THE PRODUCTION OF HIGH LEVEL SCIENCE, ENGINEERING AND TECHNOLOGY SKILLS

Role of the Dinaledi Project

Nick TAYLOR

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Produced by: Nick Taylor

Contact: Dr Miriam Altman
Executive Director, EGDI

E-mail: maltman@hsrc.ac.za

Tel: +27 12 302 2402

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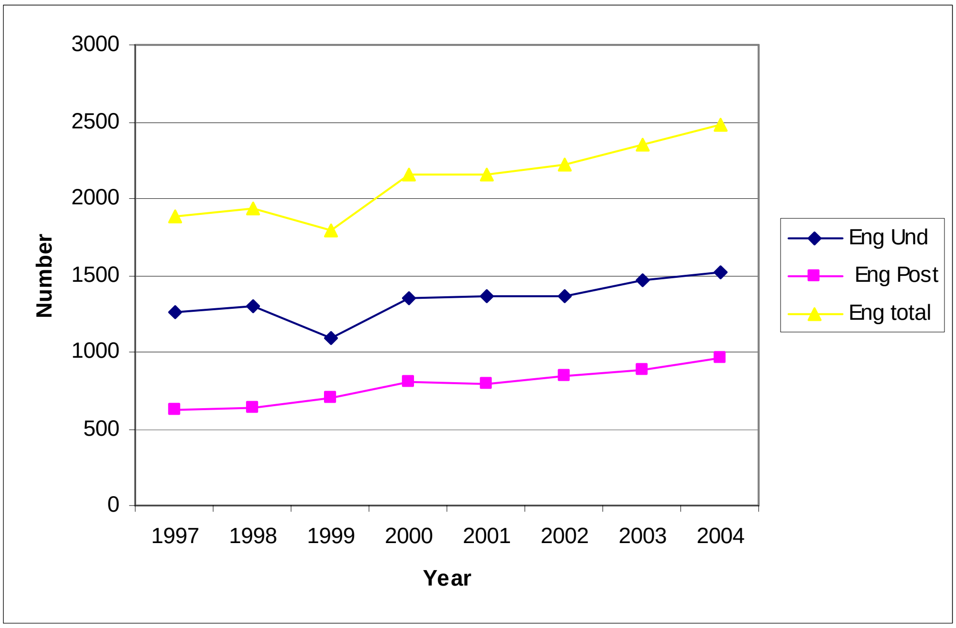
1. Introduction

The production of high level SET skills in one of the most critical supply-side factors enabling or constraining the growth of any industrial economy. We use the production of graduate engineers by South African universities as a key indicator of the capacity of the education system to deliver high level SET skills. We argue that the production of engineers, in turn, is severely constrained, by the low capacity of the high school sector to deliver matriculants with higher grade qualifications in mathematics, and also of primary schools to develop an adequate foundation in literacy and numeracy. Government is attempting to address this problem in the long term through an improvement in the quality of primary schooling. It is also, through the Dinaledi project, attempting to provide short-term improvement in the supply of high quality matriculants to the higher education system. This paper looks at the role of Dinaledi, its impact to date and the prospects of its expansion.

2. The Problem

Although there has been a steady increase in the number of engineers graduating from universities (excluding universities of technology) (see Figure 1), the average annual growth rate amounted to only 3% between 1997 and 2004.

Figure 1: Engineering graduates at universities (excluding universities of technology), 1997 to 2004

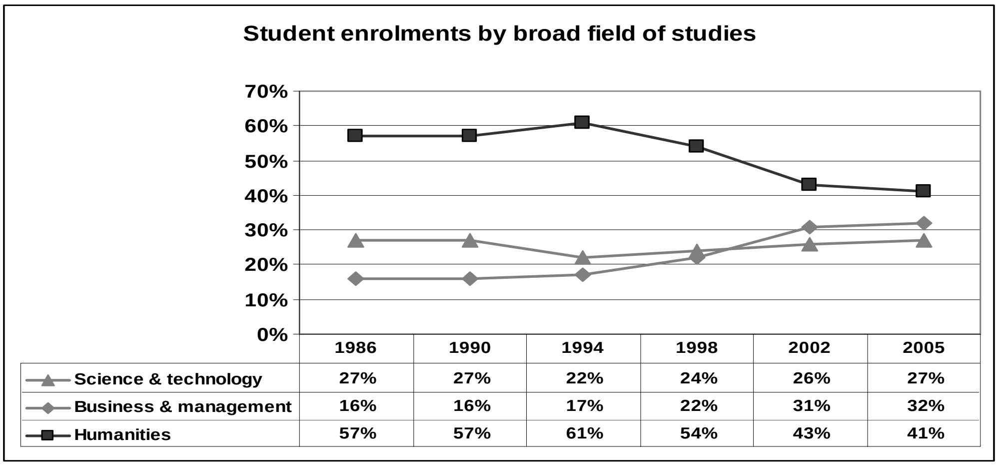


Source: Department of Education HEMIS, supplied 16/5/2007

JIPSA's requirement that the number of engineering graduates increase by 1 000 a year, was based on graduation statistics of 2004 when just over 1 500 engineers graduated from undergraduate professional degrees (Lawless et al , 2006). An increase of 1 000 engineering graduates a year means that universities will have to increase their output by 66%. In fact 1 000 additional engineering graduates a year might not be sufficient: Lawless et al (2006) state that 'given the planned 6% sustained growth, the worldwide shortage of engineering skills, the significant number of retirements expected over the next five to ten years and globalisation', the 1 000 additional engineering graduates should be seen as a 'starting target' for increased engineering graduates and that the country should aim to graduate at least 3 000 to 4 000 pa in the medium term.

The DoE appears to be working to a medium-term plan, which is characterised by modest expansion on an institution-by-institution basis, in identified fields – notably science and technology – improved throughput rates, and real increases in funding. By 2010 the enrolment target is expected to grow to 820 000 students, while throughput rates are targeted to improve from the 2005 mean of 71% to 77%, resulting in the graduation of 150 000 students in 2010 (DoE, 2007). Furthermore, the DoE aims to shift the balance of enrolments between broad fields of study, in order to increase the proportion of students in science and technology to 30% by 2010, accompanied by a reduction to 37% in those studying humanities, and an increase in those registered for courses in business and management to 33%. Trends since 1994 of student numbers in these three fields would indicate that the DoE targets are attainable (Figure 2).

Figure 2: Student headcount by field of study, 1986-2005



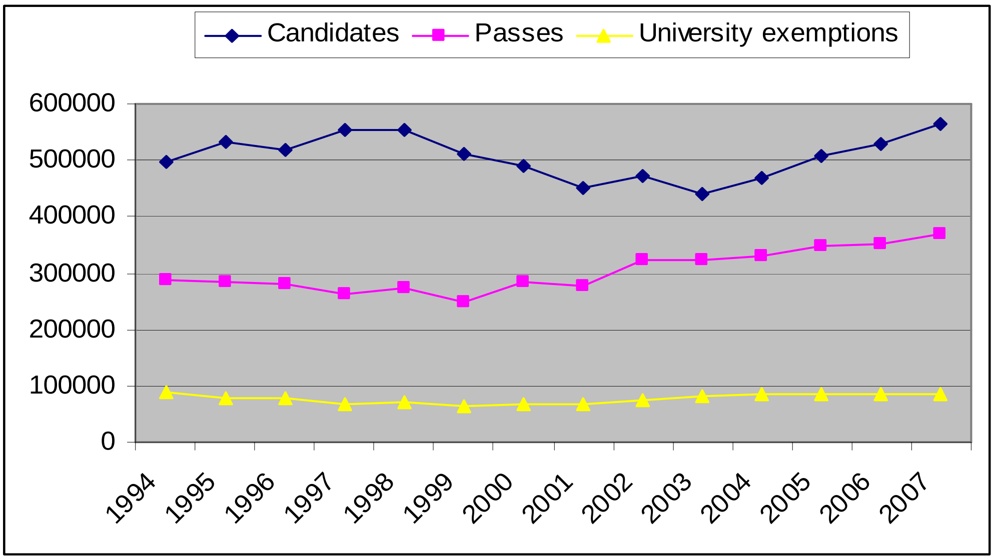
	1986	1990	1994	1998	2002	2005
Science & technology	27%	27%	22%	24%	26%	27%
Business & management	16%	16%	17%	22%	31%	32%
Humanities	57%	57%	61%	54%	43%	41%

Source: Bunting and Cloete, (2007)

The DoE targets were supported in the last two years by real increases in funding for the higher education subsector. In March 2007, the Minister announced a special grant of R4bn over 3 years to enable institutions to improve their infrastructure, while the 2007/08 budget provides for an increase of 12.8% in the higher education sector allocation, from R13.3 in 2007/08 to R15bn, while investment in both FET and HE is further boosted by increasing funds to the National Student Financial Aid Scheme by 20% pa to reach R2.3bn by 2010 (Manuel, 2008).

However, two major quality challenges face the higher education sub-sector with respect to increasing the production of SET graduates. The first concerns the low numbers of students overall with high level senior certificate (SC) results, particularly in mathematics. This problem inhibits the extent to which the higher education institutions are able to grow, particularly in fields of science and technology. Furthermore, those students who do qualify to enter the faculties of science, technology and the prestige professions, show an under-representation of the African and coloured populations. Figure 3 shows the very slow growth, if any, of students qualifying to enter university, compared with a brisk increase in candidates and a slower but significant rise in passes.

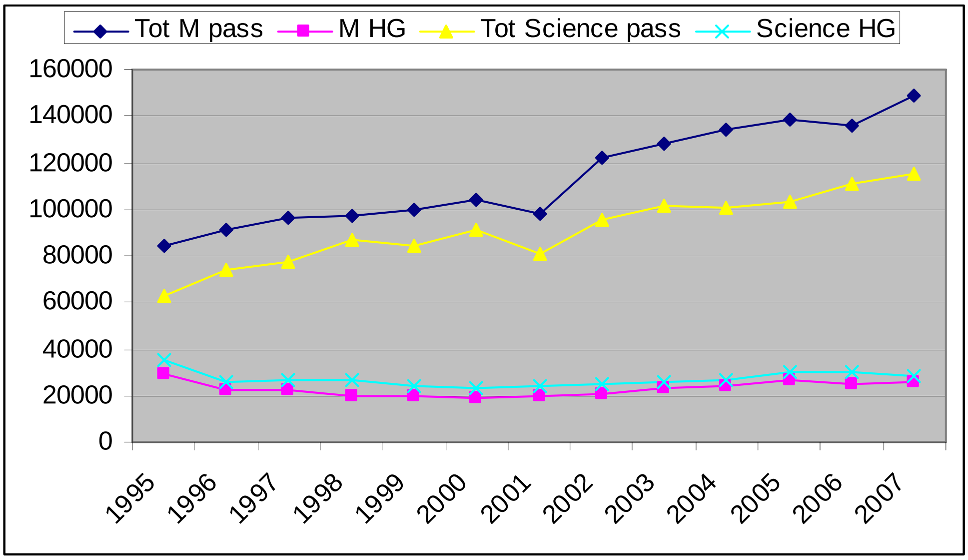
Figure 3: Growth in Senior Certificate candidates, passes and exemptions, 1994-07



Source: compiled from Department of Education SC results annually

A Senior Certificate pass with math on the higher grade (HG) is a prerequisite for entry into engineering at tertiary level. Figure 4 shows how total math and science passes at SC level have fluctuated over the last 15 years, with a steady increase since 2002, against a very much slower growth in HG passes, which remain relatively static at around 25 000. The flatness of the HG math curve places an absolute constraint on the growth of high level SET graduates.

Figure 4: Number of total and higher grade maths and science passes, 1995 to 2006



Source: compiled from Department of Education SC results annually

A second major challenge to the production of graduate engineers is the high rate of student dropout, and the sluggish progress of those who do graduate. According to the Department of Education (DoE, 2005) of the 120 000 undergraduates who entered higher education for the first time in 2000, 30% dropped out at the end of their first year of study and half of the cohort dropped out before completing their degrees (see Table 1). Only 22% of the total cohort had graduated at the end of their third or fourth year of their study. The remaining 28% were still studying in 2003 but would not qualify in that year. The DoE felt that it was possible that the first-time entering cohort of 2000 might not achieve an overall graduation rate of even 40% (DoE, 2005)

Table 1 - Progress of 2000 cohort of first-time entering undergraduate

Dropped out at end of 2000	30%
Dropped out at end of 2001	11%
Dropped out at end of 2002	9%
Total dropped out 2000-02	50%
Graduated in 2000 or 03	22%
Studying in 2003 but not completing	28%
Total in cohort	**120 000**

Source: Department of Education (DoE, 2005: 9)

This high rate of drop-out calls into question the ability of the higher education system to produce sufficient high-level skilled graduates required by South Africa. In engineering, for example, the Engineering Council of South Africa states that of the 50 570 people enrolled at universities across all engineering disciplines between 1998 and 2005, only 8 900 graduated - a rate of 17,5%. The graduation rate for engineers at universities of technology was even lower, with only a 10% graduation rate across all disciplines between 1998 and 2005 (Ray, 2008).

A Joint Initiative on Priority Skills Acquisition (JIPSA) report on increasing the supply of engineers and built environment professionals, technologists and technicians (EBEPTT) (JIPSA unpublished report, undated) found that the throughput of EBEPTTs at universities and universities of technology is around 65 percent at the 'top institutions' and about 20 percent at some others. Throughput rate is defined as the ratio of graduates to initial enrolments within 6 years of a four year programme. The report found that the throughput rate in minimal time was 'around 35 percent at the best institutions and between 5-10 percent at the others'. The report found that comparable throughput rates in East African, Indian and US institutions was around 80-90 percent.

The quality problems in higher education – low numbers qualifying for study in science and technology, a skewed demographic distribution in the sciences and most professions, and low throughput and high dropout rates – all have their roots in the poor quality of the primary and secondary school pipeline (Taylor, Fleisch and Shindler, 2008). Although academic support and bridging programmes have been in place at most HEIs for over two decades, it is widely acknowledged that they cannot compensate for the weak foundations in literacy and mathematics that the overwhelming majority of South African pupils receive at school.

3. The Long-term Solution

Government is beginning to give serious attention to the quality of primary schooling. At least three provinces (WC, KZN and GT) have instituted literacy programmes in the last three years, and in March 2008 the national Minister announced the launch of the Foundations for Learning project, designed to improve literacy and math performance (Government Gazette, 2008). Initiatives of this kind are, by their very nature, of a very long-term variety, usually taking 3-4 years to bed down, followed by the 7 years required to complete one primary school cycle, therefore only impacting at the secondary level after 10 years. Schooling has long cycles and programmes designed to improve quality are measured in decades.

4. Dinaledi: a Short-term Measure

In an attempt to effect a short-term increase in the proportions of students obtaining SC qualifications in maths and science, the Department of Education launched the Dinaledi Programme in 2001. The aim was to raise the participation and performance of historically disadvantaged learners in SC mathematics and physical science. In the first few years, the initiative focused on 102 selected secondary schools. In 2002, 2003 and 2004, the project showed mixed results. About one-third of Dinaledi schools increased the number of learners that passed HG maths and science, but many schools showed little or no change, while significant declines were evident in others (Taylor, 2007). These results are mirrored by the experience of countless donor-funded programmes over the last 20 years: while small but significant mean improvements across the range of target schools are usually discernible, when the results are disaggregated by school, it is found that well under half the beneficiaries showed any change, with the majority proving to be impervious to interventions of any kind.

On the basis of insights gained from the first Dinaledi evaluation report and other research, the project was re-authorised in 2005, and plans were put in place to strengthen the intervention model. The number of schools in the initiative was increased from 102 to 400 (7% of all high schools) in 2005. Most significantly, the criteria for selection into Dinaledi has changed, and only those schools which achieve at least 35 mathematics passes in the SC exam among African children now qualify, on the assumption that only these schools have the threshold capacity required to benefit from the programme. In 2007 29 under-performing schools were dropped from the programme and 117 new schools added, making a total of 488 Dinaledi schools.

Table 2 - Number of HG maths passes from 2004 to 2007 for the 371 schools that became Dinaledi schools in 2005

Year	2004	2005	2006	2007	Change	% Change
HG M passes	3037	3635	3912	3843	806	26.5%
SG M passes			18788	21271	2483	13.2%

Source: Department of Education, personal communication

Table 3 - Number of HG maths passes in 2006 and 2007 for the 117 schools that became Dinaledi schools in 2007

Year	2006	2007	Change	% Change
HG Math passes	2375	2246	-129	-5.4%
SG Math passes	5558	6194	636	11.4%

Source: Department of Education, personal communication

In an important sense, the Dinaledi project is a tacit acknowledgement by the DoE that, in the face of weak management in the provincial departments, and generally weak school leadership, it is powerless to act in the majority of schools which exhibit poor levels of functionality. Many private sector donors are following suit and changing their modalities of support to schools, from models which formerly selected the poorest schools irrespective of quality, to programmes which target schools which exhibit some level of functionality. The bad news is that no one has yet found an intervention model which leverages significant change in the most poorly performing schools (Taylor, 2007); as Simkins (2005) shows, these institutions constitute the overwhelming majority of South Africa's schools. **Error! Reference source not found.**7 and 8 give an indication of the success of the Dinaledi programme to date: those schools which have been in the project since 2005 have increased the number of HG maths passes by 26.5% and the number of SG passes by 13.2%. Schools which entered Dinaledi in 2007 exhibit a decline in HG passes by 5.4% and an increase in SG passes by 11.4%. Clearly, it takes time for an initiative of this kind to begin to bite. The project was also hampered in 2007 by the teacher strike, which forced the postponement of the second teacher training in a number of provinces.

It is instructive to note that, of the 488 Dinaledi schools in 2007, only 186 produced more than 10 HG math passes, while 28 had none. In contrast, 250 Dinaledi schools produced more than 50 SG math passes, while 47 of these schools produced more than 100 SG passes. These figures indicate the propensity for South African schools to 'play safe' by attempting to excel at low standards, rather then aiming for higher goals and running the risk of failure. There is every indication that a good proportion of the candidates who obtained SG math passes would have passed at the HG level: the career opportunities of these children have therefore been severely curtailed by the conservative approach adopted by their schools. While the DoE is advising schools to enter a greater proportion of candidates at the HG level, these efforts are achieving less than the desired effects, despite incentives offered by the DoE and the private sector. The point is emphasised in Table 4, which shows that, while the number of Senior Certificate candidates has grown by nearly 21% since 2004, and SG math passes have increased by 11.5%, HG math passes have grown only 5%.

Table 4 – Senior certificate candidates with passes in mathematics

Year	Candidates	Change %	HG M pass	Change %	SG M pass	Tot M pass	Change %
2001	449371		19504		72301	91805	20.4
2002	471309	4.9	20528	5.3	96302	116830	27.3
2003	443821	-5.8	23412	14.0	99426	122838	5.1
2004	467985	5.4	24143	3.1	109664	133807	8.9
2005	508363	8.6	26383	9.3	112279	138662	3.6
2006	528525	4.0	25217	-4.4	110452	135669	-2.2
2007	564775	6.9	25415	0.8	123813	149228	10.0
04-07		**20.7**		**5.3**			**11.5**

The slowness of schools to respond to Dinaledi's combination of government directive, increased resources and substantial incentives emphasizes the slow rate of change in even a sample (currently less than 8%) of high schools, highlighting the enormous task of systemic change.

5. Can Dinaledi be scaled up?

While there are variations between provinces in the criteria used to select Dinaledi schools, these are by and large formerly African-only schools which produce a minimum number of math passes, and which can therefore be categorised as top- or moderately performing (Table 5).

Table 5 - Distribution of high schools by performance in mathematics, 2004

School type	Privileged schools*	African schools	Sub-total	Prop. of total	Prop. HG M passes
Top performing**	380	34	414	7%	66%
Moderately performing	254	573	827	14%	19%
Poor performing	600	4 277	4 877	79%	15%
Total	1 234	4 884	6 118	100%	100%

* Prior to 1994, administered by the House of Assembly, House of Representatives or House of Delegates

** Top performers produce at least 30 maths passes, with at least 20% at HG; moderately performing schools produce at least 30 math passes, mostly at SG, while poorly performing schools fail to achieve 30 passes in math.

Source: Simkins, (2005)

In three provinces some formerly whites-only schools which enrol a majority of African pupils have been included in Dinaledi, but these are exceptions. Table 5 shows that, if all top- and moderately performing schools were included in Dinaledi, then its number would immediately double (CDE, 2007). However, there would be an obvious political problem in including these schools, with their history of privilege, in the programme.

Whether formerly privileged schools are included in Dinaledi or not, there is another argument that the output of the programme could be increased by providing additional human and financial resources: the CDE (2008) advocates an increased budget, the allocation of appropriate professional and administrative staff, clear and consistent rules across provinces for adding or dropping schools, and a tighter coordination of private sector participation. Such measures are likely to increase the flow of suitable candidates to higher education; again, the exclusive nature of Dinaledi makes the case for increased resources a hard political one to argue, although ncreased private sector participation would moderate objections.

6. Conclusion

Three conclusions are pertinent to the present discussion. The first concerns the evidence that the inefficiency of the Grade R to12 pipeline places a low ceiling on the production of high level SET skills. While marginal gains in efficiency within the higher education sector are probably possible, any attempt to increase significantly the production of these human resources, so critical to the management of the economy, must find a way of dealing with the pipeline problem.

The second conclusion is that systemic change is far from easy to achieve. Dinaledi schools, selected on the basis of their higher capacity relative to other high schools, represent less than 8% of the country's high schools and well under 2% of all schools. Yet, effecting change through Dinaledi is proving to be a long and slow process. Clearly, leveraging higher quality from even one small part of the pipeline is proving to be far harder than had been hoped. This has as much to do with the country's ineffectual civil service and a poor work ethic as it has with teacher's low levels of subject and pedagogical knowledge.

The third conclusion is a larger point about the politics of change, and achieving a balance of focus between equity considerations and the imperative to improve efficiency. According to Crouch and Patel (forthcoming), attention needs to be given to both a 'rights' agenda and a 'skills' agenda. It would seem that government is trying to balance equity and efficiency, with programmes which range from increased allocations to the poorest schools through the building of infrastructure (still inefficiently implemented in many provinces), QIDS UP project and the funding of Grade R classes. While these three initiatives are largely directed towards achieving greater equity of inputs in the short term, if they succeed, they will lead to sustainable improvements in the quality of the pipeline. Government programmes which are directed primarily to addressing the skills agenda include Dinaledi, the rejuvenation of the FET college sector, and the new DoE differentiated approach to higher education (Taylor, Fleisch and Shindler, 2008). These programmes can be plotted on a grid which maps the extent to which they are aimed at achieving greater equity of inputs or increased numbers of high level skills, on one axis, or the extent to which they focus on the poorest institutions, on the other (Figure 5).

Crouch and Patel (forthcoming) make the point that schooling inputs and results are much more evenly distributed than societal income, which possibly bodes well for a more equal future, but that educational results are distributed much more unequally than inputs (though much more equally than income); while input equalization is increasingly taking place, the equalization of results is seriously lagging the equalization of inputs, and thus education is not contributing as much as it could be towards a more equal future.

Figure 5: Government priorities

<table>
<tr><th></th><th>Poorest schools</th><th>Less poor schools</th></tr>
<tr><td>Equity</td><td colspan="2" rowspan="2">Infrastructure
QIDS UP
Grade R rollout

Dinaledi
FET
Tertiary funding</td></tr>
<tr><td>Efficiency</td></tr>
</table>

Source: Constructed from Taylor, Fleisch and Shindler (2008)

In the short- to medium term, the extent to which government is able to increase the output of high level SET skills will depend to some degree on the extent to which it is able to exercise greater levels of differentiation in its programmes, which in turn depends on the extent to which it is able to carry the political cost of directing additional resources to traditionally privileged institutions. The success of such a programme, in the long term, will ensure that greater equity of results is achieved, as increased levels of SET skills begin to impact on a higher growth path.

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