THE CENTRE FOR DEVELOPMENT AND ENTERPRISE

Concise summaries of ongoing policy research aimed at helping to improve the national education system

The maths and science performance of South Africa's public schools

Some lessons from the past decade

Mathematics and science at school are vital to higher education, skilled jobs, and the national economy. For this reason, CDE has taken a sustained interest in the performance of the South African schooling system in these subjects. This paper summarises the results of four statistical analyses of Senior Certificate and National Senior Certificate results since 1998. Conducted by ***Professor Charles Simkins****, they provide important new insights into the mathematics and science performance of South African schools, and identify key policy issues arising from the research.*

FOR MORE than a decade, CDE has concerned itself with the performance of Senior Certificate (SC) (now National Senior Certificate (NSC)) candidates in mathematics and science. NSC is the gateway to higher education and many skilled occupations, and the enduring shortage of matriculants with good passes in mathematics and science is constraining the production of graduates in many fields. This, in turn, has serious consequences for the South African economy. As part of this focus, CDE commissioned four comparative statistical studies of SC and NSC results since 1998.[1]

Main findings

Under the old SC, the full potential for mathematics and science passes was not realised because mathematics was not a compulsory subject. This waste has been reduced (but not eliminated) under the NSC, because either mathematics or mathematical literacy is compulsory.

The analyses showed that twice as many candidates could have passed higher grade (HG) mathematics in 2002 and 2004. Part of the reason was that some candidates who took standard grade (SG) mathematics could have taken and passed HG mathematics. Some candidates who did not take mathematics in any form could also have passed this subject at the higher grade.

Table 1 reflects learners' performance and potential performance in maths and maths literacy in the first NSC examination in 2008. The potential performance in mathematics by those who took mathematical literacy can be inferred from a comparison of correspondence tables (see table 4) which assess the overall distributions of marks in HG mathematics in 2007, mathematics in 2008, and mathematical literacy in 2008.

TABLE 1: Analysis of mathematics marks in 2008	
Maths passes above 50%	58 081
Maths literacy passes above 72% (i.e., could have got 50% for maths)	35 495
Maths passes 30–50%	73 558
Maths literacy passes 54–72% (i.e., could have got 30% for maths)	52 637
Subtotal	219 771
Maths literacy passes 30–54%[2]	122 389
Maths passes of 13%–30% (i.e., failed maths but could have passed maths literacy):	
a. in schools where mathematical literacy was available	73 649
b. in schools with no mathematical literacy	9 809
Subtotal	205 847
Failed maths and could not have passed maths literacy	80 583
Failed maths literacy	55 276
Subtotal	135 859
TOTAL	**561 477**

CDE 2010

Tens of thousands of candidates who took mathematical literacy could have passed mathematics

The most serious waste in 2008 was the 35 495 candidates (representing 38 per cent of the total pool of actual and potential passes above 50 per cent, i.e. 93 576) – who wrote mathematical literacy but could have passed mathematics with at least 50 per cent instead. In other words, whereas 58 081 learners achieved passes in mathematics above 50 per cent, 35 495 more – or an additional 61 per cent – would have passed mathematics with more than 50 per cent had they studied that subject instead of mathematical literacy. The aim of the Department of Education was to equate 40 per cent, a pass, in the old HG mathematics to 50 per cent in the new mathematics. In the event, the correspondence was more lenient. Nonetheless, one can conclude that the potential in the medium term for mathematics passes at and above the 50 per cent level is between 70 000 and 90 000 – i.e., almost three times more than in 2004. The results also suggest that the top 40 per cent of all SC candidates should take mathematics, and the rest mathematical literacy.

The number of learners with the potential to pass science at the 50 per cent is considerably lower. While this is unfortunate, the consequences are not too severe, since fewer higher education courses require NSC science passes.

Table 2 reflects learners' performance and potential performance in science in the 2008 NSC examination.

TABLE 2: Analysis of science marks in 2008	
A pass of at least 50%	33 734
A pass of 30–50%	86 479
A potential pass of at least 50% if the candidate had taken science	27 516
A potential pass of 30%–50% if the candidate had taken science	118 639
Failed science	96 034
Would have failed science if the candidate had taken it	199 075
TOTAL	**561 477**

CDE 2010

Actual and potential passes at the 50 per cent level was 61 250, with potential passes comprising 45 per cent of the total. The key issue in respect of science is learner interest. Should a campaign be launched to encourage learners to take science in Grades 10, 11 and 12, about 40 000 could pass science at the 50 per cent level in the medium term.

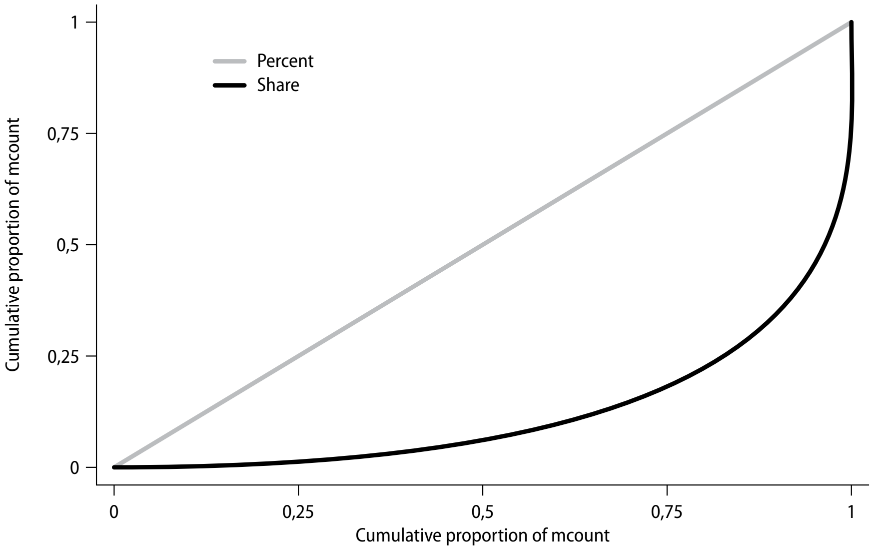
The situation therefore remains highly unequal, and wastes national resources

Schools can be placed in two broad categories in respect of performance in maths and science: independent schools and the top quintile of public schools; and the bottom four quintiles of public schools. Mathematics and science passes at the old HG level or its equivalent are heavily concentrated in the first category of schools.

In 2002, 364 schools (6.1 per cent of all schools entering candidates for the SC) accounted for 68 per cent of passes in HG mathematics. In 2004, 414 schools (6.6 per cent of all schools) accounted for 66 per cent of passes in HG mathematics. In other words, the base of schools providing most of the HG passes widened slightly.

The situation also became more equal between 2004 and 2008. Schools can be arranged by the number of mathematics passes at the 50 per cent level or higher. The fraction of schools and fraction of mathematics passes can then be cumulated, and the latter plotted against the former (see figure 1). The straight line is the hypothetical distribution if the chances of passing were the same in each school. The curve represents the actual distribution. It shows that the bottom 75 per cent of schools produced only 17 per cent of the passes, whereas 6.6 per cent of schools produced 50 per cent of the passes. The situation therefore remains highly unequal, and wastes national resources.

Figure 1: Distribution of mathematics marks, 2008 (50% or more)

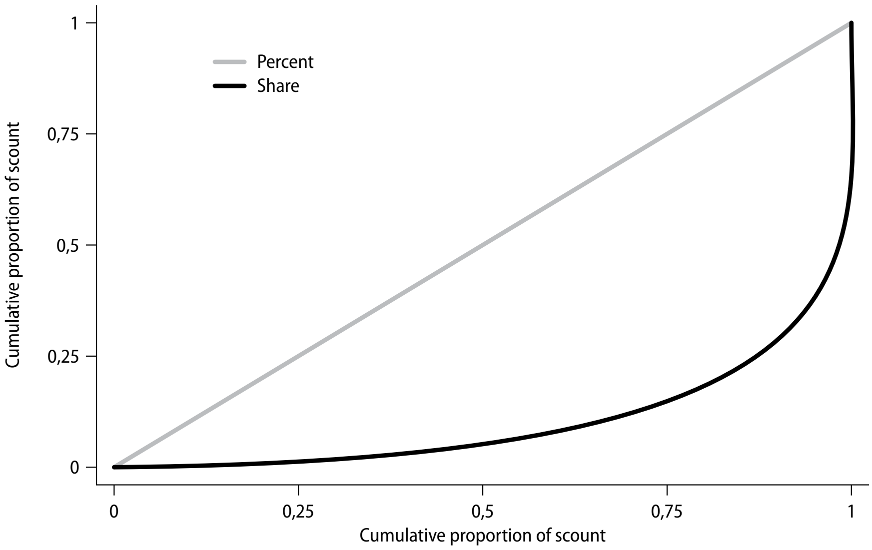


CDE 2010

The same curve can be drawn for science passes at 50 per cent or better (figure 2). Here the bottom 75 per cent of schools accounted for 13 per cent of the science passes, while 5.5 per cent of schools produced 50 per cent. Therefore, the distribution of science passes is even more unequal than the distribution of mathematics passes.

The distribution of science passes is even more unequal than the distribution of mathematics passes

Figure 2: Distribution of science marks, 2008 (50% or more)



CDE 2010

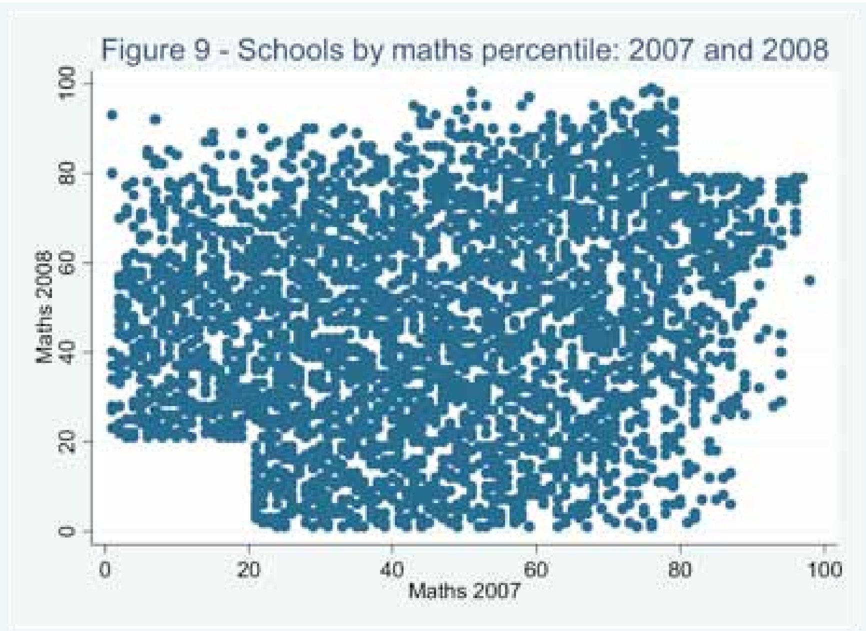
Put another way, South Africa relies on just more than 400 schools for half its mathematics passes at the 50 per cent level, and about 350 schools for half its science passes at the 50 per cent level.

This seems to suggest that, if additional resources were devoted to the second quintile of schools, the national performance in mathematics and science could be significantly improved. However, a comparison of schools by maths and science results reveals major variations in performance, which makes it difficult to identify promising schools outside the top quintile.

Schools were ranked by mathematics performance in the 2007 SC examination and the 2008 NSC examination. Percentiles were assigned for 2007 and 2008, and plotted against each other (figure 3). It shows that schools in the top quintile in 2007 were likely to be in the top quintile in 2008, and schools in the bottom quintile in 2007 (somewhat less) likely to be in the bottom quintile in 2008. In between, however, almost anything could happen.

Some variation is to be expected. Any high school teacher knows that there are good and bad 'matric years'. The change between 2007 and 2008 from the SC to NSC also introduced another major variable. But the marked lack of correlation indicates how problematic it could be to assess most schools based on a single year's NSC results.

Figure 3: Schools by maths percentile, 2007 and 2008

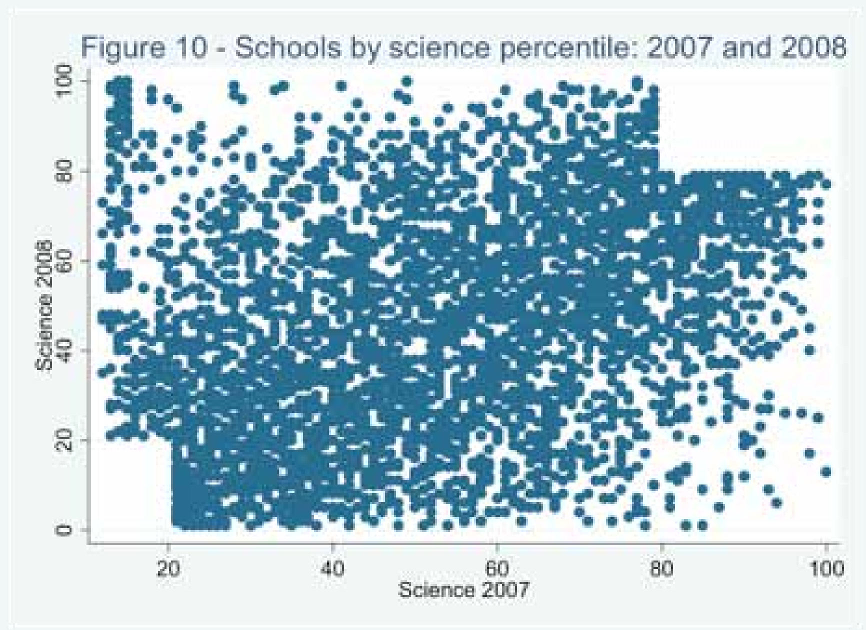


CDE 2010

A comparison of schools by maths and science results reveals major variations in performance

Figure 4 reflects the same exercise in respect of science. It shows that science results in 2007 and 2008 were more strongly correlated, but the variability remained high.

Figure 4: Schools by science percentile, 2007 and 2008



CDE 2010

Predictably, socio-economic factors associated with schools are strongly correlated with their performance

Outcomes can be explained by means of production function analysis: the relation of outputs to inputs. However, virtually no information is available on the core relationship in education between teachers and learners ('the classroom exchange') or the degree of coherent, learning-oriented tuition in schools.

Production function analysis was performed on the 2007 SC data. The input variables were:

- Human capital endowment, derived from the Annual Schools Survey 2007 of the Department of Education;
- Infrastructure data, derived from the National Education Infrastructure Management Survey 2007 of the Department of Education;
- The socio-economic quintiles of schools, calculated by the Department of Education as part of its norms and standards for non-teacher recurrent funding;
- The district within which the school is situated;
- The population group and gender of individual candidates;
- Whether the home language of candidates was English/Afrikaans or an African language; and
- Whether the school was a Dinaledi school.

Predictably, socio-economic factors associated with schools are strongly correlated with their performance. Notably, Dinaledi schools (partly designed to offset historical imbalances in education) did not achieve significantly better results.

The weakest data is probably the most important. The celebrated McKinsey report (M Barbour and M Mourshed, How the best schools come out on top, 2007) found that internationally the performance of a school is determined first and foremost by what happens in the classroom. The DoE's official Annual Schools Survey provides data on the number of teachers in every school, their qualifications, and their years of experience. It also seeks to gather data about teacher utilisation, but this part of the form is poorly designed and the data are incoherent. Even if the form were better, there is reason to doubt that the information would be accurate in a situation in which many teachers are not teaching the required minimum contact hours and curriculum. There is no system-wide information on school organisation at all. What is needed is a one in six annual sample of secondary schools, with teams from outside the schools administering a well-designed questionnaire over several days. The findings could then be compared with data from the Annual Schools Survey as well as NSC results.

What is needed is a one in six annual sample of secondary schools

Regression analysis and analysis of variance can establish the effects of a range of variables on performance in mathematics and science.

Population group, gender, socio-economic quintile, school district, English home language, infrastructure, and teacher human capital explain one third of the variance in mathematics scores in 2008. The remaining variance is partly explained by other variables which were not included in the model, but probably relate to the ability and application of SC candidates.

The variables exerting the largest effect on **mathematics scores** are population group, whether the candidates wrote English home language (an advantage of 11 per cent), whether they attended a top quintile public school or an independent school (an advantage of 7 per cent), whether they attended a Dinaledi school (an advantage of 6 per cent - up from 2007), which school district they belonged to (here the standard deviation of coefficients was 3 per cent, which meant that the advantage or disadvantage of belonging to the middle 95 per cent of districts ranged from -5 per cent to +5 per cent), school infrastructure (the advantage or disadvantage of belonging to the middle 95 per cent ranged from -5 per cent to +5 per cent), gender (male candidates have a 3 per cent advantage over female candidates), and human capital score (the advantage or disadvantage of belonging to the middle 95 per cent ranged from -2 per cent to +2 per cent).[3]

The regression for **mathematical literacy** marks on the same set of variables is broadly similar. The proportion of variance explained rises to 41 per cent. Population group still has the biggest effect, followed by whether candidates wrote English home language (an advantage of 12 per cent), whether they attended a top quintile public school (an advantage of 7 per cent) or an independent school (an advantage of 8 per cent), which school district they belonged to (the advantage or disadvantage of the middle 95 per cent ranged from -5 per cent to +5 per cent), school infrastructure (the advantage or disadvantage of belonging to the middle 95 per cent ranged from -5 per cent to +5 per cent), whether they attended a Dinaledi school (an advantage of 3 per cent) and gender (male candidates had a 2 per cent advantage over female candidates).

One third of the variance in **science scores** is explained by the same list of variables. The variables exerting the largest effect on science scores are population group, whether candidates wrote English home language (an advantage of 8 per cent), whether they attended a top quintile public school (an advantage of 4 per cent) or an independent school (an advantage of 5 per cent), whether they attended a Dinaledi school (an advantage of 4 per cent), which school district they belonged to (the advantage or disadvantage of belonging to the middle 95 per cent of districts ranged from -4 per cent to +4 per cent), school infrastructure (the advantage or disadvantage of belonging to the middle 95 per cent ranged from -4 per cent to +4 per cent), gender (here female candidates were less than 1 per cent behind male candidates) and human capital score (the advantage or disadvantage of belonging to the middle 95 per cent ranged from -0,5 per cent to +0.5 per cent).

In 2007, no detectable effect on mathematics and science performances could be found in Dinaledi schools. As noted earlier, there was a modest but useful effect in 2008.

The regression coefficients create a basis for predicting the gains from increased inputs, and can be used for finding a least-cost way of achieving a target improvement in mathematics and science performance. Reliable results will require better instruments for measuring teacher human capital, time on task, and school organisation.

Reliable results will require better instruments for measuring teacher human capital, time on task, and school organisation

The effect of introducing the NSC can be assessed by calculating how 2007 SC candidates would have performed had they written the NSC instead.

On the basis of some reasonable assumptions, one can predict how the 2007 SC candidates would have performed in 2008, and compare it with the actual NSC results in 2008 (table 3).

TABLE 3: Comparing 2007 and 2008 mark distributions		
Per cent of candidates	**2007**	**2008**
Pass: degree entrance	23.2	20.2
Pass: diploma entrance	17.4	23.3
Pass: certificate entrance	12.9	19.2
Fail	46.5	37.3
Total	**100.0**	**100.0**

CDE 2010

In the event, more 2008 candidates passed at the diploma and certificate entrance levels than expected. Fewer passed at the degree entrance level, and fewer failed. What this means is that there has been a 'growing middle', with fewer failing but fewer doing well enough to gain access to tertiary education.

On the further reasonable assumption that the underlying distribution of ability was the same among 2007 SC candidates as among 2008 NSC candidates, correspondences tables can be drawn up of various measures of mathematics and science ability.

Table 4 compares the distribution of mathematics marks in 2007 and 2008. As noted earlier, the Department intended to equate a 40 per cent pass in the old HG mathematics to a 50 per cent pass in the new NSC mathematics. However, the table reflects a slight 'grade inflation' in that a 40 per cent mark in the old HG mathematics equals 54 per cent in mathematics in 2008.

TABLE 4: Correspondences between mathematics marks, 2007 and 2008

HG maths 2007	Maths 2008	Maths literacy 2008
10	13	30
14	19	40
20	26	50
22	30	54
27	36	60
29	40	64
35	47	70
37	50	72
40	54	75
45	60	78
46	62	80
50	66	82
53	70	84
64	80	86

CDE 2010

However, the real leniency and grade inflation appears further up the scale: a distinction in mathematics in 2008 (80 per cent in the middle column) equals 64 per cent in HG maths in 2007 (bottom of the left-hand column). This explains the outcry in 2009 from universities with courses requiring a high mathematics mark for entry.

However, the real leniency and grade inflation appears further up the scale

The correspondence between mathematics and mathematical literacy in 2008 is also of interest. Anyone achieving a mark of 72 per cent or higher in mathematical literacy is capable of achieving at least 50 per cent in mathematics (compare the middles of the centre and right hand columns in table 4). As noted earlier, such learners should be taking mathematics instead.

The correspondences between science marks are reflected in table 5.

TABLE 5: Correspondences between science marks, 2007 and 2008

Higher Grade Science 2007	Standard Grade Science 2007	Science 2008
20	28	24
24	33	29
30	40	37
40	51	49
50	60	59
60	68	67
70	71	74

CDE 2010

In the case of science, the correspondences between 2007 and 2008 are much closer to the DoE's intentions – that is, to effectively eliminate HG science, and equate the former SG science with the new subject of science.

The new system has improved the situation of candidates for whom English is an additional language

The terminology for English papers has changed as follows:

TABLE 6: Changes in English subjects from SC to NSC

2007 Senior Certificate	2008 National Senior Certificate
English first language:	English home language
* Higher Grade	
* Standard Grade	
English second language:	English first additional language
* Higher Grade	
* Standard Grade	

CDE 2010

The marks in English home language in 2008 were generally lower than in HG English first language in 2007 by about 4 per cent on average (that is, 'grade deflation').

The correspondences between HG English second language in 2007 and English first additional language in 2008 are given in table 7.

TABLE 7: Correspondence table for English second/additional marks distributions in 2007 and 2008

HG English second language 2007	English first additional language 2008
30	30
40	44
50	54
60	63

CDE 2010

So the marks for English first additional language in 2008 were generally higher than those for HG English second language in 2007, suggesting a degree of 'grade inflation' (versus 'grade deflation' for home language English). Given that performance in home language and first additional language are identical for some purposes, this means that the new system has improved the situation of candidates for whom English is an additional language relative to those for whom English is their home language.

It should be borne in mind that the new system still has to settle down, and that the long-term correspondences may be somewhat different from the short-term correspondences in 2007 and 2008.

Concluding remarks

The 2008 NSC results were a mixed bag, reflecting real progress, grade inflation, and some worrying chaos in the middle of the schooling system.

The 2008 NSC results were a mixed bag, reflecting real progress, grade inflation, and some worrying chaos in the middle of the schooling system

Many more learners gained passes in mathematics in 2008, and many more who took mathematical literacy could have done so. Making either mathematics or mathematical literacy compulsory for the NSC was a major step forward, which doubled university entrance level passes over the previous year. Moreover, if more learners chose mathematics, the number of learners achieving university entrance level passes could have tripled over 2007. This means, in turn, that the schooling system has the potential to significantly increase the numbers of skilled people which the economy so urgently needs.

There is still room for improvement, not only in respect of subject choice. While the demand for science passes is lower than for mathematics passes, they are still required for some important university courses and highly skilled occupations; yet science remains an elective subject in schools. Therefore, talented learners should be actively encouraged to take it.

The 2008 NSC results reflect a significant degree of grade inflation. If this trend continues, universities and employers will begin discounting it (if they have not done so already), and examinations other than the NSC will gain in credibility. Shifting the burden of grade inflation onto universities could pressurise them into doing the same, thus devaluing the international 'exchange value' of South African public education.

These analyses also contain other, important policy implications. First, while the base of schools producing the bulk of mathematics passes has widened, three quarters of South African schools are producing very few passes. And when one examines the contributions of various contextual factors, the prospects for rapid progress do not seem auspicious.

On the other hand, just underneath the top 5-6 per cent of public schools that are currently generating 50 per cent of all science and mathematics passes lies a tantalising 'second layer'. Many of these are in former townships, and many are Dinaledi schools. Therefore, the Dinaledi programme – aimed at improving the maths and science performance of 500 selected public schools – is finally having a modest but significant impact, and this trend needs to be closely monitored in the future.

However, public sector initiatives alone will probably not be a sufficient response, and assessing learners' aptitudes and nurturing those with potential are important strategies that have been developed in private sector initiatives. This issue is dealt with in greater detail in the next report in this series, entitled *Providing opportunities to learners with potential*. These impacts could be expanded and replicated with relatively modest amounts of public resources.

A second major policy issue is how to interpret the apparent systemic chaos in the recent mathematics and science performances of the vast majority of public schools. The fact that – outside of the very top and bottom schools – there is virtually no correlation between 2007 and 2008 science and mathematics mark distributions is highly disturbing. What the data tells us is that the recent performance in mathematics and science of these schools provide parents with virtually no guide to their future performance. Admittedly, these findings were made over a short period, and also straddle a change in examining systems. Nevertheless, these random results are cause for concern, and many analysts believe they reflect an overall lack of professionalism and motivation, and a high turnover of mathematics and science teachers.

Some progress has been made, and must be acknowledged. However, some 90 per cent of our schools are still failing to meet the minimum performance standards in mathematics and science education, thus undermining the potential of millions of young South Africans, and hampering national development. This means that we have to deal with the tough but vital issue of the accountability of principals and teachers for the performance of their learners. The bulk of the public schooling system is unlikely to improve unless ways are found to link rewards to performance and achievement.

Some 90 per cent of our schools are still failing to meet the minimum performance standards in mathematics and science education

Endnotes

1 The first dealt with the SC examinations in 1998 and 2000, the second with the SC examinations in 2002 and 2004, the third with the last SC examination in 2007, and the last with the first NSC examination in 2008

2 See later in this report for the rationale behind these mark ranges.

3 However, note the qualification later in this report.

4 These are as follows: 1) the standard of an NSC paper in a given subject will lie between the standard of an old HG and old SG paper in that subject, with 33 1/3 per cent in the SG corresponding to 30 per cent in the NSC paper, and 40 per cent in the HG corresponding to 50 per cent in the NSC paper; 2) candidates meeting the language requirements for SC would also meet the different requirements for the NSC; 3) Life orientation would not present an obstacle to passing the NSC at different levels; and 4) a mark in mathematics and mathematical literacy can be imputed for those who did not take mathematics in any form in 2007.

This summary is based on a research report by **Professor Charles Simkins** entitled 'Interpreting the mathematics, science and English performance of candidates in the November 2008 National Senior Certificate examination', commissioned by CDE, Johannesburg, 2010. This report is available from CDE. Please send your request to info@cde.org.za.

CENTRE FOR DEVELOPMENT AND ENTERPRISE
Informing South African Policy

Published in September 2010 by
The Centre for Development and Enterprise
Transmedit Place, 5 Eton Road, Parktown, Johannesburg, South Africa
P O Box 1936, Johannesburg 2000, South Africa
Tel 27 11 482 5140 • Fax 27 11 482 5089
info@cde.org.za • www.cde.org.za

This study was funded by the Allan Gray Orbis Foundation and the Epoch & Optima Trusts.

The funders do not necessarily share the views expressed in this report.