

Consultant Report Securing Australia’s Future STEM: Country Comparisons

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Science, Technology, Engineering and Mathematics (STEM) in South Africa

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Introduction

As with so many other aspects of its national condition, South African provision of, and performance in science, technology, engineering and mathematics (STEM) appears as a set of paradoxes: by one set of measures it is a world leader; by another a laggard.

Any reasoned discussion of its STEM and STEM-related issues must address these paradoxes, and this demands taking cognizance of the socio-political dynamics of the country.

Two generations ago South Africa was poised to achieve technology catch up with the industrialized countries. Measured by GDP/per capita and innovation outputs the Apartheid state was then way ahead of today's Asian Tigers. The innovation system of the day provided the wherewithal for that lead. It served as the basis for the careers of four Nobel laureates in the sciences and medicine, and its technologists ensured a high degree of self-sufficiency for the state, including the design and testing of weapons of mass destruction. What Acemoglu and Robinson (2012) term extractive political and economic institutions underpinned this achievement.

Two generations ago Apartheid systematically destroyed the little quality education and training opportunities that the African majority then enjoyed. What came in its place was a diluted and massified education system of low quality. After all, as then Minister of Native Affairs Hendrik Verwoerd declared, 'What is the use of teaching the Bantu child mathematics when it cannot use it in practice? That is quite absurd. Education must train people in accordance with their opportunities in life, according to the sphere in which they live'. Hence massified low quality education. The extractive political and economic institutions rested upon this.

A generation ago the senior primary school students of Soweto, already angered at their overcrowded classrooms, rose up in revolt at the imposition of Afrikaans as the new medium of instruction, a revolt that marked the beginning of the end of Apartheid.

At that juncture the education system was fragmented by language and ethnic group, with separate schools for English and Afrikaans speaking Whites¹, for those of mixed heritage, for those of predominantly Indian origin, and for the ten main African groupings. The apex Department of National Education attended to policy for schooling, higher education, sport, language, culture, arts and heritage, and stood above another seventeen provincial, ethnic and tribal authorities. There was a multiplicity of curricula and examination systems held together under an overarching national policy.

Consistent with the design of Apartheid the eleven 'historically black universities' had no engineering faculties, and but one medical school. Black students and potential staff were also excluded from White universities. In the research performing Science Councils, but 5% of their graduate staff were black (Motala, 1994). The extreme case was the Agriculture Research Council that had but one black person among its 1000 graduate staff.

This legacy of inequality persists to the present: the Global Competitiveness Index of the World Economic Forum (WEF, 2012) data on 142 countries ranks South Africa as follows:

- Financial market development 3rd
- Health and primary education 132nd.

¹ South African racial classification was as follows: *White* - those of European origin; *Indian* - those from the sub-continent but also including Malays; *African* - members of various indigenous tribal groups; *Coloured* - those with mixed parentage. The Population Registration Act was abolished, so that racial declaration is now 'voluntary.'

The disparity is telling: at one extreme the country excels in auditing and accounting standards, and banking propriety; at the other basic health and education are weak. Its Gini coefficient is among the highest in the world.

The Rainbow Nation

1994 set out to change all that. Apartheid was abolished and Nobel Laureate Tutu's Rainbow Nation was re-unified, with nine provinces replacing the racial quilt of separate development. A Constitutional Democracy with con-federal governance was fashioned, and an overarching Reconstruction and Development Programme (ANC, 1994) served to provide the principles of righting the wrongs of the past, addressing basic needs, human resource development, economic and social development, and the democratizing of state and society. Education and training received forty paragraphs in that document; arts and culture twenty-two; science and technology, nine.

The following year the nine provincial governments commenced operations with the challenge of amalgamating a variety of pre-existing ethnic departments for each of their functions. This was to be achieved against a backdrop of high expectations and fiscal stringency imposed with the goal that macro-economic stability would promote inward investment. One device to reduce government expenditure was the mechanism of voluntary severance packages that allowed public servants to opt for early retirement. This, it was believed, would save money in the long term; it also led to a massive loss of skill and institutional memory.

In the case of schooling the con-federal model meant that the (national) Department of Education would set policy while the nine provincial departments of education would be responsible for schooling. For the first time there would be a national curriculum and national examinations. The new curriculum not only purged racist connotations, but its entire delivery was restructured according to a US model of 'outcomes-based education'. The schools and education administrations were de-racialized, and redress measures were instituted to mitigate the gross inequities of Apartheid. The curriculum was also tasked with validating and celebrating the various cultures of the 'Rainbow Nation', the achievements and artifacts of its first people and African culture being given recognition.

Like schooling, higher and further education, as well as vocational education provision were de-racialized and rationalized. The higher education system of thirty-six universities and 'technikons' (polytechnics) was reconfigured into twenty-three universities and universities of technology; teacher education ceased to be a provincial competence and was shifted to higher education; technical colleges were rationalized down to fifty. A range of projects were put in place to improve teacher qualifications and skill so that by 2008 the proportion of those officially qualified had risen to well over ninety percent.

In the workplace the apprenticeship system had weakened since its 1970s heyday. Post 1994, organized labour, inspired by Australian competency-based assessment of workplace skills, was instrumental in the adoption of a national qualifications framework, setting up the South African Qualifications Authority, the promulgation of a payroll Skills Development Levy, and instituting Sector Education and Training Authorities (SETAs). These SETAs, using the Levy, would be responsible for ensuring worker education and training that would accrue toward recognized qualifications. Other legislation introduced affirmative action, employment equity and preferential procurement to bring the previously excluded into the main economy.

In effect the country became a vast socio-political laboratory where an attempt was made simultaneously to modernize, level the playing fields, and to reduce poverty. This paper addresses the role of STEM in the agenda for change.

Promotion of STEM

The new state administration took form with the outgoing Department of National Education eventually unbundling into five standalone Departments: Basic Education, Higher Education and Training, Science and Technology, Arts and Culture, and Sports and Recreation. After 2009 policy for schooling, universities, and science and technology was now located under three separate Ministries.

Before 1994 science and mathematics had been compulsory subjects up to grade 10, after which students entered the senior secondary phase and were prepared for the Senior Certificate that also served to filter off the high flyers that would obtain matriculation exemption for university entrance.

Faced with the poor provision of mathematics and science in African and Coloured schools a host of NGOs dedicated to mitigating poor provision of science and mathematics emerged. These NGOs, funded by subsidiaries of MNCs, local capital, and foreign donors, created a space for considerable experimentation providing curriculum support in schools, and access programmes for the universities. After 1994 the expertise of their staff became available to the new administration.

Over 1995-1999 the Department of Education put in place a nationwide redress programme that drew on this expertise. This was the SYSTEM initiative (Students and Youth into Science, Technology, Engineering and Mathematics) that was designed to give students who had underperformed in science and mathematics in their Senior Certificate examinations a second-chance to obtain the matriculation exemption that would allow them to go on to studies in higher education.

SYSTEM students took an officially recognized one-year programme in physical science, biology, mathematics, ICT and communication skills. Upon successful completion they could proceed to enter university or embark upon a four-year teacher education diploma. By the time that the SYSTEM experiment ended it had seen some 1000 students proceed through its curriculum, with a hundred teachers qualifying to teach science and mathematics. SYSTEM was celebrated as the flagship redress programme of the Department of Education.

In parallel the Department of Education embarked on a radical transformation of the school curriculum, branded as *Curriculum 2005*. Nine years of 'free' and compulsory education from age 7 would lead to the award of a General Education and Training Certificate, with all students taking two languages, natural science, mathematics, technology, economic and management sciences, life orientation, social science, and arts and culture. The curriculum was forward-looking, and through the successful lobbying of an interest group included Technology as a compulsory 'learning area'.

The adoption of an outcomes-based approach was accompanied by other changes in terminology: pupils became 'learners,' and teachers became 'educators'. The Schools Act of 1998 gave autonomy to schools through new school governing bodies with powers of hiring and firing. Another key change was the abolition of corporal punishment.

In due course, and after various implementation difficulties, a set of Revised Curriculum Statements for the compulsory phase of schooling was issued. The Statements are at pains to demonstrate the link with the nation building aspirations of the Constitution that seeks to 'heal the divisions of the past and establish a society based on democratic values, social justice and fundamental human rights (and) improve the quality of life of all citizens and free the potential of each person'. To enable these goals the curriculum sets out to develop learners' abilities 'by setting the outcomes to be achieved at the end of the process. The

outcomes encourage a learner-centred and activity-based approach to education' (DoE, 2002: 1). Advocacy of a learner-centred and activity-based approach marked a clear break with existing practice that had tended toward content-led didacticism that often degenerated into rote learning. The new approach elicited wide political support, but in reality many teachers found it difficult to translate the rhetoric into meaningful practice. This was the prime reason for the issuing of the Revised Curriculum Statements.

At senior secondary level change was slower. The new qualification, the National Senior Certificate offered thirty one subjects with only four being compulsory: two languages, mathematical literacy, and life orientation, this despite the prior adoption by the ruling party of an education policy in which both a science subject (life science or physical science) and mathematics would be compulsory at senior secondary level (ANC, 1994).

The Department of Education in 1999 then set out to develop a Strategy for improving school science and mathematics. The Strategy (DoE, 2001: 14) set out to 'raise the participation and performance of historically disadvantaged learners in Senior Certificate science and mathematics; provide high-quality science, mathematics and technology education to all learners taking the first FETC and GETC; and increase and improve human resource capacity to deliver quality science, mathematics and technology education'. The Strategy drew attention to the Edusource (1997) audit of science and mathematics teachers that found that 'Although 85% of mathematics educators were professionally qualified as educators, only 50% had specialised in mathematics in their training. Similarly, while 84% of science educators were professionally qualified, only 42% were qualified in science. An estimated 8 000 mathematics and 8 200 science educators needed to be targeted for in-service training to address the lack of subject knowledge' (DoE, 2001: 6). This serves to indicate the scale of the backlogs facing the system as the point that radical change was being driven.

While recognizing the equity imperative, the Strategy made the case that 'In the context of competing priorities and limited resources, it is better to, at least in the short term, provide sufficient and adequate learning and teaching facilities to fewer schools with the aim of going full scale over a longer period of time' (DoE, 2001: 15). In addition it was recommended that emphasis be given to deepening language competences and the provision of learner support materials.

The idea to concentrate resources then led to the one hundred Focus Schools project. These would be selected from among schools in the 'previously disadvantaged' (black) community that were well-managed, that had achieved reasonable pass rates in the school-leaving examinations, and that had a track record of successful teaching of physical science and mathematics at the standard grade. The intention was to enable such schools to begin to offer these subjects at the higher grade and then to ensure that their learners would obtain scores that would allow them to enter science-based higher education programmes.

The one hundred Focus Schools of 2001 in due course grew to number 529 and are now called Dinaledi² Schools. These schools cater for close to 18% of all students that take mathematics and physical science in the school-leaving examination. As with the earlier SYSTEM initiative, Dinaledi is a signature thrust of the national Department, and as it expanded it gained repeated prominence in the annual State of the Nation address of the President, most notably in 2006:

We will, of course, also make other interventions in the area of education and training. These include eliminating fees for the poorest quintile of primary schools, targeting 529 schools to double the Maths and Science graduate output to 50

² Dinaledi means 'stars' in local language Setswana.

000 by 2008, and re-equipping and financing the Further Education and Training Colleges.

This endorsement suggests that the Dinaledi Schools would be encouraged to excel.

Literally on the other side of the street, the then hybrid Department of Arts, Culture, Science and Technology (DACST) embarked on its contribution to national development by seeking to transform the extant system of innovation and to reshape policy for arts and culture. The year 1996 thus saw the tabling of the White Paper on Arts and Culture (DACST, 1996a), and then the White Paper on Science and Technology (DACST, 1996b).

The core vision of the White Paper on Science and Technology was ‘... the conceptualisation of a national system of innovation which seeks to harness the diverse aspects of S&T through the various institutions where they are developed, practised or utilized’ (DACST, 1996b: 11). The White Paper went on to argue that: ‘a national system of innovation can only be judged as healthy if the knowledge, technologies, products and processes produced by the national system of science, engineering and technology have been converted into increased wealth, by industry and business, and into an improved quality of life for all members of society’ (idem: 19). This represents a massive practical task.

As to the issue of STEM inequity, it was noted that (idem: 72):

Programmes need to redress the inequalities which have excluded black women and men from the mainstream of South African society... Such a programme will have to address the consequences of past deliberate policies and practices that promoted racial and gender discrimination in HRD. Apart from the human rights issue, there is also the imperative for South Africa to optimise its productivity and economic performance to succeed in the global marketplace. To achieve this goal, South Africa will have to maximise the utilisation of ideas, creativity, ingenuity and innovation from the entire population.

This vision of DACST was constrained by the fact that the mandate for schooling resided in the Department of Education so that its influence was limited to out of school activities - establishing a national Science Week, organizing science camps, and science promotion through the South African Agency for Science and Technology Advancement (SAASTA), as well as support to the South African Association for Science and Technology Education Centres (SAASTEC). Besides using conditional grant mechanisms to promote science awareness, the Department worked through the National Research Foundation to channel funds toward the development of young researchers, and the provision of research studentships and grants to established researchers.

DACST was also instrumental in supporting public communication of science and technology. One such event was the media launch by the President of the results of the first Research and Technology Foresight Study. Others included the Levy-Shoemaker comet impact on Jupiter in 1996, the 2002 Soyuz voyage of local entrepreneur Mark Shuttleworth, the total solar eclipse of the same year, and support for the establishment of the Cradle of Humankind as a World Heritage Site.

DACST, and its successor, the Department of Science and Technology, also worked to promote the racial transformation of the public research organizations, these being the component of the innovation system closest to government. This transformation includes developing research and support staff, management and the control boards. Today some 60% of public research organization research staff are black.

For research and innovation policy the Department of Science and Technology developed

and sought to implement best of breed policies – the 2002 R&D Strategy; enhanced tax incentives for R&D; competitive grant funding; specifying intellectual property rights arising from public funding; the Ten Year Innovation Plan. For high-level human capital development DST funded the Research Chairs Initiative, and provided funds for both Centres of Excellence and Centres of Competence in the universities. It also pushed Big Science, most notably in its successful bid for the Square Kilometre Array radio telescope that was recognized in the joint award of the project with Australia.

The Department of Science and Technology Ten Year Plan for Innovation seeks dramatically to increase technological innovation output. This rests upon achieving an equally dramatic increase in the number of graduates, researchers and technicians. The South African Research Chairs Initiative is a move in the right direction, but it has not injected enough new blood into the system.

University researchers – qualified professionals, together with their students, undergraduate, postgraduate and post-doctoral – and other qualified professionals are the people that power innovation in the private and public sectors. Whilst recognizing that innovation does not rest solely upon the conduct of novel R&D, a good indicator of the vitality of the innovation system is provided by the stock of researchers (Table 1).

Table 1: Full-Time Equivalent (FTE) Researchers and technicians, by sector.

Sector	1992		2008	
	Researcher	Technician	Researcher	Technician
Business	3 395	2 907	6 380	3 866
Government/ Science Councils	2 428	1 810	3 052	1 687
Higher Education	3 631	289	3 643	542
Total	9 454	5 006	13 075	5 085

Source: DNE (1993) and HSRC (2011)

Two trends are obvious in the data – modest growth in the stock of researchers (40%); zero growth in the stock of technicians. The business sector shows most growth in researchers (88%), followed by government (26%), while the universities are static. Availability of technicians shrank in the state sector. These trends suggest that it will be nigh impossible to meet the Ten Year Innovation Plan goals. Researchers must have the support of technical staff, and the latter are in extremely short supply.

The stance of government toward the importance of school physical science and mathematics is unequivocal: in the 2014 action plan, targets are set to increase the number of those eligible for university study, with specific attention given to the pass rate in mathematics and physical science.

Table 2: Goals 5 and 6 of the 2014 Action Plan, (000s)

Indicator		2009	2010	2011	2012	2013	2014	2019	2024
Goal 5: Increase the number of Grade 12 learners who pass mathematics.									
5	Number of Grade 12 learners passing mathematics.	125	136	147	158	169	180	270	350
<i>Thousands of learners</i>									
Goal 6: Increase the number of Grade 12 learners who pass physical science.									
6	Number of Grade 12 learners passing physical science.	120	130	140	150	160	170	250	320
<i>Thousands of learners</i>									

Source: DBE (2011)

Patterns of STEM provision and attainment

Schooling

As already noted, the compulsory phase curriculum specifies natural science, mathematics and technology as compulsory subjects. Alongside this the Ministry committed massive expenditure toward upgrading the qualifications of primary school teachers.

For 2010 the general education and training phase gross enrolment ratio was 92%, while the grade 9 net enrolment ratio was 96.5%. In the senior secondary (FET) phase the net secondary enrolment ratios in grades 10, 11 and 12 stood at 100.3%, 81.9% and 56.9% respectively (DBE, 2012a). The grade 10 point marks the transition from compulsory to non-compulsory education for 15 year olds, and the tail off in NER as students progress to grade 11 may be understood as a mix of economic necessity (leaving school to seek work) and educational failure.

In principle therefore the base for future studies in STEM fields has been laid. This policy objective must of course be viewed alongside attainment in STEM subjects, evidence of which may be obtained from TIMSS and SACMEQ, and the more recently instituted Annual National Assessments. The WEF naturally draws on these datasets. TIMSS 2003 (Table 3) assessed grade 8 students who had been exposed to the full implementation of the new curriculum. It is noted that their performance was similar to those measured through TIMSS 1999.

Table 3: TIMSS attainment, 2003

	MATHS SCORE	SCIENCE SCORE
TIMSS 2003		
SA average score	264	244
International average	467	474
TIMSS 1999		
SA average score	275	243
International average	487	488

Source: http://www.hsrc.ac.za/Research_Programme-Page-61.phtml

TIMSS 2003 showed that formerly White schools performed at the international average level while African schools scored 200 points lower; on aggregate South Africa was last among the fifty participating countries.

The timing of this paper is fortuitous in that it was possible to include the results of the TIMSS 2011 assessment (HSRC, 2012). This provides some cheer - between TIMSS 2003 and TIMSS 2011 at grade 9 level there was an increase of 60 points for both mathematics and science. In addition the average score of the lowest quintile rose, so that overall disparity between the lowest and highest quintiles decreased. The inter-provincial disparities also showed a marked decrease, with African students in the former African administered schools improving by 63 points for science and 70 point for mathematics. Even so South Africa still ranked among the bottom three countries of the forty-five that participated in the assessment, scoring below the 400-point benchmark level.

Worse was the finding that 'the number of learners scoring above the low benchmark of 400 more than doubled, from 10.5% to 24%' (HSRC, 2012a: 11). It is worrying that the score of South Africa's 95th percentile group is below the average level of that attained in Singapore, Chinese Taipei, Republic of Korea, Japan, Finland, Slovenia and the Russian Federation. According to the TIMSS assessment framework, the highest flyers in South Africa are but average by global standing.

Some of the TIMSS under-performance may well be due to a mismatch between the local curriculum and TIMSS coverage: according to HSRC (2012) the overlap at the time of

assessment could amount to 70% for mathematics and 55% for science. What is unknown is the extent to which overlap also affects other country scores. Another factor that might be taken into account is that some 60% of South African mathematics teachers held a degree, as did 53% for science; the international norm for degreed teachers was 87% and 90% respectively.

The second insight comes from the SACMEQ programme³ that measures attainment in reading and mathematics of grade 6 students. SACMEQ III, conducted in 2007 shows the following (Table 4).

Table 4: SACMEQ Performance, 2000 and 2007

	Pupil reading score			Pupil mathematics score	
	2000	2007		2000	2007
Eastern Cape	444	448 ▶		449	469 ▲
Free State	446	491 ▲		448	492 ▲
Gauteng	576	573 ▶		552	545 ▶
KwaZulu-Natal	517	486 ▼		510	485 ▼
Mpumalanga	428	474 ▲		433	476 ▲
Northern Cape	470	506 ▲		461	499 ▲
Limpopo	437	425 ▼		446	447 ▶
North West	428	506 ▲		420	503 ▲
Western Cape	629	583 ▼		591	566 ▼
SOUTH AFRICA	492	495 ▶		486	495 ▶
SACMEQ	500	512 ▲		500	510 ▶

Values in **Green** = 10 points or more above SACMEQ II mean of 500 Values in **Black** = less than 10 points above or below SACMEQ II mean of 500 Values in **Red** = 10 points or more below SACMEQ II mean of 500

Source: <http://www.sacmeq.org/education-south-africa.htm>

Essentially in 2007, the two wealthiest provinces, Gauteng and Western Cape, were above the SACMEQ mean for reading and mathematics; the other provinces were below. Taken overall, the levels for reading and mathematics (Table 5) demonstrate improvement since the 2000 SACMEQ II, but still suggest that in reading those with the skill of 'reading for meaning' or higher rose but marginally from 49.9% to 51.7% while in mathematics those at the level of 'beginning numeracy' or higher rose more strongly from 24.1% to 30.9%.

Table 5: SACMEQ Reading and Mathematics levels, 2000 and 2007

		2000	2007			2000	2007
Level 1	Pre Reading	12.2%	9.9%	Level 1	Pre Numeracy	7.8%	5.5%
Level 2	Emergent Reading	18.8%	17.3%	Level 2	Emergent Numeracy	44.4%	34.7%
Level 3	Basic Reading	19.1%	21.1%	Level 3	Basic Numeracy	23.8%	29%
Level 4	Reading for Meaning	16.0%	14.7%	Level 4	Beginning Numeracy	8.8%	15.4%
Level 5	Interpretive Reading	9.4%	10.6%	Level 5	Competent Numeracy	6.1%	7.1%
Level 6	Inferential Reading	7.0%	9.6%	Level 6	Mathematically Skilled	5.8%	5.9%
Level 7	Analytical Reading	10.9%	10.2%	Level 7	Concrete Problem Solving	2.1%	1.9%
Level 8	Critical Reading	6.6%	6.6%	Level 8	Abstract Problem Solving	1.3%	0.6%

Source: <http://www.sacmeq.org/education-south-africa.htm>

The third measurement comes from the new system of Annual National Assessments. These draw on the experience gleaned from SACMEQ, TIMSS and PIRLS. Through the ANA it has

³ The Southern and Eastern Africa Consortium for Monitoring Education Quality is an international NGO of 15 ministries of education of the region.

become possible to make definitive statements concerning reading and mathematics attainment of grade 3 and 6 students. The official report is sombre: 'the percentage of learners reaching at least a 'partially achieved' level of performance varies from 30% to 47%, depending on the grade and subject considered. The percentage of learners reaching the 'achieved' level of performance varies from 12% to 31%. Even the best provincial figure in this regard, 46% for Grade 3 literacy in Western Cape, is well below what can be considered acceptable' (DBE, 2011: 6). 2012 saw the first ANA for grade 9. In releasing the results the Minister stated (DBE, 2012b: 1): 'It is important to note that while there has been some improvement in the achievement of learning outcomes in most grades in 2012, we still have a long way to go towards realizing the desired 60% threshold of learners mastering the minimum Language and Mathematics competencies by the end of Grades 3, 6 and 9'.

Detailed consideration is beyond the scope of this short paper. The 2012 ANA data (Table 6) show wide variation year on year so that trend analysis is really impossible. Nonetheless one notes an apparent decline in performance with progression through schooling; the attainment in grade 9 is especially troubling.

Table 6: Mathematics scores, ANA 2012

GRADE	MATHEMATICS 2012	MATHEMATICS 2011
1	68	63
2	57	55
3	41	28
4	37	28
5	30	28
6	27	30
9	13	*

Source: DBE (2012b).

One is forced to conclude that primary schooling is in deep crisis.

For the senior secondary phase the major change occurred in 2006 with the introduction of the new National Senior Certificate (NSC) with the first cohort writing the school-leaving examination in 2008. It is instructive to compare the situation before and since that change (Table 7).

Table 7: Biology, Mathematics, Mathematical literacy, and Physical Science: entry and performance, 2006-2010

	YEAR	2006			2007			2008			2009			2010		
	ENTER	529			565			554			552			537		
SUBJECT	LEVEL	Enter	Pass	%												
Biology	HG	120	51	42.5	121	54	44.6	297	118	39.7	299	119	39.8	285	147	51.6
	SG	229	131	57.2	249	141	56.6									
Mathematics	HG	47	25	53.2	46	25	54.3	299	90	30.1	290	85	29.3	263	81	30.8
	SG	271	111	41.0	301	123	40.9									
Mathematical Literacy	-	-	-	-	-	-	-	263	145	55.1	278	142	51.1	281	182	64.8
Physical Science	HG	69	30	43.5	71	28	39.4	218	63	28.9	221	45	20.4	205	61	29.8
	SG	126	81	64.3	143	88	61.5									

The year 2008 is displayed shaded to remind that this marked the transition to the new

curriculum where higher grade⁴ (HG) and standard grade (SG) were discontinued, and either mathematics or mathematical literacy became compulsory. One might reasonably compare the situations in 2006 and 2010 by when the system would have settled down.

In 1999 there were 1 318 932 grade 1 learners, and 591 848 in grade 12. The grade 1 learners of 1999 comprise the bulk of the full-time candidates that wrote the NSC in 2010 twelve years later. One notes therefore that the number of candidates has been remarkably stable over this period of time. With rising economic growth one might have expected the number to rise, but it has not. Instead one notes the persistence of a dramatic fall-off in enrolments in progression from grade 10 to grade 11 (a 15% decrease), and again from grade 11 to grade 12 (a further 28%) decrease. The reasons for these losses have not been studied.

As to the impact of the curriculum change, in 2006 a total of 529 000 candidates wrote the Senior Certificate. The pass level was set at 40% for all subjects. In 2006 some 318 000 took mathematics, 195 000 physical science and 349 000 biology; the 'corresponding' figures for 2010 were 537 000 (mathematics or mathematical literacy), 205 000 and 285 000 respectively. There seems to be a decline in enrolments for biology. The subject area of technology is not compulsory for the award of the NSC.

Direct comparison between the previous and present systems is difficult as the subjects are no longer the same and the grading system is different. However the Department of Basic Education maintains that attainment of 50% in the new mathematics subject is equivalent to the previous mathematics HG attainment of 40%.

Figure 1: Requirements for the National Senior Certificate

Subject	Achievement Level	
One Home Language	40%	
One Home or First Additional Language		
Mathematics or Mathematical Literacy	} 2 x subjects with 40%	
Life Orientation		} 3 x subjects with 30%
3 x subjects selected from Group B		} x subject less than 30% (evidence of SBA)

As part of its international benchmarking to ensure comparability, the Department collaborated with the Cambridge and Scottish examination boards as well as that of New South Wales. Higher Education South Africa was also part of this process. The four institutions expressed overall satisfaction with the standard of the items they assessed while counseling that the testing of critical thinking and problem-solving skills should be sharpened. The Department, together with media houses and NGOs also provided a wide range of support to students through camps and winter classes and educational materials through print, DVD, radio and television channels.

With these caveats in mind one notes that in 2006 a total of 47 000 candidates took mathematics HG and 69 000 took physical science HG, with 25 000 and 30 000 passes respectively, and pass rates of 53.2% and 43.5%. At standard grade the corresponding situation was: 271 000 took mathematics and 126 000 physical science. The numbers who passed SG were 111 000 and 81 000 respectively, with pass rates of 41.0% and 64.3%.

⁴ Higher grade is a more advanced syllabus than the standard grade. In effect students passing at the higher grade are selected for science-based studies in the universities.

The NSC in 2010 yielded a 70.2% pass rate with 121 000 students obtaining a ‘Bachelor pass’ equivalent to the previous matriculation exemption. This compares with 107 000 in 2008. Provincial GDP/capita and gender disparity continued to manifest: the Eastern Cape pass rate was 83%; that for Eastern Cape 58%; girls under-performed boys in all Provinces. The pass rates (at 30%) for mathematical literacy, mathematics and physical sciences were 85.9%, 46.3% and 53.4% respectively, with life orientation and all languages achieving nearly 100% pass rates. In mathematics and physical science the targets of Action Plan for 2014 have not been met (Table 8). From a promising start in 2009, mathematics had fallen to 71% of the intended level, while physical science has remained consistently below at around 68%.

Table 8: Target and pass rates (000s), mathematics and physical science, 2009-2011

	2009		2010		2011	
	Target	Pass	Target	Pass	Target	Pass
Mathematics	125	133	136	125	147	104
Physical science	120	81	130	98	140	96

Source: DBE 2011; DBE 2012a

Boys outperformed girls in both mathematics and physical science with around a ten percentage point margin, but the data show dramatically improved pass rates and the closing or reversal of the gender gap in all Provinces. Overall boys’ pass rate was around 66% compared with girls’ 63%. (The large number of candidates in Limpopo pulls down the averages).

Another assessment of secondary level attainment is provided in the World Bank (2010) impact evaluation of the Dinaledi Schools that found that enrolment rose from 6% to 12% in grade 12 HG physical science and from 5.5% to 11% in HG mathematics. However, only Kwazulu-Natal, Limpopo, North-West and Eastern Cape showed a statistically significant increase in the physical science HG pass rate. The improvements attributable to the *Dinaledi* intervention occurred in former African schools. The impact evaluation does not explain why there was no corresponding improvement in former House of Assembly (White) schools. Dinaledi, whilst laudable in intent has not performed according to expectation.

The above range of assessments point to structural weakness in schooling, with teachers themselves found wanting on the Annual National Assessments. This suggests that the improvement in qualifications has done little to raise teaching standards and the learning competence of students. Since improved qualification automatically leads to an increase in salary, South African teacher salaries measured in PPP USD are amongst the highest in the world, with a similar privilege now accruing to university staff (CEPD, 2011). The PPP USD starting salary of teachers is comparable with their counterparts in the United Kingdom.

At this point one may consider how gender and socio-economic status reveal in performance. Kahn (2005) shows that in 2003 mathematics HG and SG, across all schools (low and high fee) in each and every Province (with but one exception) African boy students outperformed African girl students by up to a half. Overall boys’ pass rate was 44% compared to girls’ at 33%. Gender marginalization has not changed much since then. The 2011 National Senior Certificate results (all groups) reveal that males outperformed females by 9.5 percentage points in mathematics and by 6.6 percentage points in physical science.

Regarding socio-economic status (SES), performance in mathematics by African students in expensive former model C⁵ (White only schools) and even more expensive private schools is radically different to their peers at other schools (Table 9).

⁵ Whilst compulsory phase schooling is ‘free,’ school governing bodies are allowed to levy fees. The former ‘model C’ schools of the white departments functioned in this way under apartheid. Today, these former model C schools, coded as ‘suburban’ schools

Table 9. African student pass rates in Mathematics HG and SG, high-fee schools, by gender and Province, 2003

PROVINCE	MATHS HG		MATHS SG	
	MALE	FEMALE	MALE	FEMALE
WC	80.6	78.6	63.4	58.4
NC	78.6	84.6	66.1	70.5
FS	62.5	79.4	69.1	78.2
EC	76.9	76.3	70.4	69.7
KZ	70.6	73.4	56.5	57.3
MP	54.9	66.3	60.4	51.8
LIM	72.0	49.7	63.3	64.3
GAU	65.2	64.3	66.4	61.9
NW	71.9	82.1	61.1	64.1

Source: Kahn 2005.

It is clear that performance in high-fee state schools is vastly better than of those attending mainstream public schools.

The Social Policy Research Group in the Department of Economics of Stellenbosch University conducted large-scale econometric studies of the drivers of education performance (van der Berg et al, 2011) and found:

- By age eight years there are already very large gaps in performance between the top quintile and the bottom four quintiles.
- Even with pro-poor targeting of funds for school resourcing the education system reinforces class distinctions.
- Salaries account for 80% of education costs, with better qualified teachers preferring to teach in more affluent schools – teacher salaries are thus an ineffective means of assuring redress in inequality.
- ‘South Africa’s rural children did far worse than rural children in most other countries ... as did the poorest quarter of South African students in comparison with the other countries in the sample’ (idem: 4) a result that is at variance with the fact that South Africa’s teachers are ‘better qualified’ and the pupil-teacher ratio is lower than in peer countries.
- Apartheid divisions persist ‘The former racially separate education departments therefore remain important categories for analysis’ (Kahn, 2005; idem: 5).
- The reasons for this are complex but there are suggestions that socio-economic status is less important than home base and the school that is attended, with school management and teacher experience being further important variables.
- ‘While teacher knowledge was lower in poor schools than in richer schools, it made little difference to learner performance’ (idem: 5).
- Curriculum coverage was inadequate as was attention given to the issuing of homework.

This represents perhaps the most authoritative and comprehensive study of education dysfunction carried out thus far. It serves to confirm the findings of many other researchers and offers a wide range of recommendations to education policy makers.

Most distressingly it shows that the massive increase in remuneration has not lead to an improvement in output. Accordingly the class and gender structure of schooling remains much as it was before 1994. The school system continues to reproduce the socio-economic status quo in which the high- performing core of pre-1994 schools is inadequately harnessed to promote wider quality improvement.

maintain a lower student: teacher ratio by levying fees at a level that enables them to hire additional teachers. In this way they have been able to ‘maintain standards.’

Higher education

The SES layering of schooling also manifests in higher education. The leading institution (the oldest) is the University of Cape Town (UCT) that in 2011 was ranked at 103 of the world best 200 universities (THES 2011). At the other extreme are three universities of technology, all of which were historically black institutions, and whose governance lapses have placed them under the direct administration of the national ministry.

The process of de-racialization and restructuring of higher education⁶ left the core of the old White (and Indian) system essentially untouched, so that the universities of Cape Town, Witwatersrand, Pretoria, Stellenbosch and Kwazulu-Natal remained 'research intensive' and produced the bulk of doctoral students and research publications. Creating 'universities of technology' eliminated the binary divide of university and polytechnic institutions.

Other than these measures, and the introduction of means-tested student loans de-racialization moved according to market forces and the ability to pay. The Council for Higher Education declares, 'The extent and pace of the de-racialization of the student body and of many institutions must be a source of pride and should be celebrated as a considerable achievement' (CHE 2009: 234). Even so the above extremes remain so that in 2009 the total enrolment rate for Whites was three times that for Africans (Table 10) in line with population proportions.

Table 10: Headcount enrolments in higher education by race, 2004 -2009

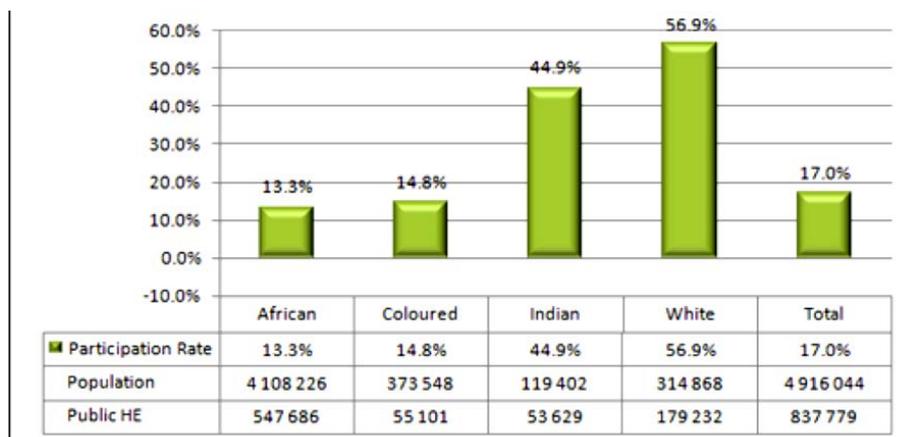
	2004	2005	2006	2007	2008	2009	Population
African	453,640	446,946	451,106	476,768	515,058	515,058	39,194,851
Coloured	46,090	46,302	48,538	49,069	51,647	51,647	4,383,092
Indian	54,315	54,611	54,859	52,596	52,401	52,401	1,278,571
White	188,687	185,847	184,667	180,463	178,140	178,140	4,607,261
Total	744,489	735,073	741,380	761,090	799,490	799,490	49,463,775

Source: Council for Higher Education (<http://www.che.ac.za/heinsa/tl/participants/#race>)

The participation (Figure 2) rate of those in the 20-24 age group for 2009 stood at 17%, below the planned 20%. For Whites it was 56.9%; for Indians 44.9%; Coloureds 14.8% and Africans 13.3%. The participation rate shows a White to African disparity of 4.3 times.

Figure 2: Participation rate of 20-24 age group, by race, 2009

⁶ Policy for the de-racialization of schooling eliminated overt use of race as a condition for entry, but also allowed a free market to operate. The result was that rich suburban schools were allowed to levy whatever fee their constituents could pay, while the state capped its subsidy in relation to the fee level. Above a relatively low minimum the state subsidy fell to zero so that any additional teachers would have to be paid for by the constituents. Many inner city formerly white schools thus saw their intake shift toward students from the black townships who would make the long daily round in minibus taxis.



Source: Council for Higher Education (<http://www.che.ac.za/heinsa/tl/participants/#race>)

The Department of Education (DBE 2012a) claims that the undergraduate ‘success rate’ for Whites is but 10% higher than that of Africans. Unfortunately the calculation masks the massive attrition rate - of 120 000 students who enrolled in higher education in 2000, 36 000 dropped out in their first year of study (Letseka and Maile, 2008) and a further 24 000 dropped out during their second and third years. Of the remaining 60 000 students, only 22% graduated within the specified three years. In other words, of 120 000 who started out, only 13 200 obtained a degree in 3 years. Of those who drop out, 71% of the African and 69% of the coloured students are from low SES backgrounds. The conclusion ‘... student poverty is the most important issue to be addressed if the student dropout rate is to be remedied’ (Letseka et al 2009). Irrespective of institution, the majority of first year dropouts are African; the majority of foreign students are Africans from north of the Limpopo River. They excel; their local cousins do not.

The Balintulo Committee that inquired into the National Student Financial Aid Scheme (NSFAS) (DHET, 2010: xiv) found that it had done little to change this state of affairs:

Only 19 percent (125 210) students have graduated, while 48 percent (316 320) have dropped out or otherwise not completed their studies. The remaining 33 percent (217 470) of NSFAS students are still studying. Of the 67 percent of NSFAS students who are no longer studying, 28 percent have thus graduated and 72 percent have dropped out or have otherwise not completed their studies.

The loan recovery to NSFAS is the second lowest in the world.

One further issue for the universities is the comparability of the National Senior Certificate with the pre-2008 matriculation exemption. In 2008 a total of 58 081 candidates scored above 50% in NSC mathematics (Simkins, 2010); by 2011 when the new examination system had settled, this had declined to 41 586 (M&G, 2012). This may be compared with the situation in 2005 when 26 383 candidates obtained a mathematics HG pass. On a simple comparative basis education productivity in STEM subjects is markedly ‘up.’

Simkins makes two important points in his analysis: first that many more students could have reached the level of 50% in mathematics but had ‘elected’ to take mathematical literacy that represented a career dead-end. On the other hand there was also evidence of grade inflation. Nonetheless he finds 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’ (idem: 1). Accordingly Simkins believes that the goal of ramping up the productivity of the school system appears to be in sight. The research universities do not appear to share Simkins’ optimism (MG, 2009).

What then the outputs from higher education? The outputs are presented disaggregated by overall enrolment and graduation (Table 11), by qualification and field (Table 12) and lastly for doctoral students by field (Table 13).

Table 11: Higher education FTE enrolments and graduates (all levels), 2006-2010*

Year	2006		2007		2008		2009		2010*	
CESM Category	Enrol	Grad								
Agriculture	12446	2269	13465	2271	13007	2335	13247	2444	14514	2580
Computer Science	33335	4496	32587	4252	34467	4368	35209	4508	38075	4756
Engineering	58192	7714	59909	8381	62961	9003	66827	9782	71172	10200
Health sciences	44861	9663	46193	9432	49868	10422	52439	11226	50615	11202
Life and physical science	29031	5084	29166	5293	29563	5595	32109	5735	46815	8593
Mathematics	14860	2063	14175	2047	16191	2427	17345	2411	15384	2036
STEM Totals	192725	31289	195495	31676	206057	34150	217176	36106	236575	39367
<i>Grand Totals</i>	741380	124676	760889	126618	799490	133241	837779	144854	892936	153325
% STEM	26.0	25.1	25.7	25.0	25.8	25.6	25.9	24.9	26.5	25.7

Source: <http://www.dhet.gov.za/Structure/Universities/ManagementandInformationSystems/Graduates/tabid/471/Default.aspx>

*: The Classification of Education Subject Matter altered in 2010 with major changes to health, life and physical science categories.

Table 12: Graduates by qualification and field, 2010 and totals 2006.

	3 yr	4 yr	Honours	Masters C	Masters R	PhD	2010	2006
Agriculture	299	820	228	169	75	64	1655	1408
Architecture	707	685	373	156	158	4	2083	1540
Business	13960	6595	5060	610	1452	106	27783	18077
Comp Sci	1169	704	626	121	47	30	2697	2759
Education	155	4509	6510	287	157	137	11755	9221
Engineering	146	4183	540	478	197	107	5651	3921
Health	811	4819	417	509	575	111	7242	7024
Law	721	3212	214	257	301	39	4744	4324
Life Sciences	1917	317	1032	429	49	210	3954	4289
Physical	1412	464	985	361	72	166	3460	-
Mathematics	826	226	363	93	33	33	1574	1738
TOTAL	22123	26534	16348	3470	3116	1007	72598	54301

Source: <http://www.dhet.gov.za/Structure/Universities/ManagementandInformationSystems/Graduates/tabid/471/Default.aspx>

*: The Classification of Education Subject Matter altered in 2010 with major changes to health, life and physical science categories.

Table 13: Doctoral FTE enrolments and graduates by field, 2006-2010*

Year	2006		2007		2008		2009		2010*	
	Enrol	Grad								
Agriculture	424	54	428	60	447	46	455	67	467	64
Computer Science	199	12	210	17	224	29	264	24	324	30
Engineering	726	105	738	86	734	83	773	97	827	107
Health sciences	1003	110	1022	131	1105	118	1254	166	1064	111
Life and physical science	1650	206	1796	232	1846	250	1963	295	2535	376
Mathematics	246	28	265	46	218	34	230	36	261	33
STEM Totals	4248	515	4459	572	4574	560	4939	685	5478	721
<i>Grand Totals</i>	9828	1100	10048	1274	9994	1182	10529	1380	11590	1421
% STEM	43.2	46.8	44.4	44.9	45.8	47.4	46.9	49.6	47.3	50.7

Source: <http://www.dhet.gov.za/Structure/Universities/ManagementandInformationSystems/Graduates/tabid/471/Default.aspx>

*: The Classification of Education Subject Matter altered in 2010 with major changes to health, life and physical science categories.

The data of Table 11 show that between 2006 and 2010 enrolments rose by 20.5% and total graduates by 22.5% suggesting maintenance of 'quality.' According to the grouping of fields to give a picture of STEM-based studies, the proportion of STEM in the total remained steady at 26%. What is significant are the shifts among the various fields, with Life and physical sciences graduations rising by 69%, followed by Engineering at 32%. These two account for the bulk of the increase. There would thus appear to be a shift toward STEM fields. Table 12 provides an indication of the composition by degree type and field of study and shows the strong uptake into Business and Education. Table 13 for doctoral graduates illustrates a number of salient features: firstly that of congestion, in that the crude enrolment/graduate ratio is in the order of 14%. Another feature is the strong and rising showing of STEM in the total now standing at 51% of the total. Life and physical science shows a growth of nearly 82%. In 2009 there were 60 856 foreign students in South African HEIs (UNESCO 2011) comprising 7.3% of all higher education students. This reflects South Africa's commitment to the SADC Protocol of Education and Training, and is an exceptionally high value among developing countries. Table 14 displays the gender and nationality characteristics of doctoral graduates.

Table 14: Doctoral graduates 2001-2007

Demographics	2000	2001	2002	2003	2004	2005	2006	2007
Gender								
Female	41%	37%	39%	39%	38%	44%	43%	42%
Male	59%	63%	61%	61%	62%	56%	57%	58%
Race								
Black African	19%	22%	23%	23%	27%	29%	30%	32%
Coloured	5%	3%	5%	5%	5%	6%	5%	6%
Indian	6%	6%	7%	9%	9%	7%	8%	8%
White	70%	69%	65%	63%	59%	59%	56%	54%
Age at graduation								
<30	15%	17%	17%	18%	15%	13%	14%	12%
30-39	43%	37%	38%	36%	38%	41%	38%	39%
40-49	29%	31%	30%	30%	30%	29%	30%	30%
50+	13%	16%	15%	16%	18%	17%	18%	19%
Nationality								
South African	84%	81%	80%	78%	78%	74%	72%	71%
Other SADC* countries	4%	4%	4%	4%	6%	8%	8%	9%
Other African countries	2%	3%	7%	7%	7%	9%	9%	9%
Rest of world	4%	6%	7%	9%	8%	8%	8%	9%
Unknown	6%	6%	2%	2%	2%	2%	2%	3%

* Southern African Development Community

Source: ASSAf (2010)

This indicates a strong increase of foreign students at doctoral level. CHE (2009) shows that foreign students form an increasingly important group: among masters graduates their proportion rose from 9% to 19% over 2000 to 2005; for doctoral graduates the rise was from 9% to 25%, with humanities the largest – from 9% to 28%.

What of the benefits of higher education? Table 15 presents estimated average earnings according to qualifications (though the cost of study and deferred income while studying are not included).

Table 15: Estimated average earnings in Rands for 25-year-old, non-unionised Africans from the Western Cape, by qualification level and gender.

		2000	2002	2002	2003	2004	2005	2006	2007
M	<Matric	658.32	746.78	748.49	855.45	999.56	1097.87	1124.92	1275.96
	Matric	1009.50	1197.10	1096.03	1266.63	1519.11	1633.23	1679.67	1853.86
	Dip or Cert	1812.95	2054.50	2372.27	2753.02	2998.68	3031.90	3141.44	3611.75
	Degree	2847.32	2672.99	2951.53	2798.94	4071.12	5586.37	5217.35	6322.68
F	<Matric	472.87	530.69	551.55	624.47	752.17	769.23	909.05	927.61
	Matric	725.12	850.69	807.64	924.63	1143.13	1144.33	1357.34	1347.74
	Dip or Cert	1302.24	1459.98	1748.07	2009.67	2256.50	2124.32	2538.60	2625.71
	Degree	2045.23	1899.50	2174.91	2043.19	3063.51	3914.13	4216.14	4596.53

2000 2001 2002 2003 2004 2005 2006 2007

Source: Cloete 2009

Note: 'Matric' = matriculation exemption.

In 2000, those with a higher education qualification were twice as likely to be formally employed compared to individuals with less than matriculation exemption. By 2007 this had increased to around three times (Cloete 2009). This serves to challenge a myth: the overstatement of black graduate unemployment. Pauw, Oosthuizen and van der Westhuizen (2006), using Labour Force Survey data claimed that between 1995 and 2005 an additional 107 000 higher education graduates joined the 'broadly unemployed'. This finding received considerable press coverage (Engineering News, 2007). Cloete (2009) finds that the number of unemployed degree holders was around 6 000, the discrepancy arising through conflating unemployed university degree graduates, diploma holders and private college graduates.

What is certain is that the fact that higher education was, and is not free serves to reproduce the middle class. Unlike Brazil where parents have to pay for high quality schooling to enable their children to compete for a place but then enjoy free tuition at a high quality state

university, in South Africa parents must pay both for quality schooling and then for variable quality higher education.

Vocational education and training

Vocational education and training (VET) has been in decline since the early 1980s when the services sectors overtook mining, agriculture and manufacturing as the major component of GDP (US, 2012). Up to that time VET was as an important adjunct to manufacturing and allowed White workers to develop their technical careers in the state-owned enterprises and large private corporations. In 1985 13 500 artisans graduated; by 2004 this had fallen to 2 548. There are many examples of artisans who began their careers in a technical college or training institute, obtained work experience and then took a degree and eventually postgraduate qualifications. In effect there was a national qualifications framework. Upward mobility took time, but it worked, at least for a few. This implies that the 'vocational school fallacy' was not an issue at that time. For Whites with no other choice, a technical career was not looked down upon.

By the early 1990s this had changed dramatically and apprenticeship withered: corporatization of the state monopolies, the end of large-scale military procurement, and globalization contributed to this. At this point the trade unions, drawing on international experience, including that of Australia, to protect their members' interests pushed for competency-based testing (CBT) and the recognition of prior learning (RPL). This campaign spilt over from trade union education circles into ANC education policy debates that in turn, recognized the need for an 'outcomes approach' for adult basic education and the then mooted Further Education Certificate. The demands for CBT and RPL eventually gained expression through the National Qualifications Framework, the Skills Development Act and Sector Education and Training Authorities (SETAs) that were intended to provide worker security and up-skilling.

At the institutional level the 152 racially defined technical colleges were merged into 50 new further education and training (FET) colleges, and in the process 'the white artisan tradition built up during the boom years of racial capitalism (the 1950s and 1960s), which was strongly linked to the FET college system, has been in reality phased out, constituting only 5 percent of total enrolments. This shrinkage represents not only a demographic correction but also the loss of crucial technical know-how in manufacturing production today – the artisan tradition' (Cosser et al 2011).

Africans now constitute 63% of academic staff, and Whites 22%, a reversal of the position a mere decade ago. According to the benchmark that staff should at least hold a degree, 57% would be regarded as unqualified, and barely 6% are qualified artisans, though three quarters of staff have three or more years experience in industry.

Cosser et al (2011) examine the data on the enrolment patterns in VET expressing grave concern at their reliability. They report on the very poor quality and completeness of the data so the best available estimate is that VET headcount enrolments across the period 2005 to 2010 were around 300 000. Student enrolments in VET have declined by a quarter over the last decade and the age and race profile has also shifted dramatically, with Cosser et al (2011: 38) stating that 'One of the greatest challenges confronting the sector is to attract working-age persons into colleges to upgrade their skills and for colleges not to be seen as the exclusive preserve of school leavers'. This has simply not happened.

Of all education sectors VET has thus seen the greatest changes:

- Staff moved from 39% black in 1998 to 77% black in 2010, rising to 87% in Kwazulu-Natal and 86%, 84% and 80% in Eastern Cape, Mpumalanga and Limpopo respectively.

- Students are now 96% black, with Limpopo at 100% and Western Cape at 90%. (Whites accounted for 17% of enrolments in 2002.)
- Students are younger with 75% under 24 years and 52% of students are female.
- Students are now predominantly self-funded.
- The vocational route to Senior Certificate equivalence (the 'N' stream) was ended in 2007 with the introduction of the National Certificate Vocational 'NC(V).'

The 'N' system operated parallel to and beyond the Senior Certificate. At the grade 10 transition point a student could elect to take one of six N1 programmes rather than the standard school subject offerings leading to the Senior Certificate and possible matriculation exemption. N3 was thereby equivalent to the Senior Certificate, with N4-N6 the technical college diploma or certificate offering a post secondary route for qualifications. This system was to be replaced with NC(V) from 2007 onward. The data of Cosser et al (2011: 67) show the continuing importance of the 'N' stream for Engineering and Business Studies as late as 2009 with 89 743 and 80 177 enrolments respectively.

What of throughput? For every 100 students who enrolled, 27 obtained diplomas in the National Curriculum (Vocational), 9 obtained an N-qualification, and 6 received 'other' qualifications. 58% obtained nothing at all. The throughput rate for N6 Engineering was 30 percent; that for Business Studies 44%. This suggests yet another waste of talent and resources.

The new NC(V) with its fourteen programmes (Table 16) led to the phasing out of the N qualification but has not been accompanied by the expected rise in enrolments. The drop from 2009 to 2010 is associated with the end of the first qualification cycle with its low throughputs. The enrolment by STEM programme mix clearly illustrates the continued preference for the N qualification – the Engineering related programmes attracted less than the outgoing N stream continued so to do.

Table 16: NC(V) enrolments (all years of study) by field, 2007-2010

Year	2007	2008	2009	2010
Field				
Office administration	5235	14944	32718	25922
Marketing	1155	3079	5536	7632
Finance, economics and accounting	2335	6202	12698	13306
Management	1185	3478	8648	8298
Building & civil construction	2667	7009	13179	10842
Engineering & related design	7177	15639	27643	18794
Electrical infrastructure & construction	6491	14334	27118	24050
Information technology & computer science	2098	6670	12578	11059
Primary agriculture	737	2745	5486	2354
Hospitality	1183	3596	7084	7061
Tourism	1151	1840	7026	7638
Safety in society	0	1206	6049	5409
Mechatronics	0	0	373	1200
Education & development	0	0	233	1124
Totals	31414	80742	166369	144689

Source: Cosset et al (2011)

In principle SETA Learnerships gain credits toward a designated qualification. These credits are structured and portable, and in principle may contribute to higher qualifications. It is this portability and credit worthiness that was the motivating force for discontinuing the apprenticeship system. By design most Learnerships are been offered by accredited private-sector service providers, with some 44 000 Learnerships being registered in 2010. By comparison the FET Colleges offered 9 607 Learnerships over the three years 2007-2009. Together these awards have been inadequate to meet industry demands and expectations.

The pre 1994 Technical College system has been completely replaced by the FET Colleges that seem to function as way stations for students with little prospect of employment.

VET students come from impoverished communities and battle to survive. As a part of his strategy to address the triple issue of poverty, inequality and unemployment, the Minister of Higher Education in 2012 announced the goal of enrolling 5 million students in VET by 2030. This target, as the above analysis shows, is highly unlikely to be met.

Teacher education, teacher supply and teacher demand

Quality schooling turns upon the quality and availability of teachers. Since the 1950s education has stood at the very centre of political discourse, from the imposition of Bantu Education to the Soweto Revolt, through the period of 'Peoples Education' and the 'pass one, pass all' slogans of the 1980s. This latter period saw teachers becoming increasingly politicized to the extent that school inspectors were denied access to many schools. This was the climate in which the South African Democratic Teachers Union (SADTU) was formed in 1990. Today with 240 000 members it is the fourth largest formation in the Congress of South African Trades Unions (COSATU). COSATU, being a professional union is highly influential within the ANC, SACP, COSTAU alliance, and its members and former members play leading roles in political structures and the senior levels of the administration. As such teachers remain a highly politicized group of employees.

During the apartheid era teacher training was a decentralized and racially divided function, so that one of the first moves of the democratic government was to consolidate and rationalize the existing teacher training colleges under the control of the nine new provinces. This was followed by the responsibility for teacher education being shifted from provincial to national control and the transfer of the teacher training functions to higher education. These various shifts have made the task of managing information on teachers extremely difficult. Generally speaking education planning shows a history of indifference toward the issue of teacher supply and demand with no real effort made to develop a centralized database (Arends, 2011). This is in the process of changing but it is still the case that planners have to rely on the limited data captured on the PERSAL payroll database and the annual school census. Neither of these sources adequately addresses the fine detail needed to determine who is qualified to teach what, and whether they are in fact posted to teach what they are qualified to teach. This information nexus couples with the politics of deployment to create and maintain education dysfunction. There is no easy solution to undoing this nexus.

Unsurprisingly the issues around teachers are cloaked in myth and misinformation. One myth is that the country is undersupplied with teachers. According to Mda and Erasmus (2005) that is simply untrue: based on the official pupil/teacher ratio there was a country surplus of 60 000 teachers in 2005. There are however wide variations by province with the poorer provinces showing more crowding than the wealthier ones.

So what is known about teacher qualifications? In 2000 being fully qualified required a three-year post secondary qualification, what was now termed the Relative Education Quality Value (REQV) 13. This was raised to REQV 14 in 2007. On this basis 48% of teachers held REQV 14, another 37% held REQV 13 and the remaining 15% held REQV 12 or less (2004 data). It is worth noting that over 1994 to 2004 the numbers with REQV 14 rose from 83 000 to 179 000. On the face of it teacher quality was undergoing rapid improvement. However the sticking point is the matter of subject competence. Arends (2011) reports that among mathematics teachers in 2009 94% of primary phase teachers were professionally qualified but only 34% had mathematics as a subject specialization; for the senior phase 81% had a professional qualification of whom 50% had mathematics as a subject specialization, while of the 36% with academic qualifications only 21% had mathematics as a subject specialization. On this basis South African teachers are under-qualified relative to their international peers.

This raises the issue of teacher education programmes. Over 1996 to 2005 a different pattern began to emerge among the 6 000 new graduates exiting first time education programmes. African graduates with BEd fell from 4 377 to 3 498 whilst those of Whites rose from 1 082 to 1 952. This indicates a problem for the future: the need for highly qualified teachers is greatest in African schools, but there is a decline in the number among those most likely to go and teach in those schools (Mda and Erasmus, 2005).

The last aspect for consideration is that of in-service education. This is provided through both formal and informal offerings. The formal comprise the Advanced Certificate in Education or the National Professional Diploma for Educators. These have both contributed to the increase among those holding REQV 14, but in the main they have not deepened subject content knowledge that is the most critical shortfall. Subject content knowledge development tends to be provided by non-governmental organizations such as PROTEC, Sediba, Thinthana, CASTME, RADMASTE and others, which mainly operate from university campuses. Their long-term impact on the quality of school instruction is unknown. As mentioned earlier many staff of these NGOs migrated into government service after 1994.

The inability of the national ministry to confront the hard issue of determining teacher competence and matching this with correct deployment sits at the heart of the quality problem. It is worth noting the stated intention of the new Mexican administration to confront the power of the organized teaching profession in that country. In South Africa calls for education to be declared an essential service have been decisively rejected by the teacher unions.

Concluding Remarks

South Africa in 1994 engaged with massive institutionally embedded challenges. To remove and transcend Apartheid divisions, it adopted an inclusive polity while maintaining the continuity of economic institutions. It then faced the impacts of accession to the World Trade Organization, the all-pervasive information and communications revolution, difficulties of its permeable borders, the rise of China, and the scourge of the AIDS pandemic.

Eighteen years into constitutional democracy, unemployment, inequality and poverty prevail and education disparity continues.

Today's school system may be likened to a road network with destinations named 'job' or 'status' or 'wealth.' Few routes lead there. Most students walk on rutted tracks and fail to arrive; some rattle along in minibuses on increasingly pot-holed blacktop; a small minority zoom by on toll roads and collect the benefits.

To quote Cloete (2009: 3) '... one finds an education system spewing out large numbers of school leavers with no hope of further study or employment; despite the existence of the NQF there is no real articulation across the education sectors. Indeed the two 'worst' things that can happen to a student is (i) to drop out of school between Grades 10–12 and (ii) to get matric (sic) without a matric exemption'.

At the other extreme is the higher education system that is essentially a university system, since there is no articulation with VET. The new VET system is struggling, with most provinces unable to manage the sector.

Surprisingly then, as judged by scientific output, the increasing numbers of graduates, and recognition through networks and prizes, the university system is in reasonably good shape.

The real danger is that university staff numbers have not grown alongside rising demand for places, and salary escalation is unsustainable. On a PPP USD basis academics are among the highest paid in the world.

Some complain that the universities are isolated from society and commerce; others in commerce recognize the value that the universities provide and express satisfaction at their quality. Complaints tend to be loudest from the more technical fields of work. This is the more disturbing given the reported difficulty that students find in obtaining workplace experience that is part of their coursework. Yet the services sector does not appear to be unduly troubled by claims that the universities are failing to articulate with the job market (Kahn and Hounwanou, 2008).

Serious effort has gone into laying the basis for STEM in the education system and the system of innovation. The collective opinion of a small sample of STEM thought leaders that were polled for this paper is that the main impact of these measures has been successfully to raise awareness of the importance of STEM in the minds of decision makers and the public at large.

How to make sense of these divergent indicators and view? The indicators tell the story of a school system in deep crisis. It does however succeed in feeding through just enough quality students to fill university lecture rooms.

Higher education, with its high levels of institutional autonomy, is in reasonably good shape. Most graduates obtain employment with a time lag not that different to what prevails in advanced economies - at least pre-2010!

From a policy perspective government has done many of the right things: in the compulsory phase of schooling science, technology and mathematics are core subjects. At secondary level it has moved more slowly, with mathematics and mathematics literacy being compulsory. A host of initiatives are in place to support the grade 12 examination candidates. But it is obvious that despite this, and otherwise well-intentioned interventions such as the Dinaledi Schools, the desired ramp up of quantity with quality has remained elusive.

These persistent shortcomings lead one to seek an extra-curriculum explanation, namely teacher performance. The facts are clear: 'improved' teacher qualification and remuneration has not been accompanied by improved student performance. This suggests underlying shortcomings – school learning climate, time-on-task, and teacher competence. All of these require the development and adoption of some type of 'education charter', a goal that appears to be presently beyond the ability (or intent) of government.

But there is new movement. Cabinet in August 2012 accepted the National Development Plan of the National Planning Commission. Eighteen months of dispassionate analysis that recognized many of the failures described in this paper preceded the tabling of the Plan.

The Plan pivots on a behavioural shift 'from a passive citizenry receiving services from the state to one that systematically includes the socially and economically excluded, where people are active champions of their own development, and where government works effectively to develop people's capabilities to lead the lives they desire' (NPC, 2012:1). Among other goals the Plan seeks to:

- Redress the injustices of the past effectively
- Achieve faster economic growth, higher investment and employment
- Improve education, health and social protection
- Strengthen links between economic and social strategies
- Develop effective and capable government

- Promote collaboration between the private and public sectors
- Foster leadership from all sectors in society.

Effecting these policy proposals presupposes a willing and capable state, and that in turn requires a well-educated citizenry.

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Glossary of Abbreviations

ANA	Annual National Assessment
ANC	African National Congress
CBT	Competency based testing
DACST	Department of Arts, Culture, Science and Technology
DST	Department of Science and Technology
GDP	Gross domestic product
FET	Further education and training
FTE	Full-time equivalent
HRD	Human resource development
HSRC	Human Sciences Research Council
MNC	Multi-national corporation
NER	Net enrolment ratio
NGO	Non-governmental organization
NSC	National Senior Certificate
NSFAS	National Student Financial Aid Scheme
PIRLS	Progress in International Reading Literacy Study
R & D	Research and development
RPL	Recognition of prior learning
SAASTA	South African Agency for Science and Technology Advancement
SAASTECH	South African Association for Science and Technology Centres
SACMEQ	Southern African Consortium for Measuring Education Quality
SADC	Southern African Development Community
SES	Socio-economic status
SETA	Sector Education and Training Authority
SYSTEM	Students and Youth into Science Technology Engineering and Mathematics
TIMSS	Third International Mathematics and Science Study
VET	Vocational education and training
WEF	World Economic Forum