The state of mathematics, science and technology in our schools

20 November 2012

Base document to guide discussions on a new mathematics, science and technology (MST) strategy for South Africa

Contents

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1 Introduction

This report is intended to guide the formulation of a new mathematics, science and technology (MST) strategy in South Africa. The last time a high profile strategy of this nature was produced was in 2001. There is a widespread belief that the education community needs to take stock of recent developments in the area of MST and re-affirm what should be affirmed and come up with new approaches where there is a need for this.

White Paper 1 on education transformation, released shortly after the advent of democracy in 1995, described the devastating legacy of apartheid on MST education. Though in certain respects the situation has improved since 1995, it is sobering that what the 1995 White Paper said is still to a large degree applicable:

> [There] is a dearth of Black students with science and mathematics qualifying for normal entry to higher education, fewer still continuing in mathematics and science-based programmes, and a trickle entering mathematics and science-based professional and technological fields in the economy. Mathematics and science programmes in universities and teachers colleges therefore have a perennial shortage of high quality Black candidates in these subjects. In particular, the number of science and mathematics teachers graduating from colleges of education, is far too small to make an impression on the need in schools, and their subject knowledge and professional confidence is generally poor. ... If this cycle is wasteful from an educational point of view, it is catastrophic from the perspective of national developmental needs[1].

As explained in this report, the challenges are especially great in the segments of the schooling system that were most marginalised under apartheid. However, it is also explained that there are challenges that must be faced by all South African learners, teachers and parents, no matter what schools they are associated with. Improving South Africa's poor average performance in the international testing programmes, and ensuring that more learners excel at the top end of the range, is a responsibility that all South Africans involved in education must share.

There is a strong emphasis in this report on improving our knowledge of the MST situation and challenges through critical summarising of key existing analyses, new data analysis and the identification of further data analysis that should occur in the near future.

There are two over-arching policy questions that guide the document:

- ***What should be done to strengthen the teaching of mathematics, natural sciences and technology in schools?*** Answering this question requires taking stock of the teacher capacity and resourcing situation as it currently stands with respect to MST subjects. It also requires addressing the difficult matter of what interventions are best suited for raising South Africa's poor and inequality-ridden learner performance, in general but also with respect to MST. How schools can better prepare learners for post-school studies in MST is a critical question.

- ***What changes are needed in the patterns of subject choices in schools to satisfy the skills requirements in the economy?*** A careful analysis of the MST skills shortfall in the country must inform any answer to this question. We need to understand trade-offs between participation rates and learning outcomes as well as the appropriateness of current patterns of subject choice beyond Grade 9.

In line with the Action Plan of the Department of Basic Education, the emphasis in this report is on how outcomes can be improved without radical changes to the basic structural elements

[1] Paragraphs 49 and 50 of the White Paper.

of the schooling system. The schooling system is said to be suffering from reform fatigue and this suggests one should focus on improving outcomes within the existing system.

Section 2 explains why a special emphasis on MST is justified and how MST skills contribute towards a country's development. Section 3 identifies the working definition for MST used in this report, with reference to the school curriculum. Section 4 describes how MST improvements are already addressed within the Action Plan. It is important that unnecessary duplication and misalignments in the new MST strategy, relative to the Action Plan, should be avoided. Section 5 addresses the first of the two questions mentioned above by breaking the question down into a number of sub-questions. Section 6 does the same for the second question mentioned above. Finally, section 7 sums up the implications of this report for the country's MST strategy.

The report includes a number of appendices which provide new analyses of specific issues that seemed to warrant a special focus.

2 Why is MST so important for a country's development?

Today many countries place a strong policy emphasis on improving MST learning in the education system. South Africa is not alone in experiencing a skills shortfall in the area of MST. The obvious solution is to improve the MST foundations laid in schools, increase the number of learners leaving school with an MST specialisation and provide additional learning opportunities for exceptionally gifted children and youths.

Society and the economy are evolving in ways that make having adequate MST skills especially important. Information and communication technologies (ICTs) increase the need for MST skills, both with respect to the development and use of these technologies. Greater complexity in the world's financial systems call for advanced MST skills not just to run these systems, but also to monitor and regulate them. This became very clear in the 2008 financial crisis. More generally, greater complexity in business, trade and government systems create new MST skills needs. To take just one of many examples, in order for South Africa's social grant system to provide its intended poverty alleviation, a range of accounting, information systems, and logistics experts are needed, all of whom need a solid MST foundation. Increased competition in the international trade of goods and services, coupled with the global mobility of individuals with skills, create new risks for any country that falls behind in the area of MST education. Increasing environmental pressures, in particular human-induced climate change, bring about new challenges that can only be solved if we improve our MST competencies.

Despite the undeniable importance of MST for human development, it is important to appreciate that human and social development depends on a basket of educational inputs, which, very crucially, includes good language and reading skills. Advances in MST are unlikely to occur if one does not also focus on advancing language skills. Moreover, in analyses linking education to economic growth, reading scores in international testing programmes are found to be as good predictors of economic growth as are the mathematics and science scores[2].

3 MST in the South African school curriculum

The following diagram provides an overview of the subjects in the South African school curriculum that can be considered MST subjects, which grades they are taught in and the time to be devoted to each subject per week according to the Curriculum and Assessment Policy Statements that started to apply in 2012. The previous rules with respect to time are indicated

[2] Hanushek and Woessman, 2009: 12.

in brackets. Time includes time devoted to assessment and reviewing where this forms part of the standard school day. All subjects are compulsory up to Grade 9. Only from Grade 10 are learners permitted to make certain choices. What qualifies as a ‘technology’ subject from Grade 10 is not defined in policy, but the selection of subjects indicated in the last column of the table is one that is commonly made.

Table 1: MST in the curriculum

	Mathematics	**Sciences**	**Technology**
Foundation Phase Grades R to 3	7h × 40w = 280h (Up to end of 2011, called ‘Numeracy’ and requiring between 7.5 and 9 hours per week, depending on grade)	No specific subject	No specific subject
Intermediate Phase Grades 4 to 6	6h × 40w = 240h (Up to end of 2012, 4.75 hours per week)	Natural sciences and technology 3.5h × 40w = 140h (Up to end of 2012, two separate subjects called ‘Natural sciences’ and ‘Technology’ requiring 3.5 and 2 hours per week)	
Senior Phase Grades 7 to 9	4.5h × 40w = 180h (Up to end of 2013, between 4.75 and 5 hours per week, depending on grade)	Natural sciences 3h × 40w = 120h (Up to end of 2013, 3.5 hours per week)	Technology 2h × 40w = 80h (Up to end of 2013, 2 hours per week)
Further Education and Training Grades 10 to 12	Mathematics or Mathematical literacy (one of the two is compulsory) 4.5h × 40w = 180h (Up to end of 2011 for Grade 10, 2012 for Grade 11 and 2013 for Grades 12, 5 hours per week)	Physical sciences, Life sciences and Agricultural sciences (all are optional) 4h × 40w = 160h (Up to end of 2011 for Grade 10, 2012 for Grade 11 and 2013 for Grades 12, 4 hours per week)	Agricultural technology, Design, Civil Technology, Electrical technology, Mechanical technology, Engineering graphics and design, Computer applications technology, Information technology (all are optional) 4h × 40w = 160h (Up to end of 2011 for Grade 10, 2012 for Grade 11 and 2013 for Grades 12, 4 hours per week)

4 What the Action Plan says about MST improvement

At the highest level, the future priorities for the basic education sector are captured within the sector plan *Action plan to 2014: Towards the realisation of Schooling 2025* and, related to this plan, the Delivery Agreement for the sector, signed by the Minister of Basic Education, the President of South Africa, and others in 2010. There are a number of other key planning documents dealing with specific topics in the sector, for instance the *Integrated strategic planning framework for teacher education and development in South Africa*, released in 2011, and the *Basic education accord*¸ also released in 2011 and dealing with partnerships in relation to initiatives such as adopt-a-school.

Whilst existing policies should not stifle innovation with respect to MST improvements in schools, it is efficient to ensure that, wherever practical, policies and initiatives are aligned.

The finding of the 2009 review of curriculum implementation of the DBE[3] that harm has been done to teaching and learning in schools as a result of too many, and often contradictory, policy and curriculum signals, serves as an important warning.

The *Action plan* as a whole should be seen as a guide for improving MST in schools. MST improvement is clearly not just an MST issue. For MST subjects to be strengthened, schools must be well managed, parents and communities should be involved in schools, schools should offer safe and inclusive environments that do not marginalise certain learners, teachers should not feel poorly treated, and so on. Of the 27 goals of the *Action plan,* seven do deal specifically with MST issues.

Three goals see improvements in mathematics performance at the Grades 3, 6 and 9 levels, as measured by the Annual National Assessments (ANA) programme, so that by 2019 75% of learners attain the basic expected levels of competency for their grade. The 2009 baseline is low, in particular for Grade 6, where it is reported to be 19%.

Two goals deal with improvements in the average level of performance of learners in mathematics, at the Grades 6 and 8 levels, as measured in the international testing programmes SACMEQ[4] and TIMSS[5]. The last wave of SACMEQ Grade 6 testing occurred in 2007 and the next one is to occur in 2013. South Africa last participated in TIMSS Grade 8 testing in 2003, and again in 2011 (South Africa did not participate in TIMSS 2007)[6]. Importantly for the monitoring of MST, TIMSS 2011 results will become available early in 2013.

Two goals deal with Grade 12 passes in the subjects mathematics and physical science. These goals see the number of passes doubling between 2009 and 2019.

Parts of the *Action plan* deal with the how of improving learning outcomes in schools. Some of the initiatives envisaged are improvements on past initiatives. For instance, an acceleration of physical infrastructure development is envisaged. Other initiatives represent new features in the schooling system. This is particularly true in the case of ANA, which was fully implemented for the first time only in 2011. ANA is expected to improve accountability in the schooling system in a number of ways, as well as more educationally-focussed parent participation. A number of milestones for the years 2011 to 2014 are explained in the *Action plan.* Milestones with strong relevance for MST development are listed below.

2011 milestones

- *Nationally developed workbooks for Grades R to 6 to support teaching in languages and mathematics are distributed to all public schools with these grades.* The mathematics workbooks have been designed with a strong focus on guiding the pacing of the teaching process through the various topics throughout the year.

2012 milestones

- *The national workbooks initiative is extended to include Grades 7 to 9.*

[3] The full title is *Report of the Task Team for the review of the implementation of the National Curriculum Statement.*
[4] Southern and Eastern Africa Consortium for Monitoring Educational Quality.
[5] Trends in International Mathematics and Science Study.
[6] Specifically, in South Africa Grade 9 learners wrote Grade 8 tests in the middle of the 2011 school year.

- *All Grade 9 learners begin participating in universal ANA.* This means that for the first time, Grade 9 learners across the country will participate in the same mathematics assessments.

- *New national textbook lists, with greater levels of advice to teachers and selectors of textbooks, are published on the national department's website.*

- *A comprehensive guide to available professional development programmes is established on the national department's website.* There is a need for better information on what teacher development options are available to MST teachers, and what options are considered the most effective.

2014 milestones

- *Teacher testing is started in a national sample of 200 verification ANA schools.* This would provide South Africa's first ever national research into the subject knowledge of MST teachers at the secondary level, where subject content knowledge is widely suspected to be a serious problem.

- *Using ICTs for teaching becomes a mandatory component of all pre-service teacher training.*

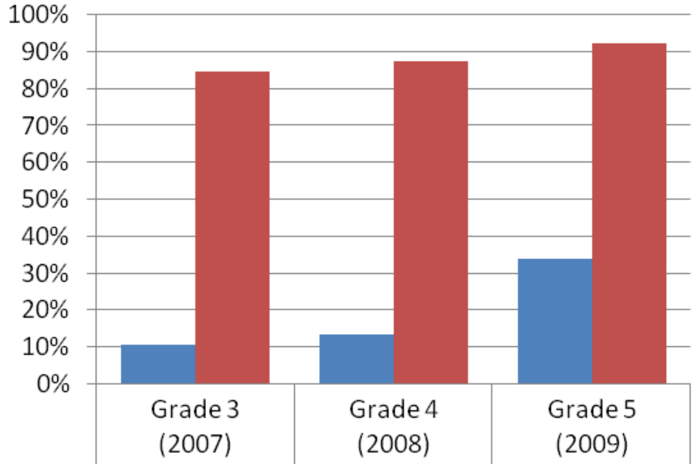
5 Strengthening the teaching of MST in schools

5.1 How poor and unequal are MST outcomes up to Grade 9?

In recent years a number of national and international surveys of educational achievement have consistently revealed alarmingly low performance amongst South African children in reading, writing and mathematics. For example, it is widely known that South Africa was the lowest-performing country in both the TIMSS 2003 surveys of Grade 8 mathematics and science and the PIRLS 2006 survey of Grade 4 reading. These surveys have also highlighted the wide inequalities that persist in educational achievement across the different parts of the South African school system. Several commentators have characterised the South African school system as effectively consisting of two very differently functioning systems (e.g. Fleisch, 2008, Van der Berg, 2008, Spaull, 2012). The underperforming system consists mainly of schools that were reserved for black and coloured children under *apartheid* (and were separately administered and insufficiently resourced) and are currently still predominantly attended by poor black children. The better performing system consists mainly of schools formerly attended by white and Indian children and now attended by mainly middle class children of all race groups.

The National School Effectiveness Study (NSES) as well as the results of the 2011 Annual National Assessments (ANA) showed that the inequalities between these parts of the school system are evident early in primary school. The NSES tested the exact same children over three years – in Grade 3 (2007), Grade 4 (2008) and Grade 5 (2009). The same literacy and numeracy tests were used in all three years. Figure 1 reports the proportions of children in each grade scoring above 50% in the numeracy test separately for those children in historically black schools and those attending historically white schools. Clearly far greater proportions of children attending historically white schools achieved above the 50% level. However, it is worth highlighting that a far greater proportion of Grade 3 children in historically white schools (84.8%) achieved above 50% than did Grade 5 children in historically black schools (33.9%). This means that by early in primary school children in the historically black part of the school system are already carrying learning deficits equivalent to well over two years of learning.

Figure 1: Proportions of children achieving above 50% in the NSES numeracy test



	Grade 3 (2007)	Grade 4 (2008)	Grade 5 (2009)
Historically Black Schools	10.8%	13.5%	33.9%
Historically White Schools	84.8%	87.4%	92.2%

South Africa's participation in the SACMEQ survey of Grade 6 mathematics and reading achievement of 2007 provides an opportunity for relevant comparison with other countries in the Southern and East African region. Interestingly, South Africa's ranking (in terms of country average scores) was higher for mathematics (8th out of 15 education systems) than for reading (10th out of 15 education systems). This indicates that although South Africa certainly faces a quality challenge in MST there is perhaps an even more acute problem in the area of learning to read. Moreover, the reading problem is no doubt a contributing factor to the MST challenge, given that reading is a crucial gateway into most other learning that must occur throughout school.

While the institutional history of schools provides one appropriate way to distinguish between the differently functioning parts of the school system, the average socio-economic status within schools also does. For the production of Figure 2 schools in the 15 education systems participating in SACMEQ were split into 5 equal sized "quintiles" of socio-economic status. Note that a measure of socio-economic status was derived using a set of questions children answered about the presence of various household assets in their homes. These quintiles are therefore not the same as South Africa's official "poverty quintiles" used for funding norms purposes. The figure demonstrates that in most countries there is a fairly gentle gradient of improving achievement as schools become more affluent. In South Africa, however, there is a sharp jump in achievement for the least poor 20% of schools. While the performance of poor schools in South Africa is low even compared with similarly poor schools elsewhere in Southern and East Africa, there is a level of inequality that is unique to South Africa.

Figure 2: Grade 6 mathematics achievement by school socio-economic status

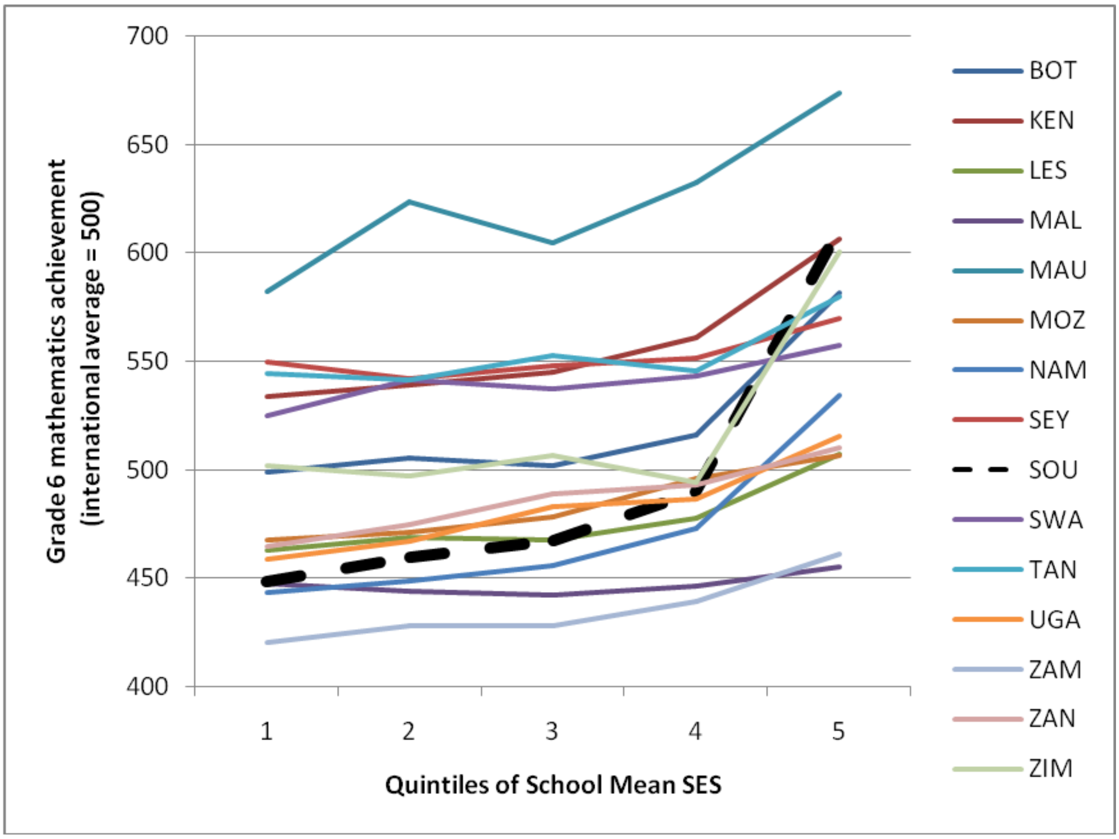
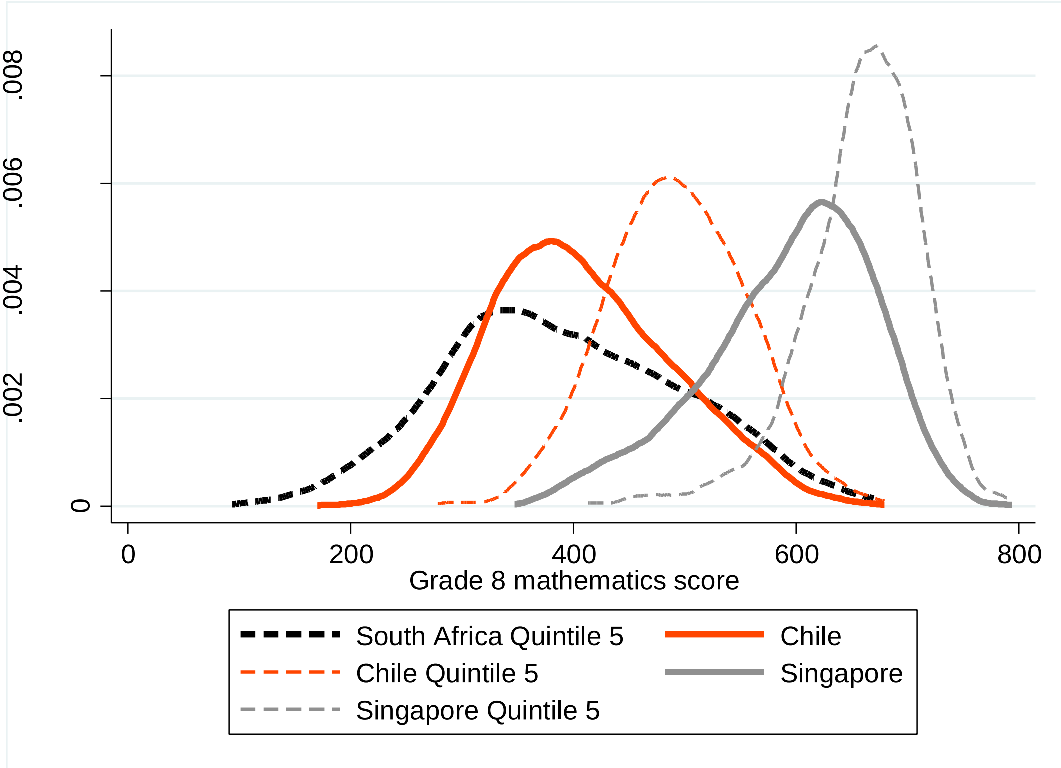


Figure 3 below depicts density distributions of Grade 8 mathematics achievement in the TIMSS 2003 survey for the most affluent 20% of South African schools, the entire sample of children in Singapore (the top-performing country in TIMSS 2003), the most affluent 20% of Singapore schools, the entire sample of children in Chile (an interesting Latin American country for comparison to South Africa), and the top 20% of schools in Chile. The curves indicate the density of children (along the vertical axis) performing at various levels of mathematics achievement (along the horizontal axis). The fattest part of a distribution indicates the highest concentration of children.

The figure shows that the distribution of achievement for the most affluent 20% of South African schools is roughly equivalent to the distribution for the entire Chile sample. When one considers that Chile performed well below the international average in TIMSS, this suggests that even the better-performing part of the South African system may not be achieving at a comparable level with developed countries. Indeed, the distributions for Singapore and for just the top 20% of Singapore schools are far superior to that for the top 20% of South African schools.

Figure 3: Kernel density distributions of mathematics achievement in TIMSS 2003



A final point to consider in this section is that performance in lower grades is strongly deterministic of ultimate educational outcomes. Reddy *et al* (2012) tracked students that participated in TIMSS in Grade 8 to when they reached matric, if indeed they reached matric. They demonstrate that Grade 8 mathematics and science achievement is strongly predictive of whether children reached matric and how well they performed in matric. Moreover, different parts of the school system varied widely in their ability to convert grade 8 achievement into matric achievement.

At the time of writing this report, the release of TIMSS 2011 was imminent. This will hopefully provide an important opportunity to assess what progress has taken place since the depths of the 2003 results.

5.2 What do we know about the supply and utilisation of MST teachers?

This sub-section and Appendix A will be expanded somewhat to include analysis of recently received Annual Survey of Schools data in order to provide a fuller picture of the situation relating to the supply and demand of MST teachers.

Insufficient data on teachers has been a recurring problem in the planning of teachers generally, and specifically in relation to MST subjects, which are seen to experience particularly acute teacher shortfalls. In 2006 and again in 2007 special surveys were run by the Department of Education (DoE) to collect teacher information from schools with Grades 10 to 12. A 2006 DoE report[7] using these data pointed to a supply of around 19,493 qualified mathematics teachers working in public ordinary schools at the Grades 10 to 12 levels.

[7] Report title is *Supply and demand of mathematics and science teachers in schools-based FET* (date 12 October 2006).

Furthermore, around 4,500 teachers were teaching mathematics without having specialised in this subject. This 4,500 figure was interpreted as one of several under-supply figures for mathematics teachers, where other figures were based on different assumptions. Using a similar approach, the supply of qualified physical science teachers was reported to be 4,518, whilst the shortfall was reported to be 700 teachers.

Fortunately, the data situation has improved recently with the recent successes in capturing most teacher questionnaire data within the Annual Survey of Schools (ASS). Appendix A provides a detailed description and analysis of the data. There are still significant data gaps, in particular relating to the formal subject specialisations of teachers. However, the new 2010 to 2011 data do provide a better basis for teacher planning.

The 2003 TIMSS data allow for an international comparison of mathematics class sizes at the Grade 8 level. In such a comparison, South Africa's class sizes appear exceptionally high and inequalities within the country with respect to class size large[8]. The average class size in South Africa was 44.7 and 16% of learners were in classes with more than 55.9 learners. To compare, in Botswana no learners were in classes with more than 45 learners.

How qualified are our MST teachers? The 2010 to 2011 ASS data do not include information on the subject specialisation within each teacher's pre- and in-service training. However, the data do include information on the type of qualification held.

The cross-country comparisons in Appendix C, using TIMSS 2003 data, suggest that South Africa's situation, both with respect to the overall level of education of mathematics teachers and whether mathematics teachers had mathematics as a major subject in their post-secondary education, is neither strikingly good nor strikingly bad. The percentage of Grade 8 mathematics teachers in 2003 who had majored in mathematics stood at 81%. This is virtually identical to the figure one obtains using the 19,493 and 4,500 figures mentioned above, which referred to the situation in Grades 10 to 12 in 2006 (19,493 over 19,493 plus 4,500 gives 81%).

The new 2010 to 2011 ASS data offer the opportunity to examine teacher utilisation in the schooling system in a manner that was not possible before. The preliminary analysis in this regard presented in Appendix A provides a few pointers. Mathematics teachers are generally not also teaching mathematical literacy. It is also relatively uncommon for mathematics teachers to also teach non-MST subjects. This suggests that increasing the supply of MST teaching in schools must largely be about injecting new teachers with the relevant subject specialisations into the system. The scope for raising the supply by re-allocating teachers, perhaps through the introduction of more *non*-MST teachers so that MST teachers can focus more exclusively on MST subjects, is limited. At the primary level, one interesting pattern revealed by the data is that the more socio-economically disadvantaged a school is, the more likely it is to have teachers teach across several grades, as opposed to concentrating on just one grade. Put differently, poorer schools tend to promote subject specialisation but with teaching across several grades, as opposed to grade specialisation (including dedicated class teaching) but with teaching across many subjects. These patterns raise important questions around what practices to promote in primary schools to strengthen mathematics and science performance. Is it optimal for poorer schools to promote subject specialisation because mathematics teaching skills are so scarce? Or are there perhaps benefits associated with a shift towards more class-oriented and grade-specific teachers, so that teachers are better able to integrate learning across the curriculum, for instance by ensuring that language learning and mathematics learning complement each other? Further analysis of the new data, combined with other research, could provide more answers than were possible for this report.

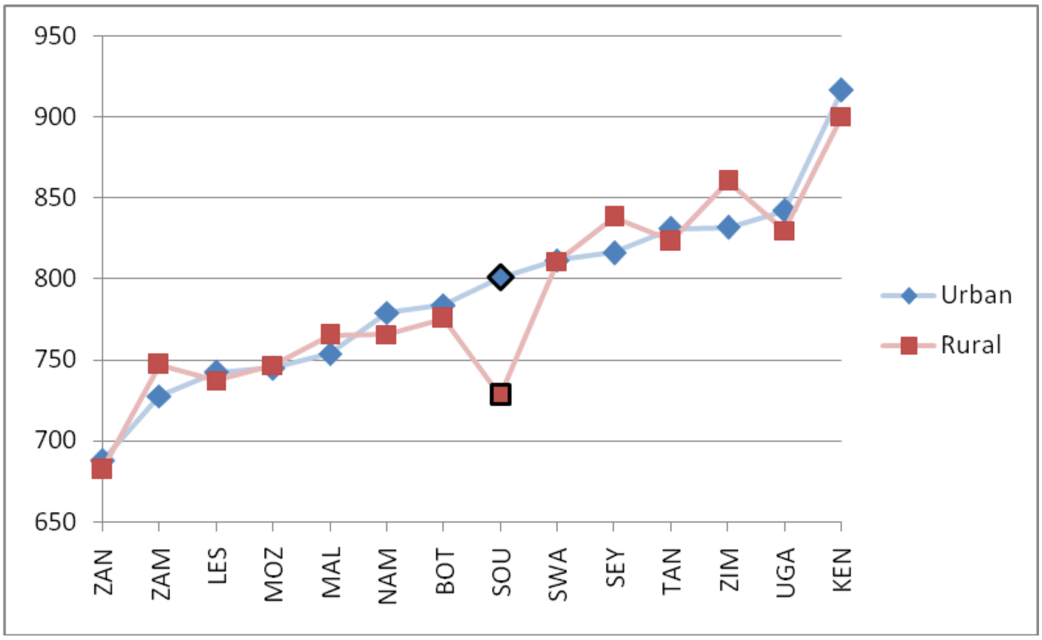
[8] Gustafsson and Patel, 2009.

5.3 How knowledgeable are our MST teachers?

Until fairly recently, there has been virtually no information available regarding the content knowledge of South African teachers. The National School Effectiveness Study (NSES) included very short tests for mathematics and language teachers, which pointed to inadequate content knowledge amongst Intermediate Phase teachers (Taylor, 2011). However, the main source of information regarding the content knowledge of South African teachers is the SACMEQ survey of 2007. This included an extensive mathematics test for Grade 6 mathematics teachers and an extensive reading test for Grade 6 language teachers.

Figure 4 depicts teacher scores in the mathematics teacher test for all countries that participated. The scores for teachers in rural schools and in urban schools are reported. This demonstrates that South African teachers located in urban schools have a content knowledge that is fairly average in regional comparison. However, there appears to be a particular problem regarding the content knowledge of rural teachers. Whereas in most countries there is little difference between the content knowledge of urban and rural teachers, in South Africa there is a marked difference. The content knowledge of South African mathematics teachers in rural areas is just about the worst in the region.

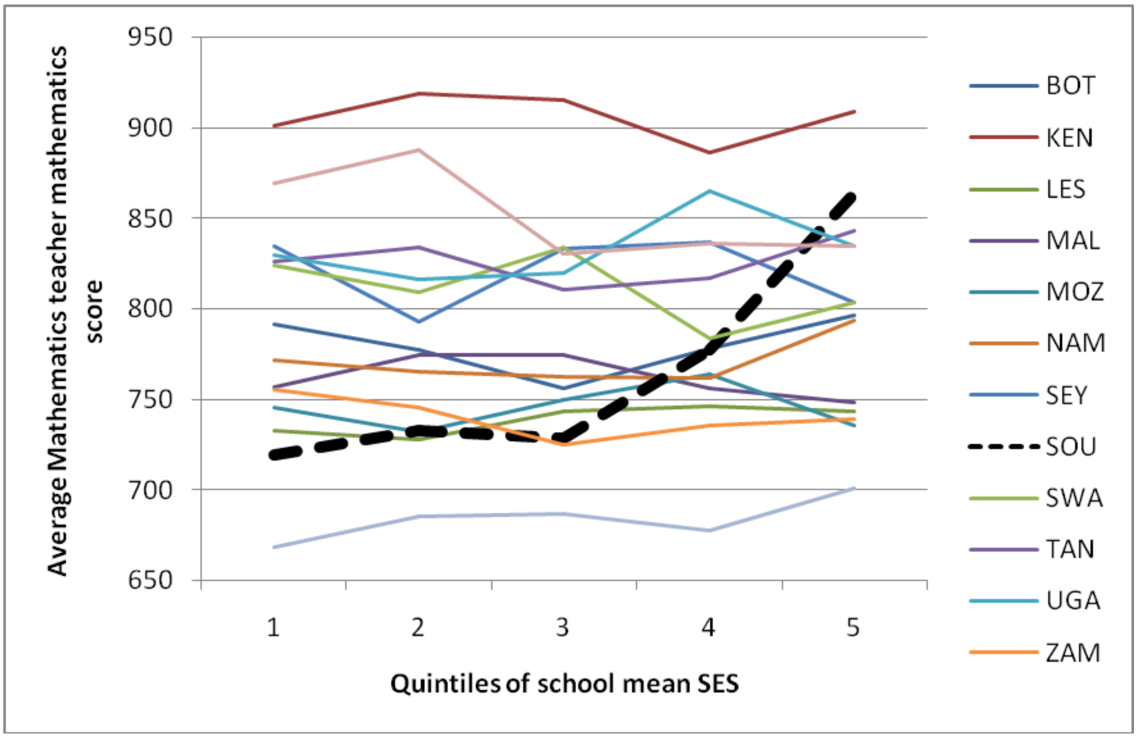
Figure 4: Grade 6 mathematics teacher content knowledge in urban and rural areas



The next figure tells a similar story, except now the distinction is on the basis of socio-economic status (SES). Mathematics teacher content knowledge is relatively good in the most affluent 20% of South African schools, but amongst the worst in the region for the poorest 60% of schools.

The poor content knowledge of many of South Africa's teachers comes despite having received more years of teacher training on average than their counterparts elsewhere Southern and East Africa, as the SACMEQ survey also reveals (described in Appendix E). This situation would suggest that either pre-service teacher training or in-service training programmes are not succeeding in developing the content knowledge of teachers.

Figure 5: Grade 6 mathematics teacher content knowledge by school SES



Considerable further research is required in order to understand how teacher content knowledge impacts on student learning. Spaull (2011a), for example, found using the SACMEQ data that the association between teacher content knowledge and learner achievement was fairly small. Additional data on teacher knowledge needs to be collected and analysed with respect to learner achievement, particularly at the secondary school level, where one might expect teacher knowledge in subjects like mathematics and science to have considerable impacts on learning.

5.4 How available are MST textbooks?

Access to texts, whether in the form of textbooks or workbooks, is an area which has seen important innovations in recent years. Workbooks are essentially textbooks in which learners write, making workbooks resources that are personally owned by individual learners and which are not passed on to other learners in the following year. 2011 saw the introduction of new national workbooks in Grades 1 to 6 by the DBE. This is easily the most ambitious national initiative to date to improve access to texts amongst learners. In 2011 all Grades 1 to 6 learners were provided with their own workbooks in two subjects, namely mathematics and home language. In 2012, the initiative was extended to Grade 9 and the intention is to make the delivery of physical workbooks a permanent annual feature of the schooling system. Electronic versions of the workbooks are available on the internet at the Thutong education portal. To illustrate, the Grade 6 mathematics workbook, illustrated in colour, consists of almost 400 pages divided across two volumes, with exercises allocated to each week of the school year.

2011 also saw the introduction of the School Monitoring Survey, a sample-based survey aimed at monitoring various education resourcing issues, including access to texts. Details on this survey are provided in Appendix B. Prior to 2011, information on access to texts amongst learners had been poor as the focus had largely been on deliveries of materials to schools, in other words the supply of texts, rather than on actual access in the classroom and the proper utilisation of texts.

The picture provided by the 2011 survey is a worrying one. What is clear is that far too many learners in socio-economically disadvantaged schools do not have access to the texts they need for proper learning to take place. This is true for MST and non-MST subjects. Yet providing access to texts is a relatively straightforward and low-cost intervention, for instance relative to the task of upgrading teacher skills. There is an important debate around the impact that simply improving access to texts can have. Clearly, such initiatives need to be linked to initiatives that improve teacher skills in using materials. However, some of the evidence suggests that simply improving access to texts can improve learning outcomes, depending on circumstances existing at the school[9].

What the 2011 survey also points to are certain difficulties in defining and understanding optimal access to texts in schools. Monitoring exercises as well as interventions need to be sensitive to these issues. Apart from access to texts at school, the ability of learners to take texts home and use them for their homework is a key matter. There needs to be a balance between school initiatives to preserve books, which could include storing textbooks in secure places, and access and utilisation during and beyond the school day. Sharing of certain books is not necessarily a bad thing, for instance where this is done in order to increase the variety of texts available in the school. Research has pointed to a critical threshold of two learners per book. Often, sharing a book in the classroom with one other learner is not worse from a learning perspective than having one's own book. However, when more than two learners share a book education is compromised[10]. There are schools where capable teachers make the choice of using loose worksheets gathered in files that each learner has, rather than books. In some schools, generally more advantaged ones, computer software is able to take the place of books. These dynamics explain to a large degree why, according to the 2011 survey, 25% of teachers in quintile 5 schools (in other words, the least poor schools) said they did not use a textbook.

The 2011 survey involved a special focus on mathematics in Grades 6 and 9. Fieldworkers visited mathematics classes, asked learners questions directly and asked to see books. Perhaps the most worrying statistic emerging from this exercise is that in the case of Grade 6, 8% of learners in quintiles 1 to 3 (the poorest quintiles) were in classes where no mathematics workbook or textbook could be shown the fieldworker, though the class was described as a mathematics class. On the positive side, in over half of quintiles 1 to 3 schools fieldworkers saw learners with *both* textbooks and national workbooks. The problems are concentrated in certain provinces. What is encouraging is that in NC, NW and WC, the phenomenon of quintiles 1 to 3 learners unable to show even one book was virtually non-existent. However, 19% of these learners in MP and 14% in FS were without books. In the country as a whole, where books could be shown the ratio of books to learners tended to be relatively good: for textbooks there were 81 books per 100 learners and for workbooks the figure was 94. The statistic for textbooks in FS, at 65 books per 100 learners, was particularly low.

The Grade 9 class visits again revealed problems in FS and MP. The percentage of quintiles 1 to 3 learners in schools where no learner could show a textbook was 36% in FS and 44% in MP. But the statistics for NC (55%) and KN (35%) were also worrying. Where fieldworkers found at least one textbook shown by learners, the average ratio of textbooks to learners was lower than at the Grade 6 level: at the Grade 9 level this ratio was 65 books per 100 learners. One might expect non-access to textbooks to have been partly alleviated by the introduction of Grade 9 workbooks in 2012. However, by the Grade 9 level textbooks would have become particularly important for learning and the non-availability of this resource imposes a ceiling on what can be learnt.

[9] Spaull, 2011a: 19.
[10] Spaull, 2011a.

Data collected just from teachers within the 2011 survey indicate that access to texts amongst learners was much better at the Grade 12 level than at the lower grades. These data pointed to 90 Grade 12 mathematics textbooks per 100 learners, counting all schools with Grade 12, for instance. This is likely to be a reflection of the emphasis placed on performing well in the Grade 12 examinations, but also an insufficient emphasis on laying the foundations properly at the lower grades. The data also show that the full range of MST subjects at the Grade 12 level enjoys a textbook to learner ratio of around 90 per 100. What has thus not happened within Grade 12 is the marginalisation of less prioritised subjects, such as life sciences, in favour of high-profile subjects such as mathematics, at least not as far as textbooks are concerned. The prioritising of learning in Grade 12 is also evident in the statistics on the percentage of learners who can take their textbooks home with them. In Grade 12 mathematics the figure is 81%. The corresponding figures for Grades 6 and 9 are 56% and 68%.

The 2007 SACMEQ data, one of the few pre-2011 sources we have offering some information on textbook access, painted a picture with respect to textbooks that was similar to the 2011 picture emerging from the School Monitoring Survey. SACMEQ furthermore placed South Africa just below the middle in the ranking of 15 countries in the region with respect to access to Grade 6 mathematics textbooks. Given that South Africa is an exceptionally high spender in per learner terms within the region, the fact that our textbook situation should be relatively poor should be viewed as a call for decisive action.

To sum up, we need to understand why, despite the existence of policies that should ensure access to learning materials, 8% of quintiles 1 to 3 learners in Grade 6 (and presumably other grades too) do not have access to either workbooks or textbooks in their mathematics classes. This understanding should then lead to appropriate action, be this the unblocking of funding and book delivery channels to the school, or fixing the management of resources within the school. Clearly improving the flow of resources to schools is a large part of the solution. Two-thirds of the teachers in problem schools stated that they had not received resources they thought they should have received. In the context of limited funding, careful attention should go towards assessing how schools use textbooks, which have existed for a long time, and the relatively new national workbooks, to complement each other. In schools where, for instance, there are 20 learners or more for every mathematics textbooks in Grade 6 (the 2011 data indicate that 10% of Grade 6 learners find themselves in this situation), it may be optimal to aim, as an interim measure, a ratio of two learners per textbook, in particular if national workbooks are arriving in schools as they should.

5.5 What do we know about classroom practices?

This sub-section provides only a very brief overview of some of the key findings surrounding classroom practices, where possible specific to MST. More detail about classroom practices that affect learning is provided in Appendix E. Five challenges with respect to classroom practices are highlighted here.

Language practices. The difficulties surrounding the language of instruction policy and actual classroom practice have received considerable attention. Firstly, children are not learning to read effectively during the Foundation Phase either in their first language or in a first additional language. This compounds the difficulties faced by learners when transitioning into English as the language of learning and teaching in Grade 4, as is the common practice for the majority of learners. Partly due to these challenges teachers often end up "code-switching" between languages. Over and above the obvious disadvantage of learning in a second language, code-switching is sub-optimal due to the extra time that it takes to cover work and the lack of uniformity of academic language.

Time. Research indicates that time for effective learning at school is eroded in at least three ways. Firstly, teacher absenteeism appears to be more frequent in South Africa than in most other Southern and East African countries, largely due to the South African phenomenon of strike activity. Secondly, inefficient allocation of teachers to subjects and timetabling within the school also contributes to large classes and poor use of time. Thirdly, time is eroded through a lack of academically engaged time.

Curriculum coverage. Closely related to the use of time is the matter of curriculum coverage and curriculum pacing. Hoadley (2003) found that curriculum pacing was very slow in many classrooms with the pace for everyone being set by the slowest students. The review of learner exercise books conducted in the NSES established that coverage of the curriculum, as indicated by the number and types of exercises that had been done over the course of a school year, was far from complete. Moreover, the extent to which the curriculum was covered in the year was strongly associated with learner performance in literacy and numeracy (Taylor, 2011).

Low cognitive demand. A number of studies have pointed to the low cognitive demand of lessons and exercises administered in South African classrooms (e.g. Prinsloo, 2008, Hoadley, 2007, Ensor et al, 2009). The learner exercise book review in the NSES also showed how seldom children in grades 4 and 5 undertake complex exercises in mathematics (defined as exercises requiring more than one computation or involving a word sum). Taylor and Reddy (forthcoming) present a rich analysis of the theoretical importance of writing (and representation) in learning mathematics. Based on a review of learner exercise books conducted as part of the NSES, Taylor and Reddy conclude that "children in South African mathematics classrooms are systematically deprived of access to written text, whether this is in the form of being exposed to ideas, explanations and activities through reading, or in the form of expressing themselves in writing."

Instructional leadership. One cannot separate the quality of school management and leadership from classroom practice. Several authors have promoted the concept of "instructional leadership". Hoadley, Christie and Ward (2009), for example, find that the majority of principals do not regard the oversight of curriculum and teaching as their main task, but feel that the responsibility for this lies with subject heads and heads of department (HODs). Perhaps as a consequence of this perception amongst principals, aspects of instructional leadership did not appear to take up the majority of their time but rather administrative duties and learner discipline. Hoadley et al (2009: 381) find that successful instructional leadership occurs through ensuring curriculum coverage, good management of resources, facilitating parent support and structuring the school day effectively. It is clear how this feature of school leadership feeds directly into the other aspects of classroom practice referred to above.

5.6 What does foreign and local evidence suggest should be done?

As pointed out in section 2, improving MST outcomes in schools is largely about improving the schooling system generally. Better MST outcomes require better reading and writing skills amongst learners, ongoing support for teachers, committed school principals, a well functioning education administration, and so on. Realising these goals is a difficult task. Perhaps one role MST specialists in the education system have is to promote a more scientific approach to improving learning outcomes in schools. School improvement is not just a matter of science. It is also about good leadership and judgement, and the promotion of appropriate values. Yet the evidence suggests there is room for South Africa to be far more scientific in the task of tackling educational under-performance. One thing that is becoming increasingly clear in the research of educational improvement, is that 'looks deceive'. Interventions to improve schooling that look good at face value have often proven to make virtually no difference to what learners learn. This should guard all those who want to improve learning outcomes against false complacency with current approaches. Even apparently well organised and logical interventions may not have the desired impact. Actual learning outcomes, or educational impact, and not just intermediate indicators such as number of teachers undergoing in-service training, or number of textbooks delivered, must be closely monitored. Preferably, this monitoring should occur in a way that makes it possible to know which interventions to strengthen, and which interventions to adapt or discontinue.

Another thing that is becoming clearer is that different interventions are needed at different stages of development, whether this be the development of an entire country or individual schools. This point is argued strongly both in the planning and management literature (see for instance Mourshed, Chijioke and Barber [2010]) and the school improvement literature (see Hopkins and Harris [1997]).

In general, and not just in relation to MST subjects, what is likely to work in the South African context, keeping in mind the questions relating to education inputs that have been asked in the previous sections? The literature addressing this question is vast. Here only a couple of key messages emerging from this literature will be addressed.

Formal impact evaluations of both system-wide and more targeted interventions are increasingly providing important information on what works within a developing country context. In particular, the greater use of techniques such as randomised control trials (RCTs) in developing countries is encouraging. RCTs have the advantage that they are able to identify what specific actions or inputs cause improvements in learning outcomes in a relatively robust and scientific manner. One disadvantage is that each RCT can focus on only a limited set of interventions, often just one, yet the schooling process is a complex one involving a multitude of inputs which influence each other. Multivariate techniques such as education production functions do permit a multitude of school factors to be considered simultaneously. However, it is usually difficult to obtain sufficiently comprehensive data for such analysis. Moreover, production function-type analysis is limited in its capacity to identify causal linkages. To illustrate, production functions will often point towards unexpected and unlikely improvement factors, such as swimming pools, because such factors are linked to parent education and income, whilst parent education may not be well reflected in the data used for the analysis.

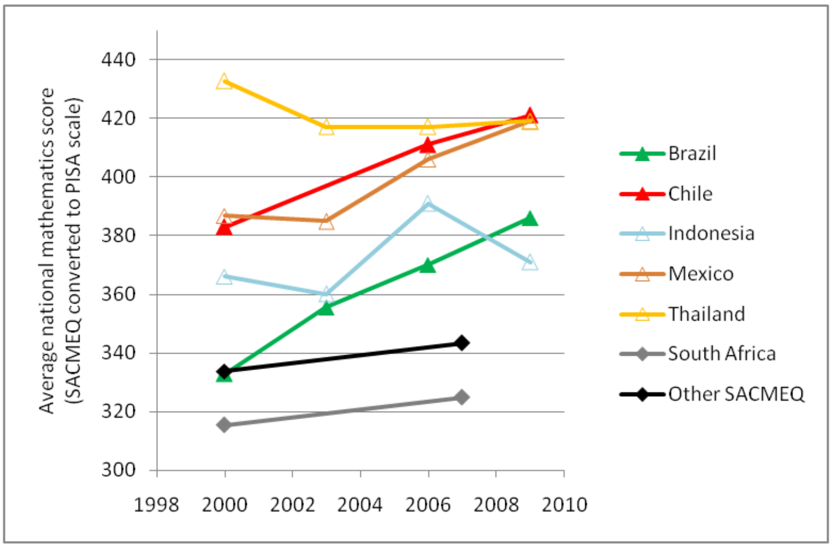
Bruns, Filmer and Patrinos (2011) provide what is arguably the best summary and critique of recent impact evaluations in developing countries. Their focus is on ‘accountability reforms’, or better information on educational performance being made available to managers and communities and being linked to support initiatives, incentives (in particular for teachers) and sanctions. The 22 impact evaluations critiqued by Bruns et al (2011) indicate that with the right degree of design rigour, a difference can be made to learning outcomes. Reliable testing systems and systems to verify and disseminate the data are necessary. But the manner in which information is collected and how it is used is crucial for improving results. Teacher in-service training of a sufficient intensity, for instance through two-week out-of-school training, combined with accountability reforms, can add value to the schooling process.

Interventions involving better access to good texts for learners have also been shown to produce positive results. Glewwe, Kremer and Moulin (2007) provide references to previous studies but also indicate, using data from Kenya, that textbook interventions render better results for more capable learners and that weaker learners are far less likely to enjoy these benefits.

What type of in-service teacher training to pursue is a vital question. As pointed out by Bruns et al (2011: 62), the impacts of teacher development initiatives, on the few occasions where impacts are measured, have been found to be disappointing. Training must occur, but the planning of this activity must be cognisant of the risk of no impact and should ensure that sufficient monitoring takes place. A multi-faceted monitoring approach involving qualitative feedback from trainees, expert assessment of training materials and statistical analysis (including analysis of learner results) seems preferable[11].

It is important to learn from countries, in particular developing countries, which have shown clear evidence of improvements in recent years. Figure 6 illustrates the exceptional and consistent improvements seen in the PISA[12] mathematics results for Brazil and Chile (PISA focuses on 15 year olds). South Africa's trendline in SACMEQ mathematics has been recalibrated to the PISA scale. Brazil's average annual improvement between 2000 and 2009 has been over four times as large as South Africa's between 2000 and 2007, in terms of PISA points. Moreover, Brazil's improvement can be considered real and substantial. The South African improvement is too small to be regarded statistically significant, in other words it is possible that there has been virtually no improvement and that the small apparent improvement is due to a sample of schools having been used[13]. It is important to note that Brazil faces many of the socio-economic and institutional challenges faced by South Africa. Identifying what lies behind the improvements in countries such as Brazil and Chile is a matter that is open to debate, but analysts tend to emphasise the role played by improvements in the measuring of learning outcomes, and the linking of measurement to accountability, targeted support and sanctions (see for instance OECD [2012] on Brazil).

Figure 6: Mathematics improvements in developing countries



Sources: The various data sources as well as the methodology for converting SACMEQ scores to PISA-type scores are provided in Gustafsson (2012).
Note: All the non-African countries have trends based on their PISA results. Developing countries with results for four or three points in time within the PISA programme were selected.

5.7 How successful have we been at addressing the challenge post-1994?

Probably the most significant initiative to arise out of South Africa's 2001 national MST strategy for schools[14] was the Dinaledi programme. This programme has involved targeting schools offering Grade 12 that showed promise in the area of MST and on the whole are socio-economically disadvantaged (a few advantaged schools were included). Targeted

[11] De Chaisemartin (2010) offers a rare example of an impact evaluation of a South African teacher training programme, which included training in mathematics. A variety of impact evaluation techniques was employed in this study.
[12] Programme for International Student Assessment.
[13] Makuwa, 2010.
[14] Department of Education, 2001.

schools received additional resources such as books, calculators and science laboratory equipment, as well as additional teachers and teacher in-service training. Since 2008, the programme has comprised 500 schools. Starting in the 2011/12 fiscal year, Dinaledi funding has occurred through a national conditional grant in order to strengthen spending accountability and the cohesiveness of the programme across the country. Before 2011/12, Dinaledi was funded through less formal agreements between the national and provincial departments as to how much funding should be devoted to the programme. To provide an idea of the level of public spending on Dinaledi schools, in 2011/12 this amounted to around R130 per Dinaledi learner, or about 1.0% over the typical spending on a secondary level learner (there are around 550,000 learners in Dinaledi schools). The support received by Dinaledi schools has differed to a significant degree from school to school due to factors such as differentiated provincial approaches to the programme and the fact that some Dinaledi schools have benefited from partnerships between government and non-public donors which involved special packages of additional support for certain schools.

A formal impact evaluation of the Dinaledi programme was conducted in 2010 by analysts from the World Bank, who compared trends for Dinaledi and non-Dinaledi schools for the years 2004 to 2007[15]. The analysis is important partly because proper impact evaluations have rarely been conducted on education interventions in South Africa, meaning that valuable methodological lessons can be drawn from the study. The Dinaledi programme was found to have had a significant and positive impact on the number of physical science and mathematics passes. For instance, where Dinaledi schools had on average seven additional learners passing higher grade physical science in 2007 compared to 2004, the figure for non-Dinaledi schools with similar characteristics was just one. One recommendation made by the analysts is to make the improvement strategy within Dinaledi more transparent so that in future impact evaluations it becomes easier to identify what aspects of the intervention made the greatest difference and the likely impact of taking the various aspects of the intervention to scale[16].

Two recently introduced initiatives aimed at strengthening MST subjects in schools through better availability of texts deserve special mention, though the initiatives are too new for proper evaluations of their impact to have occurred yet. The first is the workbooks initiative, which includes the distribution of national workbooks in mathematics. This was described in section 5.4. The second initiative is the introduction of more affordable, yet high quality textbooks for MST subjects in Grades 10 to 12. This initiative is the product of a partnership between the DBE and the Shuttleworth Foundation. The approach has been to bring new, but exceptionally talented, South African teachers into textbook-writing teams and to produce textbooks that would be ‘open source’ materials, in other words materials that can be freely reproduced in hard copies or over the internet, without the usual copyright restrictions[17]. The DBE produced hard copies of the mathematics and physical science textbooks for all learners in Grades 10 and 12 and distributed these to schools for the 2012 school year. For the 2013 school year, Grade 11 books in the two subjects are also being distributed. Two of the nine provinces, WC and LP, decided to adopt the new textbooks as core textbooks and have thus moved away from the ordering of other textbooks. In the remaining seven provinces, the Shuttleworth textbooks are considered supplementary textbooks, in addition to other textbooks that have been ordered. One great advantage with the Shuttleworth books is that

[15] See Blum, Krishnan and Legovini (2010) and a summary in World Bank (2010).

[16] One matter that will need to be taken into account in future impact evaluations of the Dinaledi programme is the question of the selection of learners. This was not fully taken into account in the 2010 study. Specifically, it is possible that the Dinaledi schools attracted better learners in the areas of mathematics and science, because such learners would have sought out Dinaledi schools but perhaps also because in some ways the schools would have made an effort to attract learners with strengths in these subjects. This might have influenced the number of passes in the Dinaledi schools, but even of non-Dinaledi schools in the vicinity of Dinaledi schools.

[17] The original methodology has been documented in Petrides, James and Nodine (2007). The textbooks can be accessed online at http://www.mathsexcellence.co.za/mindset_gr_10-12_textbooks.php.

they cost around a quarter of what other textbooks of the same length cost, which is partly indicative of various problems in the South African textbook market that have pushed prices up beyond what they should be. The new initiative puts needed pressure on publishers and provincial departments to find ways of reducing costs. Lowering costs is one way of ensuring that the serious access to texts problems in South African schools described in Appendix B are overcome.

5.8 What should be prioritised to strengthen MST?

What does the above discussion suggest should be prioritised to strengthen MST learning in schools? Prioritisation is needed. One critique that has been made of the 2001 national MST strategy is that to some extent it succumbs to the 'wishlist' effect and is not sufficiently cognisant of the need to prioritise actions which are expected to have the greatest impacts, taking into account the financial and human costs of these actions. Just three recommendations are provided below. Obviously they do not cover everything that is important. The *Action plan* provides a far more comprehensive set of activities that need to be pursued to improve MST outcomes, and education outcomes generally. The emphasis here is on four tasks that in many ways elaborate on parts of the *Action plan*, that have potential long-term as well as immediate impacts, and that can to some extent be pursued by various champions of change simultaneously. With regard to the last point, government has an important role to play, but it is not the only roleplayer. Moreover, within government there are various points where people can take action that makes a difference, from the school to the national and provincial planning offices. Outside of government, MST champions in universities, NGOs and the private sector are crucial partners in the change process.

The three recommendations are as follows:

- *Better advice on learning materials to MST teachers.* The DBE has recently assumed additional responsibilities around the determination of approved textbook titles, apart from the DBE's initiative of national workbooks. The *Action plan* envisages a situation where teachers and school principals would have easy access to guides on what materials are best suited for different school contexts and different teaching styles. The underlying assumption is that the choice of texts used in the classroom is a critical one. In the case of MST subjects, what would be needed is bringing together the research of different parties relating to the selection and use of materials, and the dissemination of the research to schools. In line with what has been discussed earlier, monitoring of the initiative would be needed to ensure that schools in fact find the advice they receive appropriate and useful. This recommendation relates to a need that has often been identified in MST circles, namely the need for far more pro-active research and development around textbooks and other MST materials.

- *Exemplary assessments of selected MST in-service training programmes.* There are many different in-service training programmes for MST teachers in South Africa. Whilst the processes flowing from the 2009 Teacher Development Summit led to some stocktaking of what training was available, there has been very little assessment of the impact of this training on teacher capacity and, ultimately, learner performance. Impact evaluations are not easy to undertake because they require very special data. However, impact evaluations can take various forms. Even highly qualitative monitoring of impact is better than no monitoring at all. The National Planning Commission (NPC), in its 2011 national development plan, points to the need for competency testing of teachers as an integral part of teacher in-service training (NPC, 2011: 281). What is envisaged in this recommendation is a partnership between government and a few universities to carry out the assessments. The medium- to long-term benefits would take the form of information that can guide future choices around what training to promote. A short-term benefit could be that the partnership would raise awareness that a positive impact cannot be taken for granted, which in turn could improve the focus on impact in existing training programmes. This short-term benefit, assumes, however, discussion of the work in the media, with teacher unions and at research conferences.

- *A rewards for maths knowledge programme.* Of the three recommendations, this one would result in the most high-profile initiative. The NPC's national development plan envisages a system of voluntary examining of the subject knowledge of teachers, where teachers displaying adequate levels of competence would receive a monetary reward (NPC, 284). Mathematics and physical science at the secondary school level would offer a good point of departure for such a programme, partly because the need to improve teacher competencies in these subjects is so acute. There are a number of benefits associated with this type of initiative, and lessons can be drawn from countries such as Chile which have experience in this area[18]. The programme can be made available only to teachers in the poorest school quintiles, partly to ensure that teachers with the greatest need to strengthen their subject knowledge are targeted. One advantage of the programme is that it removes some of the difficulty around matching the right teachers to the right top-down training programmes. Teachers themselves have an incentive to find the capacity building approach that serves them best. The programme does not remove the need for structured in-service training, but it can strengthen less formal approaches, such as what is implied by locally-driven professional communities of development. To begin with, the programme could be piloted in a limited geographical area. This could facilitate impact evaluation from an early stage.

6 Matching MST supply and demand

6.1 What do we know about South Africa's MST skills shortfall?

The skills shortfall in the South African labour market is widely acknowledged. Government's delivery agreement on skills says the following[19]:

> South Africa suffers from the twin scourges of high unemployment and a shortage of critical skills needed to drive economic growth and social development. The skills shortage underpins many of the challenges which government faces with regards to service delivery and the expansion of decent work for a rising proportion of the population.

Quantification of the skills shortfall is difficult to find and is an inherently complex task. Some work has occurred with respect to selected occupations, for instance nursing[20]. Private sector employers have reported that skills shortfalls and the associated problem of skills poaching is a serious problem that surpasses other problems such as conflict with trade unions. Employers have also reported a perception that the mathematics and science skills of school leavers have declined over the years[21]. Whilst this is a perception and not a verified fact, that this perception exists should be cause for concern. It could be an indication that the level of mathematics and science skills required in the labour market is rising, for instance as a result of technological change. The skills shortfall has a prominent racial dimension, with adequately trained black South Africans being in extremely short supply in many occupations. Not only is this a problem in terms of the post-apartheid transformation of society, it makes compliance with the representativity goals of the Employment Equity Act difficult. To illustrate, in 2007 only 3.5% of chartered accountants were African, though Africans constitute around 62% of the labour market. Moreover, only 20% of chartered accountants were women[22]. The situation has been improving, however. For instance, the percentage of

[18] See Bruns, Filmer and Patrinos (2011: 179) and Taut, Santelices and Stecher (2011).
[19] Presidency, 2010.
[20] Wildschut and Mqolozana, 2008.
[21] Centre for Development and Enterprise, 2007a.
[22] SAICA, 2009: 67.

young accountants who are African rose from 13% to 23% in the period 2002 to 2007. Accounting is one of many university subjects which require high Grade 12 mathematics results. A large part of the African under-representation problem is low numbers of high achieving African learners in mathematics in Grade 12. As shown in Appendix G, only 42% of learners achieving at least 70 points out of 100 in mathematics in the 2011 examinations were African, though Africans constitute around 82% of youths in the population[23].

Understanding the dimensions of the skills shortfall is important for planning the qualitative and quantitative improvements required in the schooling sector. At the same time, the literature makes it clear that a 'manpower planning' approach to the problem, where precise demand numbers are generated per occupation, is not feasible[24]. Yet figures such as those presented in Appendix D suggest that doubling the number of school graduates in key MST subjects over the next ten years (an aim pursued in the *Action plan*) is required.

Apart from employers, universities and other post-school education institutions have to deal with skills shortfalls amongst those leaving school. These institutions have repeatedly reported on skills shortfalls amongst school leavers, especially with respect to MST subjects. But they also report that learners too often take subject combinations at schools that make post-school studies difficult[25]. Despite these problems, higher education institutions have succeeded in increasing their own output, for instance Masters and PhD graduates increased in the 1999 to 2003 period from 12,600 to 15,800 (an increase of 5.8% per year) [26]. In the 2004 to 2007 period the number of higher education graduates (at all levels) specialising in MST subjects increased by 1.8% a year[27]. This should be seen against a backdrop of annual increases in the number of Grade 12 mathematics and physical science passes of around 5% a year but almost no change with respect to passes at the higher grade (see figures presented in the next section). Further Education and Training colleges have complained about the ability of school leavers to cope with mathematics at the colleges. In 2002, only 51% of college students were passing maths[28]. In 2009, only 33% of students taking mathematics were passing this subject in their first year of the new NC(V) programmes[29]. Currently, around half of the students entering FET colleges have completed Grade 12, whilst the other half has completed a lower grade in the Grade 9 to 11 range. Improvements in MST performance across all these school grades would facilitate vocational training at colleges.

6.2 What have been the Grade 12 MST outcomes?

The following two graphs illustrate the trend since 2000 with respect to the overall number of mathematics and physical science Grade 12 passes emerging out of the public examinations system (in which around 6,100 public schools and 450 independent schools participate[30]). It is essential to realise that because the examination system changed between 2007 and 2008 in fundamental ways, comparisons of trends up to 2007 against trends from 2008 are to a large degree a matter of comparing apples with pears. Nonetheless, these comparisons are made as the question of mathematics and physical science outputs from the schooling system is a matter of such great national importance. Below, the trend will be discussed, but it should be emphasised that one cannot read too much into the differences between the years 2007 and 2008.

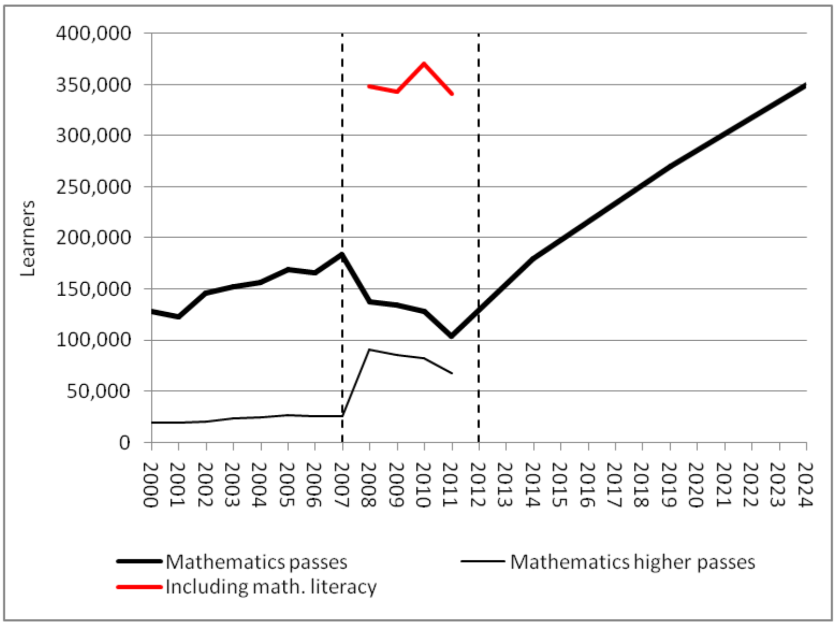
[23] See Table 21. Population percentage from Stats SA's 2011 mid-year population estimates, ages 15 to 19 used.
[24] See for instance Bertrand (2004).
[25] Kraak and Press, eds., 2008: 425.
[26] Kraak and Press, eds., 2008: 360.
[27] Council on Higher Education, 2009: 37.
[28] Kraak and Press, eds., 2008: 269.
[29] From official 2009 college examinations report of the Department of Higher Education and Training.
[30] Participants also include adult centres.

What is clear from both graphs is that there was a rise and then a drop in the total number of passes, with the turning point being 2008, a year after the new curriculum was implemented in Grade 12 (this is why the first vertical dotted line is inserted at 2007). The trend is most evident for mathematics, where the 2011 number of passes was around 20% lower than the 2000 number of passes. In physical science, the 2000 and 2011 levels are about the same. Seen over a longer period, the trend is more encouraging, however, given that the number of passes in both subjects more or less doubled between 1995 and 2007[31]. In contrast to the post-2007 decline in the overall number of passes, the number of 'higher passes' or passes that could be considered of a higher standard, saw what is apparently a sharp increase between 2007 and 2008. The 2007 to 2008 comparability problems in this regard are discussed below. For the years up to 2007, what is counted here is the number of 'higher grade' mathematics or physical science passes, where these are passes in an examination that was different from the 'standard grade' examination. From 2008, what is counted is the number of passes achieving 40 points out of 100, as opposed to just 30 out of a 100, where 30 would be the minimum pass mark. From 2008, there was just one mathematics examination and one physical science examination.

Given the sudden post-2007 increase in the number of higher passes, there has been some questioning of the equivalence of the two standards. Simkins (2010) analysed 2007 and 2008 examinations data and concluded that learners narrowly passing the mathematics higher grade examination in 2007 would be the equivalent of learners achieving 54 points (and not 40 points) in the new 2008 mathematics examination. A similar analysis for physical science pointed to a critical threshold of 49 points in that subject. If one applied this threshold to the 2007 to 2008 trend in physical science, one would not see the marked increase seen in Figure 8. However, the situation is more complex for mathematics, where the fact that from 2008 all learners had to take some form of mathematics, either mathematics proper or the new subject mathematical literacy, meant that the overall quantity of higher level skills in mathematics produced by the schooling system increased. Simkins (2010: 19) estimated this increase to be 40% between the two years.

[31] Taylor, 2008: 7.

Figure 7: Mathematics passes since 2000

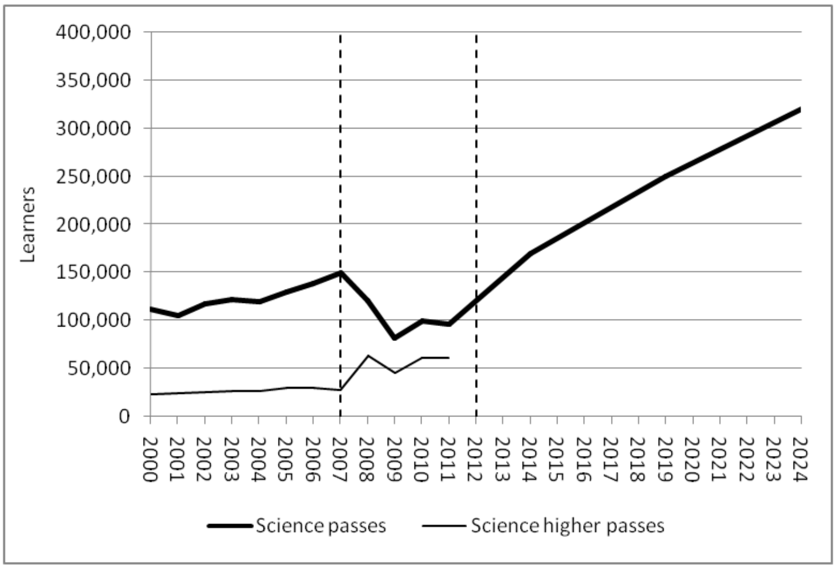


Note: In this graph and the next one, the first vertical dashed line indicates the last year of the old examination system and the second one indicates the first future target value. In both graphs, the 2008 to 2010 values (but not the 2011 values) are the results after taking into account supplementary examination results. The 'Including math. literacy' curve reflects mathematics passes plus mathematical literacy passes.

What do the trends seen in the two graphs mean in the context of the need to increase Grade 12 mathematics and physical science outcomes? The trend shown beyond 2011 is the trend is the desired trend according to the Action Plan. Whilst the drop in the historical trend between 2007 and 2008 in the overall number of passes is almost certainly a reflection of more demanding standards in the new system, the fact that there was no noticeable improvement in the 2008 to 2011 period is worrying, given that the Action Plan envisages an increase of around 5% a year in the number of passes. However, trends need to be seen in the context of changing demographics. Appendix F suggests that between 2008 and 2011 demographic factors would, all else being equal, reduce the number of passes, either in overall terms or with respect to 'higher passes' by 13%. However, three of the four 2008 to 2011 declines over this period are larger than 13%. It is only the physical science higher passes trend which clears this threshold. Here there was a decline of 3% if one compares 2008 to 2011, implying that that relative to demographic shifts there was an improvement of around 10% (13% minus 3%).

As explained in Appendix F, the drop in the number of youths available for the Grade 12 examinations is a temporary one lasting a few years, and is the outcome of Grade 1 admission policy changes made over a decade earlier. The dip is particularly noticeable for the 2011 and 2012 Grade 12 cohorts, but will have passed by 2014.

Figure 8: Physical science passes since 2000



Two issues influence the number of Grade 12 passes (overall, or per subject) and can give rise to confusion. The two issues are the fact that a number of learners improve their results after the year-end examinations through the supplementary examinations that occur at the start of the year and that learners can repeat the examinations in a subsequent year as part-time candidates. The Grade 12 numbers usually quoted in the media and research are numbers that exclude part-time learners completely and do not take into account how the picture changes as a result of the supplementary examinations. The DBE does produce reports with post-supplementary statistics, but these statistics are not widely used. The supplementary examinations have in recent years raised the number of mathematics passes by a small margin. For instance, learners having passed mathematics after the supplementary examinations early in 2011 was 3% or around 3,000 learners more than the number of passes after the 2010 year-end examinations. The two previous graphs include the number of passes obtained through the supplementary examinations from 2008 onwards. The number of learners writing supplementary examinations is large, however. For instance, around 40,000 learners wrote mathematics supplementary examinations at the start of 2011. There are thus opportunities to support large numbers of learners in preparing for the examinations not just prior to the year-end examinations, but also prior to the supplementary examinations.

The number of part-time learners grew substantially between the 2008 and 2009 examinations, from just over 1,000 to around 40,000 (here '2008 examinations' means the examinations occurring at the end of 2008, which would be followed by supplementary examinations early in 2009)[32]. This large increase occurred due changes that made it easier for youths who fared poorly in their first attempt at the examinations to improve their results by re-writing some examinations. The number of part-time learners remained high in the 2010 and 2011 examinations. The 2011 examinations database was examined to identify features of the part-time candidates. Virtually all take fewer than the seven subjects required of full-time candidates. Around 65,000 part-time learners wrote the mathematics examinations and of these 11,578 passed mathematics, giving a pass rate of 18%, much lower than the pass rate of 45% applicable to full-time mathematics students. These figures provide an idea of the extent of under-reporting in the two preceding graphs – in both of these graphs part-time students are not counted. However, what should also be taken into account is that the same learner may pass mathematics in one year as a full-time candidate and then pass mathematics again a year later as a part-time candidate. This type of pattern would occur where learners wanted to

[32] Number of part-time candidates taken from official 2009 report.

improve their mathematics scores, from one pass score to a better pass score, possibly with a view to fulfilling specific entrance requirements at universities. Around 3,800 part-time learners passing mathematics in the 2011 examinations also passed mathematics as full-time learners in 2010. In fact, full-time students can re-register as full-time students in a subsequent year if they were not happy with their initial results. To provide a sense of the magnitude here, around 1,500 learners passed mathematics as full-time learners in 2010 and again in 2011. These learners would constitute a double-counting of passes in Figure 7. If one wanted to take into account part-time mathematics passes, but eliminate double-counting, then the 2011 overall mathematics passes reflected in Figure 7 would need to be inflated by 5%. This would not change the overall picture of a decline in overall passes between 2008 and 2011, yet there seems to be a need for a tighter accounting of the number of passes produced by the schooling system each year, in a manner more systematically caters for the impact of supplementary examinations, part-time candidates and repetition of the same candidates across several years.

The analysis presented in Appendix H indicates that certain provinces have been more successful than others when it comes to improving Grade 12 mathematics outcomes. The 2011 and 2005 examinations databases were compared to provide a picture of developments over a period that included the important 2006 provincial demarcation process, where around 155 schools with Grade 12 moved from one province to another. An important finding is that certain province-to-province movements appear to be associated with unusually large improvements, suggesting that the way individual provinces administer and support schools has an impact on the outcomes of schools, and that the practices of some provinces are better than those of others. Specifically, the 30 schools that moved from NW to GP saw increases in their national rankings with respect to high-level mathematics passes per school (passes of at least 70 marks in 2005 and 2011) that exceeded the ranking improvements in schools that stayed in NW or that stayed in GP. The 15 schools that moved from EC to KN saw on average an eight-fold improvement in their number of high-level mathematics passes, an improvement larger than that seen in any province. One province stands out as having improved its Grade 12 mathematics outcomes rather well, against several different indicators of performance. This province is MP. The analysis in Appendix H suggests that to improve results across all schools, planners should pay particular attention to practices found in GP, KN and MP.

Appendix G points to interesting patterns with respect to how mathematics performance (and probably performance in other MST subjects) is concentrated in certain pockets of the schooling system. Given the very strong need to increase the numbers of well-performing African learners, schools with a strong presence of African learners receive considerable attention in the analysis. The country's top 500 schools in mathematics with only or mainly African learners were identified in order to see what opportunities exist with respect to the nurturing of exceptionally well-performing schools in historically disadvantaged communities. It should be kept in mind that the 500 Dinaledi schools were never conceptualised as an elite tier of schools, but rather as a set of schools in the middle of the performance range which showed the potential to improve. 85 schools are both Dinaledi schools and schools in the top 500 set identified in Appendix G. How do Dinaledi schools compare to the top 500 African? Though schools in the latter group are on average less than half the size of Dinaledi schools (at least with respect to Grade 12 enrolments), they produce as many learners achieving 70 or more in mathematics, and their performance is considerably better if one looks only at African learners. Turning to the matter of African learners in historically white schools, although this has often been considered an area offering opportunities for increasing the number of high-achieving African learners, the basic magnitudes in the schooling system suggest that this area is a relatively marginal one. To illustrate, 11 times as many high-achieving African learners (70 or above in mathematics) come from schools that are predominantly African, compared to schools whose enrolments suggest they are historically white[33]. What is clear is that even fairly small improvements in the average performance of predominantly African schools are likely to push up the number of high-achieving African learners substantially. One very noteworthy pattern is that of the top 500 African schools, 184 are in LP. This is partly because the schools in question are smaller in LP, but analysis presented in Appendix G indicates that however one views the examinations data, LP is the best or one of the best provinces nationally when it comes to high-level performance of African learners in mathematics. That this should occur despite the fact that LP is a clear *under*-performer in mathematics at the primary level begs further research.

6.3 What are the MST subject choice challenges?

For over ten years the percentage of Grade 12 learners taking mathematics has been within the range of 40% to 60%[34]. The percentage of learners taking mathematics, as opposed to mathematical literacy, has declined in the 2008 to 2011 period, from 53% in 2008 to 45% in 2011. Of those taking mathematics in the ten or so years up to 2007, between 10% and 30% would take mathematics on the higher grade. Physical science participation has historically been lower than mathematics participation and has been within the range of 25% to 40%. Up to 2007, between 30% and 55% of physical science learners were taking the subject on the higher grade.

The evidence suggests that better information and better guidance would result in a situation where learners would avoid subjects they were unlikely to succeed in and where the overall number of mathematics and physical science passes would rise. Simkins (2010: 6) estimated that close to 90,000 learners in 2008 would have passed mathematics had they switched from mathematical literacy to mathematics, because their mathematical literacy scores were sufficiently high. Thus a large proportion, around 16%, of learners forfeited post-school study opportunities associated with a mathematics pass. Simkins (2010) also argues that there were mathematics learners who failed the subject but would have passed had they taken mathematical literacy. Gustafsson (2011: 39) estimated that around 9% of Grade 12 learners would have passed instead of failed the overall examinations in 2009 had they taken mathematical literacy and not mathematics[35]. Here poor subject choices resulted in learners forfeiting the opportunities associated with having a National Senior Certificate. Taylor *et al* (2011), in comparing 2002 Grade 8 mathematics results in the TIMSS programme to 2006 and 2007 Grade 12 mathematics results, find that in historically African schools, the TIMSS scores for those who took mathematics in Grade 12 and those who did not were similar. What this suggests is that choosing mathematics as a subject in Grade 10 was dependent on factors other than abilities in mathematics. This is clearly an undesirable situation and points to the need for more rigorous assessment and guidance, in particular at the Grade 9 level, to ensure that learners make suitable subject choices in Grade 10[36].

Gustafsson (2011) also found that a substantial number of learners would have passed the overall 2009 Grade 12 examination, when in reality they did not, had they switched from physical science to another subject. Appendix G shows that provinces with a high proportion of examination candidates passing physical science or mathematics at a high level (70 or above) are also those provinces with relatively low percentages of learners taking these

[33] Some predominantly African schools would be historically white, but this would not influence the ratio presented here to any significant degree.
[34] See Department of Education (2001) and Simkins (2010).
[35] The 9% is 444 divided by the sample of 5,000 learners.
[36] Lam *et al* (2011), in a paper titled ‘Schooling as a lottery’, found that in the Cape Town area, historically African schools displayed a particularly weak correlation between repeating a grade at the secondary level and performance in externally administered standardised tests. In other words, in these schools many learners who should have repeated were not and many learners who should have repeated were not repeating. This finding is similar to that of Taylor *et al* (2011).

subjects. What this may point to is that in schools where there is more informed advice to learners about their chances of passing mathematics and physical science, there is also an environment that is more conducive to excellent results, perhaps because better performing learners are not held back in the class by learners who have an insufficient grounding in the subject.

As explained in Appendix G, one way in which apartheid-era differences by race seem to have persisted is in the exceptionally low participation in mathematics amongst coloured learners. The proportion of learners in Grade 12 in predominantly coloured schools who take mathematics is half the national average. Whilst conclusive research into the underlying reasons for this seems not to be available, the situation appears to require urgent attention as opportunities for individual learners and for addressing national skills shortfalls are being lost in the schools in question.

6.4 In summary, what should be done?

Appendix G describes a mix of five areas of action that would raise the number of mathematics passes by around 60% between now and 2020 and raise the number of mathematics passes at a high level, of 70 out of 100 or more, by around 85% over the same period. Whilst the magnitude of these improvements fall somewhat short of official targets, they would take the country in the right direction with respect to MST outcomes and would result in a situation that is much better than today's. The improvement scenarios painted in Appendix G are by no means impossible if one considers that between 1995 and 2007 the number of passes in mathematics and physical sciences more or less doubled (see section 6.2 above). Whilst Appendix G deals largely with mathematics, similar opportunities would exist with respect to other MST subjects.

So what should be done? Of the five areas of action described in Appendix G, two deal specifically with the matter of subject choice. On the one hand, there is an urgent need to provide better guidance to Grade 9 learners when they make subject choices in preparation for Grade 10. This includes evaluating what methods are currently used in schools and the mass media to guide learners. If certain methods are not good for learners, then these methods must actively be discouraged. The new Grade 9 Annual National Assessments should be used to provide learners with benchmarks for subject choices, in particular the choice of whether to take mathematics or mathematical literacy.

On the other hand, as discussed in section 6.3 above, the strikingly low level of participation in mathematics (as opposed to mathematical literacy) in historically coloured schools needs to be addressed. The simulations in Appendix G indicate that correcting this imbalance would contribute 16% of the overall national improvement envisaged with respect to the number of learners passing mathematics.

Two of the areas of action described in Appendix G deal with improved usage of focus schools that are targeted to serve as model schools and to some extent magnet schools (or schools attracting high achieving learners, in particular from disadvantaged backgrounds). Firstly, it is proposed that investments made over the years in Dinaledi schools be consolidated to improve further the situation in these schools. The fact that there appear to be gaps with respect to both research into Dinaledi schools and a clear statement of the 'Dinaledi improvement model' suggests that there are clear opportunities for taking the programme to a new level. Secondly, it is proposed that there be a more deliberate focus on the *best* performing predominantly African schools, which are mostly not Dinaledi schools, in a manner that gets these schools both to guide the system and serve as nodes for expansion. With regard to the latter, it is noteworthy that the best performing African schools are relatively small schools.

The fifth area of action is multi-faceted and is largely dealt with in the existing *Action Plan.* Essentially this area of action is about improving average performance through mechanisms such as those already discussed in section 5.8 above.

7 What a new strategy should contain and how it should be driven

A new maths, science and technology (MST) strategy for the schooling system would, like other strategies, need to inspire and guide people and organisations. Concretely, it would need to be reflected in other plans that are required by law and are linked to budgets, in particular the annual performance plans of the ten government departments dealing with basic education. It would need to be produced whilst keeping in mind that there is already a number of high-profile guides on how learning and teaching should be improved in schools, not in MST subjects specifically, but in general. These guides include the 2011 teacher development framework[37], the full version of the *Action Plan* released in 2012, and the new Curriculum and Assessment Policy Statement (CAPS) documents currently being introduced in schools. The findings of the 2009 review of curriculum implementation on the problems created by too much policy complexity in the schooling system are worth noting[38]:

> In summary, the current documents are not user friendly. Many are overly long and unwieldy, and at times verbose, and there is repetition across documents. Many of the documents also contain errors and contradictions. They are also unnecessarily complex, partly because a number of documents need to be read together in discerning what is to be taught and learnt, and how.

Clearly, in producing a new MST strategy it is critical to be clear on whom it is intended for. Should it be a document to be used mainly by the administration? Or should it be aimed at the school? Whoever the intended audience, it is important to consider how the strategy will add value, or fill a gap that has been identified. It should make the work of improving learning and teaching easier, not more complex or difficult.

What can be learnt from the MST strategies of other countries? A search within the IIEP's[39] Planipolis online repository of policies revealed little, suggesting that strategies focussing specifically on strengthening MST subjects are not prioritised elsewhere, perhaps because quality improvement tends to be treated in a cross-curricular manner. One exception is the United Kingdom's *National numeracy strategy*[40], released in 1999. This document summarises the elements and other documents comprising the national 'Framework for Teaching Mathematics from Reception to Year 6'. Essentially a set of high quality guides and materials were produced to provide direction to what happens in the classroom when it comes to numeracy. These materials are a bit like our CAPS documents, though arguably they provide clearer guidance with more examples. A strategy aimed at schools themselves, using recent research and expert opinion to guide teachers in overcoming typical challenges experienced in the MST subjects, is one possibility that warrants serious consideration.

On hindsight, there are aspects of our 2001 29-page *National strategy for mathematics, science and technology education* which we should probably not repeat. One is to determine a strategy without first looking carefully at the 'size and shape' of the current MST challenges and without assessing what kinds of interventions have worked and which have not. The current report is intended to at least partly fill this gap. The 'wishlist' syndrome should be avoided, meaning the strategy should propose future actions that are realistic in terms of the human capacity and budgets available. Clearly, this involves making difficult choices. For

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[37] *Integrated strategic planning framework for teacher education and development in South Africa.*

[38] Page 20 of *Report of the Task Team for the Review of the Implementation of the National Curriculum Statement.*

[39] International Institute for Educational Planning.

[40] See http://www.ness.uk.com/maths/Old%20Framework%20File/introduction.pdf.

instance, it may be optimal to pay special attention to a specific phase in the schooling system and specific subjects in order to ensure that there is sufficient rigour in the approach. Focussing very strongly on numeracy in, say, the foundation phase need not imply abandoning the other phases. If interventions are sufficiently focussed and are well documented, they are likely to inspire similar work at other levels of the system, initiated by individual provincial departments, NGOs and schools themselves. Arguably, what is missing in South Africa's education transformation landscape is a few initiatives that can be considered role models of how to get things right.

Crucially, what was missing in the 2001 strategy was an indication of how progress would be monitored, and by whom. As a result, even a high-profile initiative such as Dinaledi has not generated the data required for effective monitoring of trends and best practices (this was one of the remarks made by the producers of the 2010 Dinaledi impact evaluation). What should also be clarified in a new strategy is exactly who the champions of the strategy will be. It is not enough to say that a strategy should be owned by a variety of stakeholders. That may be true, but it is also important for a specific group of people to champion the strategy. Responsibilities here would include publicising and propagating the strategy through a variety of media, performing monitoring where this is not happening elsewhere, ensuring that the necessary research is commissioned and, importantly, assessing the appropriateness of the strategy on an ongoing basis and making adjustments when this is required.

The fact that there was no statistically significant improvement in South Africa's average mathematics score in SACMEQ between the 2000 and 2007 waves of the programme is a stark reminder that the 2001 strategy did not succeed in bringing about the desired systemic change. Clearly, this time we need to do things differently.

The 73-page *Gauteng Department of Education MST improvement strategy 2009-2014*[41], released in 2010, offers a recent example of an important provincial strategy in the MST area. The Gauteng document includes more empirical analysis than was the case with the 2001 national strategy, partly because by 2010 there was more data available. However, it has been argued that this strategy too lacks a sufficient sense that certain things need to be prioritised.

One option then, is for the strategy to be a document aimed very much at schools, as mentioned above. If a more system-oriented strategy were pursued, it could include or adapt a number of the interventions that have been proposed in this report, specifically in sections 5.8 and 6.4.

[41] See http://www.nstf.org.za/ShowProperty?nodePath=/NSTF%20Repository/NSTF/files/Home/Newsletter/MSTStrategy.pdf.

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Appendix A: Information on MST teachers from the 2010-2011 ASS

There have been recent improvements in the availability of the data relating to individual teachers collected through the Annual Survey of Schools (ASS). This appendix explains key elements of the data, some of the problems that still exist, and uses the data to provide an analysis of patterns of teacher utilisation. The analysis is by no means exhaustive and can be considered indicative of further analysis that should occur to inform MST improvements in schools.

The focus in the ASS with respect to individual teachers is on collecting data on the types of qualifications held (but not formal subject specialisation, which results in an important knowledge gap), grades taught and finally subject-and-grade taught. For the latter, which is particularly valuable as both the subject and grade dimensions are used simultaneously, only information for teachers teaching Grades 10 to 12 is available. The subject-and-grade taught data are spread across two tables in the survey form (this form is designed to be filled in by each educator), one dealing with language subjects and the other with non-language subjects. The first three columns of Table 2 reflect the percentage of schools for which data from the non-language and language tables were available. In the dataset that was available for this analysis, there was no 2010 data from the language table. The South African 13-digit identity number is used as the unique identifier for each educator in the dataset – Persal number is also available, but the 13-digit ID number is a more feasible identifier as not all educators in the data are employed by the state. 98% of the ID numbers in the dataset were within a range one would expect. The middle panel of Table 2 reflects the teachers appearing in either the language or non-language table. If one compares these figures to 2010 Snap Survey data on educators in public schools, one arrives at data completeness ratios of 0.69 and 0.79 for the years 2010 and 2011. The last two columns give a picture of the percentage of educators for whom individual data are available, relative to what is found in the Snap Survey, with the analysis occurring at the level of the school[42].

Table 2: Figures relating to the completeness of the 2010-11 ASS teacher data

	% of schools with individual teacher non-language subject data		% of schools with individual teacher language subject data	Teachers across both the language and non-language tables		Snap Survey number of educators (public ordinary schools)	Median completeness of individual schools	
	2010	2011	2011	2010	2011	2010	2010	2011
EC	99	99	98	63,546	62,754	69,921	91	90
FS	78	73	23	16,452	14,975	22,979	97	95
GP	95	98	96	52,207	53,513	57,886	97	95
KN	43	66	65	29,811	56,424	90,424	86	91
LP	94	96	70	50,199	51,068	56,857	96	95
MP	73	86	39	21,219	24,148	34,226	93	86
NC	78	96	96	5,622	7,918	8,946	97	95
NW	89	70	21	20,109	15,367	25,098	100	92
WC	65	98	96	15,286	29,646	32,504	76	94
SA	78	86	71	274,451	315,813	398,841	93	92

To sum up, for 2011 around four-fifths of the expected teacher records were available and where schools submitted the teacher data, what was submitted was relatively comprehensive for the school. This means that the data can be used to provide a relatively accurate picture of

[42] The distribution of this ratio where 2011 teacher records were compared to 2010 Snap Survey educator counts was such that the values at the national level were in the range 0.50, 0.81, 0.92, 1.00 and 1.17 for the 5th, 25th, 50th, 75th and 95th percentiles.

patterns of teacher utilisation and teacher qualifications (the two themes that these teacher-level data lend themselves most to).

The next table offers an example of the type of teacher utilisation analysis the new data makes possible. For this table, the utilisation of the 17,324 teachers who teach either mathematics or mathematical literacy in Grades 10 to 12 in 2011 were examined. Only public ordinary schools were considered, here and in the analysis that follows. Of these 17,324 teachers, 16,339 had combinations of subjects taught and grades taught where there were at least 100 teachers in each combination. There are 54 combinations reflected in the table, represented by the 54 values in the largest panel in the table. The most common combination involved 972 teachers. These teachers taught mathematics only – see the ‘X’ values at the top of table. They also taught in Grades 10, 11 and 12 but also in at least one grade below Grade 10 – see the values ‘X’ at the left of the table. All the values in the large panel should be interpreted in this way. The values at the extreme top right of the table refer to number of teachers, of the 16,339, teaching mathematics, mathematical literacy and other subjects. Clearly these three values will add up to more than 16,339 because many teachers are found in several of the three categories. Similarly, there are values at the bottom left of the table representing teachers teaching in each of the grades. It should be kept in mind that this particular table looks only at teachers who teach mathematics or mathematical literacy in Grades 10, 11 or 12 at the 4,889 public schools which had data on these teachers. There were 6,270 public ordinary school offering grades in the range Grades 10 to 12 in 2011.

Table 3: Mathematics teacher utilisation table (Grades 10 to 12 in 2010)

			Mathematics	X	X	X	X			9,475
			Mathematical literacy	X	X			X	X	8,664
			Other subjects	X		X		X		6,030
<Gr10	Gr 10	Gr 11	Gr 12							
X	X	X	X	173	447	573	972	627	584	3,376
X	X	X			171	172	268	271	234	1,116
X	X		X			140	146	124		410
X	X					183	647	220	688	1,738
X		X	X			116	313	120	273	822
X		X					215		213	428
X			X				178		161	339
	X	X	X	275	522	849	852	931	590	4,019
	X	X			214	185	232	183	222	1,036
	X		X		106	123	164	137	105	635
	X					121	197	106	170	594
		X	X		176	185	453	216	405	1,435
		X					107			107
			X				180		104	284
8,229	12,924	12,339	11,036	448	1,636	2,647	4,744	2,935	3,645	16,339
Teachers with less typical combinations not reflected above										985
Total teachers analysed										17,324

Note: The teachers reflected in the above table are from 4,889 schools.

What information can we extract from Table 2 that can assist in improving teacher utilisation? One thing that the analysis tells us is that mathematics and mathematical literacy are to a large extent allocated to different teachers in the school. Specifically, only 1,636 of the 16,339 teachers teach both subjects. Thus it may be efficient to conduct teacher development activities for the two subjects separately and not, for instance, in the same training workshops. What the table also reflects is that around half of mathematics teachers also teach a non-mathematics subject, where mathematical literacy is counted as one of those subjects. Of the 9,475 teachers teaching mathematics, 4,731 also teach something else. This suggests that some opportunity exists to improve the supply of mathematics teachers through the provision of teachers in other subjects, and thus freeing up the time of mathematics teachers to teach only mathematics (but see the discussion around the next table, which points to a different conclusion).

The next table provides a picture of the subject combinations of teachers who teach Grades 10 to 12. Only their subjects in these grades are considered. Around four to five thousand teachers teach only mathematics, mathematical literacy, physical science or life sciences. Amongst the approximately 2,200 mathematics teachers who also teach other subjects, mathematical literacy, physical science and life sciences are the most common other subjects. Only around 500 of the approximately 9,500 mathematics teachers teach non-MST (including language) subjects. The same can be said for other MST teachers. What this indicates is that there is in fact *little* scope for freeing up more MST teaching time by relieving MST teachers of teaching responsibilities in non-MST subjects. Thus although it may appear that there is scope for reallocation because mathematics teachers are teaching other subjects too, those other subjects are on the whole other MST subjects, in other words subjects where there is generally considered to be a shortage of teachers. Solutions must therefore focus largely on increasing the overall stock of MST teachers.

Table 4: Subject combinations of Grades 10 to 12 teachers

Mathematics	Mathematical literacy	Physical science	Life sciences	Agricultural sciences	Computing-related subjects	Other MST subjects	Non-MST non-language subjects	African language	English	Afrikaans	Life orientation	
			X									5,279
X												5,071
	X											4,058
		X										3,863
X	X											2,070
						X						1,697
				X								1,394
X		X										1,261
					X							1,156
	X	X										799
			X								X	676
	X						X					613
		X	X									400
			X						X			387
	X		X									365
			X	X								356
			X				X					326
					X		X					298
X			X									298
				X							X	283
			X					X				273
X	X	X										271
				X			X					232
X							X					230
	X										X	219
				X				X				197
				X					X			164
X											X	154
	X							X				152
	X								X			136
X									X			118
		X									X	115
9,473	8,683	6,709	8,360	2,626	1,454	1,697	1,699	622	805	0	1,447	32,911
Teachers with less typical combinations not reflected above												2,927
Total teachers analysed												35,838

Note: The teachers above are from 5,084 schools.

The next table is a bit difficult to read because there are so many combinations of grades taught. The focus in this table is largely on Grades 1 to 9 teachers. The figures tell as that in Grades 1 to 3, by far most teachers teach just one grade. For instance, of the 25,908 teachers teaching Grade 3, 19,215 teach only Grade 3. However, beyond Grade 3 the picture changes. In Grade 4, for instance, 55,393 teachers are teaching this grade but just 11,176 of them teach only Grade 4. These patterns are examined more succinctly in Table 6.

Table 5: Grade combinations of teachers

Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 7	Gr 8	Gr 9	>Gr 9	
X	X	X	X	X	X	X				1,008
X	X	X								2,683
X	X									2,553
X		X								703
X										24,843
	X	X								2,292
	X									18,361
		X								19,191
			X	X	X	X	X	X		1,598
			X	X	X	X				13,060
			X	X	X					14,906
			X	X		X				1,378
			X	X						7,384
			X		X	X				1,682
			X		X					1,900
			X			X				1,193
			X							11,163
				X	X	X				6,471
				X	X					5,209
				X		X				1,974
				X						7,642
					X	X	X	X		931
					X	X				8,752
					X					7,197
						X	X	X	X	852
						X	X	X		12,333
						X	X			1,827
						X		X		1,079
						X				9,603
							X	X	X	22,260
							X	X		10,095
							X		X	17,170
							X			3,325
								X	X	19,488
								X		3,236
									X	48,270
31,845	26,937	25,908	55,395	60,771	62,856	63,897	70,562	72,041	108,390	314,330
Teachers with less typical combinations not reflected above										16,560
Total teachers analysed										330,172

Note: The teachers above are from 21,426 schools.

Certain patterns in the next table are important for planning. In Grades 1 to 3 class teaching predominates, whilst in Grade 4 and above, the great majority of teachers teach more than one grade. However, the pattern differs by quintile. In both the intermediate and senior phases (Grades 4 to 9), teachers in socio-economically more advantaged schools are more likely to focus on just one grade. This pattern is particularly pronounced for Grades 4 to 7. Whether this is advantageous for learning and teaching is a matter that has barely been examined previously, partly due to lack of data.

Table 6: Percentage of teachers teaching in just one grade

	Q1	Q2	Q3	Q4	Q5	Total
Gr 1	69	72	78	76	60	71
Gr 2	58	59	69	68	52	61
Gr 3	62	64	71	68	51	63
Gr 4	9	13	21	32	27	18
Gr 5	5	8	13	20	18	11
Gr 6	5	7	12	19	16	10
Gr 7	8	10	15	23	21	13
Gr 8	3	3	5	7	4	4
Gr 9	4	4	5	7	2	4
Gr 10	6	6	6	6	2	5
Gr 11	3	3	4	4	1	3
Gr 12	5	5	5	5	3	5

The patterns seen above have implications for the professional development of MST teachers. In the grades and schools where there is more teaching across several grades, the teaching of mathematics and science subjects is more likely to be a specialisation handled by a few teachers. This has potential advantages and disadvantages. It is possible to strengthen MST through the development of fewer teachers. However, there could be advantages associated with having the same teacher teach, for instance, languages and MST subjects as this facilitates integration across the curriculum.

Appendix B: Recent data on the availability of textbooks and workbooks

This appendix provides statistics from recent years on learner access to textbooks, in particular as far as MST subjects are concerned. Breakdowns by province are provided, given the likelihood that textbook access is strongly dependent on the actions (or lack thereof) of the provincial departments.

First, 2007 SACMEQ data are used. This sample covered 9,083 Grade 6 learners in 392 schools. Thereafter, data from the 2011 School Monitoring Survey, which covered a national sample of around 2,000 schools, is used. Importantly, this survey occurred towards the end of the year (November) in which national workbooks were introduced. Moreover, the survey represents the most ambitious attempt ever to gain a clear national picture of the degree of textbook access amongst learners in South Africa.

The figures in the next table are derived from the following question, posed to the learner, in the 2007 SACMEQ survey: 'How do you use the Mathematics textbooks in your classroom during the lessons?'

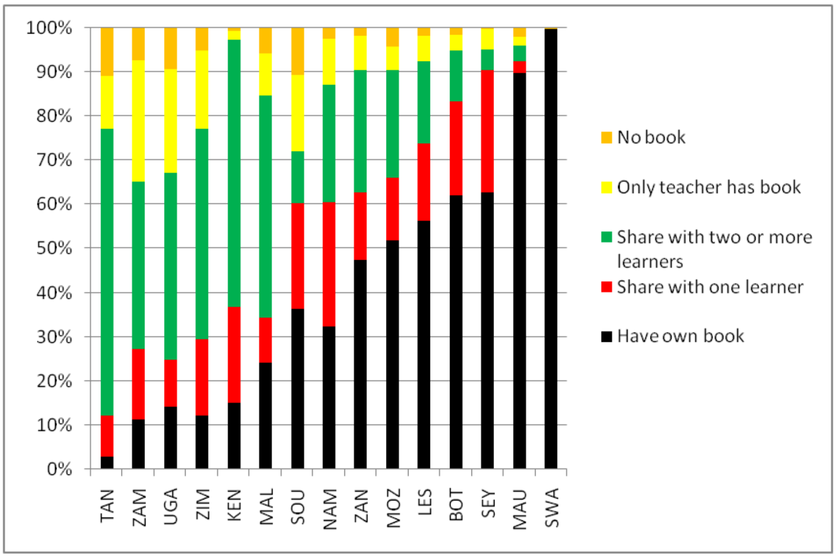
Table 7: Grade 6 access to 'mathematics textbook' (SACMEQ 2007)

	No book	Only teacher has book	Share with two or more learners	Share with one learner	Have own book	Total	Textbooks per 100 learners
EC	15	15	17	19	33	100	49
FS	8	10	17	28	37	100	57
GP	10	22	8	27	33	100	49
KN	11	23	16	25	25	100	43
LP	11	15	6	21	47	100	60
MP	8	8	10	21	53	100	67
NC	11	17	9	32	31	100	50
NW	12	12	14	21	41	100	56
WC	4	18	4	27	47	100	62
SA	11	17	12	24	36	100	52

The figures in the final column of Table 7 consider 'Have own book' as 100% coverage, 'Share with one learner' as 50% coverage and 'Share with two or more learners' as 33% coverage (sharing between three is assumed) in order to create a composite idea of the level of access to textbooks. The smallness of the SACMEQ sample at the provincial level means that provincial statistics should be considered rough indications only of the degree of textbook access at that level.

The following graph indicates that South Africa's level of access to mathematics textbooks in 2007 was not good in the regional context. Countries have been sorted in the graph according to estimated textbooks per 100 learners, calculated as described above. To illustrate, this ratio was 77 in Botswana (BWA), against South Africa's (SOU) 52. In Swaziland (SWA), the ratio was 100. Assuming that access to textbooks contributes towards better learning outcomes, improving this access to textbooks, or some equivalent materials such as workbooks, appears to be a relatively cost-effective way of addressing South Africa's under-performance challenges.

Figure 9: Access to mathematics textbooks in SACMEQ countries 2007



Turning to the 2011 survey, fieldworkers visited Grade 6 and Grade 9 classes, spoke to teachers and learners, and asked to be shown books used in language and mathematics. Moreover, a less rigorous approach was employed for all grades and subjects in the school. Specifically, one teacher in the school was asked to gather from other teachers in the school estimates of the percentage of learners with access to books by grade and subject. The data were collected in such a way that it was possible to compare the two methods with respect to the data values generated.

Where there was more than one class per grade, the class was randomly selected for the purposes of the visit. The mathematics visit had to occur during the mathematics class. As indicated in Table 8, 83% of Grade 6 learners were in classes where the teacher answered yes to the question 'Is a textbook being used to teach Mathematics in this class?'[43]. Of the 17% of learners in classes where the teacher did not use a textbook, 67% were in classes where the reason for the non-use, according to the teacher, had to do with a shortage of textbooks. Other reasons for non-use of a textbook would include the fact that the teacher had decided to use non-textbook materials, such as worksheets, instead. This largely explains why the non-use of textbooks was relatively widespread amongst quintile 5 (the least poor) schools. In quintile 5 25% of learners were in classes where the teacher did not use a textbook. The fieldworker asked learners to show their mathematics textbooks. 72% of learners were in schools where at least one such textbook could be shown and the average ratio of textbooks to learners in these schools was 0.81 (or 81 textbooks per 100 learners). After having seen the textbooks, the fieldworker asked learners who had not shown a book to stand up and to raise their hands if the answer to the question 'Did you receive the textbook?' was yes. The resultant data should have provided a composite picture of textbook access. However, there were anomalies in the data that were difficult to interpret, so no composite statistics are reported here. Perhaps the statistic that reflects textbook access problems best is the percentage of quintiles 1 to 3 learners in classes where it was not possible to see a single book. Nationally, this statistic stood at 28% in 2011.

[43] In this analysis, non-responses, which in general amounted to 5% of the sample, were completely ignored in the calculation of statistics.

Table 8: Grade 6 access to mathematics textbooks (2011)

	Teacher said a textbook was being used	% of previous column where textbook shortage was the cause for non-use	At least one book could be shown to fieldworker	Average shown textbooks per 100 learners (where there was at least 1)	No textbook shown amongst just quintiles 1 to 3 schools
EC	87	71	74	78	32
FS	50	59	39	65	62
GP	80	49	70	86	18
KN	86	81	75	78	22
LP	84	72	71	80	30
MP	67	80	54	83	46
NC	86	27	68	83	26
NW	91	74	85	78	13
WC	98	0	97	94	1
SA	83	67	72	81	28

Note: All statistics are except the textbooks per 100 learners ratio are percentages of learners. The same applies to the similar tables appearing below. Sampling weights were used.

The 2011 values seen in the previous table are more or less in line with the 2007 values seen in Table 7. In particular, one can calculate an overall ratio of textbooks per 100 learners at the national level in 2011 by deflating the 81 value in the fourth column of Table 8 by the 72 value in the third column, which results in 58 textbooks per 100 learners. This is not very different from the 52 textbooks per 100 learners seen in Table 7. However, there appears to be far more inter-provincial variation in 2011 than in 2007.

The following table examines workbooks, using the same format as for the previous table. The fieldworker asked separately about the mathematics Workbook 1 and Workbook 2 (intended for the first and second halves of the year respectively). For the analysis presented here, the presence or use of either of the two workbooks was considered.

Table 9: Grade 6 access to mathematics workbooks (2011)

	Teacher said a workbook was being used	% of previous column where workbook shortage was the cause for non-use	At least one book could be shown to fieldworker	Average shown workbooks per 100 learners (where there was at least 1)	No workbook shown amongst just quintiles 1 to 3 schools
EC	77	77	70	90	30
FS	80	69	79	93	19
GP	66	83	54	94	35
KN	87	90	81	92	20
LP	90	72	88	95	13
MP	59	79	53	97	50
NC	85	69	84	98	18
NW	91	49	86	96	10
WC	92	11	90	98	13
SA	80	77	75	94	23

If neither workbooks nor textbooks were present in a classroom, this would point to a particularly serious problem. On the other hand, the presence of one type of book but not the other may not be problematic as teachers may have decided to focus on just one type of book on the day of the fieldworker visit. The last column in the next table is important. The values should all be zero, meaning there should no class in quintiles 1 to 3 where no book (either a workbook or a textbook) could be shown by learners. The fact that the first six provinces in the table, from EC to MP, should display worryingly high values should be of great concern. One province, MP, stands out as experiencing a particularly serious situation.

Table 10: Grade 6 access to either mathematics textbook or workbook (2011)

	Teacher said a book was being used	% of previous column where book shortage was the cause for non-use	At least one book could be shown to fieldworker	Average shown books per 100 learners (where there was at least 1)	No book shown amongst just quintiles 1 to 3 schools
EC	96	73	90	89	11
FS	91	62	84	92	14
GP	90	68	80	92	9
KN	96	84	92	93	6
LP	97	70	93	96	8
MP	89	76	82	93	19
NC	99	46	98	95	0
NW	96	51	94	96	3
WC	100	9	99	99	0
SA	95	70	90	94	8

The following table examines the data for Grade 9 on textbooks[44]. As there were no Grade 9 workbooks in 2011, fieldworkers visiting Grade 9 classrooms focussed on textbooks. The procedure was very similar to that applicable to the Grade 6 class visit. The textbook access figures for Grade 9 are similar to those for Grade 6 seen in Table 9. However, a comparison of the previous table and the next table indicate that access to texts in general was considerably worse in Grade 9 than in Grade 6, because Grade 9 learners did not have the benefit of a workbook as a backup where textbooks were absent. The values in the final column of Table 11 are worrying, in particular as far as FS, KN, MP and NC are concerned.

Table 11: Grade 9 access to mathematics textbooks (2011)

	Teacher said a textbook was being used	% of previous column where textbook shortage was the cause for non-use	At least one book could be shown to fieldworker	Average shown textbooks per 100 learners (where there was at least 1)	No textbook shown amongst just quintiles 1 to 3 schools
EC	89	89	83	75	5
FS	63	46	59	75	36
GP	88	82	78	75	10
KN	76	66	66	52	35
LP	93	62	82	50	17
MP	73	88	61	74	44
NC	62	58	51	74	55
NW	100		92	60	8
WC	80	43	79	78	0
SA	83	67	74	65	21

Apart from the fieldworker visits to classrooms, the School Monitoring Survey included a process whereby a teacher familiar with the textbook situation in the school was given a form and asked to collect, from other teachers, estimates of the percentage of learners having access to textbooks across a wider range of grades and subjects than was possible for the classroom visits. This process became known informally as the 'light touch' survey as it involved far less data verification than the classroom visits. The mean for Grade 6 mathematics in the following table, which is 72 books per 100 learners, when compared to the ratio of 58 discussed above and derived from Table 8, suggests that the two methods of data collection yielded rather different results. If one makes the same comparison for mathematics in Grade 9, one obtains a gap between a ratio of 48 derived from Table 11 against the mean of

[44] There was a larger non-response problem with respect to Grade 9 textbooks, compared to Grade 6. 8% of schools had missing data. The three worst provinces, EC, FS and NW, had a non-response rate of between 15% and 20%.

66 in Table 12. An examination of the distribution of the two statistics indicates that most of the difference has to do with the percentage of learners in schools where there are no textbooks at all. To illustrate, according to the 'light touch' process, 6% of learners are in schools where, according to the data, no-one has access to a Grade 9 mathematics textbook. This figure is 26% (100 minus 74) if one reads Table 11 and if one makes the assumption that if no learner was able to show a textbook in the class to the fieldworker, then no learners had access to textbooks. Clearly this latter assumption is flawed. What is very possible is that learners sometimes used textbooks, either textbooks they could keep at home or textbooks usually kept in a storeroom at school, but did not have these textbooks with them on the day of the fieldworker visit. This may represent a different kind of access to textbooks problem if one's assumption is that learners should always have their textbooks with them in their mathematics class. Clearly, textbook access is not easy to gauge, partly because one must depend on a number of assumptions and because data collection can be difficult. Yet this aspect of schooling must be monitored and the statistics obtained through the 2011 survey, though not perfect, are a significant step in the right direction, especially given how little was known about textbook access previously.

Table 12: 'Light touch' survey results for Grades 3, 6 and 9 (2011)

	% of learners with textbook				% able to take textbook home
	10th p'tile	Median	90th p'tile	Mean	
Grade 3					
Numeracy	0	90	100	67	43
Grade 6					
Mathematics	5	90	100	72	54
Natural sciences	0	70	100	64	50
Technology	0	55	100	56	47
Grade 9					
Mathematics	5	70	100	66	68
Natural sciences	0	70	100	65	67
Technology	0	65	100	61	64

Note: To illustrate, the 10th percentile value is the percentage of learners accessing textbooks amongst the schools with the worst situation, specifically schools one-tenth from the bottom of the list of ranked schools. In this calculation, schools are weighted by total learners in the grade in question.

One important thing that the 'light touch' data show, if one looks at the previous and the next table, is that there has not been a substantial bias in favour of the more high profile MST subjects, such as mathematics, with respect to textbook resourcing. The situation is very similar across all MST subjects.

Table 13: 'Light touch' survey results for Grade 12 (2011)

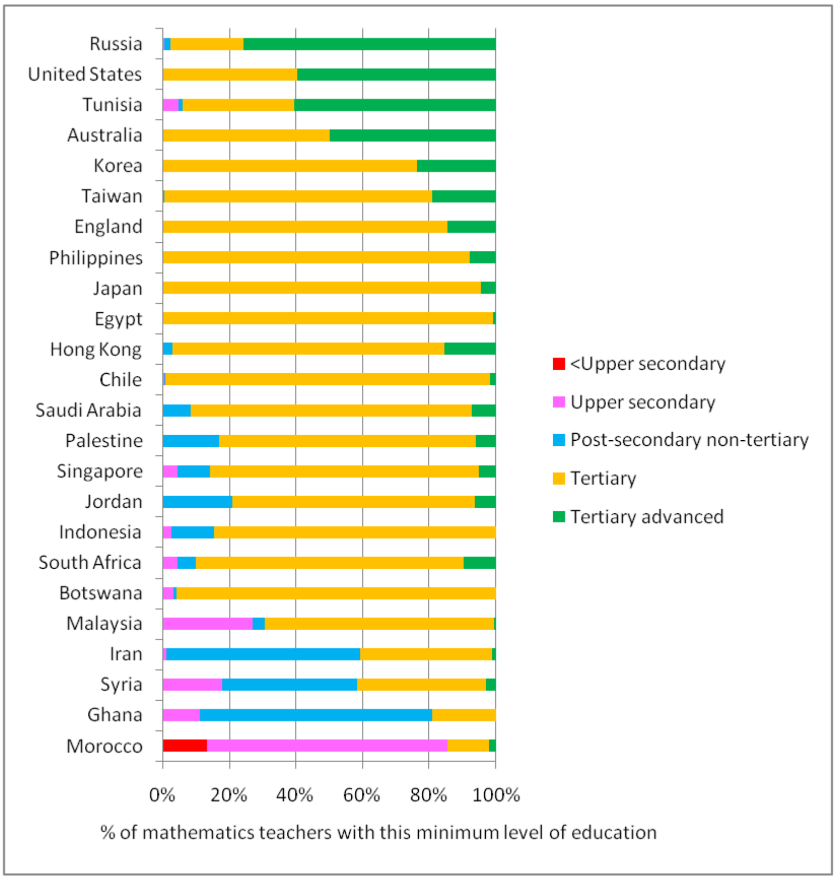
	% in schools offering this	% of learners with textbook				% able to take textbook home
		10th p'tile	Median	90th p'tile	Mean	
Mathematics	100	52	100	100	90	81
Mathematical literacy	93	40	100	100	85	80
Physical sciences	91	50	100	100	88	81
Life sciences	95	50	100	100	86	79
Agricultural sciences	39	45	100	100	82	74
Agricultural technology	1	0	100	100	62	91
Design	3	100	100	100	91	79
Civil technology	12	0	100	100	74	75
Electrical technology	7	40	100	100	77	83
Mechanical technology	11	45	100	100	90	84
Engineering graphics and design	20	50	100	100	91	87
Computer applications technology	36	80	100	100	93	87
Information technology	16	100	100	100	95	89

Appendix C: Country comparisons of school resources using TIMSS 2003

The 2003 TIMSS international dataset, apart from allowing a comparison of mathematics and science outcomes across countries, also allows for a comparison of the resources schools, teachers and learners have. The TIMSS 2003 data are of course dated. However, one reason why these data are still relevant is that they will be comparable to the 2011 TIMSS data, which become available early in 2013. The data across the two years will provide an indication of the progress that has been made with respect to results and school inputs between 2003 and 2011, for South Africa and other participating countries.

The first graph below illustrates responses to the question, asked to Grade 8 mathematics teachers, 'What is the highest level of formal education you have completed?'. Countries are ranked according to a scale where the lowest level (less than upper secondary) was assigned a value of 1 and one additional point was added per level (so tertiary advanced would correspond to 5 points). All developing countries plus a few developed countries from the TIMSS 2003 participants were selected for the graph. Though South Africa finds itself in the bottom half of graph, the situation in the country with respect to formal qualifications is not strikingly bad.

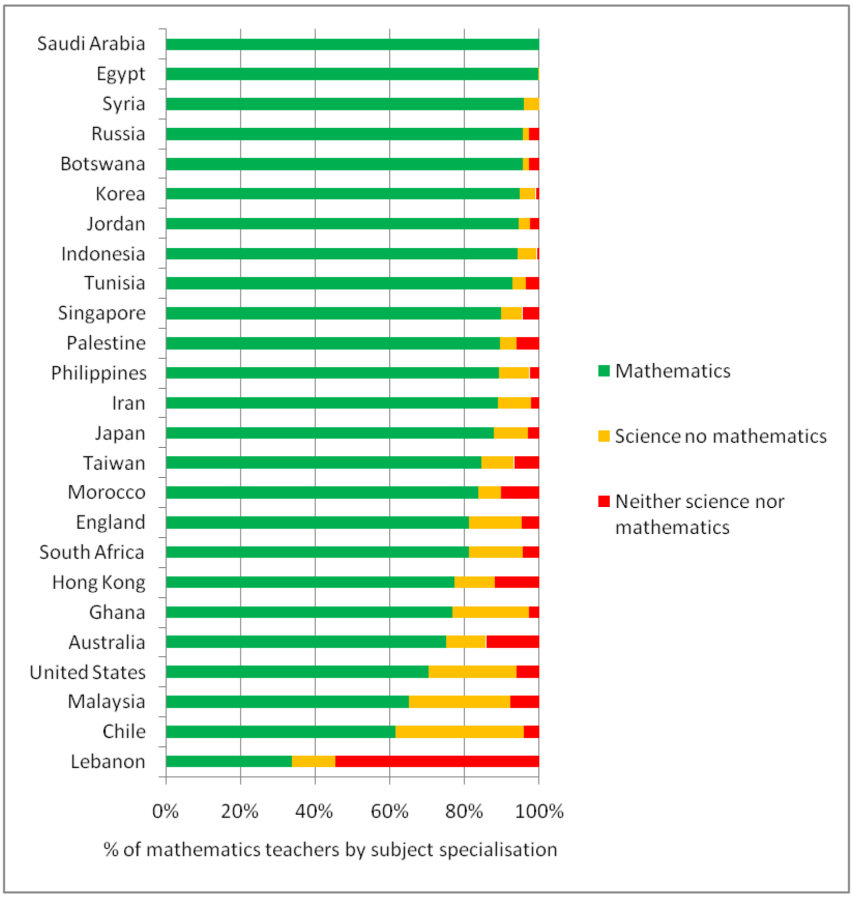
Figure 10: Level of education of mathematics teachers (2003)



Note: Sampling weights from the 2003 TIMSS dataset were used, here and in the analyses that follow.

The next graph illustrates responses, also by Grade 8 mathematics teachers, relating to the 'major or main area of study' during the teacher's post-secondary education. According to the data, just over 80% of South Africa's teachers had specialised in mathematics (this measure was used to sort countries in the graph). 4% had specialised in neither mathematics nor science. As in the previous graph, South Africa finds itself within the bottom half of the graph, yet South Africa's situation is not remarkably bad. For instance, it was better than that in the United States and Chile. This suggests that strategies to improve learning outcomes should focus on improving the ways teachers teach, rather than on their formal qualifications. To some extent more formally qualified teachers may be better teachers, but there is no guarantee of this.

Figure 11: Subject specialisation of mathematics teachers (2003)

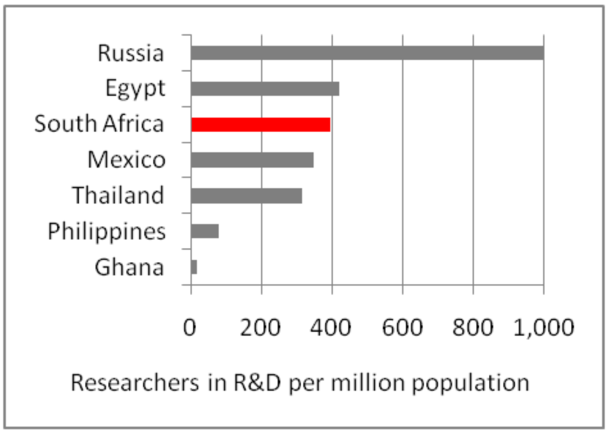


Appendix D: Cross-country comparisons of MST skills in the economy

Obtaining an idea of the magnitudes of the skills shortfall in the South African labour market within an international comparison is less straightforward than one may think. The UNESCO Institute for Statistics (UIS) online database appears to include both graduation and participation figures for specific MST areas such as engineering. However, an examination of the data reveals that not only is much information missing, some of the values are clearly incorrect. The following four graphs provide some sense of the challenges, using international data that seemed relatively reliable. For all the graphs, 17 middle income countries were selected against which South Africa is often compared. Only for Figure 15 were values available for all 18 countries (with South Africa included).

Researchers working in research and development (R&D) are reflected in the first graph. Here South Africa's position does not appear to be notably weak, though few countries had data values.

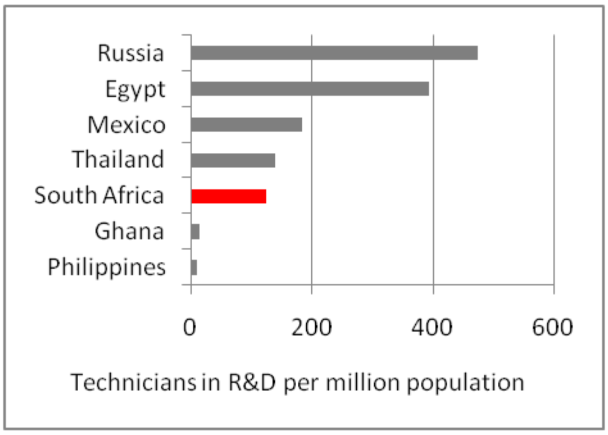
Figure 12: Researchers in R&D



Source: World Bank data at http://data.worldbank.org.
The most recent values available in 2012 are reflected.

The situation for South Africa appears less favourable with respect to technicians in R&D.

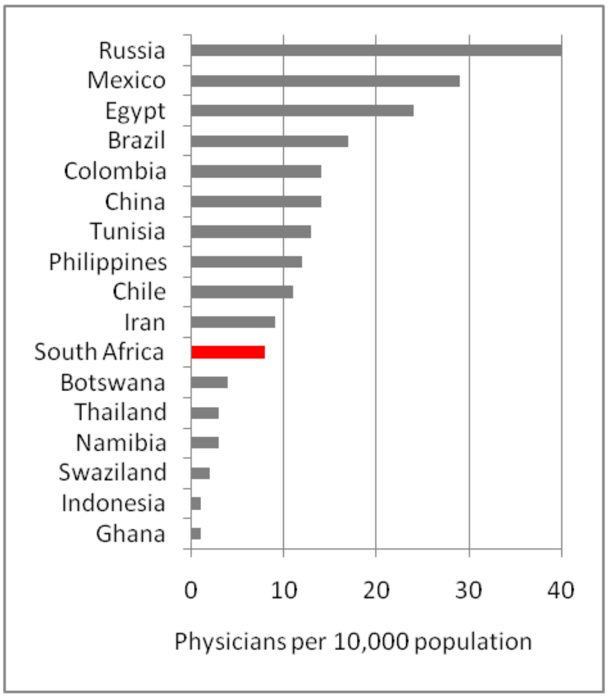
Figure 13: Technicians in R&D



Source: As for Figure 12.

In terms of medical doctors relative to the population, South Africa (and its neighbouring countries) perform poorly. Roughly, the figures suggest that South Africa should be aiming to increase its number of medical doctors by between 50% and 100%.

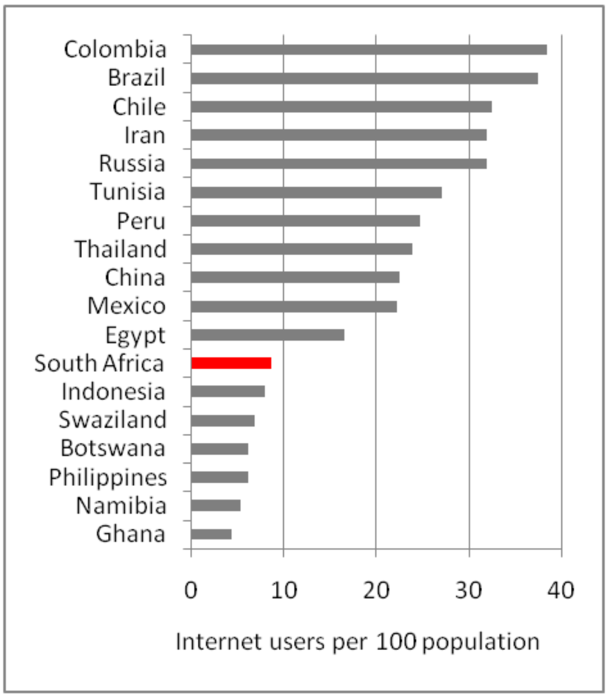
Figure 14: Physicians



Source: UNDP, 2010: 197.

Internet usage is partly driven by supply factors such as the price of connectivity. However, it is also driven by how skilled the population is with respect to internet technology specifically and how educated the population is generally. The figures in the graph suggest that the education system in South Africa should pay careful attention to improving access to the internet. Part of the challenge would be for government to promote internet-based services that improve people's access to information they need.

Figure 15: Internet usage



Source: UNDP, 2010: 211.

Appendix E: Factors affecting educational achievement in South Africa

This paper represents a brief review of what literature and recent data suggest are the major factors influencing educational achievement in South Africa. The paper begins with some consideration of relevant international research and then moves on to deal with South African studies. While there is a wealth of educational research using numerous methodologies it is typically those using more quantitative methodologies that set out to identify factors that influence educational achievement. Therefore, the reviews of both the international and local research tend to draw on studies with quantitative methodologies. Both large and small scale studies are considered, but those with an empirical focus on testing theory and identifying quantifiable relationships are dealt with rather than those with a more descriptive, theory-building approach.

INTERNATIONAL CONTEXT

The Coleman Report of 1966 can be seen as having laid the foundation for the School Effectiveness literature. James Coleman was commissioned to investigate inequalities in educational opportunity in America. Several unexpected findings emerged in the study, notably that school funding was not as strongly predictive of educational outcomes as was often assumed. Instead, the home background of students, and especially the socioeconomic background of their peers, was the predominant driver of achievement.

The Coleman Report was widely interpreted to imply that schools could not be expected to impact substantially on students given the strong deterministic influence of their home backgrounds. This sparked a vigorous debate in the literature around the ability of schools and teachers to influence outcomes. A major contribution to the debate was made by Heyneman and Loxley (1983), who contended that the Coleman Report conclusion about the weakness of school effects was a generalisation based on only a few of the world's education systems, namely those in North America, Europe and Japan. They investigated the relative impacts of pre-school influences and school quality on academic achievement in Asia, Latin America, Africa and the Middle East. Heyneman and Loxley set forth a case that in low income countries student socio-economic status accounted for less of the variation in achievement than it did in high income countries. Furthermore, they found that the effect of school quality was greater in low income countries than in high income countries. They therefore argued that when considering a more representative sample of students from around the world it is clear that the predominant influence on academic achievement is school quality (Heyneman and Loxley, 1983: 1162). This finding of weak school effects in high income countries and stronger school effects in low income countries was very influential and became known in the literature as the "Heyneman-Loxley effect".

The so-called "Heyneman-Loxley Effect" has in turn been challenged in the literature (e.g. Baker, Goesling and Letendre, 2002). On balance, there are enough studies finding significant effects of school and teacher characteristics to indicate that although socio-economic status may be the strongest driver of educational outcomes, schools and teachers can make a considerable difference.

What factors then do influence achievement over and above socio-economic status? Hanushek (2002) argues persuasively that input-based education policies around the world have failed to produce any systematic improvement in achievement. According to Hanushek, the more effective avenues for improving achievement have proven to be aspects of teacher quality that are unrelated to resources and policies that change the incentives facing teachers. However, Hanushek (2010) describes the literature on teacher quality as consistently pointing to the central importance of teachers for student achievement but not consistently pointing to any specific characteristic of teachers being important. Most of the easily observed characteristics such as teacher experience and teacher qualifications are generally not strongly associated with student achievement.

One possible reason for the lack of consistent evidence around teacher characteristics that improve learning is that effective teaching practice may be context-dependent and involve an inter-related set of characteristics. The following quote from a seminal study using TIMSS video classroom observation in Germany, Japan and the US expresses this view:

> Teaching is not just a collection of individual features, it is a system of tightly connected elements. And the system is rooted in deep-seated beliefs about the nature of the subject, the way students learn, and the role of the teacher. Attempts to change individual features are likely to have little effect on the overall system (Stigler and Hiebert, 1997, quoted in Hoadley, 2010: 4).

A useful and very different body of evidence is accumulating from experimental research designs, often known as Randomised Control Trials (RCTs). The major strength of this research methodology is that it is explicitly designed to identify the causal impact of specific interventions. Another advantage of this research is that much of it has been undertaken in developing countries making it relevant to the South African context. Experimental research in education initially focussed on ways to get more children to attend school, but experimental studies aiming to understand how to improve achievement amongst those in school are becoming more widespread. The remainder of this section summarises the major findings emerging from experimental research in education.

Studies testing methods to improve teacher attendance have generally found that direct monitoring such as through the use of cameras can improve teacher attendance (e.g. Duflo, Hanna and Ryan, 2012), whereas personal monitoring by principals or community members tend to be undermined and ineffective (Kremer and Holla, 2008).

Incentivising learner performance through the offer of merit scholarships has had some success in improving achievement and reducing learner absence and in leading to the spillover benefit of reduced teacher absence (Kremer, Miguel and Thornton, 2009).

Another group of RCTs have found positive effects of providing information to students and parents about child performance, relative school performance and even about expected earnings associated with particular levels of educational attainment.

Experimental evidence has also pointed to the potential benefits of using contract teachers. Duflo, Dupas and Kremer (2012) found that contract teachers cost less, are absent less often, and produce better learning outcomes than permanently employed teachers.

Experiments designed to test the benefits of increasing teacher inputs (through reducing class size) or increasing other inputs (such as textbooks) have typically not demonstrated any improvements in learning (Kremer and Holla, 2008). One potential reason for these results is that the effectiveness of such inputs may be conditional upon other systemic or contextual factors, such as the ability of children to read textbooks (Glewwe, Kremer and Moulin, 2007).

Interventions that prescribe what teachers do, through for example introducing scripted lesson plans, have shown more impact. One subset of these studies comprises RCTs testing specific early grade reading interventions. In several countries, notably in Liberia, it has been demonstrated that reading coaches, scripted lesson plans and report cards can improve the acquisition of reading with benefits that persist and are transferable into other learning areas (Gove and Wetterberg, 2011).

Although experimental research designs represent the gold standard for identifying the causal impacts of educational interventions, there are some challenges regarding the scalability of impacts (Bold *et al*, 2012).

FACTORS AFFECTING EDUCATIONAL ACHIEVEMENT IN SOUTH AFRICA

The South African school effectiveness literature, including the education production function literature, of the early 2000s demonstrated that socio-economic status was the most important determinant of educational achievement, with language[45] and school management practices also appearing important (Crouch and Magoboane, 1998, 2001; Van der Berg and Burger, 2002). Additional school resources have generally not been found to have substantial effects on school performance. The effectiveness of resources appears to be conditional on the managerial efficiency of schools to convert resources into outcomes (Van der Berg, 2008). Managerial and teaching practices therefore represent the important dynamics to understand. However, due mainly to data limitations, school effectiveness studies have typically been unable to uncover what specific managerial and teaching practices improve learning outcomes.

A number of smaller studies, though lacking in national representativeness, have provided some evidence on the kind of teaching practices that prevail and affect learning outcomes. A fairly substantial body of evidence jointly demonstrates that coverage of the curriculum is far from complete, with the result of accumulating learning deficits. One aspect of classroom practice that contributes to this problem is the low level of cognitive demand

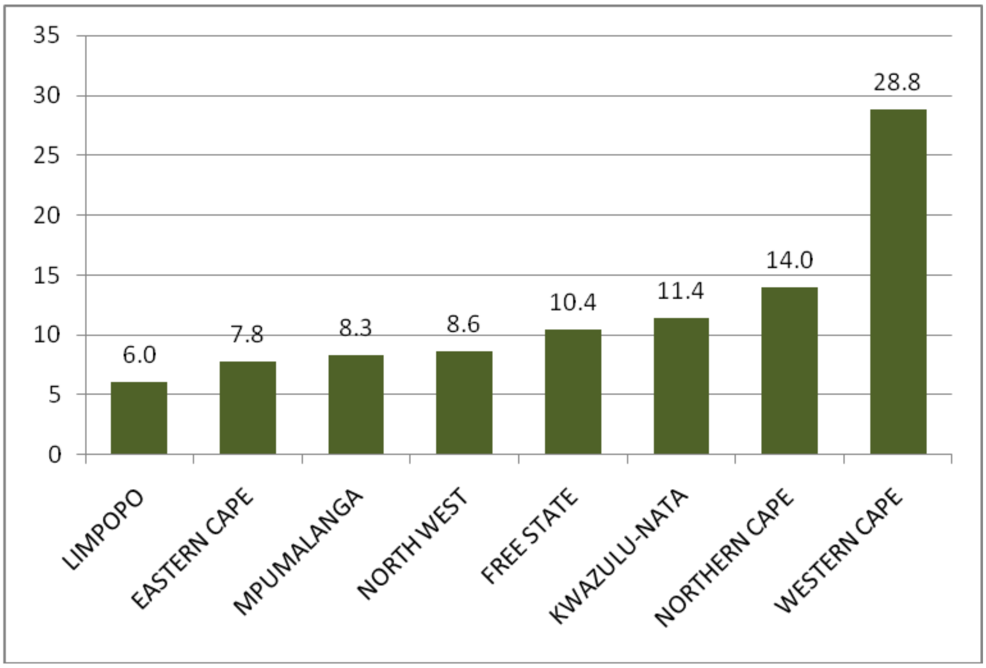
[45] A number of studies have emphasized the strong relationship between being taught in one's first language and educational outcomes (Howie *et al*, 2007, Fleisch, 2008). However, the causal impact of language remains something that has not been well understood due to the fact that language divisions overlap with other important determinants of educational achievement, notably socio-economic status and geography. Therefore, it is not clear to what extent language issues influence achievement, though intuitively one would expect it to be important.

required by lessons. Low cognitive demand in the Foundation Phase means, amongst other things, that reading is not sufficiently taught. An HSRC study of grades 1 – 4 classrooms in 20 Limpopo schools found that very little reading activity occurred, that the use of texts was limited and that when reading was taught the predominant activity was the teacher reading to the class (Prinsloo, 2008). This evidence from classroom observation provides important context to the results of large scale sample surveys, such as PIRLS (2006) which indicates that roughly 85% of South African children had not learned to read effectively by the fifth grade.

The nature of low cognitive demand in classroom practices is also demonstrated by Ensor *et al* (2009). They found an overuse of physical classroom apparatus at the expense of text, with the consequence that children favoured concrete approaches to problem-solving rather than abstract and algorithmic approaches. Hoadley (2007), comparing four working class classrooms with four middle class classrooms, found that mathematics classes in the working class context tended to focus on everyday knowledge rather than principles and procedures. There was also very little feedback to children in response to mistakes. This is confirmed by the learner workbook analysis done as part of the National School Effectiveness Study (NSES), which found very little evidence of paragraph length writing and of complex mathematics exercises.

Figure 1 shows the average number of complex exercises (defined as requiring more than one step or involving a word problem) that were found in the mathematics workbook of the “best learner” (according to the teacher’s judgement). Note that fieldwork was undertaken roughly three-quarters into the school year so enough time had passed in which to do a fair amount of work. As the figure shows, the undertaking of complex exercises varied considerably across the provinces. Due to the presence of some schools with fairly high numbers of complex exercises the averages perhaps understate the severity of the problem. It is telling that just over 50% of grade 5 students were in classes where fewer than 5 complex exercises could be found in the “best” learner’s mathematics workbook.

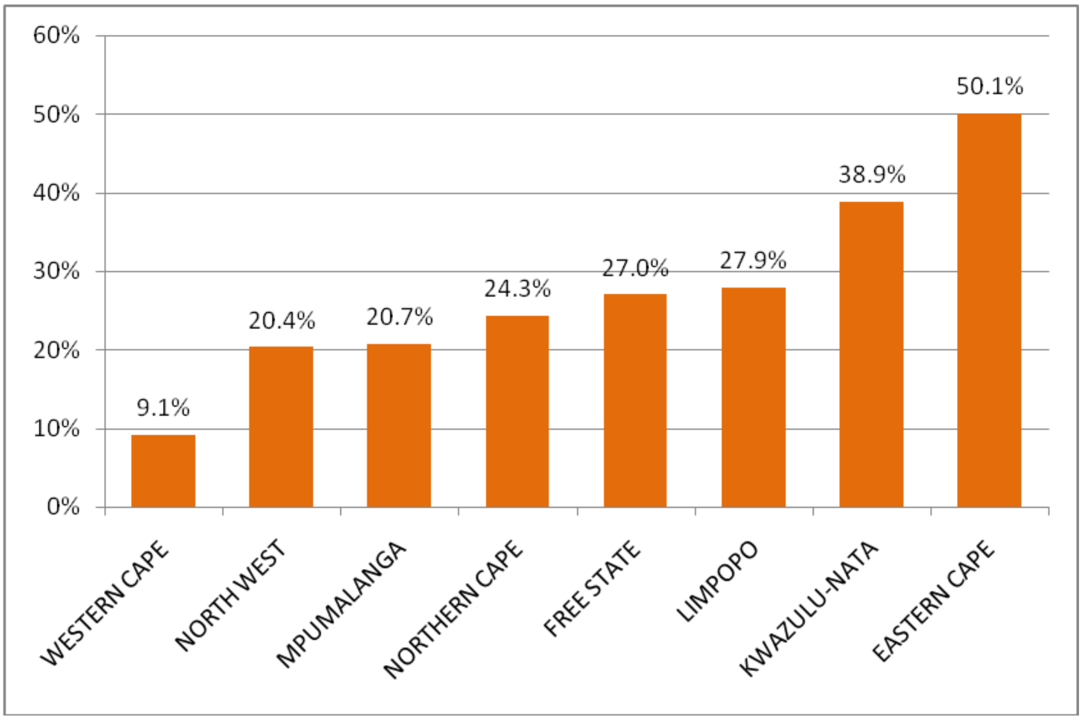
Figure 1: Average number of Complex Maths Exercises observed in the best learner's workbook (Grade 5, 2009)



Source: Own calculations based on NSES

The next figure shows the percentage of grade 5 children that were in classes where no paragraph writing appears to have taken place. Again, considerable differences exist by province. More than half of children in the Eastern Cape were in classes where paragraph writing seems not to have occurred.

Figure 2: Percentage of grade 5 children in classes in which the best learner's workbook revealed no evidence of paragraph length writing (data from 2009)



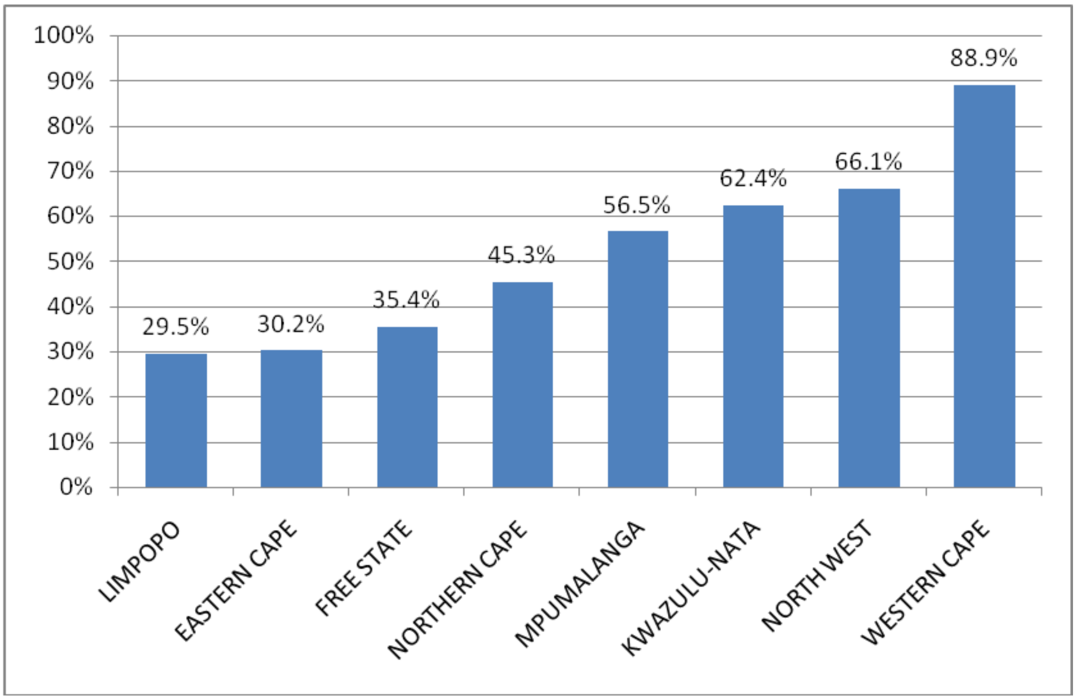
Source: Own calculations based on NSES

Apart from the low cognitive demand of exercises to which many teachers restrict themselves, curriculum coverage and consequently learner performance is also negatively affected by poor use of time within schools. Hoadley (2010) describes the research focussing on time as falling into three broad categories: studies focussing on the allocation of time such as time-tabling, studies focussing on academically engaged time, and studies focussing on pacing. This last more fine-grained approach relates to the issue of curriculum coverage.

Hoadley (2003) found that curriculum pacing was very slow in many classrooms with the pace for everyone being set by the slowest students. Similarly, Ensor *et al* (2009) and Schollar (2008) found slow pacing to be prevalent and that this was often combined with a general erosion of time-on-task. Teacher absenteeism, weak allocation of teachers and time within the school day, and insufficient academically engaged time within a lesson all contribute to the erosion of effectual teaching time. The Educator Workload Project (Chisholm *et al*, 2005) found that the proportion of overall available teaching time that was spent on instruction varied from 6% to 56%. This combination of slow pacing and time erosion unsurprisingly lead to insufficient curriculum coverage.

Figure 3 shows that teaching time varies considerably across the provinces. Approximately 30% of grade 5 children in Limpopo and the Eastern Cape were taught by teachers who reported spending at least 20 hours per week in class teaching. Bearing in mind that self-reports on a question such as this are likely to be upwardly biased, this result points to a serious time-on-task issue in certain provinces.

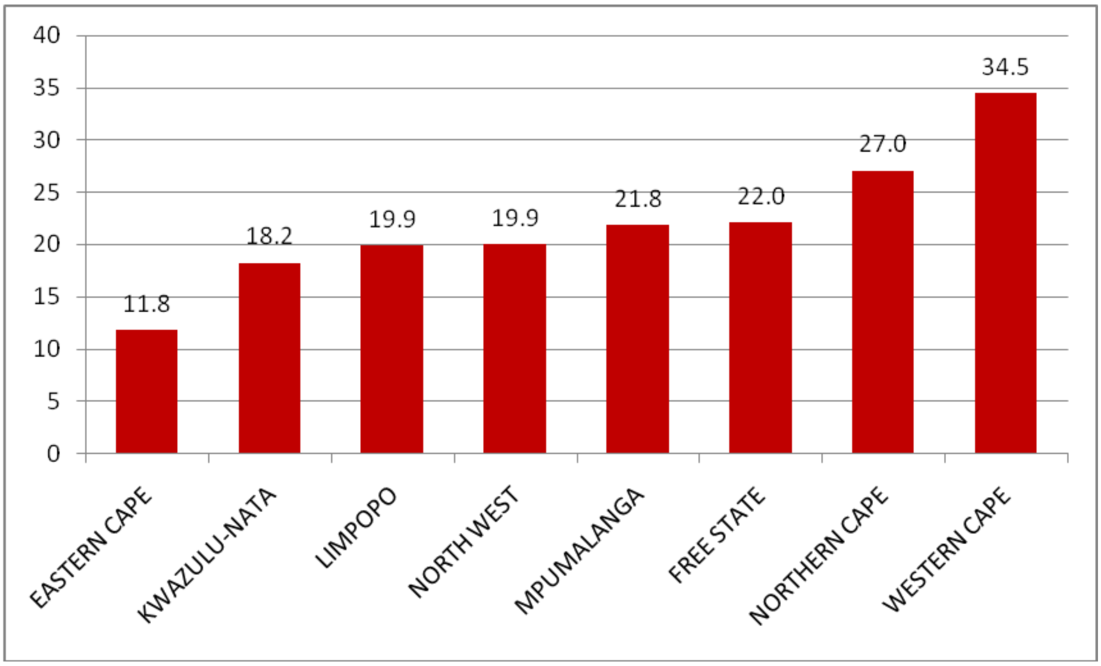
Figure 3: The percentage of grade 5 children taught by teachers who report spending more than 20 hours teaching per week (data from 2009)



Source: Own calculations based on NSES

Perhaps partly as a consequence of low time-on-task, curriculum coverage was also particularly low in most provinces. The learner workbook analysis in the NSES shows that on average 11.8 out of the specified 85 mathematics curriculum topics had been covered in Eastern Cape classes. It would probably be unrealistic to expect schools to have covered all topics by three-quarters of the way through the year, but the level of coverage observed here is sufficiently low and variable across the schools as to indicate that a serious problem exists.

Figure 4: Average number of Maths Assessment Standards (as specified in the curriculum) observed in the best learner's workbook (Grade 5, 2009)



Source: Own calculations based on NSES

Multivariable regression analysis of the NSES data confirms that various measures of curriculum coverage are predictive of student achievement and learning gains after accounting for other important determinants (Taylor, 2011). The number of maths curriculum topics covered and the frequency of undertaking complex mathematics exercises were associated with mathematics performance, while the frequency of undertaking literacy exercises, particularly those involving extended writing, was associated with literacy achievement.

Taylor and Prinsloo (2005) summarise the key findings from the evaluation of the Quality Learning Project (QLP) that was undertaken in 524 South African high schools between 2000 and 2004. They found that curriculum planning and coverage was lacking in many high schools. In particular, it was found that curriculum coverage was neglected in the lower grades relative to the higher grades as was coverage of language subjects compared with mathematics.

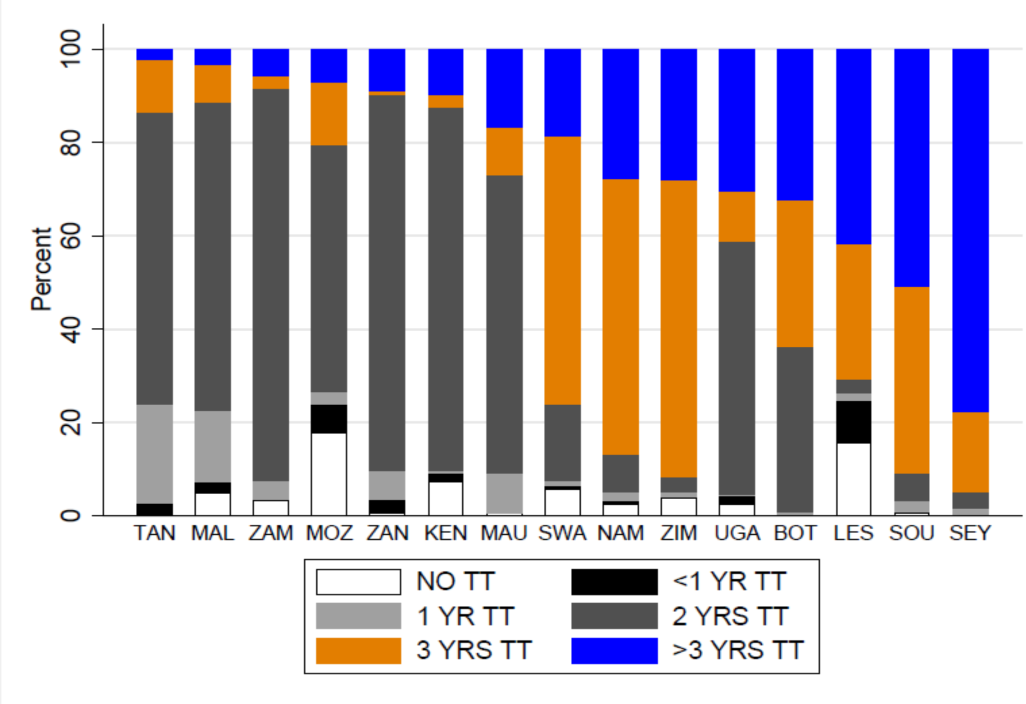
Carnoy *et al* (2012) compared student achievement and learning gains between grade 6 children on either side of the border between Botswana and the North West Province in 2009. The idea underlying the study was that children on either side of the border were essentially similar in terms of socio-economic status, language and culture, and that any observed learner performance differences between the two groups of children therefore reflects on aspects of teacher quality, school practice and education policy that differ systematically between Botswana and South Africa.

The main finding of the study was that children in Botswana outperformed those in the North West, both in terms of the initial "pre-test" mathematics achievement and in terms of the learning gains accrued during grade 6. The study focussed mainly on two determinants of mathematics achievement: **teacher content knowledge and curriculum coverage**. Teachers who scored better on a mathematics test also were more dynamic teachers (as measured by video analysis) and covered more of the mathematics curriculum (as observed in learner workbooks). This relationship between teacher knowledge and curriculum coverage held even after accounting for learner socio-economic status, thus pointing to the probability of a causal relationship. Batswana teachers scored better than North West teachers on the content knowledge test and their observed lessons were of a higher quality. The learner workbook review revealed that whereas 130 daily lessons could have been taught in the period of observation, an average of 78 lessons were administered in Botswana and only 50 in the North West. Teachers in both regions tended to engage children mainly in simple mathematical procedures rather than in understanding the underlying mathematical principles.

Why might curriculum coverage and the level of cognitive demand in South African classrooms be so low? One can think of at least four possible explanations. Firstly, it may simply be that teachers face weak incentives to attend school and to maximise the use of time at school to produce learning. This is no doubt at least part of the problem as it is in many other developing countries. Monitoring curriculum coverage by observing learner workbooks therefore presents one available means to address the issue. Secondly, it could be that the slow pace adopted by many teachers is necessitated by the learning deficits of the children they receive. However, there is evidence to suggest that in many underperforming schools teachers grossly overestimate how many of their children are performing at the level required by the curriculum (Van der Berg *et al*, 2010). Moreover, even if teachers did slow their pace to cater for previous learning deficits this then points to poor teaching in earlier grades and can therefore not be an ultimate explanation for poor curriculum coverage. Thirdly, it may be that teachers themselves are not confident to engage with more advanced sections of the curriculum as a result of their own weak content knowledge. Fourthly, they may not have been exposed to the kind of pedagogical methods required for teaching the more advanced sections of the curriculum.

There is some evidence to support these last two possible explanations for low cognitive demand and curriculum coverage. As discussed above, Carnoy *et al* (2012) found that more knowledgeable teachers taught more lessons and covered more curriculum topics in those lessons. Information about the content knowledge of South African teachers has been very limited although we now have fairly rich information from the teacher testing that was undertaken in the SACMEQ survey of 2007. This shows some interesting patterns in how South African teachers compare with others in the region. As Figures 5 and 6 show, South African teachers have received a considerable amount of pre-service training in comparison with most other Southern and Eastern African countries, but perform slightly below the average in the region. This pattern holds both for mathematics teachers and language teachers, which means that it is unlikely to be explained by poor within-school allocation of teachers to subjects. The pattern therefore raises questions about the content of pre-service training and about the extent to which teachers continue to develop their own professional skills once in the profession.

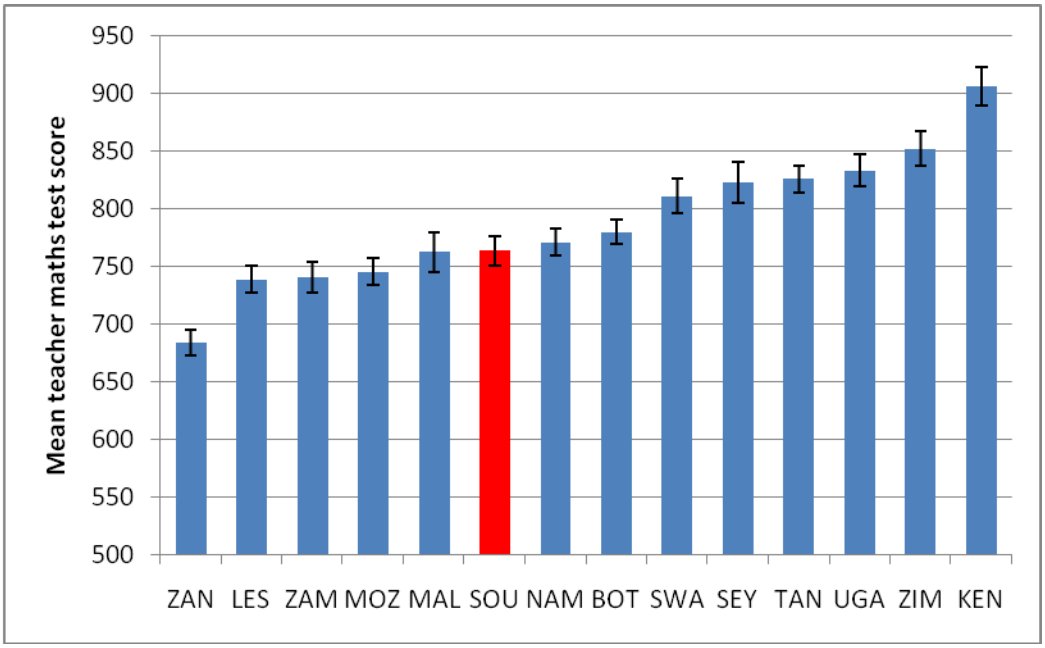
Figure 5: Self-reported years of teacher training for countries in SACMEQ 3 (Mathematics teachers)



Source: Own calculations based on SACMEQ 2007

Note: The percentages in the graph correspond to the proportions of children taught by teachers with those levels of teacher training.

Figure 6: Mean mathematics teacher test scores by country in SACMEQ 3



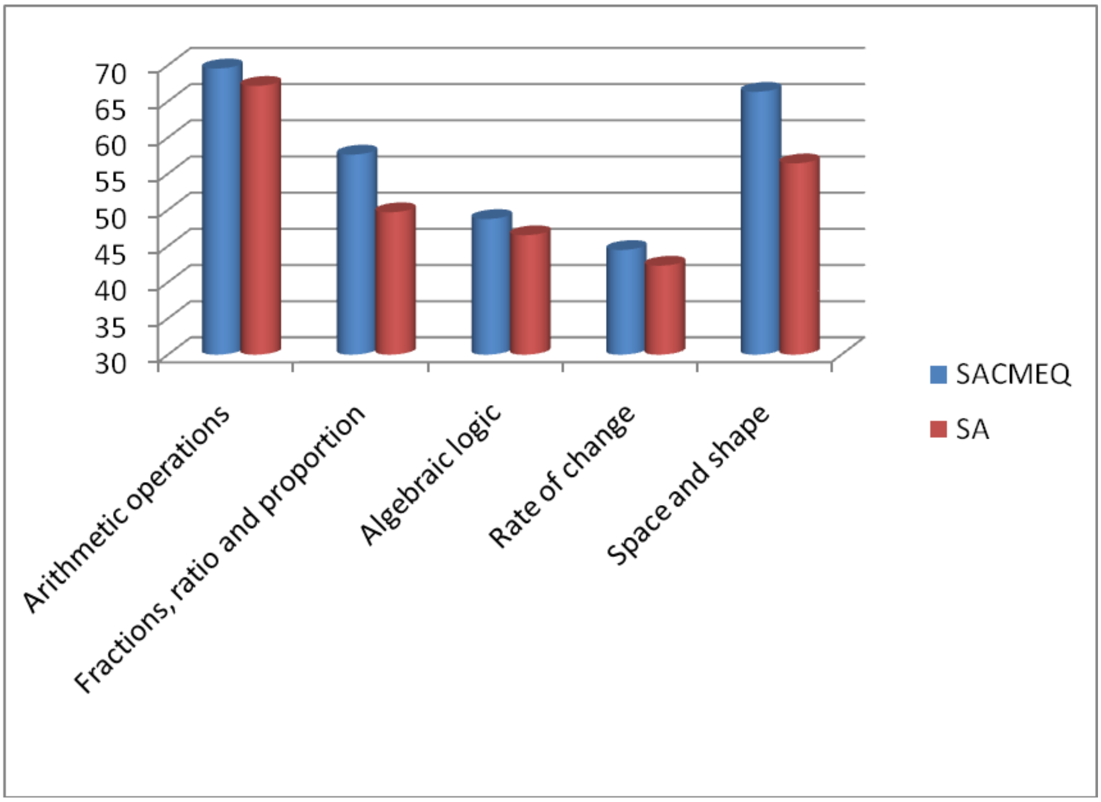
Source: Own calculations based on SACMEQ 2007

An item analysis of the SACMEQ teacher tests reveals some interesting patterns. As Table 1 (and the corresponding graph) show, South African teachers performed similarly to teachers in the rest of SACMEQ in three of the five learning outcomes that were tested. This indicates that South African teachers are not generally less mathematically competent than other teachers. However, in the cases of "fractions, ratio and proportion" and "space and shape" South African teachers performed considerably worse than the rest. This points to knowledge gaps in specific content areas – something that can be fixed through ensuring sufficient pre-service and in-service attention is given to these areas.

Table 1: Teacher percentage scores on the SACMEQ maths test

	Arithmetic operations	Fractions, ratio and proportion	Algebraic logic	Rate of change	Space and shape	Total
SACMEQ	69.55	57.65	48.75	44.47	66.33	57.47
SA	67.15	49.68	46.51	42.30	56.44	52.39

Figure 7: Teacher percentage scores on the SACMEQ maths test



Although this descriptive analysis of teacher content knowledge raises interesting questions, multi-variable regression analysis only shows a fairly small association between teacher content knowledge and grade 6 student performance (Spaull, 2011). Apart from the possibility that teacher knowledge actually doesn't have a big impact on learning, one possible reason for this result is that in South Africa teacher knowledge is closely correlated with a plethora of other aspects of school quality and school socio-economic status. This makes it difficult to identify the impact of differences in teacher knowledge between schools with otherwise similar characteristics. Future research with a more nuanced design will be needed to bring clarity around the relationship of teacher knowledge and learner performance.

School leadership and management practices are widely believed to be key factors in driving educational performance but are particularly difficult to measure. The National School Effectiveness Study (NSES) collected more extensive information about school and teacher practices than other large-scale sample surveys have done. Taylor (2011) found that aspects of school time management, curriculum planning, teacher absenteeism, the management of LTSM and organised assessment practices were all associated with student performance. These observed measures should not be interpreted as activities which themselves generate improved performance but should rather be understood as indicators of a wider constellation of practices typical of good management, which are driving the observed better student performance. Therefore, command and control measures to ensure that these practices are followed may only produce compliance behaviour. Rather, measures to incentivise better overall management and ensure that the best managers take up school leadership positions might be expected to produce better results.

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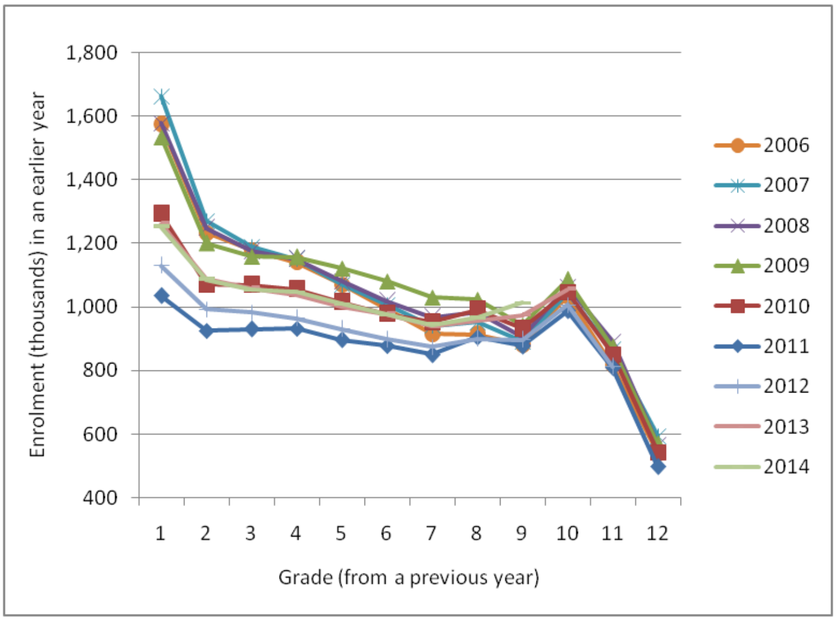
Appendix F: Historical enrolment trends and Grade 12 outcomes

The following graph provides an atypical but important view of enrolment patterns since 1994. The source data for the graph are total enrolment by grade in public ordinary schools for the years 1994 to 2011. Each curve in the graph indicates approximately the level of enrolment in an earlier grade of a specific Grade 12 group. For instance, the 2011 curve, starting from the right, points to Grade 12 enrolment in 2011, Grade 11 enrolment in 2010, Grade 10 enrolment in 2009, Grade 9 enrolment in 2008, and so on. Each curve thus provides a rough idea of the level of enrolment to expect in Grade 12 in a particular year. The indication is rough above all because details on grade repetition are not considered in the analysis. (Grade repetition values obtained either from schools or households require complex adjustments, meaning the rough analysis provided here is easier to perform and explain.) What stands out is that the lowest curve in the graph is the 2011 curve, meaning that one would expect Grade 12 enrolment in 2011 to be unusually low. The reasons behind this are largely related to changes in the age of admission policies that were initiated in 1999.

Figure 16: Historical enrolment trends



It is possible to predict more or less what Grade 12 enrolments to expect in future years. The 2012, 2013 and 2014 curves in the above graph do not reach Grade 12 because we do not have enrolment statistics for the future. The next table indicates the relative cohort size represented by each curve in the above graph, for the grades for which enrolment data were available. For instance, for the anticipated Grade 12 enrolment in 2014, Grades 1 to 9 enrolments for previous years were available to provide an indication. What is clear from the table is that historical enrolments do more or less predict Grade 12 enrolments, as one would expect. The value for the 2011 Grade 12 cohort is low whether one looks at all grades (see the middle column) or just Grade 12 (see the last column). Based on pre-Grade 12 enrolments, we can expect the Grade 12 enrolment in 2012 to be around 3% higher than in 2011, and we can expect the Grade 12 enrolment in 2013 and 2014 to be around 10% higher than in 2011.

Table 14: Relative sizes of pseudo-cohorts

Grade 12 year	Index of pseudo-cohort size	Index of Grade 12 size
2006	102	98
2007	105	108
2008	106	103
2009	107	103
2010	99	99
2011	89	90
2012	92	
2013	99	
2014	99	

Each index value represents the vertical height of a curve (or a point in the case of just Grade 12) in the previous graph relative to the other curves. 100 is the average across all curves (or points). In determining the height of a curve, each grade was weighted equally.

Appendix G: Views of the 2011 NSC database

In this appendix selected views of the 2011 National Senior Certificate (NSC) database are provided. The focus is on MST subjects and on views on the data that were not included in the official year-end report on the examinations published by the Department of Basic Education. The data include supplementary examination results. This is one reason why totals may differ slightly from totals in the official year-end report of the DBE.

Whilst a score of 30 out of a 100 is counted as a pass for MST subjects, a score of 40 is considered a critical threshold for a number of reasons, including the fact that every learner must obtain at least 40 in two non-language subjects in order to obtain the National Senior Certificate. The following table indicates the number of learners obtaining at least 40 in what were considered to be MST subjects. If one considers the fact that 84% of full-time learners participating in the 2011 examinations were African, it is easy to see that African under-representation amongst passes is a serious challenge. Only in one subject are Africans over-represented, namely agricultural sciences, where Africans account for 98% of the row in the table. The high number of Africans in this subject is an inheritance from the pre-democracy period. African representation is particularly low in the more specialised MST subjects appearing in the last six rows of the table.

Table 15: MST subject passes with at least 40 by race in 2011

	African	Coloured	Indian	White	Total
Mathematics	44,940	3,524	3,732	15,059	67,710
Physical sciences	44,464	2,582	3,046	10,694	61,142
Life sciences	94,749	8,281	4,532	14,368	122,397
Agricultural sciences	30,273	66	2	354	30,771
Agricultural technology	226	18	0	295	542
Computer applications technology	12,490	4,012	703	11,596	28,911
Information technology	876	156	508	1,677	3,266
Civil technology	2,818	1,036	222	2,502	6,590
Electrical technology	2,378	155	27	663	3,245
Engineering graphics and design	8,767	1,214	844	8,091	18,990
Mechanical technology	2,053	352	166	1,378	3,958

Note: All full-time students in the examination, regardless of school type, were counted. Part-time students were not counted. The total column includes students whose race was not specified as one of the four in the database.

Table 16 provides an indication of the provinces where specific MST subjects may require a ‘boost’, which could be with respect to availability of the subject in schools, participation by learners and the quality of teaching and learning. The percentage of all NSC candidates in NC achieving a score of at least 40 in mathematics is particularly low. The same applies to physical science. With respect to figures for the subjects in the last seven rows, four provinces stand out as particularly weak. These provinces are, in ascending order of an indicator which is simply the sum of values across the seven subjects are: LP (worst), EC, MP, KN.

Table 16: MST subject passes with at least 40 by province in 2011

	EC	FS	GP	KN	LP	MP	NC	NW	WC	Tot.
Mathematics	10.9	13.2	16.9	11.3	12.8	12.0	9.9	13.0	18.7	13.2
Physical sciences	9.9	13.1	13.9	11.0	12.8	11.6	7.1	12.0	13.4	11.9
Life sciences	20.4	28.7	26.6	20.9	26.6	20.8	22.1	25.5	28.5	23.9
Agricultural sciences	8.6	2.2	0.5	6.1	12.7	9.2	2.1	5.8	0.8	6.0
Agricultural technology	0.1	0.4	0.0	0.0	0.0	0.3	0.3	0.2	0.2	0.1
Computer applications technology	3.8	9.6	9.6	2.6	1.8	4.5	7.0	6.6	14.8	5.6
Information technology	0.3	0.4	1.4	0.6	0.2	0.3	0.2	0.8	1.1	0.6
Civil technology	0.6	2.4	2.0	0.8	0.5	0.8	1.2	2.2	3.1	1.3
Electrical technology	0.4	1.1	0.9	0.6	0.4	0.5	0.8	1.0	0.4	0.6
Engineering graphics and design	1.9	5.1	6.0	3.7	1.8	2.4	3.6	5.1	5.4	3.7
Mechanical technology	0.5	1.2	1.2	0.7	0.3	0.6	1.3	1.4	0.8	0.8

Note: Percentages represent passes with at least 40 divided by all students who wrote the examinations, counting only full-time students.

It is important to view any ratio relative to all NSC exam-takers in a province against the backdrop of the ratio of youths who get to participate in Grade 12 in the first place. The next table provides estimates of the latter. If one looks at the previous table and the next table together, one sees for instance that the percentage of a youth cohort achieving a 40 score level in mathematics is 7.8% in LP (12.8% multiplied by 61%) and just 5.7% in NW (13.0% multiplied by 44%). These statistics suggest that despite being average in the previous table, NW should be improving its mathematics outputs through better participation in Grade 12. Similar adjustments can be made for other provinces and other subjects.

Table 17: NSC exam-takers relative to the population (2011)

	NSC exam-writers in 2011 as a % of the average population cohort size ages 15 to 19
EC	41
FS	47
GP	61
KN	62
LP	61
MP	67
NC	51
NW	44
WC	55
SA	56

Note: 2011 mid-year population estimates published by Stats SA were used for the denominator.

Many university courses require a pass in both mathematics and physical science. The next table suggests that there is a relatively high overlap between doing well in one subject and doing well in the other. For instance, of the approximately 12,000 learners achieving over 70 in mathematics, 9,178 also achieved at least 70 in physical science. Yet the proportion of youths achieving 70 or above in both subjects is small. Only around 1.8% of those who wrote the examinations achieved this. But the proportion of an age cohort of youths achieving this result is only 0.8%. The racial inequalities can be seen in the fact that this latter statistic becomes 0.4% if one considers only African learners and 2.9% if one considers learners in the other three race categories. Though Africans constitute around 84% of all youths, just 39% of those excelling in both mathematics and physical science are African.

Table 18: Excellence in both mathematics and physical science in 2011

Physics➔ Maths🡻	0-29	30-39	40-49	50-69	70-79	80-100	Total
0-29	64,377	14,544	3,244	423	5	2	82,595
30-39	7,076	11,905	7,406	1,891	11	1	28,290
40-49	1,362	5,046	8,001	5,614	86	2	20,111
50-69	219	1,128	4,374	14,231	2,511	290	22,753
70-79	4	10	82	2,300	2,621	1,459	6,476
80-100	1	1	7	288	1,110	3,988	5,395
Total	73,039	32,634	23,114	24,747	6,344	5,742	165,620
				Students with 70 or more in both subjects			9,178

Table 19 is like the previous table, but here only African learners are considered.

Table 19: As for previous table but just African students

Physics➔ Maths🡻	0-29	30-39	40-49	50-69	70-79	80-100	Total
0-29	62,367	13,768	3,063	394	5	1	79,598
30-39	6,588	10,809	6,617	1,685	10	1	25,710
40-49	1,263	4,429	6,775	4,609	74	2	17,152
50-69	186	936	3,362	10,045	1,524	165	16,218
70-79	3	5	58	1,348	1,290	619	3,323
80-100	0	1	4	157	523	1,157	1,842
Total	70,407	29,948	19,879	18,238	3,426	1,945	143,843
				Students with 70 or more in both subjects			3,589

One thing that stands out in the next table is that the provinces which perform relatively well with respect to producing top-end results, in particular GP and WC, are also the provinces where the lowest proportion of learners overall take both subjects. This could point to a more focussed approach in these provinces, whereby less promising learners are advised not to take the subjects and the available resources are concentrated on fewer learners.

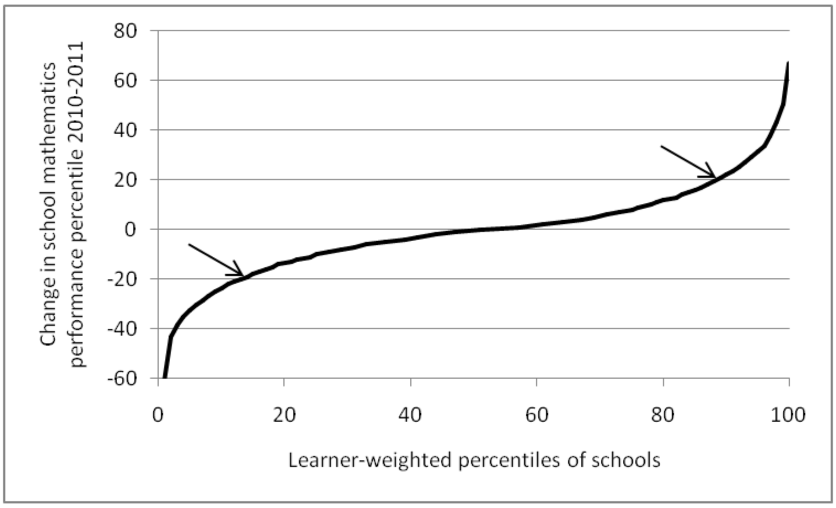
Table 20: Mathematics and physical science combinations per province

	EC	FS	GP	KN	LP	MP	NC	NW	WC	Tot.
Both at least 70	1.1	1.8	2.7	1.3	1.3	1.4	1.1	1.7	4.2	1.8
One at least 70	1.9	2.9	4.3	2.1	2.3	2.5	1.9	2.8	5.8	2.9
Both at least 40	7.1	9.9	11.7	7.7	9.5	9.1	6.2	9.3	11.8	9.2
One at least 40	11.5	13.8	14.8	12.4	14.4	13.2	8.6	13.4	14.1	13.2
One at least 30	19.4	20.5	19.5	19.7	22.5	19.6	13.7	20.1	17.3	19.8
Remainder	38.7	31.0	27.4	34.3	36.1	33.3	23.8	30.7	22.3	32.3

Note: Percentages represent learners at that level divided by all students who wrote any of the examinations, counting only full-time students. The figures are cumulative, meaning they include the categories above the row as well. The bottom row thus represents the percentage of all students who wrote both subjects.

In identifying schools that perform well, it is important to keep in mind that school-level results vary to a large degree from one year to the next. This point is highlighted in Simkins (2010) and is illustrated in the next graph. For instance, around a quarter of schools moved up or down by at least a quintile (or 20 percentiles) between 2010 and 2011 with respect to their average mathematics scores.

Figure 17: Volatility of school-level results 2010 to 2011



The analysis that follows is aimed at using patterns seen in the 2011 (but also 2010) NSC examinations databases to identify specific areas, broken down by province, where room for improvement seems to exist. The analysis is done only for mathematics, but it could be done for other MST subjects too. Only full-time learners are considered. The focus is not only on increasing the number of mathematics passes, as required by the targets illustrated earlier in Figure 7, but also on increasing the number of learners, in particular African learners, who attain a score of at least 70 in mathematics.

The next table breaks learners down by race composition of the school, a factor which is still considered important due to the apartheid legacy. 66% of all full-time exam-takers (or exam-writers) are in schools where every learner is African according to the examinations database. Most of the remaining 33% of the system was split into six fairly large categories of schools depending on which of the four race groups was represented by more than 10% of the school's exam-takers. For instance, 'Mostly African' means no other race constituted more than 10% of exam-takers. Finally a remainder category was created for those schools with relatively unusual combinations. The categories represented in the table would to a large degree coincide with the apartheid categories, but not entirely. For instance learners with at least 10% white learners would tend to historically white schools. However, mostly African schools could also be historically white schools where the demographics had changed over the years.

Table 21: Mathematics performance according to racial composition of schools

	African	Coloured	Indian	White	All[46]	African	Coloured	Indian	White	All
	Number of mathematics passes					Number of learners obtaining at least 70 in mathematics				
Just African	170,425				170,425	3,461				3,461
Mostly African	53,393	567	219	139	54,641	1,302	16	31	16	1,387
Mostly African + coloured	4,540	3,138	84	53	7,845	157	108	18	2	287
Mostly African + white	3,627	258	326	4,445	8,748	430	32	104	1,095	1,705
Mostly white	139	88	18	7,925	8,184	16	9	11	2,296	2,338
Mostly African + Indian	2,109	75	2,308	14	4,515	104	5	358		470
Mostly coloured	150	3,294	31	13	3,513	8	123	7	1	141
Remainder	2,955	2,360	2,657	6,394	14,632	312	343	950	2,150	3,848
Total	237,338	9,780	5,643	18,983	272,503	5,790	636	1,479	5,560	13,637
	Average non-zero mathematics score[47]					Percentage of all exam-takers who took mathematics				
Just African	26				26	45				45
Mostly African	28	29	40	44	28	45	36	45	37	45
Mostly African + coloured	30	30	48	43	31	32	23	47	26	28
Mostly African + white	46	48	56	55	51	50	40	72	45	48
Mostly white	47	46	71	57	57	34	21	60	48	47
Mostly African + Indian	33	38	44	44	39	29	25	47	44	36
Mostly coloured	33	32	46	39	33	28	22	67	28	22
Remainder	45	48	59	60	55	46	38	73	50	49
Total	27	36	52	57	30	44	26	58	48	44

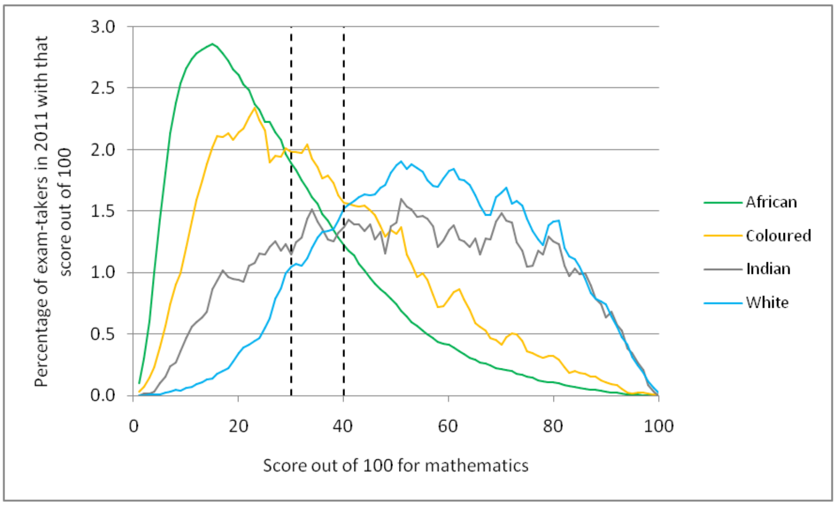
[46] This column includes a few learners whose race is not one of the four reflected in the table.

[47] Zero scores were excluded given the high numbers of learners with zero scores, relative to low scores. Thus a score of zero was treated as non-participation in the mathematics examination. Overall, 2% of full-time exam-takers in mathematics obtained a score of zero. Whilst 5,051 learners obtained a score of zero, 81 obtained a score of 1, 264 obtained a score of 2, and 794 obtained a score of 3.

The figures should reveal why it is still unfortunately necessary to plan whilst taking into account race. The required interventions are often correlated with the racial composition of the school. For instance, it is clear that there is an exceptional problem with under-enrolment in mathematics as far as coloured learners are concerned. Only 26% of coloured exam-takers took mathematics, compared to at least 44% for the other race groups. ‘Just African’ schools are mostly likely to be rural and township schools and their low average mathematics mark confirms the need for interventions to pay special attention to these schools. However, Africans in historically coloured and Indian schools (the third and sixth categories) also perform relatively poorly. Where African learners do perform well is in historically white schools. This is likely to be partly the result of better resources, in particular better trained teachers, in these schools, but also partly the result of the relatively high socio-economic status (and hence parent education) of these African learners. The particularly high rate of participation in mathematics amongst Indian exam-takers means that relative to the total number of exam-takers, there are more high-level (70 or above) mathematics passers amongst Indians than whites. Clearly, the performance challenges relate largely to African and coloured learners.

Figure 18 below illustrates the performance distribution in mathematics for the four races. The challenge is to shift the curves to the right in the graph, in particular as far as Africans and coloureds are concerned. Yet if we consider the point made in see section 5.1 above, that even at the top end South Africa performs poorly by world standards, a stronger presence at the high end, with respect to all races, is needed.

Figure 18: Distribution of performance by race



Note: Scores can only be whole numbers, so a score in mathematics of, say, 45.5 does not exist.

The following three graphs focus on just African and coloured learners. Figure 19 confirms the advantage enjoyed by African learners in schools with mainly African and white learners (‘African A + W’). The desire amongst many urban African households to make use of the ‘ex-Model C’ schools is understandable in this context. However, for the purposes of planning, it is important to consider overall numbers. Figure 20 reminds us that the magnitudes of the schooling system are such that historically African schools account for the great majority of high-level mathematics performers amongst African learners. Specifically, 11 times more African learners with a score of 70 or above are from African schools (‘just’ or ‘mostly’) than from African plus white schools. Even a small rightward shift in the three highest curves in Figure 20 (the two African curves plus the coloured curve) would result in particularly large increases in the number of high-achieving black mathematics matriculants. Identifying which African and coloured schools have high concentrations of better achieving mathematics learners is important for a number of reasons. These schools can be promoted as role models for the rest of the system, and they can be targeted for expansion to make optimal use of the teaching and management capacity that exists in these schools.

Figure 19: Distribution of performance by racial composition of school

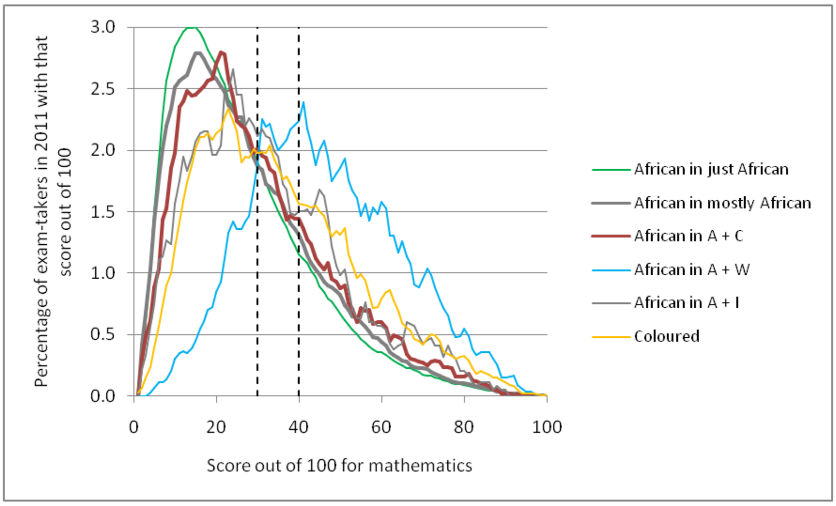


Figure 20: As for previous graph, but with absolute numbers

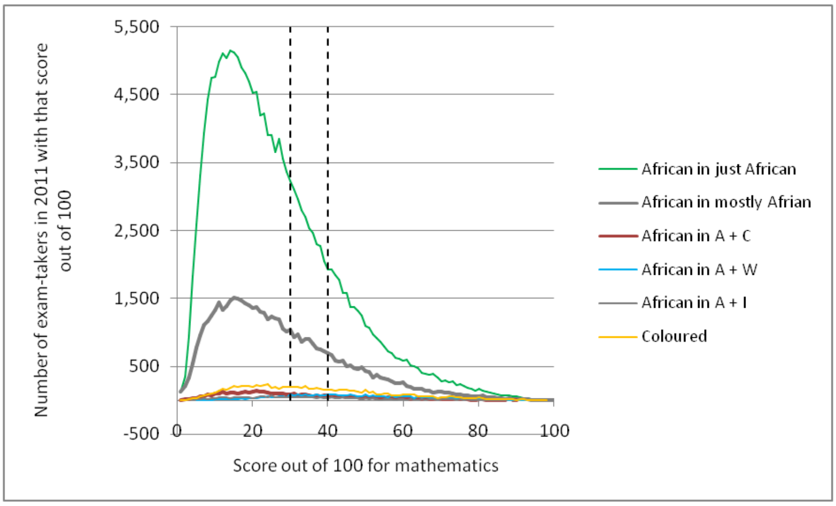
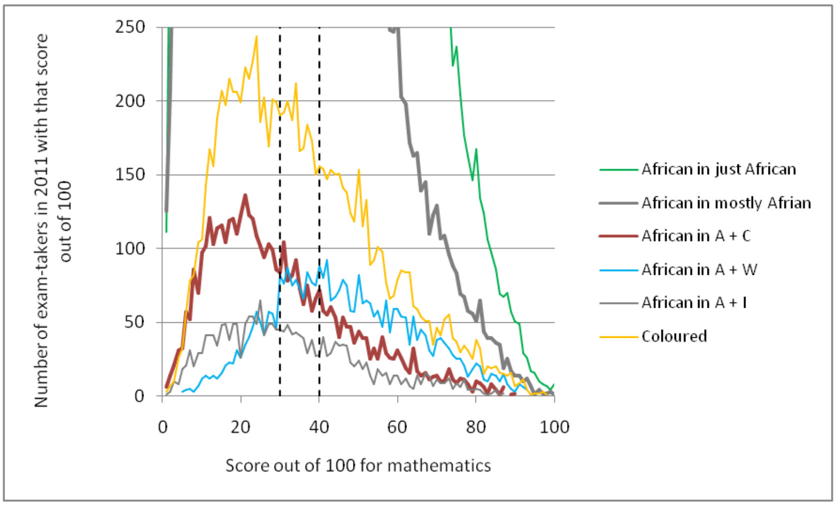


Figure 21: Magnification of previous graph



In some ways, schools in the Dinaledi programme constitute model schools for the promotion of mathematics learning amongst black learners. However, it is important to note that the 500 Dinaledi schools were not selected into the programme because they displayed the best results, but rather because they were schools that were not performing poorly and that seemed promising as far as future improvements were concerned. The Dinaledi curve in Figure 22 below reflects the 86% of Dinaledi exam-takers who are African (a further 8% are coloured). The performance curve in the Dinaledi schools is relatively disappointing and not unlike that for other mostly African schools in the country. As seen in Table 22, the average mathematics score in Dinaledi schools is just 32 (against around 27 in mainly African schools and 46 for Africans in historically white schools). At the same time, Figure 22 makes it clear that Dinaledi schools produce a high proportion of all high-level African mathematics matriculants. Dinaledi schools account for 34% of African learners with a mark of 70 or above in mathematics, though Dinaledi schools account for just 13% of African exam-takers.

The 'African top 500' curve in Figure 22 represents a selection of schools that was made for this analysis. Schools were selected from the 'Just African' and 'Mostly African' categories. A score was calculated for each school based on both 2010 and 2011 data (one year's data would have been inadequate given the year-on-year fluctuations discussed above). The school-level score took into account both average learner scores in mathematics and the percentage of learners taking mathematics, in 2010 and 2011[48]. The distribution shown in Figure 22 refers to just the 2011 results. 392 of the 500 schools are 'Just African' schools. 85 of them are also Dinaledi schools. More details on the 500 schools are provided below. From Figure 22 it is clear that above a score of around 40, the output of the top 500 African schools and the Dinaledi schools is almost identical. However, Dinaledi produces this output at a higher cost insofar as for every pass (above 30) in the Dinaledi schools there is a larger number of learners who do not pass. Specifically, whilst 52% of Dinaledi mathematics exam-takers pass, the figure is 82% for the top 500 African schools. Are Dinaledi schools perhaps performing worse because their learners are from more socio-economically disadvantaged backgrounds? School quintile data do not support this hypothesis. Whilst 61% of Dinaledi schools are from the poorest three quintiles, the figure for the top 500 African schools is 82%. One notable difference between the two (somewhat overlapping) groups of schools is that Dinaledi schools are larger. They have on average 160 exam-takers per school (counting all races, and not just mathematics learners), against 71 for the top 500 African schools. This suggests that the top 500 African schools could be expanded.

[48] For this indicator two values were used. The first value was the simple average of all non-zero mathematics scores across the two years. The second value was an extended average where learners who did not take mathematics or obtained zero in the examination were all given a value of zero for the purposes of the calculation. The first value carried a weight of 2 and the second a weight of 1 for the indicator.

Figure 22: Performance distributions of African learners

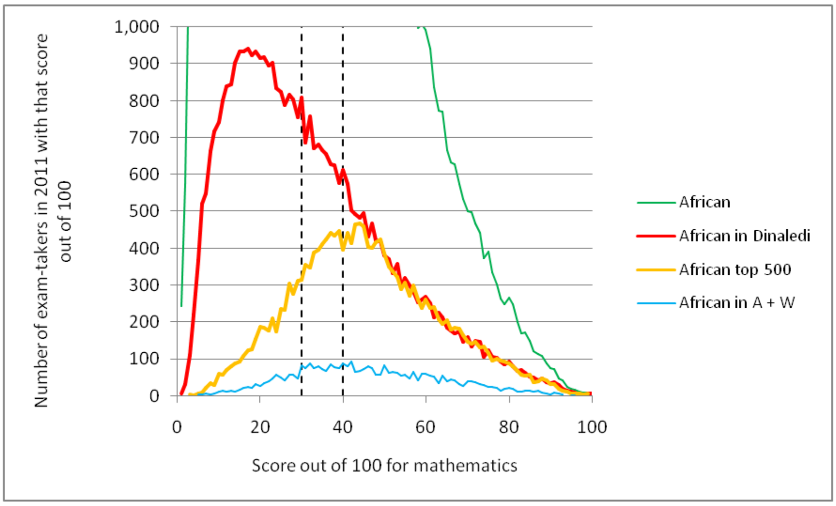


Table 22: Dinaledi and top 500 African

	African	All	African	All
	Number of mathematics passes		Number of learners obtaining at least 70 in mathematics	
Dinaledi	13,129	17,025	1,138	2,036
Top 500	15,268	15,497	1,905	1,961
	Average non-zero mathematics score		Percentage of all exam-takers who took mathematics	
Dinaledi	29	32	56	54
Top 500	46	46	53	53

There are of course many ways one could create scenarios, using the structure of the analysis provided above, of improvements in general passes and high-level passes. One approach is described below. A key assumption made here is that improving the mathematics outcomes of the schooling system is a national priority. Thus the focus here is on making use of those pockets of the system that show promise, regardless of province. At the same time, the scenario provided below is broken down by province as provincial education departments are instrumental in bringing about the desired changes.

The scenario involves increasing Grade 12 mathematics outputs through five different means, which would be pursued concurrently. It is assumed it would take around eight years, or to 2020, to reach the full scenario. The full scenario involves reaching an output of around 185,000 passes per year (against the figure of around 106,000 applicable in 2011), of which around 25,000 would be achieving at a level of at least 70 out of 100 (compared to around 14,000 at this level in 2011). In terms of passes, the scenario falls short of the targets shown in Figure 7. Those targets imply reaching around 270,000 mathematics passes by 2020. If we inflate the 185,000 in the scenario by the 5% upward adjustment that was applicable in 2011 to deal with full-time students and repeaters, one obtains 194,000 passes in 2022, a figure still well below the 270,000 target. This latter target implies increasing the 2011 number of passes by a factor of 2.5. Achieving 185,000 passes implies an improvement factor of just 1.6. One point in favour the scenario presented below, however, is that it would improve the number of high-level passes by a somewhat better factor of 1.85. It should be remembered that the skills shortfall is to a large degree a problem of high-level mathematics skills. The official targets are of course important, but like all long-range targets set by any government, they are ambitious and are driven to a large degree by aspirations, as opposed to modelling. The official targets are not impossible. However, it could be argued that if something like the scenario that follows (which is an exercise in fairly detailed and realistic modelling) could be achieved, the skills shortfall in the country would have been dealt with to a considerable degree. In many respects, what is more important than the final year figures is the identification of the mechanisms through which improvements could be brought about.

The five different means for achieving the desired growth are the following:

1. **Mathematical literacy to mathematics switch.** Following the discussion in section 6.3 above, learners taking mathematical literacy who are likely to achieve at least a score of 50 in mathematics, are made to switch from mathematical literacy to mathematics. The methodology from Simkins (2010) was applied to the 2011 examinations data. As shown in Table 23, this change results in an increase in the number of mathematics passes of 14%. The effect would be achieved both through better advice to learners and better standardised assessment of mathematics in Grade 9, when critical decisions about subject choices need to be made.

2. **Expansion in enrolments of the top 500 African schools.** Following the earlier discussion that pointed to the fact that these schools were relatively small and could take in more learners, enrolments in these 500 schools is assumed to increase by 50%. This is done by taking African mathematics learners from African schools ('just African' and 'mostly African') that are not in the top 500 on a random basis, from within the database, and assuming that they are able to achieve the level of performance of learners currently in the top 500 African schools. The expansion in these schools would be achieved partly through investments in infrastructure and possibly bursaries for poorer learners to attend these schools. Even if new teachers would need to be added to these schools, it is assumed that the existing capacity and culture in the school would be able to guide new mathematics teachers so that the past performance of the school could be replicated. Importantly, it is not assumed that the expansion would occur through the 'creaming' of the best mathematics learners from neighbouring schools. If this creaming did occur, the net impact would be smaller than what is seen in Table 23 because average performance in other schools would be affected negatively. It should be emphasised that the expansion of the 500 schools described here is an exploratory idea that would need to be investigated further if there was interest in putting it into practice. There are a number of factors that would need to be considered before one could arrive at a reasonable level of certainty around impact and a set of workable procedures. One thing that would need to be established is why the 500 schools are of a below average size. Does the smallness of the schools play a role in their relatively high mathematics performance? Why have these schools not attracted learners from other schools previously? How would one avoid creaming from other schools, and is creaming perhaps not so undesirable after all? Are the 500 schools performing well because they are in relatively well to do areas so that socio-economic advantages lie behind the better performance? The data suggest that the latter is not the case. A whole 82% of the 500 schools which are public schools are in quintiles 1 to 3, or in the poorest approximately three-fifths of the school system. Yet there could be socio-economic advantages experienced by the 500 schools which are not reflected in the quintile data.

3. **Rightward shift in all curves equal to two-thirds of Brazil's PISA trend.** The improvement seen in Brazil's PISA mathematics score, illustrated in Figure 6, comes to an improvement of 0.06 standard deviations per year over a nine-year period[49]. It was assumed that for eight years, South Africa's performance could improve at a rate of 0.04 standard deviations per year, which converts to 1.17 points on the 0 to 100 scale of the South African mathematics examinations. This means that in each year the curves seen in

[49] This is the standard deviation for just Brazil's learners, not for all PISA learners from all countries. Brazil's data were obtained from http://www.oecd.org/pisa.

the previous graphs would move to the right by 1.17 points each year, over eight years. The improvements would be brought about through the various actions described in the *Action Plan*, including critical improvements in the availability of good textbooks and workbooks.

4. **Additional rightward shift for just Dinaledi schools.** Here it is assumed that one would be able to reap the benefits of several years of investments in Dinaledi schools, by getting these schools to move slightly faster up the achievement ladder. Concretely, it is assumed that these schools would improve as quickly as the average improvement in Brazil. The assumption that Dinaledi schools would be able to advance faster than other schools would of course need to be given careful thought and should be subjected to further analysis. Specifically, is it reasonable to assume that the kinds of interventions that have occurred in Dinaledi schools, such as teacher development, take many years to take effect and that the full effect of the interventions to date has not been felt yet?

5. **Increase in coloured mathematics enrolment ratio to 43.6%.** Here the participation ratio in mathematics of coloured learners is raised from 25.5% to the national average of 44% seen in Table 21. The new learners would take on the performance characteristics of existing coloured learners (after the effect of the previous four changes had already occurred). The strategy to bring this improvement about would need to be informed by the reasons why coloured participation in mathematics is so poor. There appears to be limited formal research into this matter, though certain education experts are likely to have a good general idea of the problem.

Table 23: Number of passes in the improvement scenario

	0: Baseline (based on 2011 situation)	1: Mathematical literacy to mathematics switch	2: Expansion in enrolments in the top 500 African of 50%	3: Rightward shift in all curves equal to two-thirds of Brazil's PISA trend	4: Additional rightward shift for just Dinaledi schools	5: Increase in coloured mathematics enrolment ratio to 43.6%	Increase
All mathematics passes							
EC	14,103	15,119	17,122	22,533	22,944	24,289	1.72
FS	5,489	6,463	6,849	8,148	8,324	8,597	1.57
GP	25,727	30,271	31,146	36,647	37,157	38,445	1.49
KN	26,848	30,608	33,657	42,693	43,346	43,664	1.63
LP	16,452	17,301	19,032	23,688	23,920	23,954	1.46
MP	9,472	10,528	11,128	13,678	13,914	13,985	1.48
NC	1,715	2,044	2,114	2,569	2,650	4,084	2.38
NW	5,688	6,644	6,970	8,420	8,650	8,790	1.55
WC	10,419	12,890	13,097	14,835	15,087	21,426	2.06
Total	115,913	131,868	141,115	173,211	175,992	187,234	1.62
Increase	1.00	1.14	1.22	1.49	1.52	1.62	
African	87,747	95,390	104,637	134,275	136,849	136,849	1.56
Passes at least at the 70 level							
EC	1,191	1,192	1,411	2,205	2,306	2,501	2.10
FS	640	640	722	1,076	1,138	1,188	1.86
GP	3,576	3,578	3,773	5,572	5,820	6,022	1.68
KN	2,321	2,321	2,762	4,221	4,412	4,477	1.93
LP	1,446	1,446	1,763	2,785	2,916	2,923	2.02
MP	1,002	1,002	1,152	1,680	1,753	1,767	1.76
NC	201	201	214	320	334	561	2.79
NW	671	671	760	1,109	1,182	1,207	1.80
WC	2,589	2,589	2,625	3,450	3,533	4,556	1.76
Total	13,637	13,640	15,182	22,418	23,394	25,202	1.85
Increase	1.00	1.00	1.11	1.64	1.72	1.85	
African	5,790	5,793	7,335	12,018	12,798	12,798	2.21

Which of the five interventions have a particularly large envisaged effect? Table 23 indicates that much of the improvement would have to depend on general improvements across the entire system (see particular improvement 3). However, the second-largest improvement strategy is simply to get the right learners to take mathematics after Grade 9 (improvement 1). Improving mathematics participation amongst coloured learners has a relatively large effect on output as a whole.

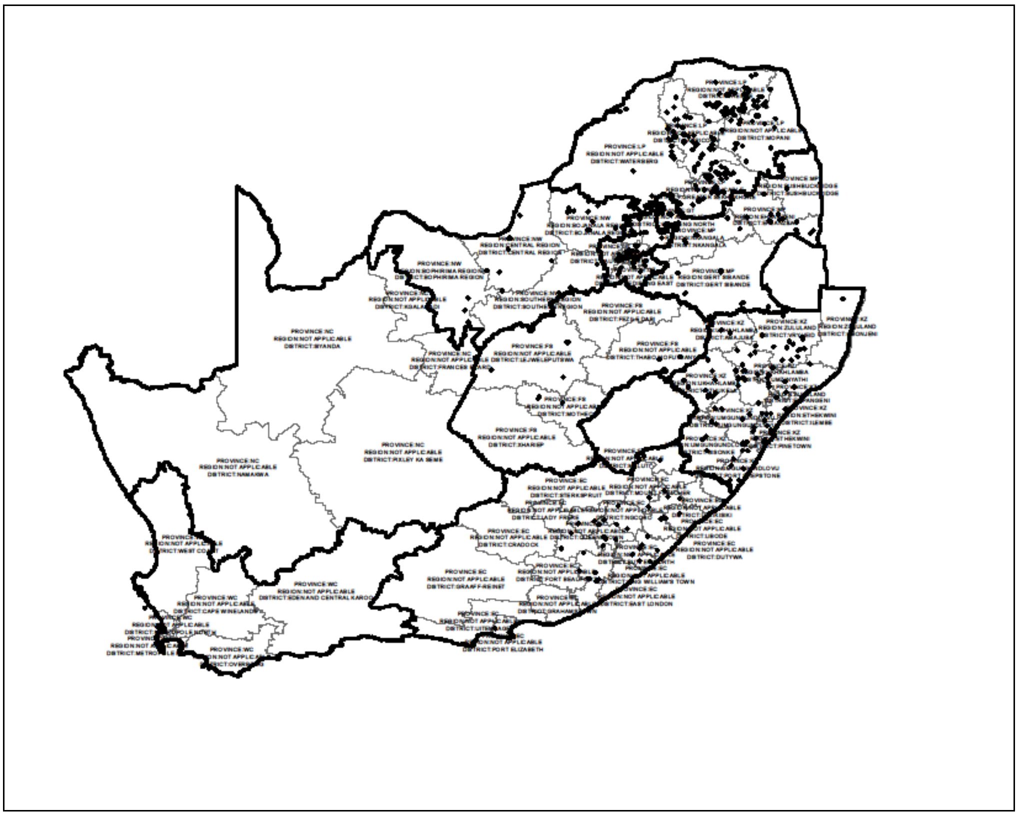
Table 24 provides details on the top 500 African schools, as these details stood in 2011. NC is not included as none of the schools were in this province. What is immediately striking is that 184 of the 500 schools are in LP. This is partly because well-performing schools in this province are relatively small as seen in the average number of exam takers per school. However, the fact that 11% of African exam-takers in this province should be within the selected schools, a figure substantially higher than for the other provinces, does point to better high-level mathematics performance for African learners in this province. Of the 500 schools, 122 are independent. What is particularly striking is that of the 83 selected schools in GP, 77 should be independent.

Table 24: Details on the top 500 African schools

	Top 500 schools	Identified schools which are also independent schools	Identified schools which are also Dinaledi schools	Total NSC exam-takers in identified schools	Average exam-takers per school	African NSC exam-takers in identified schools	% of NSC exam-takers in identified schools who are African	Total mathematics exam-takers in identified schools	Average mathematics exam-takers per school	% of all African NSC exam-takers in the province in these schools
EC	48	4	8	3,492	73	3,436	98	2,649	55	4
FS	18	3	6	1,888	105	1,862	99	1,018	57	7
GP	83	77	13	7,922	95	7,702	97	3,062	37	8
KN	96	11	11	6,776	71	6,672	98	3,679	38	5
LP	184	18	22	9,682	53	9,616	99	5,953	32	11
MP	37	5	11	3,575	97	3,481	97	1,506	41	7
NW	31	2	14	2,089	67	2,067	99	905	29	8
WC	3	2	0	204	68	202	99	127	42	1
SA	500	122	85	35,628	71	35,038	98	18,899	38	7

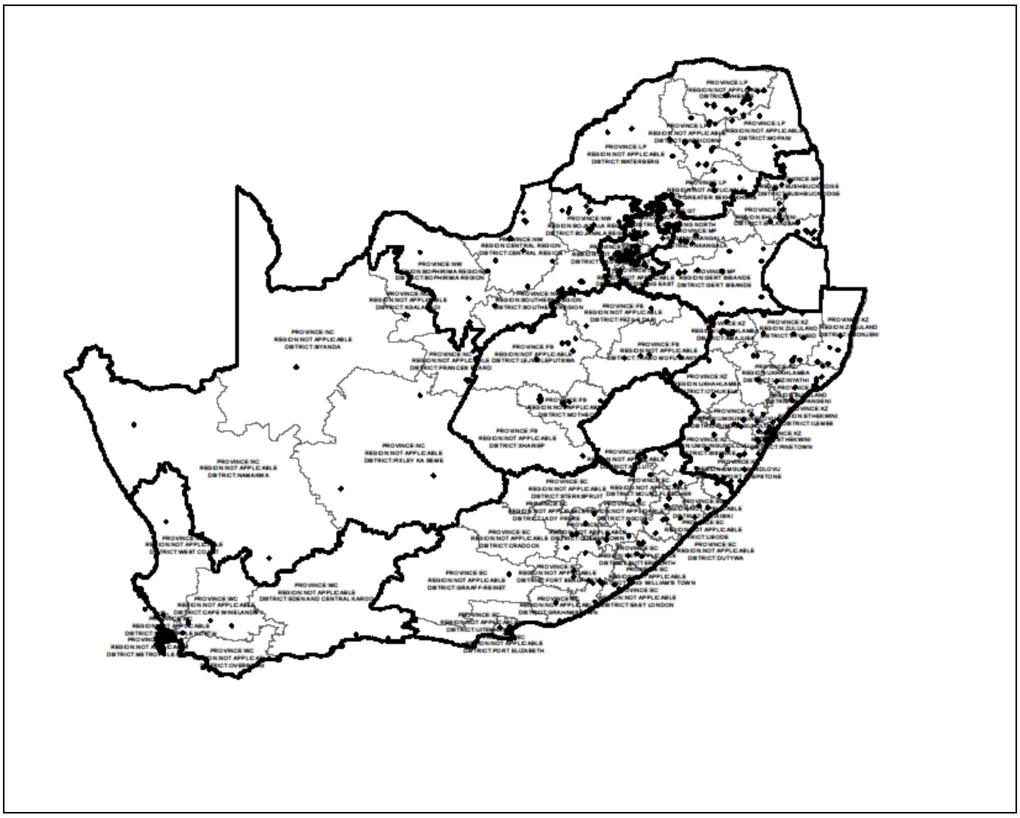
The following two maps illustrate the geographical distribution of the schools discussed above.

Figure 23: Map with top 500 African schools[50]



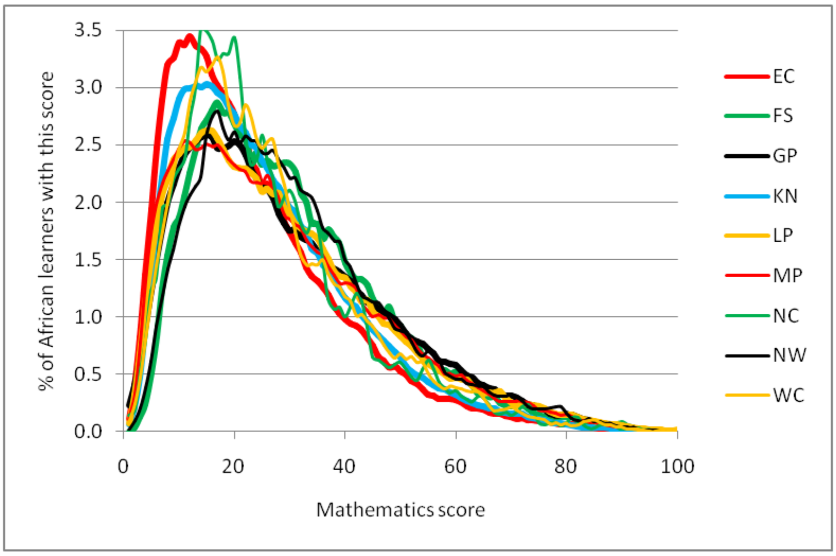
[50] This map and the next one produced for this report by Hilton Visagie of the DBE.

Figure 24: Map with Dinaledi schools



If one considers recent administrative problems in LP and the fact that at the primary school level LP is clearly the *worst* performing province in the country[51], it may seem counter-intuitive that so many top performing African schools should be in LP. The next two graphs and Table 25 confirm that the relatively good level of mathematics performance in LP, for African learners, is not just an outcome of the methodology used for selecting the top 500 African schools. LP is amongst the best provinces when it comes to the production of results of 70 and beyond in mathematics. Whether one looks at high-level African achievers relative to all African exam-takers or just mathematics candidates, LP's performance is the top in the country or almost the top (NW is another province that does well in this regard). Why this should be the case needs to be researched further. One pattern that one sees in the 2011 examinations dataset is that exam-takers in LP are on average slightly older than exam-takers in other provinces, but by a small margin. For instance, the average age of African learners passing mathematics in LP is 20.18 years, which is the highest figure in the country and compares to a figure of 20.06 for African mathematics passers in the other eight provinces. A part of the explanation may be that appropriate grade repetition is employed to ensure that learners enter Grade 12 when they are more ready for this grade.

Figure 25: African mathematics performance by province[52]



[51] Spaull, 2011b.
[52] The first five provinces – EC, FS, GP, KN and LP – carry the thick lines, whilst the remaining provinces carry thin lines.

Figure 26: Magnification of previous graph

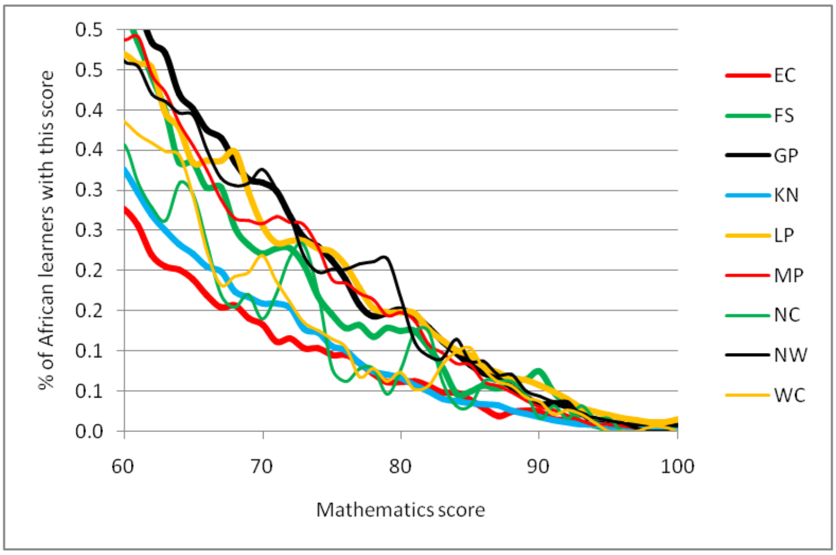


Table 25: High-level mathematics achievement amongst Africans by province

	% of African NSC exam-takers achieving 70 or above in mathematics	% of African mathematics exam-takers achieving 70 or above
EC	0.8	1.5
FS	1.0	2.7
GP	1.4	3.3
KN	0.8	1.6
LP	1.5	3.4
MP	1.2	3.1
NC	0.7	2.1
NW	1.3	3.5
WC	0.7	2.1
SA	1.1	2.4

Appendix H: Grade 12 mathematics trends and changing provincial borders

Below, Grade 12 school-level results in mathematics from 2011 are compared to results from 2005. One element that makes such a comparison especially interesting is that between 2005 and 2006 around 710 schools moved from one province to another as provincial boundaries were changed . Around 160 of these schools were public ordinary schools offering Grade 12. This creates a natural experiment, where a factor that theoretically should influence educational outcomes, namely the province that administers you as a school, changed in a random manner, or at least in a manner where the change was not deliberately correlated with learning outcomes. Put differently, there was no attempt to make better or worse performing schools move between provinces. This means that there would be no reason to expect affected schools to improve or deteriorate relative to other schools in either the province they left or in the province they joined other than because of the change in administration. Therefore, if one does in fact observe that such schools improved relative to others this can be attributed to the causal impact of better provincial administration. Usually, this causal inference is not possible. For example, the typically better performance of the Western Cape relative to Limpopo cannot be attributed to better administration because it is unclear to what extent other factors such as socio-economic status are to account for the observed differences between these two provinces.

Table 26 below sums up the changes that occurred between 2005 and 2011 in the 5,810 public and independent ordinary schools which could be linked across the two years. A bottom row examines the Dinaledi schools which could be linked and the very last row focuses on independent schools. Eight indicators of performance or output with respect to Grade 12 mathematics are considered. These indicators are referred to in the column headings. Schools which moved from one province to another are reported on in their own rows and each school belongs to just one province row. Thus, for instance, the 589 schools in the 'GP' row are schools which were in GP both in 2005 and 2011. The signs in the table reflect the degree to which the average national ranking of schools, against the indicator, moved up or down. The symbol '+++' means that the average difference between the old and new percentile ranking of schools in that row was over 10. '++' means the average difference exceeded 5, and '+' means the average difference exceeded 3. No symbol means that the average difference was between -3 and +3. One, two and three minus signs mean an average difference of at least -3, -5 and -10. Note that in virtually no cases would the average difference be a round number. The percentile ranking difference for one school between 2005 and 2011 would of course be a round number within the range of 0 to 99. For instance, if a school moved from the 12th percentile (a poorly performing percentile) to the 32nd percentile (a better performing percentile), the difference would be positive 20. However, the average percentile ranking difference across several schools in a province, or province-to-province category, is likely not to be a round number.

What does Table 26 suggest has occurred? Firstly, it is important to view the information in the context of what was discussed in section 6.2, namely the fact that mathematics outputs from Grade 12 have remained more or less static over the 2005 to 2011 period. Plus signs in Table 26 are thus likely to reflect absolute improvements whilst minus signs are likely to reflect absolute declines. The absolute values underlying the symbols are provided in Table 28 to Table 30. Two of the indicators deserve special attention: Firstly, the number of high-level passes, meaning here the number of learners obtaining at least 70 out of 100 in mathematics higher grade in 2005 or mathematics in 2011, is an indication of the ability of the schooling system to provide enough university entrants for fields such as engineering. Secondly, the average mark spread across all candidates[53] takes into account both the level of

[53] For 2005, this was the sum of the raw marks of all mathematics learners (which were out of 300 in the case of standard grade mathematics and 400 in the case of higher grade mathematics) divided by all Grade 12 learners participating in any subject examination. For 2011, this was the sum of all the scores

performance of mathematics students and the percentage of Grade 12 learners who take mathematics in the first place. It is noteworthy that schools that moved from NW to GP experienced substantial improvements with respect to high-level passes, though schools remaining in NW saw a slight deterioration in their ranking. This could point to better support systems in GP compared to NW. However, as seen in Table 28, schools that moved from NW to GP were weaker than other NW schools to begin with. The average province-switching school was producing only 0.4 high-level passes per school, against 1.0 in non-switching NW schools, though the statistics in Table 27 suggest that the switching schools were slightly larger than the non-switching schools. The low point of departure could have made it easier for the switching schools to improve their standing. Nonetheless, the fact that the schools in question showed the largest improvements in their rankings with respect to the high-level passes indicator (relative to schools reflected in other rows) suggests that GP succeeded in making a difference in these schools and that administrative practices in this province might be worth emulating in other provinces.

Schools moving from EC to KN may also have experienced benefits arising from a better administration, but here too it is not possible to draw firm conclusions without further analysis. What is noteworthy is that the 15 schools in question improved their average number of high-level passes from 0.1 to 1.1 per school. This is an eight-fold increase (if the exact values are used), and an increase far higher than for any other province category (see Table 28). The increase was mostly attributable to improvements in four of the 15 schools.

MP is the province that appears to have experienced the greatest performance gains. Against all the eight indicators except for percentage of learners taking mathematics, MP scores at least a '++' symbol.

Turning to the average mark spread across all candidates, it is noteworthy that the rows with the four best trends, with respect to the average percentile ranking, were MP, the two province-to-province categories discussed above (NW to GP and EC to KN) as well as another province-to-province category, namely NW to NC (see Table 30). This seems to offer further evidence that MP has been an improver province and that what provincial administrations do can make a difference to school results. To elaborate on the last point, both GP and KN (and perhaps also NC) appear to pursue practices that are good for school results, relative to practices in other provinces.

The bottom two rows of the tables indicate that Dinaledi and independent schools were relatively good at producing more high-level passes. Dinaledi schools were moreover relatively good at improving their ranking with respect to the total mark divided across all exam-takers.

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out of 100 in mathematics, divided by all Grade 12 exam-takers (in other words mathematical literacy was not considered at all in the numerator).

Table 26: Summary of province-specific mathematics trend 2005-2011

Province	Schools	Number of passes (SG included for 2005)	Number of passes (SG excluded for 2005)	Number of high-level passes	% taking mathematics (SG included for 2005)	% of mathematics-takers passing mathematics	Average mark (SG included for 2005)	Average mark (SG excluded for 2005)	Average mark spread across all candidates
EC	859	--	+		++	---	---	---	
EC->KN	15	--	+++	++	++	---	---		
FS	303	-				---	---	---	--
GP	589	-	-	++	---	+	++		---
KN	1,488		+		-			--	-
LP	1,240	++	-		++	++	++	+++	+++
LP->MP	84	+++		+	+++	++		+	+++
MP->LP	15				--	+++	+++	+++	++
MP	367	+++	++	+++		+++	+++	++	++
NC	106		---			--	--	--	--
NW->GP	30		++	+++	---	+++	+++		-
NW->NC	11		+++	--	++			--	
NW	341	-		-	--	++	++	--	
WC	362	--	--	+	---	--	-		---
Total	5,810								
Dinaledi	484		+	++	+	-	--	--	
Indep.	273	++	--	++	--			++	--

Table 27: Basic statistics on the categories of schools

	Total schools	... of which independent schools	... of which Dinaledi schools	... of which just or mostly African schools	Exam-takers 2005	Exam-takers 2011	Avg. school Gr 12 groups size 2005	Avg. school Gr 12 groups size 2011
EC	859	24	58	752	67,901	65,267	79	76
EC->KN	15	0	2	15	1,298	1,323	87	88
FS	303	9	36	235	25,882	25,853	85	85
GP	589	114	97	379	74,906	74,155	127	126
KN	1,488	35	86	1,300	118,791	117,735	80	79
LP	1,240	29	51	1,224	79,934	67,380	64	54
LP->MP	84	2	3	82	7,361	8,044	88	96
MP->LP	15	2	0	15	984	661	66	44
MP	367	14	41	320	35,231	35,347	96	96
NC	106	2	12	20	7,931	8,282	75	78
NW->GP	30	0	1	30	4,226	3,727	141	124
NW->NC	11	0	2	11	1,016	905	92	82
NW	341	11	51	293	30,694	24,241	90	71
WC	362	31	44	63	38,217	38,627	106	107
Total	5,810	273	484	4,739	494,372	471,547	85	81

Table 28: Detailed 2005-2011 comparison I [54]

	% taking mathematics (SG included for 2005)							Number of passes (SG excluded for 2005)							Number of high-level passes						
	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)
EC	27	14	51	44	-7	17	-7	2	14	41	44	3	24	5	0.6	1.3	45	44	-1	26	-1
EC->KN	33	21	64	59	-5	22	-5	1	21	45	59	14	27	14	0.1	1.1	37	45	9	35	9
FS	30	18	59	55	-4	15	-5	5	18	56	55	0	22	4	1.4	2.1	54	52	-1	27	0
GP	53	30	71	68	-3	14	-4	13	30	72	68	-4	15	-3	3.6	5.4	64	68	4	25	7
KN	26	15	51	50	-1	18	0	4	15	46	50	4	23	6	1.0	1.4	48	47	-1	26	-1
LP	14	11	34	42	8	19	8	2	11	47	42	-4	22	-4	0.3	1.0	46	46	0	27	0
LP->MP	8	11	23	47	24	28	24	2	11	47	47	0	19	0	0.2	0.7	45	48	3	23	3
MP->LP	18	12	46	45	-2	13	-2	1	12	45	45	-1	19	-1	0.1	0.7	48	50	2	24	2
MP	25	20	52	62	11	17	12	4	20	52	62	10	22	12	0.9	2.4	51	61	10	26	10
NC	22	13	46	44	-2	12	-4	4	13	55	44	-11	21	-6	0.9	1.7	53	50	-3	21	-1
NW->GP	33	19	65	65	0	17	0	4	19	59	65	6	21	6	0.4	1.5	48	62	13	25	13
NW->NC	19	8	43	40	-3	17	-3	0	8	27	41	13	16	13	0.0	0.0	37	30	-8	24	-8
NW	26	15	51	47	-4	15	-5	4	15	50	47	-2	20	-1	1.0	1.8	51	49	-3	26	-3
WC	45	26	67	57	-9	17	-7	12	26	64	57	-7	20	13	4.6	6.8	63	59	-4	25	4
Total	27	17	50	50	0	17	1	5	17	50	50	0	21	2	1.3	2.2	50	50	0	26	1
Din	67	45	84	83	0	11	1	14	45	79	84	4	13	6	3.1	5.8	69	75	6	22	7
Indep	25	19	47	55	8	19	7	7	19	63	55	-8	22	-4	2.3	4.7	59	63	4	25	8

[54] The 2005 and 2011 average values are per school, with no weighting of the data. The average percentile ranking for each year is the average across the various school-level percentile ranks, where 1 would be the worst and 100 the best school. The simple difference between the two average percentile rankings is given. The average of the absolute differences is found by making all school-level year-on-year percentile differences positive. This statistic thus provides a sense of the degree of variation occurring between the two years. The last column in each panel provides the simple difference one would obtain if one did the analysis only for schools which are primarily or exclusively African with respect to the Grade 12 exam-takers in the school.

Table 29: Detailed 2005-2011 comparison II

	Number of passes (SG included for 2005)							**% of mathematics-takers passing mathematics[55]**							**Average mark (SG included for 2005)**						
	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)
EC	27	14	51	44	-7	17	-7	2	14	41	44	3	24	5	0.6	1.3	45	44	-1	26	-1
EC->KN	33	21	64	59	-5	22	-5	1	21	45	59	14	27	14	0.1	1.1	37	45	9	35	9
FS	30	18	59	55	-4	15	-5	5	18	56	55	0	22	4	1.4	2.1	54	52	-1	27	0
GP	53	30	71	68	-3	14	-4	13	30	72	68	-4	15	-3	3.6	5.4	64	68	4	25	7
KN	26	15	51	50	-1	18	0	4	15	46	50	4	23	6	1.0	1.4	48	47	-1	26	-1
LP	14	11	34	42	8	19	8	2	11	47	42	-4	22	-4	0.3	1.0	46	46	0	27	0
LP->MP	8	11	23	47	24	28	24	2	11	47	47	0	19	0	0.2	0.7	45	48	3	23	3
MP->LP	18	12	46	45	-2	13	-2	1	12	45	45	-1	19	-1	0.1	0.7	48	50	2	24	2
MP	25	20	52	62	11	17	12	4	20	52	62	10	22	12	0.9	2.4	51	61	10	26	10
NC	22	13	46	44	-2	12	-4	4	13	55	44	-11	21	-6	0.9	1.7	53	50	-3	21	-1
NW->GP	33	19	65	65	0	17	0	4	19	59	65	6	21	6	0.4	1.5	48	62	13	25	13
NW->NC	19	8	43	40	-3	17	-3	0	8	27	41	13	16	13	0.0	0.0	37	30	-8	24	-8
NW	26	15	51	47	-4	15	-5	4	15	50	47	-2	20	-1	1.0	1.8	51	49	-3	26	-3
WC	45	26	67	57	-9	17	-7	12	26	64	57	-7	20	13	4.6	6.8	63	59	-4	25	4
Total	27	17	50	50	0	17	1	5	17	50	50	0	21	2	1.3	2.2	50	50	0	26	1
Din	67	45	84	83	0	11	1	14	45	79	84	4	13	6	3.1	5.8	69	75	6	22	7
Indep	25	19	47	55	8	19	7	7	19	63	55	-8	22	-4	2.3	4.7	59	63	4	25	8

[55] Here 2011 learners who obtained zero in the mathematics examination are considered exam-takers.

Table 30: Detailed 2005-2011 comparison III

	Average mark (SG excluded for 2005)							Average mark spread across all candidates						
	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)	Avg. 05	Avg. 11	Avg. p'tile 05	Avg. p'tile 11	Diff.	Avg. abs. p'tile shift	Diff. (African)
EC	27	14	51	44	-7	17	-7	2	14	41	44	3	24	5
EC->KN	33	21	64	59	-5	22	-5	1	21	45	59	14	27	14
FS	30	18	59	55	-4	15	-5	5	18	56	55	0	22	4
GP	53	30	71	68	-3	14	-4	13	30	72	68	-4	15	-3
KN	26	15	51	50	-1	18	0	4	15	46	50	4	23	6
LP	14	11	34	42	8	19	8	2	11	47	42	-4	22	-4
LP->MP	8	11	23	47	24	28	24	2	11	47	47	0	19	0
MP->LP	18	12	46	45	-2	13	-2	1	12	45	45	-1	19	-1
MP	25	20	52	62	11	17	12	4	20	52	62	10	22	12
NC	22	13	46	44	-2	12	-4	4	13	55	44	-11	21	-6
NW->GP	33	19	65	65	0	17	0	4	19	59	65	6	21	6
NW->NC	19	8	43	40	-3	17	-3	0	8	27	41	13	16	13
NW	26	15	51	47	-4	15	-5	4	15	50	47	-2	20	-1
WC	45	26	67	57	-9	17	-7	12	26	64	57	-7	20	13
Total	27	17	50	50	0	17	1	5	17	50	50	0	21	2
Din	67	45	84	83	0	11	1	14	45	79	84	4	13	6
Indep	25	19	47	55	8	19	7	7	19	63	55	-8	22	-4

It is instructive to perform a multivariate analysis to examine the degree to which the suggestive findings discussed above are supported. Table 31 below provides the results of a regression analysis examining the relationship between improvements in the 2005 to 2011 period (the two key indicators discussed above were considered), on the one hand, and on the other hand province status but also whether the school is a Dinaledi school, whether the school's enrolment is mostly or wholly African, whether the school is independent, the school quintile, the size of the Grade 12 group and whether the size of this group grew over the period. The starting value in 2005 was also entered as an independent variable. Coefficient (Coeff.) values indicate the improvement in the value of the outcome (for instance number of high-level passes) associated with a change in the input variable if one holds other input variables constant. For instance, being a Dinaledi school increases the number of high-level mathematics passes in 2011 per school by 181%, relative to not being a Dinaledi school (because the dependent variable is in the natural log form, 1.81 means a 181% improvement and not an improvement of 1.81 high-level exam passes).

The high-level passes model uses a log-log specification. The natural logarithms of both the 2005 and 2011 number of high-level passes and the total Grade 12 enrolments are used. The implications of using an entirely linear specification are discussed below. The left-hand panel of Table 31 indicates that even when factors such as school quintile are taken into account, relatively large and statistically significant improvements are seen where schools moved from NW to GP and for schools in MP. Specifically, being a 'NW to GP' school is associated with a 166% increase in the number of high-level passes whilst the increase is 142% for MP schools. These trends are thus robust within an analysis where a number of additional explanatory variables are controlled for. Other provincial statuses associated with relatively more high-level passes are GP and LP. In the previous analysis of Table 28 only GP stood out as a noteworthy improver. A key reason why LP appears to perform well in Table 31 is that this province experienced unusual and sharp declines in its Grade 12 enrolments during the 2005 to 2011 period. This can be seen in Table 27. Total Grade 12 enrolment in the schools examined fell by 15% in LP. NW also saw a large decline, of 21%.

If the high-level passes model uses an entirely linear specification, the adjusted R^2 value rises to 0.793 (against the 0.364 seen in Table 31). However, in that version of the model no provincial dummy variables, or province switching variables, display a substantial and significant association with the number of high-level passes.

Table 31: Regression results

Dependent variable:	Number of high-level passes in 2011 (natural logarithm)			Average mark spread across all candidates in 2011 (untransformed values)		
	Coeff.		t-value	Coeff.		t-value
2005 high-level passes[56]	0.32	***	19.86	0.2	***	59.49
2011 exam-takers (all subjects)	0.02	***	18.83	0.0		-1.52
Increase in exam-takers[57]	0.04		0.46			
Is EC	-0.42	*	-1.85	1.3		
Is EC->KN	-0.18		-0.20	1.5		0.87
Is FS	0.27		0.94	-1.0	*	-1.87
Is GP	0.77	***	3.04	-1.4	***	-3.03
Is KN	-0.19		-0.88	0.9	**	2.22
Is LP	0.92	***	4.17	3.3	***	8.21
Is LP->MP	-0.06		-0.13	2.5	***	3.10
Is MP->LP	1.43		1.53	1.2		0.72
Is MP	1.42	***	5.27	2.6	***	5.28
Is NC	-0.62		-1.50	-1.5	**	-1.96
Is NW->GP	1.66	**	2.44	0.0		0.03
Is NW->NC	-1.94	*	-1.78	-1.0		-0.49
Is NW	Reference			Reference		
Is WC	-0.98	***	-3.39	-1.1	**	-2.03
Is Dinaledi	1.61	***	8.73	3.3	***	9.72
Is African	-0.96	***	-5.26	0.4		1.31
Is independent	0.74	***	2.78	2.6	***	5.33
Is quintile 1	-1.71	***	-8.45	0.7	*	1.85
Is quintile 2	-1.75	***	-8.68	0.1		0.31
Is quintile 3	-1.07	***	-5.61	0.2		0.58
Is quintile 4	-0.98	***	-5.00	-0.8	**	-2.19
Is quintile 5	Reference			Reference		
n	5810			5810		
R squared (adj.)	0.364			0.494		

*Note: ***, ** and * indicate that the coefficient is significant at the 1%, 5% and 10% levels respectively (*** thus indicates a high degree of significance).*

If one focuses on the right-hand panel of Table 31, what is seen is that the two best provinces with respect to improvements in the 'overall stock' of mathematics output in the sense of total marks divided by all Grade 12 learners, are LP and MP. The three provinces that fared worst with respect to the trend were GP, WC and NC. As seen in Table 30, the performance against this indicator in 2011 was *best* in the case of GP and WC. What the above model is showing is that the *trend* in GP and WC was not as good as the trend in the other provinces. To some extent one would expect this as improvement when one already performs relatively well can be difficult. However, it should be noted that NC did not perform well against this indicator in 2005 or 2011 and saw a decline in its performance (against this indicator) during the period.

[56] In the case of the first model the natural logarithm was used for this and the next variable.

[57] In the first model, this is the natural logarithm of the following: exam-takers in all subjects in 2011 divided by the corresponding value for 2005.