i.e. Uganda perform higher in level 3 but lower in average score across levels.

The Zimbabwe Early Learning Assessment (ZELA) was a programme to support national capacity to monitor and review student assessment. Measurements were taken over the course of an Educational Development Fund (EDF) programme (2010-2015) (UNICEF, 2016a). In 2012 grade 2 students scoring at or above grade-appropriate level in mathematics was 46 per cent rising to 63 per cent in 2013 and 67 per cent in 2014. Grade-appropriate performance for English was 49 per cent in 2012, 54 per cent in 2013 and 51 per cent in 2014. Scores were higher in mathematics than English and English scores show a less pronounced upward trend from 2012 to 2013 and then a slight downward trend in 2014. Girls outperform boys in both subjects throughout the period. Children in urban schools outperform those in rural schools. School-level variance was high, different schools produce different level results.

Asia

There is a dearth of high-level data on mathematics attainment in developing Asian countries at primary level. Data exist for primary completion rates but not mathematics specifically. Some data exist for grade 8 and 15 year olds but this study is interested in primary level data.

An average mathematics assessment score is available for grade 4 students in Thailand from 2011 on the TIMSS scale, the average score is 458. This is some way below the 500 average, but the average is taken across 48 countries including a number of developed countries. The same statistic for Yemen was 248, 385 for Oman and for Kazakhstan 501. In 2011 in Thailand, 77 per cent of grade 4 pupils were reported to be at or above the lowest benchmark performance on the TIMSS scale. This statistic was 9 per cent for Yemen and 46 per cent for Oman.

Regional

A survey of 70 teachers across 6 countries (Cameroon, Democratic Republic of Congo, Ethiopia, Nigeria, Rwanda, and Uganda) asked if they thought their students were making good progress in mathematics (Bethall, 2016). 8.6 per cent strongly agreed, 67.1 per cent agreed, 7.1 per cent disagreed and 1.4 per cent strongly disagreed suggesting teachers' perception (or perception they wanted to give in the survey) is that students are learning.

5. Teacher capacity and improving foundational mathematics learning

A World Bank commissioned study on mathematics education in Sub-Saharan Africa highlights teacher capacity as a priority area for improvement. Enhancing their knowledge and equipping them with technologies (Bethall, 2016).

A study of six countries (Ghana, Kenya, Mali, Senegal, Tanzania and Uganda) investigating factors shaping teacher educators, trainee teachers, and newly qualified teachers found there needs to be a focus on how mathematics is taught and not just on improving teachers knowledge (Pryor et al., 2012). Primary mathematics tutors often felt ill-equipped to teach mathematics and relied on knowledge from fellow tutors and textbooks which were often out-of-date. There was little classroom interaction observed in teacher training sessions. Discussion amongst trainees as

to how to apply understanding and methods to effectively promote meaningful learning is needed.

Trainees were often taught mathematical topics above the level at which they were teaching which was not a valuable use of their time. Trainees spoke of experiencing negative attitudes from more senior teachers on new teaching methods. Induction and mentoring should be improved. The common problem across countries was "poor ability to generate representations for mathematical concepts using concrete materials" (Pryor et al., 2012, p471). Teachers often came away from training with the idea that following prescribed teaching steps will lead to students mathematical understanding. Training has been found to induce misplaced confidence (Akyeampong et al., 2012). Teachers take comfort in learning standardised approaches which do not necessarily improve student learning. Questioning of teaching and learning materials should be encouraged rather than relying upon steps (Pryor et al., 2012). Teachers need to be supported in making connections between materials and conceptual understanding.

Bold et al. (2017) note in a journal article investigating teacher effort that few, if any, studies identified how to effectively improve teacher knowledge and skills and therefore impact, and that this is an important gap to address. The challenges in how to effectively teach children are similar to looking at how to teach teachers.

6. Barriers

Barriers to students learning in mathematics are often parallel to issues for general learning. A study looking at variability of mathematics results in 4,819 grade 7 children in Uganda found student-level characteristics were the greatest source of variability (68.8 per cent) (Kiwanuka, 2017). Classroom-level indicators accounted for 14.2 per cent and school-level factors 17.0 per cent.

The World Bank study identifies cultural negative attitudes towards mathematics as a key barrier to progress (Bethall, 2016). An expectation of failure is also highlighted as a problem.

Learning in local languages is recommended to improve mathematics learning (Akyeampong et al., 2012). Teachers may not know local languages and materials are often in English. A study sampling 275 Namibian schools looked at the effect of language of instruction on mathematics results and find a significant effect (Garrouste, 2011). Students tested in Burundi, Comoros, South Africa, Botswana and Zimbabwe scored higher if they spoke the test language at home than the majority, who did not (UNICEF, 2016b).   .

7. Curricula

The link between curriculum content and effective learning in foundational mathematics was not widely discussed in the literature.

A UNESCO Institute of Statistics report was identified which looks at how cognitively challenging the curricula are in different developing countries in grades 5 and 6 finding high variation (Benavot, 2012). Guatemala, Bermuda, Costa Rica, Chile and Thailand have a high proportion of

demanding performance expectations in official guidelines or textbooks. Whilst other countries include relatively few in official guidelines (such as Sri Lanka, Belize, Jamaica, Botswana, El Salvador) or in their textbooks (e.g. Cambodia, Saint Lucia).

This area requires further research.

8. Technology

Technologies are identified as having potential to assist with mathematics teaching and learning but the best approach has not yet been ascertained (Bethall, 2016). Cost-effectiveness and long-term sustainability are a concern. Hardware should be flexible and be able to run a number of different software packages. Harnessing the internet is suggested as a good and viable option.

Mathematics instruction that can be shared using technology has good cost-effectiveness potential as cost per user goes down the wider it is shared (Winthrop et al., 2016). The language of instruction however would likely be English or French for wider sharing.

A number of trials (mostly small-scale) with technology have been identified and results tend to be positive:

- Literacy Education Math Lab in Columbia, Dominican Republic, and Panama uses low tech puzzles and games (Winthrop et al., 2016). It allows children to teach themselves. Shows promise but as yet there are no evaluations.

- Pixatel, developed in India, has adapted early curricula into a tablet-based learning platform and is working on evaluation.[19]

- Positive results in mathematics have been found from E-Learning Sudan which provides games on a tablet or computer for out-of-school children (Stubbé et al., 2016; War Child Holland, 2015).

- An interactive learning app was found to be beneficial for teaching basic mathematics to children with Special Educational Needs and Disabilities in a small-scale study in Malawi (Pitchford et al., 2018). An electronic learning programme designed for hearing impaired children in Kenya improved basic mathematics learning (Kiboss, 2012).

- A computer assisted learning programme allowed children to learn at their own pace in India was found to significantly improve student mathematics scores and was deemed to be cost effective (Banerjee, 2007; Kremer, Brannen, & Glennerster; 2013).

- Reports on technology use in Early Literacy and Maths Initiative (ELMI) in Rwanda found participants were excited but also fearful and uptake depended upon being able to use technologies without glitches (Tikly & Milligan, 2017). Users had to recognise the need for the technologies to be willing to put in the effort and often they did not work properly.

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[19] http://inclusion.digitaldevelopment.org/innovations/pixatel-tablet-based-adaptive-learning-platform

- A maths app developed by onebillion©[20] was tested in a randomised control trial with 283 pupils in one urban primary school in Malawi (Hubber et al., 2016). After eight weeks children using the app showed significantly higher attainment in early curriculum and conceptual knowledge. The authors suggest more research is needed to assess impact on raising on standardised assessments and cost-benefit analysis. Some more recent research in Malawi on early-grade mathematics learning with apps developed by onebillion© found the method of instruction improved gender equality of learning outcomes compared to standard pedagogical practices (Pitchford et al., 2019).

- A study pooling results from 16,856 primary school students in China assessing student achievement in mathematics with computing aided learning find positive results (Mo et al., 2015). Achievement gains are higher when the learning programmes are run out-of-school. Student self-efficacy improved through the problem-solving process.

9. Opportunities and recommendations

There is some consensus that mathematics learning outcomes will increase with improvements in overall school quality (Bethall, 2016). The World Bank report notes the complexities contributing to low mathematics achievement and that there is no simple answer to improve them. It is difficult to make shifts in large education systems. Government and stakeholder efforts must be sustained long-term.

Early childhood development programmes should be considered as an opportunity for accelerating progress in foundational mathematics. Children in Botswana and South Africa who had taken part in early numeracy activity with parents had higher learning outcomes (UNICEF, 2016b). Activities include counting different objects, card games, playing with shapes and building blocks. The Early Literacy and Maths Initiative (ELMI) in Rwanda implemented in homes and in childcare settings produced positive results in preliminary evaluation of school-readiness in mathematics (Save the Children, 2015). Maternal education level and socio-economic status also played a role in Rwanda which adds some limitation to findings.

Some reports of different models of school have been found to produce better mathematics results. Evaluations of low-cost private schools in developing countries have shown higher mathematics achievements compared to government schools (Winthrop et al., 2016). Escuela Nueva (originating in Colombia) is a multi-grade classroom model which allows students to work through lessons at their own pace and has shown promising evaluation results in mathematics in Guatemala (Baessa et al., 2002).

Impact assessment of USAID Primary Math and Reading (PRIMR) Initiative in Kenya finds positive results (Piper et al., 2016). The initiative supplied books for pupils, and supported teachers with training and instructional support. Significant improvements were found for procedural numeracy in early grade, and smaller effects in conceptual numeracy. There was found to be less emphasis on mathematics than English in the programme. The teachers were

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[20] https://onebillion.org

not always following the teaching guides or mastering the instructional improvements. The study notes that there is little evidence on improving mathematics education in the developing world.

Interventions suggested in the World Bank mathematics education study include (Bethall, 2016):

- Classify raising mathematics standards as a national priority.
- Changing attitudes within the public and education sector. This should include highlighting the benefits of mathematics knowledge and skills; that mathematics is for everyone and not just for especially skilled people; and better results are achievable with hard work in and out of school. Changing the view where it is held that mathematics is a subject for boys.
- Improving initial teacher training. Teacher training initiatives must change to increase priority in mathematics; curricula must be better delivered; tutors delivering the training must have the appropriate skills and attitude; and advantages of technologies should be utilised, such as e- and m-learning, with up-to-date material. Teaching teachers requires similar improvements to teaching children. Tutors with first-hand experience in teaching mathematics in primary schools would be particularly advantageous but are difficult to find. There tends to be inertia in teacher training institutions which makes progress slow.
- Existing teachers must be reinforced with improved knowledge and practices. In-service training should follow recommended guidelines. (Walter & Briggs, 2012). Pedagogy needs to move from teacher-led and rules focused to collaborative exploration. Improved content knowledge is required alongside this. Supportive collaboration between mathematics teachers is beneficial.[21]
- More textbooks are needed but must be the right textbooks and teachers must be correctly trained in working with them. To ascertain the right textbooks requires extensive testing before publishing. Published materials on the internet may be used as an alternative.
- Technologies should be utilised to help teachers gain access to ideas, models, materials and tools. Technologies could also be used for sharing among communities of teachers.
- International assessments such as PISA[22] and TIMSS are less relevant for countries far below international norms. Training for tests which are not suited to the learning needs of the specific population may be a barrier to progress. Regional and national assessments may be more beneficial. SACMEQ and PASEC have become more refined and should continue with becoming more formalised through common agreements for standard operations. Attempts at establishing national standards have had limited success. There are exam boards which do not make data available. Open data should be mandated.
- Self-learning technologies can be a useful supplement, particularly where adequate teaching is lacking. Access must be free and made known to local communities.

A report from CfBT (now Education Development Trust) on enhancing mathematics in primary schools (Burghes, 2012) focuses on lessons from developed countries (particularly Hungary, Japan, and Finland) but may offer some useful ideas. The report outlines a change model starting with a recognition of the need to change, then bringing in external experts to reflect on current practice. Continuing professional development should then focus on what is identified,

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[21] E.g. See for example the 1 + 4 project in South Africa
http://documents.worldbank.org/curated/en/538251476977591230/pdf/ACS19117-V2-Version-2-Full-report-final-P152990-PUBLIC.pdf
[22] http://www.oecd.org/pisa/

working on experimenting and refining, then school-wide implementation and ongoing reflection. The report recommends a Japanese version of lesson study[23] with teachers setting their overall aims. The report highlights the importance of having a mathematics coordinator within a school, encouraging, reviewing and intervening when necessary. Mathematical competence is also required alongside the other recommendations.[24]

Gaps warranting further research suggested in the World Bank report on mathematics learning in Sub-Saharan Africa (Bethall, 2016) include:

- Looking at how to monitor trends.
- Understanding how learners learn and approach problems.
- Investigating the effectiveness of textbooks and technologies.
- Improving national assessments.

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[23] A model of teacher-led research. Participants collaboratively research, plan, teach and observe a series of lessons, using ongoing discussion, reflection and expert input to track and refine their interventions. See https://tdtrust.org/what-is-lesson-study

[24] For more developed country guidelines see 'Maximizing Student Mathematical Learning in the Early Years' http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/CBS_Maximize_Math_Learning.pdf

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