Research report no 13

FROM LAGGARD TO WORLD CLASS

Reforming maths and science education in South Africa

THE CENTRE FOR DEVELOPMENT AND ENTERPRISE

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13

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CDE Research: Policy in the making is a vehicle for disseminating research findings and policy recommendations on crucial national challenges. Each issue is based on in-depth research, including numerous specially commissioned background research reports written by experts in the field.

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TABLE OF CONTENTS

Chapter 1

NOBODY'S FAULT; EVERYBODY'S PROBLEM

Educational planners and others involved in this sphere in virtually every country in the world are concerned about the poor quality of education in mathematics and physical science in their schools, and about the small numbers of learners leaving school with sufficiently high grades to enter maths- and science-based courses at tertiary institutions. They are also concerned about the small numbers of students being trained to become educators in these two subjects. Given this shortage of educators, and the fact that many of those who do teach these subjects are not confident about their abilities, the quality of teaching and learning in these subjects is declining in many countries, with a number of negative consequences for those societies.

In a recent influential book, *Changing the subject*, in which they review innovative maths and physical science projects in numerous countries, the internationally renowned educationists Paul Black and J Myron Atkins conclude that:

> Educational reform is under way everywhere. No one seems satisfied with the schools anywhere. At the moment, science, mathematics and technology education in particular are the subjects of special attention. Partly because there are apparent connections between these fields and economic productivity, partly because they seem essential for survival in what appears to be an increasingly complex, technological, puzzling, and risky world.[1]

South Africa is no exception. As long ago as the 1970s, concern among key figures in the private sector resulted in the funding of projects such as the Science Education Project. In an era in which education was strictly centrally controlled, the tolerance of the government of the day for such projects was surprising (presumably, it did not believe that they would have a significant effect). Private and public initiatives in maths and physical science education continued throughout the 1980s, though without the profile of much more politicised concerns about the education system in general which started with the 1976 student uprisings in Soweto and elsewhere.

Following South Africa's transition to democracy, the state launched major initiatives to improve maths and physical science education (see chapter 4), and the private sector also stepped up its contributions to this area (see chapter 6). However, while these efforts may have had some impact, they have had no discernible effect on the system as a whole. Enrolment for SG maths has increased significantly in recent years, but the pass rate in 2003 was only 44,7 per cent – less than the pass rate in 1991, and far less than the SC average of 73,3 per cent. Conversely, the pass rate in HG maths has improved – but enrolment has plummeted, from 65 616 in 1995 to 35 959 in 2003. The same broad pattern is discernible in physical science. The upshot is that the maths and science education system is producing only a fraction of the skilled SC graduates required to meet the country's needs. Also, maths and physical science learners in South African schools consistently perform the worst in comparisons with learners in other developing countries (chapters 2 and 3 tell the full story.)

In 2006 the SC is to be replaced by a Further Education and Training Certificate (FETC), based on a new curriculum and a new model of assessment. While the FETC will have obvious effects on teaching and learning, its specific impact on maths and physical science cannot be predicted with any accuracy. However, as chapter 4 shows, it is unlikely that the levels of participation and performance in SC maths and physical science will improve dramatically in the short term, particularly in the new subject 'mathematics' (the equivalent of SC HG maths).

The greater publicity given to SC results in recent years, and the improved collection of information from all nine provinces, has led to a greater public awareness of the problems in the maths and physical science education subsystem. In 1999 these concerns manifested themselves at the highest level when president Thabo Mbeki, in his first opening address to parliament, committed his government to a special initiative to boost maths and physical science education. In July 1999 the then minister of education, Professor Kader Asmal, featured the shortcomings in these two subjects in his Tirisano Programme, an ambitious statement of intent to improve all aspects of the education system that remains the mission statement of the national department of education (NDoE) to this day. A few months later, a deputy minister was appointed with specific responsibility for this area (these and other government initiatives are discussed in detail in chapter 4.)

Also, as the new millennium began, leading South African companies became more aware than ever of national deficiencies in maths and physical science education, and increased their social expenditure in that area.[2]

Inter alia, these businesses became concerned about the following:

- In a context of globalisation, economies are increasingly dependent on entrants who are well grounded in maths and physical science. They are needed not only as technical experts but also as effective managers and administrators who are capable of utilising sophisticated technology in order to achieve gains in efficiency and efficacy. Shortages of new entrants to the workplace with maths and science qualifications is a worldwide phenomenon, but are more acute in developing countries. Indeed, this has become one of the markers of underdevelopment.
- The growing importance of technology in all spheres of life has made it more important than ever before to develop communities with a reasonable understanding of science and technology. For example, many poorer people are disadvantaged by an inability to make use of electronic communications, or access information by computer. Many analysts believe the survival of genuine democratic participation in the 21st century depends on technologically literate citizens.
- The South African educational system is not producing the numbers of people skilled in science and technology which the economy requires. As a result, the country is experiencing huge numbers of vacancies for skilled workers on the one hand, and high levels of unemployment among unskilled workers or work-seekers on the other.

In October 2000, CDE convened a workshop aimed at assessing whether yet another study of the problems associated with maths and physical science education at school level might help to improve the pass rates in these subjects, and, if so, how it should be designed. Participants included representatives of maths and physical science departments at universities, NGOs, and privately funded projects, as well as individual experts. The CDE study was launched in November 2000, with the financial support of a consortium of private sector companies and organisations (see appendix 1).

OBJECTIVES OF THE STUDY

This study is aimed at proposing changes in national education policy as well as practical interventions that will improve the performance of the maths and physical science education system – specifically, to double the pass rate in HG SC maths and physical science within five years.

Generating these proposals has meant venturing into areas of curriculum, assessment, educator development, and school practice, in South Africa and internationally. However, the purpose of this study – and thus the research question that CDE has sought to answer – remains simple**:** to identify changes in policy and practical interventions that will enable the existing maths and physical science education system to generate growing numbers of SC graduates with better marks, especially in the higher grade.

Numerous education projects have demonstrated that South African learners are quite capable of mastering maths and physical science, even in areas where opportunities for teaching and learning remain poor. Indeed, extraordinary examples exist of learners' capacity to succeed under adverse circumstances.

Therefore, the task at hand is not to demonstrate why South African youths cannot learn these two subjects in their current form, or taught with current methods (the subject of traditional research). Rather, it is to propose changes to the existing system that will allow far larger numbers of learners to succeed.

Therefore, we will not consider or propose innovations based on an alternative theory of how maths and physical science should be taught. Instead, we will propose a set of focused interventions for resolving specific problems at the SC level which, if implemented, will have a positive and cumulative impact on the rest of the system.

More specifically, the proposals are aimed at achieving the following outcomes:

- an increase in the number of schools with competence in these subjects;
- greater learner participation, and improved performances;
- more competent teachers, preferably university graduates; and
- an increase in national confidence in maths and physical science education at senior secondary schools.

These outcomes would lay the foundation, and create the time, for the comprehensive, system-wide reforms that will ultimately be required. CDE believes some of them can be achieved in the short term, and within the confines of the present system. We believe that by building on the strengths of the existing system, and the successes achieved by existing schools, a framework can be established for a longer-term, sustainable, and gradually expanding programme that will take the country towards its educational goals.

A STRATEGIC PERSPECTIVE

In the course of determining new strategies, the most productive step is often to decide what *not* to do; the challenge is to identify a manageable number of key objectives, and formulate achievable plans for achieving them. In pursuing a limited number of practical and achievable outcomes, this study does not address a number of issues that experts in maths and physical science education might regard as important or essential.

First, it does not propose an alternative theoretical base for maths and physical science education in South Africa. This decision is not meant to imply that all is well theoretically or conceptually with these two subjects, their curricula, or the methods used to teach them. Certainly, in the longer term there is much that should be improved in all these fields. For example, the curricula for the proposed FETC are currently being redesigned; however, the changes will not be introduced before 2006. Meanwhile, there is clear evidence that many more South African learners *can* succeed in SC maths and physical science under the present dispensation (see chapter 3), and go on to further study and/or productive employment, without large-scale and potentially disruptive changes to the system as a whole.

In fact, should such changes be introduced all at once, they would almost certainly have a negative effect. The fragile maths and physical science delivery system is already staffed by too few qualified personnel, and most educators would battle to adopt wholesale new approaches. CDE is convinced that it is more important in the short to medium term to increase the number of learners succeeding within the present dispensation, not only because our research has shown that this is possible, but also because we believe that the 'new' FET dispensation will still take some time to bed down.

Secondly, the study accepts and confirms the important tenet that improvements in the quality of teaching and learning largely hinge on the performance of educators. It is therefore also important to attract a higher percentage of school-leavers with HG maths and physical science to tertiary education, so that they can be trained as teachers in these subjects in turn, and to ensure that posts are available for them once they qualify. Given a larger number of better qualified educators who are more confident about their subject matter and educational techniques, changes in the curriculum and teaching methods are far more likely to succeed. This study focuses on ways in which this can be achieved, within a framework that already exists in part, and within a realistic time frame of about five years.

Thirdly, the study rejects any reliance on a single 'bottom-up' approach to changing the system. South Africa does not have the time or the resources (especially the educators) to do this. Our research and analysis have convinced us that there is a large pool of potentially successful SC candidates in these subjects. But many of them are not attempting these subjects, and those who do are not performing as well as they could. If we change this element of the cycle, it will lead to further changes, such as building a larger and better qualified educator corps.

These considerations have led to a decision to focus on only the upper level (grades 10–12) of school maths and physical science, and particularly in the HG. This is not meant to imply that all is well with primary and lower secondary school maths and physical science education, or with standard grade (SG) SC performance. But statistics as well as the case studies commissioned for this study show that significant numbers of learners are reaching grade 10 with measurable potential, and could in fact pass either or both subjects in question in the HG in grade 12 provided conditions for teaching and learning, motivation, and subject and career counselling during the final three school years are improved.

Our immediate challenge is to realise this potential within the present system. Then, with the confidence bred by success, we can aim for more ambitious targets.

Good work is being done, and successful initiatives are under way. Nonetheless, the fact remains that the system is consistently failing to deliver the number of SC graduates in HG maths and science which the education system and the economy needs.

Therefore, there is cause for alarm. However, in undertaking this study, CDE has been guided throughout by the realities of reform, and the difficulties of implementation in a developing country recovering from the legacy of apartheid. We have continually looked for what is working, trying to identify elements on which a new system could be built.

Our own experiences in analysing and assessing complex national policies and very large systems and programmes of delivery have led us to this approach. However, we found support for this approach in the international education reform literature reviewed for this project. Black and Atkin, for example, support a balanced view of education reform. Two further excepts are relevant here. In the first, the authors rightly criticise the tendency to characterise every educational system as a failure:

> There is another cause for concern in today's approaches to educational reform. There is a too-ready assumption abroad that all past endeavours to improve schools have failed. The implications are very serious. A belief that there is a general and fundamental breakdown of our schools – not an uncommon view in some countries – leads policy makers to 'solutions' that challenge many of the foundations of their public education system. [They propose] new solutions, but no one can be sure that they will not create new and even tougher problems.[3]

Rather than supporting changes based on a pervasive sense of failure, or on radical theories demanding that educational systems be changed instantly and totally, Black and Atkin believe that reforms should build on existing strengths. They argue that educational systems are always changing ('… there can be no end to educational reform'[4]), and propose that a more evolutionary approach should be adopted:

> Where the direction of policy is towards finding fault rather than finding virtue, it is difficult to move to a more evolutionary view of educational change, one that recognises that there is normally much of value in the existing system. What needs improvement has not necessarily failed.[5]

We encountered these views early on in our research; they resonated with our own, and therefore helped to set the tone for this study.

BOX 1.1: THE REPORT IN OUTLINE

Chapter 1 explains why maths and physical science education is vitally important to a new democracy with an emerging market that has to integrate with the global economy. It states the purpose of the project; describes the nature of the research conducted; identifies the financial supporters of the project; and explores the project's commitment to research-based proposals for incremental reform of the maths and physical science education system.

Chapter 2 provides a first analysis of the empirical comparative data, both quantitative and qualitative. Although many countries are dissatisfied with their results from comparative tests, South Africa fares much worse than other countries. And the weaknesses extend across the entire system. There is no evidence that it is getting better. A preview of the CDE approach to reforms is outlined. These must be: systemic; change 'of' not 'in' the system; participatory; build on virtues; practical. All require motivation and dictate focus on areas likely to produce results quickly to give evidence of a turn around in the trends.

Chapter 3: The most detailed analysis yet undertaken of SC results over time shows that the number of candidates entering maths and physical science exams is increasing at SG level, but declining at HG level. Pass rates are lagging at both levels, as are absolute numbers passing HG. This is caused by a complex set of reasons, leading to a need for disaggregated data and more precise targeting of policies and strategies. CDE's methodologies provide the means to analyse data by province, school and individual candidate, including gender and (since 2002) 'race'. Gender is no longer in itself a key reason for failure. The most important determinant is the school and the qualification and experience of the educator. A higher level of proficiency in English is vital for success by first African language speakers. A large number of potentially successful candidates are not studying the subjects or entering the exam because of preconceptions of failure. On average, educators are underqualified (especially as regards content knowledge) and inexperienced. Only 14 per cent of schools have sufficiently qualified and experienced educators.

Chapter 4 deals with government initiatives since 1994. The chapter considers efforts at establishing a new unified national education system in the first decade of democracy. The Further Education and Training (FET) band is analysed and efforts at phasing in OBE into the FET curriculum examined for their impact on learning and teaching, and on the subjects maths and physical science in particular. At national level there have been 8 initiatives launched to target maths and physical science education, while at least 2 others have had effects on maths and physical science, though these were not intended. All provinces have specific initiatives in the field. After analysis of each we have regrettably to conclude that not a single initiative has yet had a measurable, beneficial impact, despite large scale expenditure. Some have even had negative effects, for instance the ill-advised redeployment of and packages offered to maths and physical science educators in the 1990s and the current model of 'pro-poor funding' applied without awareness of changing situations. The most important current project, Dinaledi, is soundly-based, but shows several flaws in conceptualisation and implementation. The key reasons for government failures are: over-ambitious policies, policy discontinuities, inadequate preparatory capacity building, inattention to the human aspects of the process of change and inadequate time scales for implementation.

Chapter 5: New research by CDE is reported, analysing the views of educators, researchers, officials and examiners and presenting 13 detailed case studies of what actually happens in schools where maths and physical science are being taught and learnt with different degrees of success. Everyone knows there are problems; mostly they know what the problems are and what needs to be done to improve the situation. What they do not want or need is further intervention based on theoretical and over-ambitious plans and policies. They want focussed help so that they can improve performance within a system that is stable (at least for the moment) so that results can improve, more educators can be trained and gain experience, and the factors for school success can be consolidated. In this way a base for successful system change can be built.

Chapter 6: A review of private sector maths and physical science initiatives based on a national directory of engagement is presented, with analysis of the various categories of private sector involvement across the full range of such initiatives from single once-off inputs to complex nationwide corporate consortium-funded school development programmes. The nature of current private sector engagement with the public sector in large 'whole school' development programmes is considered, and their defining features and programme characteristics outlined together with an evaluation of their systemic effects on maths and physical science learner participation and performance. We ask the question 'How can the private sector under current conditions and working with the education authorities can best make a difference in terms of our project goal of improving maths and physical science HG participation and performance rates?'

Chapter 7: A review of the current literature on reforming maths and physical science education worldwide contains more than enough insights applicable to South Africa. The most important are: maths and physical science education is a sub-system of the education system and systemic change/reform provides the best basis for successful actions; policies are necessary, but should be highly focused and specific, and depend on carefully planned implementation; change must begin with the professional development of educators, itself based first on improving and updating content knowledge; teaching methods remain important but will not change positively if educators are unsure or ignorant of the content; changes must be incremental and achievable, but cumulative in impact; announcing large scale changes that are then not achieved is counter-productive; participation by all stakeholders including parents is required; modern development theory and practice shows that people respond to incentives, not to pressures; accordingly incentives should be offered to educators, principals, learners, parents and the private sector.

CDE 2004

It is a very different approach to one which says that everything is wrong with a given system, and we must therefore change everything at once. Experiences over the past ten years in many sectors of South African life have served to emphasise the importance of identifying 'what works', and building incrementally on that base to achieve increased delivery that is more sustainable, effective, and fair. Throughout this report, we will refer to this guiding philosophy of change.

At the same time, it is clear that this vital element of our education system is failing to deliver; indeed, in 2003 the system produced only 2 735 more HG maths passes – and

2 958 more HG physical science passes – than it did in 1991. Given the massive growth in the number of SC candidates since then, it is clear that a national crisis has developed in maths and physical education, with serious implications for economic growth. Moreover, the poor quality of schooling in these subjects is probably the single biggest obstacle to African advancement in this country.

THE SCOPE OF THE PROJECT

The goals of this project are ambitious, and we will propose some interventions that may seem controversial or different from those currently favoured by the government and the private sector. However, CDE believes strongly that this study is as wide-ranging and systematic as any other single investigation of this area in South Africa to date. It covers many dimensions of the research question set out above, and has drawn in more people concerned with maths and physical science education than have been involved in any single previous research enterprise. Participants in workshops, interviewees, researchers, data collectors, educators, learners, and others involved in the study in one way or another total more than 1 000.

Twenty-nine research reports and many more background research papers have been produced. They are summarised below, and listed in appendix 2.

The research method used has been developed and tested by CDE during a number of previous investigations in other fields. As previously indicated, an initial workshop was held, attended by experts and practitioners, in order to identify the main area of enquiry. Once initial research funding had been obtained, a project team was appointed; its members are listed in appendix 2. Drawing on the results of the workshop, and the expertise of the project team, the initial research briefs were finalised and researchers contracted to carry these out.

Research and data collection continued throughout 2001 and 2002. Each researcher or team of researchers submitted a draft report that was scrutinised and commented on by the project team, and then revised. In two cases, prominent external readers (one of international standing) were engaged to conduct peer reviews of the research.

A small number of focused investigations were launched in late 2002 and early 2003 to cover areas whose importance had become evident during the research process.

Early drafts were criticised by the project team, and later drafts discussed during three testing meetings held with a wide range of interested parties, including senior education officials in the NDoE and the provinces, and members of the education and NGO community and the private sector. The draft was appropriately revised, although not all views could be accommodated. The final draft was then discussed and approved by the project team.

RESEARCH COMPONENTS OF THE PROJECT

Ultimately, 29 research reports will be made available. These are listed alphabetically by author(s) in appendix 2. They cover the following areas:

- a statistical analysis of overall trends in performance in maths and physical science SC examinations in 1998-2002;
- a study amplifying the basic data, and providing a more detailed analysis of the results of SC examinations in maths and physical science between 1998 and 2003;
- a report relating the individual results, performance by individual schools in these subjects, and language to a range of determinants in various communities;
- a comparison of South Africa with ten other developing countries, two of them African, based on quantitative and qualitative data obtained from the Third International Mathematics and Science Study (TIMSS-R);
- an analysis of 40 structured interviews conducted with officials, educators, and experts in maths and physical science education in South Africa;
- 13 case studies of schools in five provinces whose students perform well in maths and physical science at SC levels, and a composite analytical report;
- an international literature review for 1996–2002;
- a study of 'teacher incentives' worldwide and their possible relevance to maths and physical science education in South Africa;
- a report on four workshops on SC maths and physical science examination papers;
- an overview (certainly not exhaustive, due to difficulties in data collection) of private and privately funded initiatives (including research) in maths and physical science education in South Africa during the late 1990s;
- a confidential paper on current dynamics in education policy reform in South Africa;
- a study of specialised maths, physical science, and technology schools in England and their relevance to South Africa;
- an evaluation of initiatives in maths and physical science education undertaken by national and provincial governments in South Africa since 1994;
- a report on current proposals for the FETC and their significance for maths and physical science learning and teaching; and
- a review of the Dinaledi ('102 schools') programme, 2001–2003.

CONCLUSION

Many maths and physical science learners are succeeding under the present system, though not in sufficient numbers, nor in enough secondary schools. We believe we have identified some of the reasons for this, and how these successes have been achieved. Using 'best practice' approaches, we propose changes to the system that will encourage larger numbers of learners to enrol for these subjects at the SC level, and to improve their performances. We then argue that incentives should be provided for many more successful learners to enter teaching careers in these two subjects. A larger, more recently qualified educator corps will provide an effective platform for improving maths and physical science education throughout the system. This will take time; however, without this the system cannot be changed. CDE believes that South Africa has the essential components in place to improve the system in an orderly and incremental way. This approach is supported by virtually all experts in managing educational change, including international experts. We therefore believe that, if we concentrate the resources of all stakeholders in education, and gradually, through common effort, begin to raise the bar, the maths and physical science education system will look very different in five years' time than it does today.

ENDNOTES

1 P Black and J Myron Atkin, *Changing the subject*, Routledge, 1996, p 187.

2 Trialogue, *Corporate Social Investment Handbook 2000*, Cape Town.

3 Black and Atkin, *Changing the subject*, Routledge, 1996, p 198.

4 Ibid, p 199.

5 Ibid, p 199.

Chapter 2

OBVIOUSLY WE HAVE A CHALLENGE – BUT EXACTLY WHAT IS IT?

Albert Einstein once observed: ‘No problem can be solved at the level at which it was created.’ This chapter is influenced by this observation, and culminates with an attempt to place proposals for reforming the maths and science education system on a new and higher level. But we first need to define the ‘problem’ in its own terms.

To do so, we provide a quantitative picture of learners’ performance in maths and physical science at South African schools, show how this compares with the situation in a number of other countries, and present data on the numbers and qualifications of maths and physical science educators in South African schools.

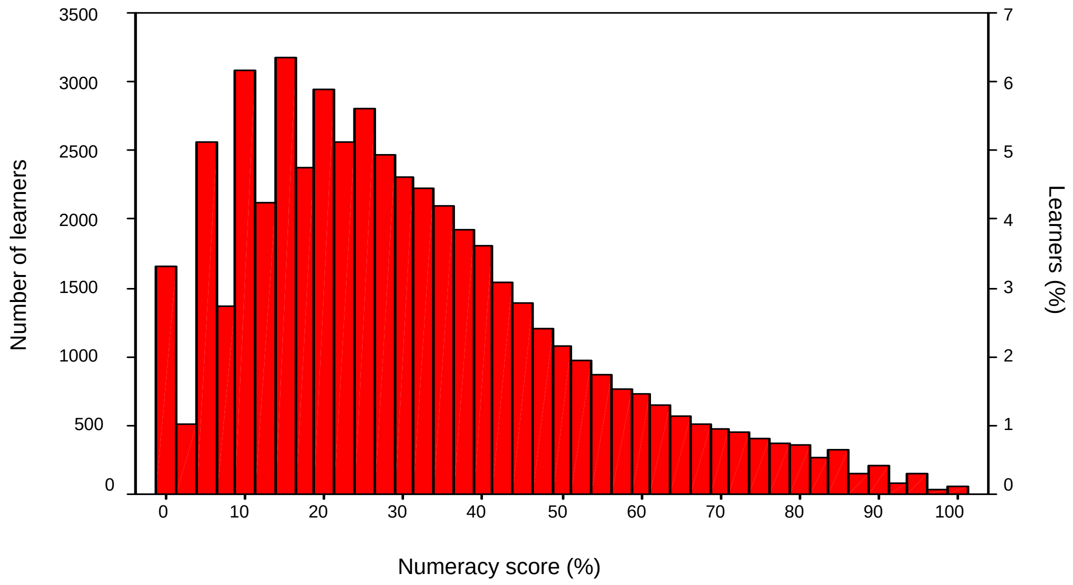
We conclude with a preview of the most recent international thinking on the centrality of maths and physical science to any modern educational system. We are then in a position to outline a higher-level solution.

EARLY SIGNS OF THE CHALLENGE: GRADES 3 TO 11

In 2001, the NDoE evaluated the literacy and numeracy of a 5 per cent sample of grade 3 learners at urban, rural, and farm schools. The results were disturbing; average scores were only 54 per cent in literacy tests, and only 30 per cent in numeracy tests. The literacy score was higher because the participants scored 68 per cent on average in listening comprehension; however, they only scored 39 per cent in reading comprehension and writing.

Figure 2.1 illustrates the distribution of numeracy scores, showing that most learners did very badly:

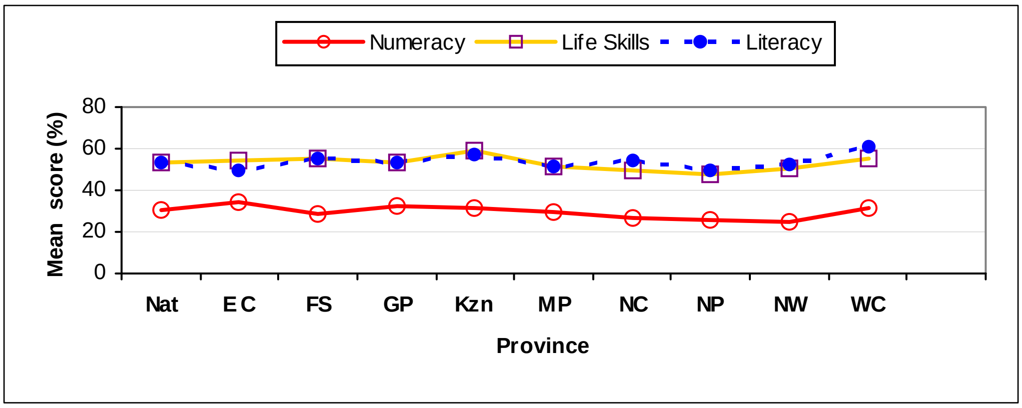
Figure 2.1: Distribution of numeracy scores



Source: National Department of Education, Foundation Phase Systemic Evaluation 2001 (Mainstream), p 60.

These results were broadly similar across all provinces, as figure 2.2 illustrates.

Figure 2.2: Learner scores by learning area and province



Source: National Department of Education, Foundation Phase Systemic Evaluation 2001 (Mainstream), p 62.

The report concludes: 'The poor numeracy and literacy skills of learners within the system point to the need for urgent intervention to address this situation.'[1]

Taylor, Muller, and Vinjevold provide information about nine other studies conducted by the Joint Education Trust (JET) in the period 1998 to 2002 that included learner assessments relevant to maths and physical science,[2] covering grades 3, 4, 5, 6, 7, 9, and 11.

The authors report that, following their pilot studies, all the tests had to be made easier just to obtain data that discriminated between learners at the grade level being tested; for example, the difficulty of the grade 3 study had to be reduced to grade 2 level to obtain measurable results. At the original level of difficulty, a majority of learners did not score at all. Even after reducing the difficulty by one grade, and allowing for a reasonable degree of learner unfamiliarity with the tests and testing process, the results indicate very low levels of maths and physical science competency. Observations from three of the assessments include the following:

- **JET Grade 3 numeracy assessment**: This assessment involved tasks in counting and ordering, addition, subtraction, and multiplication. The average score of the whole sample in counting and ordering was 42 per cent; in addition, 60 per cent; in subtraction, 53 per cent; and in multiplication, 45 per cent. This implies that between 40 per cent and 58 per cent of grade 3 learners actually failed grade 2-level numeracy tests of the simplest kind.
- **Monitoring learner assessment**: As part of an international survey of 12 countries, JET applied standardised numeracy and literacy tests to 10 000 South African grade 4 learners. Their average score in the numeracy test was 30 per cent – the lowest of all 12 countries. A large proportion of learners scored below 25 per cent, and only 2 per cent scored above 75 per cent.
- **Quality Learning Project baseline evaluation**: JET conducted this study among grade 9 and 11 learners at 17 separate locations in order to determine the quality of learning. The average scores of grade 9 learners were 22 per cent in maths; 30 per cent in English; and 58 per cent in Afrikaans. The average scores of grade 11 learners were 20 per cent in maths, 33 per cent in English, and 50 per cent in Afrikaans.

The authors comment:

> Studies conducted in South Africa in the last five years suggest that learner scores are far below what is expected at all levels of the schooling system, both in relation to other countries (including other developing countries) and in relation to the expectations of the South African curriculum.[3]

International comparative data indicate that South African learners may be in a worse position than those in virtually any other country that gathers and/or publishes information about its education system. One widely accepted comparative measure is that provided by the Third International Mathematics and Science Study-Repeat (TIMSS-R), conducted in 1998–9. South Africa was among 38 countries that participated in this study. Some of the other participants were developed countries, and legitimate questions arise about the grounds for comparisons between them and South Africa. However, the sample also includes at least ten other countries that are closely comparable to South Africa. CDE decided to focus its analysis on these ten developing countries; the results are given in table 2.1.

Table 2.1: A comparison of 11 countries that participated in the TIMSS-R in terms of selected social and economic data

Country	GNP per capita (US$)	Expenditure on education as % of GNP	% unemployment (% of total labour force)[4]	Population (millions)	Area (1 000 km²)	Life expectancy at birth	Adult literacy rate (%)
Chile	4 740	3.6	8.9	15.0	757	75	94.5
Czech Republic	5 060	5.1	9.4	10.0	79	74.5	–
Indonesia	580	1.4	6.4	207.0	1 905	65.5	85.5
Korea	8 490	3.7	6.3	47.0	99	74.5	97.5
Malaysia	3 400	4.9	3.4	23.0	330	72.5	86.6
Morocco	1 200	5.0	22	28.0	447	67	47.0
Philippines	1 020	3.4	9.6	77.0	300	69	95.0
SA	3 160	7.9	32,6	42.0	1 221	63.5	84.5
Thailand	1 960	–	3.0	62.0	513	72.5	95.0
Tunisia	2 100	7.7	15.8	9.0	164	72	68.5
Turkey	2 900	2.2	7.7	64.0	775	69.5	84.0

Source: S Howie and P Vinjevold, Report on 11 countries that participated in TIMSS-R, CDE background research report, 2002.

South Africa scored lowest in unemployment, and highest in expenditure on education. Yet it was by far the worst performer in maths and physical science in grades 8 and 9, as shown in table 2.2.

Table 2.2: Average learner mean scores in maths and science tests, TIMSS-R, 1999

	Maths		Science	
	Mean score out of 800 points	Std error	Mean score out of 800 points	Std error
Chile	392	4.4	420	3.7
Czech Republic	520	4.2	539	4.2
Indonesia	403	4.9	435	4.5
Korea	587	2.0	549	2.6
Malaysia	519	4.4	492	4.4
Morocco	337	2.6	323	4.3
Philippines	345	6.0	345	7.5
South Africa	275	6.8	243	7.8
Thailand	467	5.1	482	4.0
Tunisia	448	2.4	430	3.4
Turkey	429	4.3	433	4.3
International average	487	0.7	488	0.7

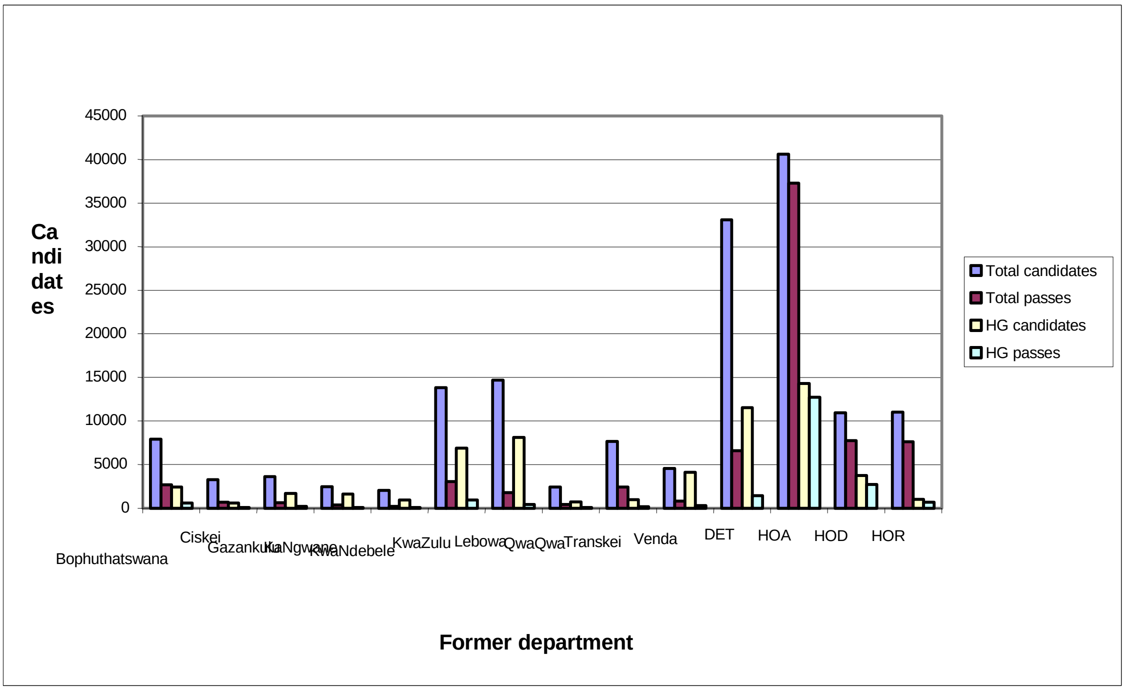
Source: S Howie and P Vinjevold, Report on 11 countries that participated in TIMSS-R, CDE background research report, 2002.

In maths, South Africa's mean score was a full 70 points below that of the next lowest country, and in physical science, 80 points below. The inescapable conclusion is that South Africa is experiencing severe problems in maths and physical science in grades 8 and 9, even when compared to countries at similar stages of development, and certainly in relation to expenditure on education.

Outcomes at the SC level

Learners' performances in the SC examinations – the final school-leaving examination – have never been satisfactory. The apartheid order skewed educational achievement by race, as is evident from figure 2.3. Figures 2.3 and 2.4 show that enrolment and output in both maths and physical science was dominated by departments of education falling under the white, coloured, and Asian houses of the tricameral parliament, and particularly that under the white house of assembly.

Figure 2.3: Candidates and passes in SC maths by government department, 1993

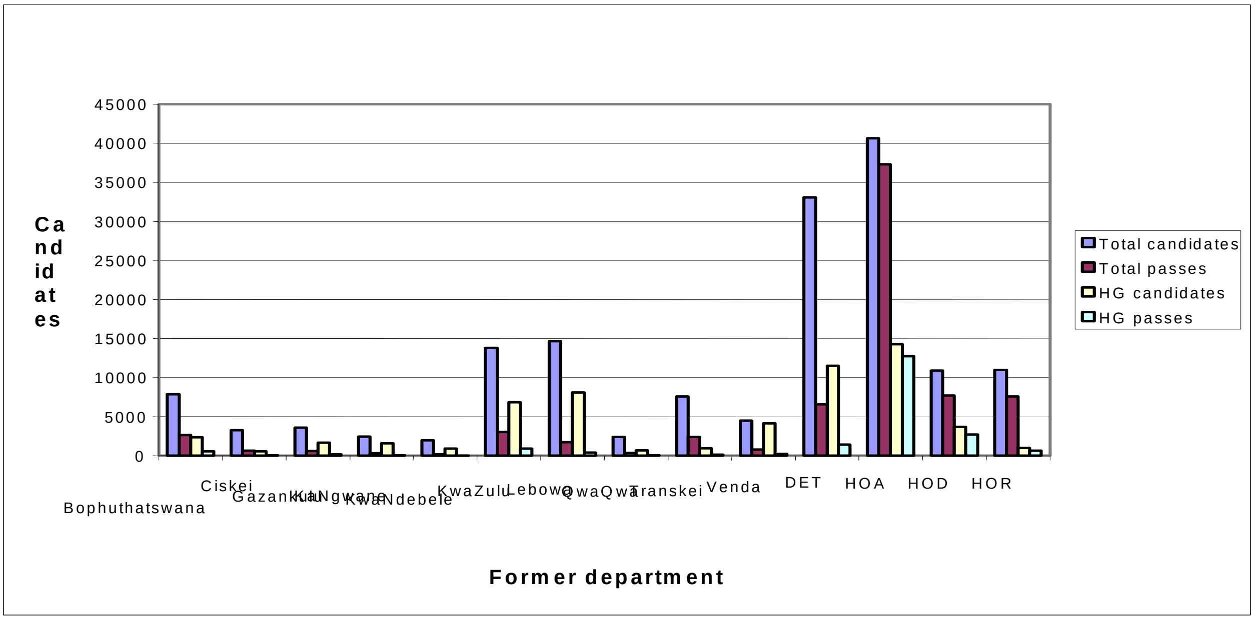


Source: H Perry, Mathematics and physical science performance in the Senior Certificate examination, 1991-2003, CDE background research report, 2004.

More specifically, our research shows that in, 1993, some 39,6 per cent of all maths candidates and 32,5 per cent of all HG maths candidates fell under the tricameral departments; however, these candidates produced 73,1 per cent of all maths passes, and 79,4 per cent of all HG maths passes.

Candidates falling under the black department of education and training (DET) achieved a pass rate of 19,9 per cent. Therefore, while this group constituted 20,9 per cent of all candidates, only 9,1 per cent of them passed.

Figure 2.4: Candidates and passes in SC physical science by government department, 1993

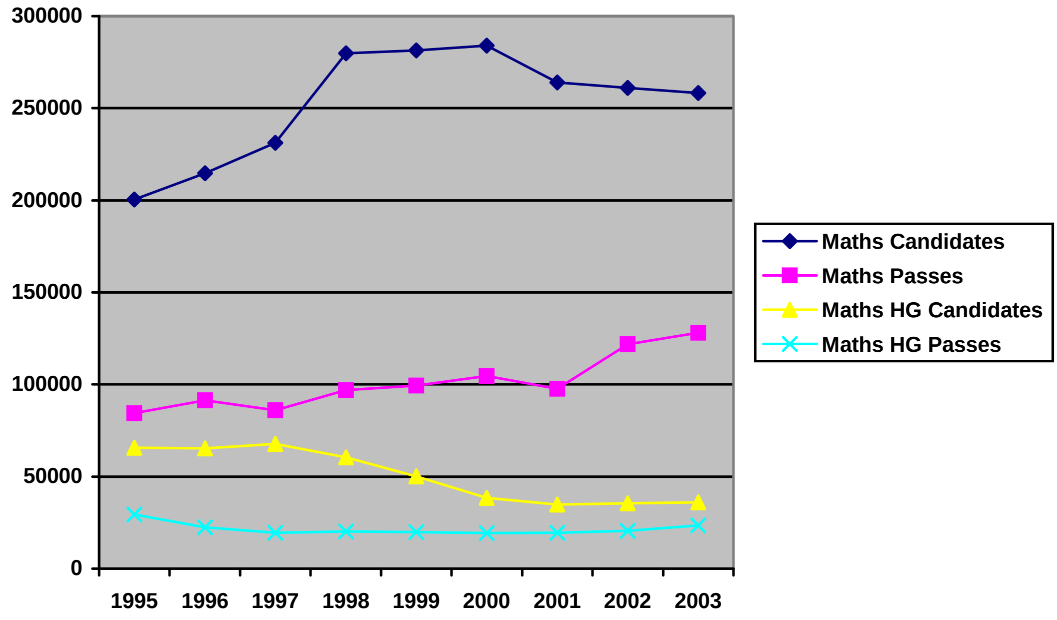


Source: Perry, Mathematics and Physical Science performance in the Senior Certificate Examination.

As regards physical science, in 1993, some 42,6 per cent of all candidates and 35,9 per cent of all HG candidates fell under the tricameral departments. However, 60,9 per cent of all physical science passes and 75,0 per cent of HG passes fell under these departments. While candidates under the DET constituted 22,2 per cent of the total physical science candidates, only 13,9 per cent of them passed.

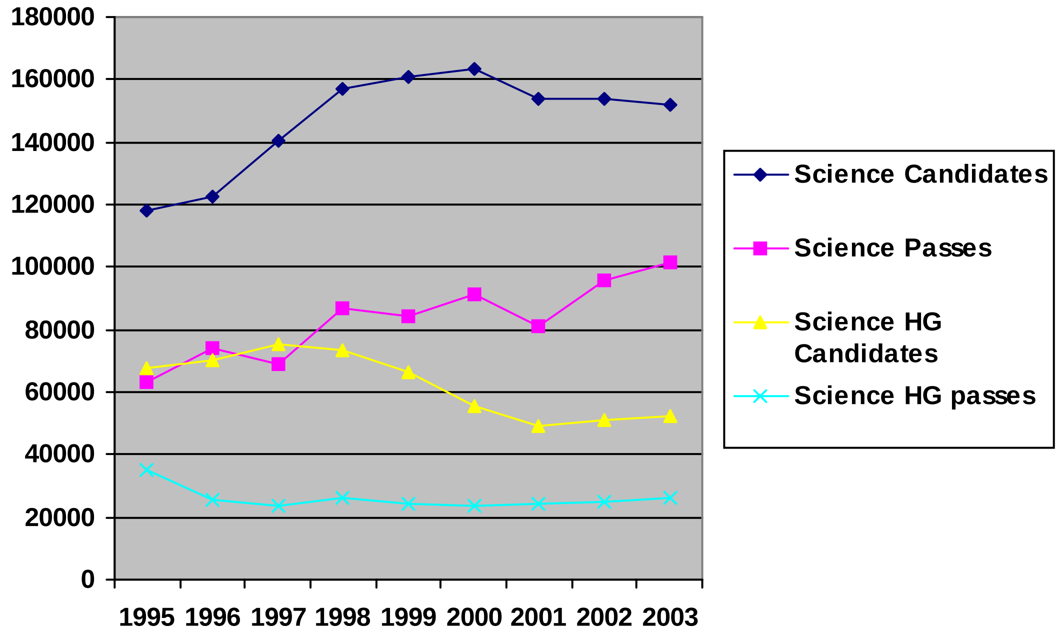
These figures convey the heavily skewed situation just before the transition to inclusive democracy. Figures 2.5 and 2.6 depict developments since then.

Figure 2.5: Full-time candidates and passes in SC mathematics, 1995–2002



Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Figure 2.6: Full-time sc candidates and passes in SC physical science, 1995–2002



Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

These two tables show a consistent inverse relationship between enrolment and performance; the more learners enrol for any of these four subjects, the worse their pass rate, and vice versa. Experts say this demonstrates the widespread approach by school principals and educators pursuing good SC results to discourage all but the most talented learners from enrolling for HG maths or science. Thus the improved pass rates in HG maths and science are being achieved at the expense of participation, and the improved participation in SG maths and science are not being translated into results.

Overview of data

These selected statistics show that South Africa faces a massive problem. From an early stage in their schooling, large numbers of learners are falling behind in the two key subjects of a 21st-century curriculum. By grade 8, the country is decisively disadvantaged internationally. By grade 12, only a fraction of learners studying maths and science do so in the HG, however much they are needed to fill key jobs and, above all, become properly trained and qualified maths and physical science educators who can help to reverse these trends in the schools.

The qualifications of maths and physical science educators

Data from the NDoE's Education and Management Information System (EMIS) were used to get a picture of the qualifications of educators teaching maths and physical science in secondary schools. At the time of compiling this report, this was the most recent data available and even then did not cover Limpopo (previously Northern Province), or reflect data about individual educators. The 1999 database was available, but did not include data on individual Western Cape educators. The results are presented in table 2.3 below.

Table 2.3: Educators at secondary schools, and those specialised in maths and physical science, 1998

Province	Total educators in EMIS	Number of educators with individual records	Educators with maths specialisation	% of educators	Number of educators teaching maths	% of educators	Educators with physical science specialisation	% of educators	Number of educators teaching science	% of educators
Eastern Cape	15 715	15 284	2 647	17.3%	2 185	14.3%	2 290	15.0%	2 024	13.2%
Free State	8 283	8 185	1 265	15.5%	973	11.9%	756	9.2%	722	8.8%
Gauteng	19 805	19 436	3 750	19.3%	3 095	15.9%	2 367	12.2%	2 128	10.9%
KwaZulu Natal	26 305	25 447	4 887	19.2%	4 111	16.2%	3 347	13.2%	3 600	14.1%
Mpumalanga	9 078	8 482	1 649	19.4%	1 287	15.2%	1 099	13.0%	1 044	12.3%
Northern Cape	2 349	2 430	494	20.3%	233	9.6%	222	9.1%	231	9.5%
Limpopo	-	-	-		-		-		-	
North West	8 316	7 001	1 201	17.2%	961	13.7%	1 127	16.1%	690	9.9%
Western Cape	10 452	7 309	1 354	18.5%	943	12.9%	833	11.4%	916	12.5%
Total	100 303	93 574	17 247	18.4%	13 788	14.7%	12 041	12.9%	11 355	12.1%

Note: 'Specialisation' is a term used in the EMIS database; it means that educators need to have graduated in maths and/or physical science in the course of a higher education qualification.

Source: C Simkins, School and community determinants of mathematics and physical science results in the SC examinations of 1998 and 2000, CDE background research report, 2003.

The table shows that some 4 000 maths and physical science teachers (about 4 per cent of the total) with specialisations in maths and/or physical science were not teaching these subjects. Therefore, despite the shortage of maths and physical science educators, those who were available were not being properly utilised. Only 14,7 per cent of educators teaching maths have a maths specialisation; for science, the figure is 12,1 per cent.

Table 2.3 shows the percentage of educators at secondary schools with mathematics or physical science specialisations who have a university degree. Unfortunately, the EMIS98 database does not show whether the degree is in mathematics, physical science, or some other subject altogether.

Table 2.4: Educators teaching in secondary schools with specialisations in mathematics and physical science, and percentage with a degree (not necessarily in mathematics or physical science), 1998

Province	Educators with maths specialisation	Percentage with a degree	Educators with physical science specialisation	Percentage with a degree
Eastern Cape	2647	39.2%	2290	50.5%
Free State	1265	15.3%	756	14.6%
Gauteng	3750	44.1%	2367	52.2%
KwaZulu Natal	4887	26.8%	3347	29.6%
Mpumalanga	1649	23.4%	1099	19.1%
Northern Cape	494	33.8%	222	53.7%
Limpopo	-		-	
North West	1201	35.5%	1127	36.4%
Western Cape	1354	51.7%	833	48.3%
Total	17247	34.0%	12041	39.7%

Source: Simkins, School and community determinants of mathematics and physical science results in the SC examinations of 1998 and 2000.

This table shows that, even in the best resourced province in maths (Western Cape), only about half the number of maths educators have a university degree; also as noted earlier, there is no way of confirming whether this is a degree in maths, or with maths as a subject. Northern Cape is the best resourced province in terms of physical science.

THE CHALLENGE REVIEWED

We can now see that the challenge to be met in respect of maths and physical science education has five components:

1. Domestic research shows clearly that the problems surrounding maths and physical science begin very early in the school system.
2. International comparative research shows that the difficulties in South African schools are clear by grade 6, and have become acute by grades 8 and 9.
3. The negative patterns reveal themselves again in grades 10–12 and in the SC examinations, which is, regrettably, the only national standardised assessment of learners during the entire South African school system. SC results will be analysed in greater detail in chapter 3.
4. Given the poor pass rates in SC HG maths and physical science, very few learners can enrol for higher education qualifications requiring these subjects, including university degrees in education. Moreover, not all those who do enrol for tertiary courses actually succeed, and many of those who do graduate at universities or (now) technikons and enter the teaching profession later leave it to pursue other more lucrative careers.

5. As a result, South African schools have far too few appropriately qualified educators in maths and physical science. Newly qualified educators also take time to accumulate the experience required to achieve above-average teaching results, while those with experience now require new content knowledge, given the recent changes in curricula (see chapter 4).

Reconceptualisation of the challenge

In *Changing the subject*, Black and Atkin state:

> Every country that participated in our international study is dissatisfied with the education of its students in science, mathematics, or technology. Every country is trying to make changes. Every country seems to be more or less unhappy with what it has today.
>
> The fact is important, because each nation's vision of the science and mathematics education it desires very much depends on where it perceives its present deficiencies. The electorate is distrustful, even angry. When citizens or governments advocate and support educational change, their motive is to correct perceived ills as often as to achieve some completely new goal. At the moment, however, each country will be preoccupied by different perceived ills.... Each country is fighting its own demons.[5]

Clearly, any assessment of the shortcomings of maths and physical science education in South Africa must take account of its historical 'demons'. However, any plan of action to improve the national performance in these subjects must aim at achieving fresh goals as well.

CDE does not believe that, in the course of 'fighting South Africa's demons' in this area, the existing system of maths and physical science education should be swept away. Rather, it will propose a strategy for reforming this system, which may be likened to what an influential contemporary commentators on maths and physical science education in Africa has described as a 'participatory change model', which s/he contrasts with a fragmented 'project' approach:

> Participatory change models search for strengths to build on; projects search for weaknesses to fix. Participatory change models are awkward for funders, since their objectives are ill-defined; [this is because] they evolve as people evolve, and because there is no time limit on human development.[6]

CDE's notion of a 'participatory change model' will be discussed in depth later in the report. The key point here is that transforming maths and physical science education will require more than individual 'projects', however innovative they may be, or whether they are publicly or privately funded. It will require a model of incremental change of the whole system of education in these subjects, based on a realistic assessment of its strengths and weaknesses, and supported by all stakeholders, especially educators. It must also draw on assets the system already has, or can easily mobilise.

In proposing this approach, CDE is following a marked trend in the field of maths and physical science education research in Africa and internationally. Papers from a conference on maths and physical science education in Africa held in Durban in 1998 contain overwhelming evidence that what is required are focused, sustained, practical initiatives that build on assets which educational systems already have, without introducing unfamiliar approaches or inappropriate priorities requiring resources that they do not possess.[7]

Professor Emmanuel Yoloye of Ibadan University, Nigeria, suggests a number of ways of applying this idea:

> To derive optimum results from external aid, policy-makers in science education must clearly identify their needs and order their priorities. Funded programmes should originate from their intended beneficiaries. Science education programmes require a long period of gestation if they are to engender sustainable change in education systems: planners need to adopt a long-term approach. In view of scarce human resources, networking should be vigorously pursued through regular communication, exchanges, collaborative research and joint action. Tested approaches to curriculum change can be successful in primary and secondary schools. The range of actors needs to be broad, including NGOs, the private sector, teachers' associations and institutions of higher learning.[8]

As regards the methods to be utilised, the elements identified by Yoloye are a good starting point: establish needs; sequence priorities; look at what the intended beneficiaries want; plan for the long term; involve all actors; and use tested and proven approaches.

CONCLUSIONS

If maths and physical science education in South Africa is to be improved, the problem needs to be reconceptualised; in Einstein's words, the 'solution' must be formulated at a different level than that 'at which the problem was created'. To achieve this, we must:

- understand maths and physical science education as a discrete domain within the education system;
- set about improving it in the longer term, initially through small, strategic initiatives, preferably based on existing strengths and capacities;
- accept that large systems can only be changed incrementally, and that changing too much too quickly will probably worsen the situation even further;
- carefully assess the strengths ('virtues') of the system as well as its weaknesses ('faults'), with the firm intention of building on the former in order to overcome the latter;
- accept that, if incremental changes are introduced successfully, the chances of changing the whole system in the longer term are much better;

- realise that the system is a dynamic one, with internal as well as external relations, before deciding where to start the change process. International experience of large-scale education reforms (see chapter 7) shows conclusively that it is never a good idea to start at the bottom. The skills levels needed to successfully change a system from the bottom up can only be produced at the highest levels of the same system. One first has to build the capacity to build capacity to achieve systemic changes.

Once it is understood that change must be introduced incrementally, and that changing the whole system will take a long time, two other strategic issues present themselves: inclusive stakeholder participation, and sustained motivation. We found no evidence of successful models of educational change that was sustained by a government department of education alone, even at provincial or state levels. Allies from many other social spheres are needed. Likewise, no systemic educational change is possible without long-term 'national' partnerships of stakeholders with government that transcend short-term political processes. Motivation for change must be a firm national objective, capable of being sustained across shorter-term political events (changes of government, etc). These objectives have to be supported by top political leaders and senior government officials. Similarly, public–private partnerships need to be rooted in long-term national goals.

ENDNOTES

1 National Department of Education (NDoE), Foundation Phase Systemic Evaluation, National Report, Chief Directorate Quality Assurance, NDoE, 2001.

2 N Taylor, J Muller, and P Vinjevold, Getting schools working: research and systemic school reform in South Africa, 2003.

3 Ibid.

4 Ibid.

5 P Black, and J M Atkin, Changing the subject: innovations in mathematics, science and technology education, 1996, p 12

6 P Naidoo and M Savage, African science and technology education in the new millennium: practice, policy, priorities, Kenwyn: Juta, 1998, p 55.

7 Ibid.

8 Quoted in ibid, pp 20–21.

Chapter 3

GETTING THE NUMBERS RIGHT – AND MAKING THEM MEANINGFUL

South Africa's public schooling system accommodates more than 12,3 million learners, taught by 365 000 educators in 27 500 schools (2002 figures). The private schooling system accommodates an additional 285 000 learners, taught by 27 000 educators in 1 500 schools. Almost 28 per cent of the entire South African population are at school, compared with an international average of 20 per cent. Given a schooling system of this size, educational policy must be based on a sound quantitative understanding of that system; policies that work in smaller systems may well fail in larger ones.

With this in mind, CDE commissioned three major quantitative studies (see appendix 2) that enabled the project team to build up a unique understanding of maths and physical science education at the SC level.

The use made of this data has been heavily influenced by an observation by the author of one of these studies. After painstakingly collecting and correlating data, and analysing many factors, Simkins concludes:

> The analysis here displays the high degree of heterogeneity in South Africa's secondary school system and, more specifically, in the production of mathematics and science passes at the various levels in senior certificate. It will not be good enough to announce a general policy of improvement in mathematics and science education, particularly in the short and medium run. There needs to be a debate about more specific goals, e.g. (i) whether the output mix needs to be shifted in quality terms towards the higher end or not; (ii) how important improvements in science are compared with improvements in mathematics; and (iii) how the trade-off between effectiveness and inclusivity is to be handled. Only once one has greater clarification on goals can the analysis here be deployed to assist in making concrete policy recommendations.[1]

This comment confirms the findings of international research over the past decade, and the experience of private sector sponsors of initiatives in South African education over a considerable period, namely that successful reform should be based on particular initiatives targeting specific points in the system, but within a general longer term framework of intervention. Reformers must first understand the education system as a system, before developing goals against the background of that system's capacity and potential to absorb the reforms. The most successful reforms generally start at the 'top' of the system, where the capacity to absorb inputs is greatest, but with the aim of then strengthening other parts of the system in the medium to long term.

The huge and obvious differences between different parts of the South African education system, and the very wide disparities in the quality and outcome of maths and physical science education, have prompted CDE to accept that the system is hugely heterogeneous and diverse in its various components. The South African education system is simply too large and too diverse for one-size-fits-all approaches to or policies in respect of the system as a whole, or any of its parts. Approaches must be based on local and sector analyses, build on actual strengths, and have very specific goals.

Study 1: a verification of SC exam results

To ensure an accurate and unchallengeable quantitative foundation for this study, CDE commissioned a thorough verification and interpretation of SC examination results in maths and physical science in both the public and private schooling systems since 1991. This turned out to be a task that occupied skilled researchers for nearly six months.

The official databases up to 1997 were found to be deficient and inconsistent, to the extent that for some years the overall results simply could not be determined at all, even after extensive additional research and 'cleaning' of data.

Given the massive task faced by the education authorities of creating a single, non-racial education system following the democratic transition, this is hardly surprising, as well as understandable; prior to 1994 there were no less than 19 separate departments of education in South Africa; from 1994 onwards, the government undertook the massive task of integrating these institutions, creating a single, non-racial education system, and restructuring education administrations into a single national department and nine new provincial ones. This task was further complicated by the fact that it took some time before the new provinces were delimited, and provincial governments began to function efficiently. Moreover, all other aspects of the education system were extensively revised over a commendably short period. From 1998 onwards the results are presented in greater detail, broken down into relevant categories for more detailed analysis, which allowed for a more reliable time-series database to be constructed. The results were submitted to the NDoE's statistical adviser, and another expert.

Study two: amplifying the data, and analysing recent data more closely

Because of the problems with the departmental statistics over the period reviewed in study one, our second study amplified the published departmental data with data from the database of individual SC results maintained by Phambile Educational Technologies on contract from the national and provincial departments of education. Using this data, we were able to fill the gaps on supplementary examinations, 'conditional endorsements',[2] and the performance of part-time candidates. Other analytical categories were also developed, including the performance of first-language speakers, gender and race representation, and others. A more detailed analysis was then performed of SC results from 1998 to 2003.

Study three: linking the SC data to socio-economic information

In a third study, data on SC results were linked to data drawn from the NDoE's Educational Management and Information System (EMIS), its School Register of Needs, and the 1996 Population Census. This created a rich resource for statistical analysis, allowing SC results to be related to conditions at schools and in surrounding communities. This significantly deepened and broadened the study, and provided a series of additional insights.

The statistical profile that follows has been drawn from these three studies. (They are listed in appendix 2, and may be ordered from CDE.)

The statistics presented here differ from all those published previously on these aspects of South African education, and place the debate on performance in the SC exams in these subjects on a firmer basis than before. We believe that, given the state of the original databases used, the figures are now as accurate as it is possible to make them.

AN OVERVIEW OF PARTICIPATION AND PERFORMANCE IN SC MATHS AND PHYSICAL SCIENCE, 1991-2003

This section provides a broad overview of maths and physical science education at the SC level over the 13 years from 1991 to 2003 inclusive. These figures are based on the NDoE's published data for full-time candidates only.

Tables 3.1 and 3.2 paint a picture of trends in enrolment for SC maths and physical science, both internally as well as in relation to enrolment for SC as a whole. This is done by means of figures for the numbers of candidates who entered the SC examinations.

Table 3.1: Candidates for the SC maths exams plus total SC candidates, 1991–2003

Year	Total SC	Total maths	% of total SC	Maths SG	% of total maths	Maths HG	% of total maths
1991	408 468	135 659	33.21%	82 028	60.5%	53 631	39.5%
1992	448 491	145 557	32.40%	86 722	59.6%	58 835	40.4%
1993	472 458	157 797	33.40%	99 392	63.0%	58 405	37.0%
1994	495 408			-		-	
1995	531 453	200 444	37.72%	134 828	67.3%	65 616	32.7%
1996	518 225	214 733	41.44%	149 510	69.6%	65 223	30.4%
1997	559 233	231 312	41.36%	183 601	70.7%	67 744	29.3%
1998	552 862	279 733	50.60%	219 386	78.4%	60 347	21.6%
1999	511 474	281 304	55.00%	231 199	82.2%	50 105	17.8%
2000	489 941	284 017	57.97%	245 497	86.4%	38 520	13.6%
2001	449 371	263 945	58.74%	229 075	86.8%	34 870	13.2%
2002	443 821	260 989	58.81%	225 524	86.4%	35 465	13.6%
2003	440 267	258 323	58.67%	225 033	86.1%	35 959	13.9%

Source: Helen Perry, Mathematics and physical science performance in the Senior Certificate examination, 1991-2003, CDE background research report, 2004.

This table shows that the number of SC maths candidates grew significantly, from 135 659 to 258 323 (90,4 per cent), and that the proportion of SC candidates writing maths increased from 33,21 per cent to 58,67 per cent. However, it also shows that this growth took place in SG maths only; while the number of SG maths candidates grew from 82 028 to 225 033 (174,33 per cent), the number of HG maths candidates dropped from 53 631 to 35 959 (32,95 per cent). While the proportion of maths candidates writing SG maths grew from 60,5 per cent to 86,1 per cent, the proportion of maths candidates writing HG maths declined from 39,5 per cent to 13,9 per cent.

Table 3.2: Candidates for the SC physical science exams versus total SC candidates, 1991–2003

Year	Total SC	Total science	% of total SC	Science SG	% of total science	Science HG	% of total science
1991	408 468	84 019	20.57%	33 065	39.3%	50 954	60.7%
1992	448 491	89 887	20.04%	33 847	37.6%	56 040	62.4%
1993	472 458	93 375	19.76%	36 223	38.8%	57 152	61.2%
1994	495 408	-		-		-	
1995	531 453	118 266	22.25%	50 522	42.7%	67 744	57.3%
1996	518 225	122 521	23.64%	52 252	42.6%	70 269	57.4%
1997	559 233	140 431	25.11%	64 950	46.2%	75 481	53.8%
1998	552 862	157 197	28.43%	83 837	53.3%	73 360	46.7%
1999	511 474	160 949	31.47%	94 463	58.7%	66 486	41.3%
2000	489 941	163 187	33.31%	107 486	65.9%	55 701	34.1%
2001	449 371	153 847	34.24%	104 851	68.1%	48 996	31.9%
2002	443 821	153 855	34.67%	102 863	66.9%	50 992	33.1%
2003	440 267	151 791	34.47%	99 711	65.7%	52 080	34.3%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

This table shows a broadly similar pattern. The number of SC physical science candidates grew from 84 019 to 151 791 (80,66 per cent), and the proportion of SC candidates writing this subject grew from 20,57 per cent to 34,47 per cent. However, while the number of SG physical science candidates grew from 33 065 to 99 711 (201,56 per cent), the number of HG candidates increased only slightly, from 50 954 to 52 080 (2,2 per cent). While the proportion of physical science candidates writing SG physical science grew from 39,3 per cent to 65,7 per cent, the proportion writing HG physical science declined from 60,7 per cent to 34,3 per cent.

The next two tables paint a picture of trends in the performance of SC maths and physical science candidates, both internally as well as in relation to candidates' performances in the SC as a whole.

Table 3.3: Results of SC examinations, total and mathematics, 1991–2003

YEAR	TOTAL			MATHEMATICS									
				TOTAL			HIGHER GRADE			HG conv to SG pass	STANDARD GRADE		
	Cand	Pass	Pass rate	Cand	Pass	Pass rate	Cand	Pass	Pass rate		Cand	Pass	Pass rate
1991	383 514	210 314	55.0%	135 659	64 941	47.9%	53 631	20 677	38.6%	4 343	82 028	39 921	48.7%
1992	447 904	243 611	54.0%	145 557	75 772	52.0%	58 835	21 558	36.6%	5 646	86 722	48 568	56.0%
1993	442 528	226 943	51.0%	157 797	72 040	45.7%	58 405	20 365	34.9%	7 434	99 392	44 241	44.5%
1994	495 408	287 343	58.0%	-	-	-	-	-	-	-	-	-	-
1995	531 453	283 742	53.4%	200 444	84 422	42.1%	65 616	29 475	44.9%	-	134 828	54 947	40.8%
1996	518 225	279 487	54.4%	214 733	91 326	42.5%	65 223	22 416	34.4%	9 296	149 510	59 614	39.9%
1997	559 233	264 795	47.4%	231 312	85 912	37.1 %	67 744	19 575	28.9%	8 668	183 601	65 580	35.7%
1998	552 862	272 488	49.3%	279 733	96 955	34.7%	60 347	20 130	33.4%	8 510	219 386	68 315	31.1%
1999	511 474	249 831	48.9%	281 304	99 366	35.3%	50 105	19 854	39.6%	7 333	231 199	72 179	31.2%
2000	489 941	283294	57.9%	284 017	104 508	36.8%	38 520	19 327	50.2%	5 550	245 497	79 631	32.4%
2001	449 371	277206	61.7%	263 945	97 685	37.0%	34 870	19 504	55.9%	5 880	229 075	72 301	31.6%
2002	443 821	305774	68.9%	260 989	121 817	46.7%	35 465	20 528	57.9%	4 987	225 524	96 302	42.7%
2003	440 267	322492	73.3%	258 323	128 119	49.6%	35 396	23 412	66.1%	5 281	222 367	99 426	44.7%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

This table shows that:

- While the pass rate for the SC in general grew from 55 per cent to 73,3 per cent, the pass rate for maths grew only slightly from 47,9 per cent to 49,6 per cent.
- While the pass rate for HG maths increased from 38,6 per cent to 66,1 per cent, the pass rate for SG maths declined from 48,7 per cent to 44,7 per cent.
- The total number of passes over the 12-year period grew from 64 941 to 128 119 (or 97,28 per cent). However, while SG passes increased from 39 028 to 99 426 (154,75 per cent), HG passes only increased from 20 677 to 23 412 (13,22 per cent). In fact, in 2003 the system produced only 2 735 more HG maths passes than it did in 1991.

Table 3.4: Results of SC examinations, total and physical science, 1991–2003

YEAR	TOTAL			PHYSICAL SCIENCE									
				TOTAL			HIGHER GRADE			HG conv to SG pass	STANDARD GRADE		
	Cand	Pass	Rate	Total	Pass	Rate	Cand	Pass	Rate		Cand	Pass	Rate
1991	383 514	210 314	55.0%	84 019	54 288	64.6%	50 954	23 109	45.4%	8 963	33 065	22 216	67.1%
1992	447 904	243 611	54.0%	89 887	56 937	63.3%	56 040	24 172	43.1%	9 175	33 847	23 590	69.7%
1993	442 528	226 943	51.0%	93 375	62 186	66.6%	57 152	23 835	41.7%	14 366	36 223	23 985	66.2%
1994	495 408	287 343	58.0%	-	-	-	-	-	-	-	-	-	-
1995	531 453	283 742	53.4%	118 266	62 915	49.6%	67 744	34 895	44.9%	-	50 522	28 020	55.4%
1996	518 225	279 487	54.4%	122 521	74 110	60.5%	70 269	25 462	36.2%	18 342	52 252	30 306	58.0%
1997	559 233	264 795	47.4%	140 431	77 231	55.0%	75 481	26 658	35.3%	15 989	64 950	34 584	53.2%
1998	552 862	272 488	49.3%	157 197	86 777	55.2%	73 360	26 473	36.0%	17 107	83 837	43 197	51.5%
1999	511 474	249 831	48.9%	160 949	84 543	52.5%	66 486	24 191	36.4%	16 337	94 463	44 015	46.6%
2000	489 941	283 294	57.9%	163 187	91 167	55.8%	55 701	23 344	41.9%	12 939	107 486	54 884	51.1%
2001	449 371	277 206	61.7%	153 847	80 768	52.5%	48 996	24 280	49.6%	11 174	104 851	45 314	43.2%
2002	443 821	305 774	68.9%	153 855	95 651	62.2%	50 992	24 888	48.8%	14 022	102 863	56 741	55.1%
2003	440 267	322 492	73.3%	151 791	101 760	67.0%	52 080	26 067	50.1%	13 937	99 711	61 756	62.0%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Similarly, this table shows that:

- While the pass rate for SC in general grew from 55 per cent to 73,3 per cent, the pass rate for physical science grew only slightly from 64,6 per cent to 67,0 per cent.
- While the HG pass rate increased from 45,4 per cent to 50,1 per cent, the SG pass rate declined from 67,1 per cent to 62,0 per cent.
- While the total number of passes in physical science increased from 84 019 to 151 791 (or 80,66 per cent), SG passes increased from 22 216 to 61 756 (177,97 per cent), and HG passes from 23 109 to 26 067 (12,80 per cent). Again, in 2003 the system produced only 2 958 more HG science passes than it did in 1991.

Trends and preliminary implications

These figures reveal a consistent inverse relationship between enrolment and performance; the more learners enrol for any of these four subjects, the worse their pass rates, and vice versa. This means that the improved pass rates in HG maths and science are being achieved at the expense of participation, and the improved participation in SG maths and science are not being translated into results.

These trends point to the wisdom of disaggregating the general data, leading, in turn, to specific strategies for increasing SG pass rates, increasing the numbers of HG candidates, and so on.

CLOSER ANALYSIS OF MATHS AND PHYSICAL SCIENCE RESULTS, 1998–2003

In this section, SC examination results from 1998 to 2003 are examined in greater detail. As noted earlier, these are some of the most comprehensive figures yet available, and include results of:

- public year-end examinations for full-time candidates;
- public year-end examinations for part-time candidates;
- the Independent Examinations Board (IEB) year-end examinations for full-time candidates (the IEB does not permit part-time candidates); and
- public supplementary examinations held early each year for candidates qualifying for them.

This enables a more comprehensive analysis of the general patterns and trends identified in the previous section to be completed, and the sorts of conclusions that can be drawn from this.

Table 3.5: Maths and physical science results, 1998—2003

Candidate type	Higher grade			Standard grade			Total HG and SG		
	Candidates	Passes	Pass rate	Candidates	Passes*	Pass rate	Candidates	Passes	Pass rate
1998									
MATHS									
Full-time	60 347	20 130	33,4%	219 386	68 315	31,1%	279 733	88 445	31.6%
Part-time	11 728	982	8,4%	32 129	8 242	25.7%	43 857	9 224	21.0%
Supplementary	2 023	133	6,6%	9 803	1 292	13.2%	11 826	1 425	12,0%
IEB	1 906	1 801	94,5%	2 019	1 849	91,6%	3 925	3 650	93%
Total	76 004	23 046	30,3%	263 337	79 698	30.3%	339 341	102 744	30.3%
PHYSICAL SCIENCE									
Full-time	73 360	26 473	36%	83 837	43 197	51,5%	157 197	69 670	44,3%
Part –time	13 003	1 221	9,4%	12 644	7 565	59.8%	25 647	8 786	34.3%
Supplementary	2 838	142	5%	3 288	1 274	38.7%	6 126	1 416	23.1%
IEB	1 938	1 779	91,8%	563	526	93,4%	2 501	2 305	92,2%
Total	91 139	29 615	32,5%	100 332	52 562	52,4%	191 471	82 177	42.9%
1999									
MATHS									
Full-time	50105	19584	39.1%	231199	72179	31.2%	281304	91763	32.6%
Part-time	8101	857	10.6%	29326	6963	23.7%	37427	7820	20.9%
Supplementary	1433	99	6.9%	9149	1361	14.8%	10582	1460	13.8%
IEB	2294	2248	97,9%	2439	2284	93,6%	4733	4532	95,8%
Total	61933	22788	36,8%	272113	82787	30,4%	334046	105575	31,6%
PHYSICAL SCIENCE									
Full-time	66486	24191	36.4%	94463	44015	46.6%	160149	68206	42.6%
Part-time	10009	880	8.8%	11596	2871	24.8%	21605	3751	17.4%
Supplementary	2353	205	8.7%	3490	1331	38.1%	5843	1536	26.3%
IEB	2308	2242	97,1%	716	652	91,1%	3024	2894	95,7%
Total	81156	27528	33,9%	110265	48869	44,3%	190621	76387	40,0%

Candidate type	Higher grade			Standard grade			Total HG and SG		
	Candidates	Passes	Pass rate	Candidates	Passes *	Pass rate	Candidates	Passes	Pass rate
2000									
MATHS									
Full-time	38 520	19 327	50,2%	245 497	85 181	34,7%	284 017	104 508	36,8%
Part-time	4 829	582	12,1%	26 891	5 078	18,9%	31 720	5 660	17,8%
Supplementary	1 102	125	11.3%	9 982	1 001	10.0%	11 084	1 126	10.2%
IEB	2 366	2 255	95,3%	2 359	2 144	90,9%	4 725	4 399	93,1%
Total	46 817	22 289	47.6%	284 729	93 404	32.8%	331 546	115 693	34.9%
PHYSICAL SCIENCE									
Full-time	55 701	23 344	41,9%	107486	54 884	51,1%	163 187	78 228	67,9%
Part-time	7 243	692	9,6%	12 078	4 923	40.8%	19 321	5 615	29.1%
Supplementary	2 118	164	7.7%	3 987	1 346	33.8%	6 105	1 510	24.7%
IEB	2 385	2 198	92,2%	629	573	91,1%	3 014	2 771	91,9%
Total	67 447	26 398	39.1%	124 180	61 726	49.7%	191 627	88 124	46.0%
2001									
MATHS									
Full-time	34 870	19 504	55.9%	229 075	72 301	31.6%	263 945	97 805	34.8%
Part-time	5 106	803	15,7%	29 420	5 380	18.3%	34 526	6 183	17.9%
Supplementary	838	62	7.4%	9 588	635	6.6%	10 426	1 048	10.05%
IEB	2 574	2 477	96.2%	2 598	2 424	93.3%	5 172	4 901	94.8%
Total	43 388	22 846	52.66%	270 681	80 740	29.8%	314 069	109 937	35.0%
PHYSICAL SCIENCE									
Full-time	48 996	24 280	49.6%	104 851	45314	43.2%	153 847	69 594	45.2%
Part-time	6 817	1 022	15.0%	14 064	4 618	32.8%	20 881	5 640	27.0%
Supplementary	1 594	81	5.1%	4877	409	8.4%	6 471	1 470	22.7%
IEB	2 482	2 400	96.7%	791	751	94.9%	3 273	3 151	96.3%
Total	59 889	27 783	46.4%	124 583	51 092	41.0%	184 472	79 855	43.3%
2002									
MATHS									
Full-time	35 465	20 528	57.9%	225 524	101289	44.9%	260 989	121817	46.7%
Part-time	6 082	1 102	18.1%	32 070	7 884	26.9%	38 152	9 741	25.5%
Supplementary	202	14	6.9%	6444	378	5.9%	6646	392	5.9%
IEB	2 742	2 645	96.5 %	2 500	2 240	89.6 %	5 242	4 885	93.2 %
Total	44491	24289	54.6%	266538	111791	41.9%	311029	136835	44.0%
PHYSICAL SCIENCE									
Full-time	50 992	24 888	48.8%	102 863	70763	68.8%	153 855	95 651	62.2%
Part-time	8 352	1 216	14.6%	16 519	4 710	40.4%	24 871	7 888	31.7%
Supplementary	473	31	6.6%	3091	353	11.4%	3564	384	10.8%
IEB	2 682	2 505	93.4%	610	581	95.2%	3 292	3 086	93.7 %
Total	62 499	28 640	40.8%	123 083	76 407	53.6%	185 582	107 009	49.6%
2003									
MATHS									
Full-time	35 956	23 412	65.1 %	222 367	104 707	47,1 %	258 323	128 119	49,6 %
Part-time	-	-	-	-	-	-	-	-	-
Supplementary	202	14	6,9 %	6 444	378	5,9 %	6 646	392	5,9 %
IEB	2 831	2 617	92,4 %	2 599	2 280	87,7%	5 430	4897	90,2 %
Total	38 989	26 043	66.8%	231 410	99 426	43.0%	391 615	133 408	34.1%
PHYSICAL SCIENCE									
Full-time	52 080	26 067	50,1 %	99 711	75 693	75,9 %	151 791	101 760	67.0 %
Part-time	-	-	-	-	-	-	-	-	-
Supplementary	473	31	6,6 %	3091	353	11,4 %	3 564	384	10,8 %
IEB	2 783	2 499	89,8 %	674	615	91.4 %	3 457	3114	90,1 %
Total	55 336	28 597	51.6%	103 476	76 661	74.1%	158 812	105 258	66.3%

** includes conversion from HG to SG pass*

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Table 3.5 shows the following:

- A confirmation of the general patterns identified in the previous section.
- A drop in the numbers of HG maths and physical science candidates between 1998 and 2001, stabilising in 2002 and 2003;
- Lower pass rates among part-time and supplementary candidates, especially in the HG; and
- A greater propensity to enter at the HG and to pass at both levels among IEB candidates.

Our findings confirm that the maths and physical science education subsystem – and, for that matter, the school-based education system generally – has many different parts that behave in different ways. This is clearly illustrated by the data on pass rates in IEB SC maths and physical science, for example. The schools writing these examinations – South Africa's so-called private schools – are obviously a valuable national resource, especially in these subjects. However, there are also categories of public schools that are distinguished by their participation and performance patterns which the analyses in this section fail to bring out clearly – notably the former 'model C' schools. Recognising this, we turn now to a more disaggregated analysis of the SC data.

OVERVIEW OF SCHOOL PERFORMANCE

As noted earlier, improved data from 1998 onwards has made it possible to disaggregate the data on SC maths and physical science. One of the results is that we can analyse the performance of individual schools.

Table 3.6: Distribution of SC pass rates among schools, 2000

Pass rate	Schools
0% - 20%	9.9%
21% - 40%	24.8%
41% - 60%	24.6%
61% - 80%	18.6%
81% - 100%	22.2%

Source: Charles Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000, CDE background research report, 2004.

One would expect table 3.6 to show the equivalent of a bell curve, with fewer schools in the lowest and highest categories. In particular, in a system with high failure rates, far fewer schools should achieve the highest pass rates. However, this is not the case. In fact, the number of centres achieving 81–100 per cent passes is very close to those in the 21-40 per cent and 41-60 per cent categories. This suggests that educators at certain schools and the support of – or competition against – other candidates at those schools play an important role in the success of individual candidates.

The pattern of entries for maths and physical science corresponds to this distribution. Table 3.7 sets out the number of schools offering maths and physical science in the HG and SG, according to the percentages of candidates who wrote these subjects.

Table 3.7: Schools by percentages of SC candidates writing maths and physical science, 1998 and 2000

% candidates in schools	Maths			Physical science		
1998						
	HG	SG	Any form	HG	SG	Any form
0%	1 747	339	164	1 488	1 355	785
1-20%	2 504	726	325	2 502	2 306	1 156
21-40%	801	1 878	1 540	1 115	1 343	2 239
41-60%	213	1 619	1 689	209	298	893
61-80%	67	553	1 013	42	50	203
81-99%	26	174	510	8	10	67
100%	16	85	133	10	12	31
Total	5 374	5 374	5 374	5 374	5 374	5 374
2000						
	HG	SG	Any form	HG	SG	Any form
0%	2 759	231	177	2 099	1 157	800
1-20%	2 215	411	253	2 437	1 886	874
21-40%	504	1 445	1 150	875	1 783	2 327
41-60%	136	1 976	1 790	216	698	1 266
61-80%	50	1 074	1 405	48	117	295
81-99%	14	351	679	4	28	91
100%	10	200	234	9	19	35
Total	5 688	5 688	5 688	5 688	5 688	5 688

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

Table 3.7 shows that:

- In 1998 there were a significant number of schools with no maths and/or physical candidates; two years later the number of schools with no maths candidates had grown by 7,3 per cent, and those with no physical science candidates by 2 per cent.
- The number of schools in which 1–20 per cent of SC candidates wrote maths (either HG or SG) was relatively small: 325 (6 per cent of the total) in 1998, and 253 (4,7 per cent of the total) in 2000. In 1998, the largest number of schools (1 656, or 30,8 per cent) were in the 41--60 per cent band. This was roughly true in 2000. From 1998 to 2000 there was a large increase in the number of schools in the 60 per cent-plus bands – from 1 656 schools to 4 108 schools.
- The numbers were far higher in respect of physical science: 1 156 (36,1 per cent) in 1998, and 874 (29,4 per cent) in 2000. The modal class was 21-40 per cent, with only 301 schools (5,6 per cent) in 1998 and 421 schools (7,4 per cent) in 2000 having more than 60 per cent of completing candidates writing physical science.

These figures confirm that factors at the school level determine decisions to study maths and physical science; decisions to study these subjects in the SG or HG; and candidates' chances of success.

THE PERFORMANCE OF INDIVIDUAL SCHOOLS, 1998-2002

The performance of individual schools in mathematics and physical science was investigated in two ways.

First, data for 2000 and 2001 were collated and analysed to illuminate various aspects of school performance.

Second, an index was created that allows the performance of all schools with SC maths and physical science candidates to be compared for the period 1998-2002 inclusive. It allows the identification of schools whose performance has improved, and the degree to which this has happened; schools whose performance has remained at the same level; and schools whose performance has declined. From now on, the index can be updated every year, once the full set of results is available.

Performance of schools by province, 2000 and 2001

In 2000 a total of 973 schools out of 5 688 (17,1 per cent) did not have any candidates in maths or physical science, and were removed for the purposes of this exercise, leaving 5 513 schools to be considered. Their performance by province is shown in table 3.8.

Table 3.8: Number of schools by pass rate category in SC maths and province, 2000

Province	Schools with maths candidates	A 0% - 19%	B 20% - 39%	C 40% - 59%	D 60% - 79%	E 80% +
Eastern Cape	855	168 (20%)	205 (24%)	206 (24%)	130 (15%)	146 (17%)
Free State	315	94 (30%)	76 (24%)	52 (16%)	23 (7%)	70 (22%)
Gauteng	611	102 (17%)	164 (27%)	77 (13%)	82 (13%)	186 (30%)
KZN	1259	314 (25%)	296 (24%)	265 (21%)	198 (16%)	186 (14%)
Mpumalanga	385	130 (34%)	123 (32%)	59 (15%)	27 (7%)	46 (12%)
Northern Cape	101	8 (8%)	11 (11%)	13 (13%)	13 (13%)	56 (55%)
Limpopo	1259	628 (50%)	346 (27%)	147 (12%)	80 (6%)	58 (5%)
North West	366	92 (25%)	112 (31%)	70 (19%)	44 (12%)	48 (13%)
Western Cape	362	31 (9%)	53 (15%)	63 (17%)	63 (17%)	152 (42%)
Total	5513	1567 (29%)	1386 (25%)	952 (17%)	660 (12%)	948 (17%)

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

A number of important conclusions can be drawn from these figures.

- There are more highly successful schools than a simple statistical progression would indicate.

- High performance is often being achieved under adverse circumstances. Many of the 948 schools in the top category (E) are not located in privileged communities.
- After a relatively high percentage of schools in the C category, there is usually a sharp drop to the D category.
- Similar observations apply at the provincial level. For instance, Free State is above average in the E category, considerably below average in the D category, and average in the C category. These observations lend support to the need for more focused interventions.
- Of the 5 513 schools with maths candidates, only 2 929 entered candidates at the HG.

Table 3.9 shows the distribution of HG marks among schools in each province.

Table 3.9: Numbers of schools by pass rate category in HG maths by province, 2000

Province	Schools with HG maths candidates	A 0% - 19%	B 20% - 39%	C 40% - 59%	D 60% - 79%	E 80% +
Eastern Cape	194	71 (37%)	10 (5%)	21 (10%)	9 (5%)	83 (43%)
Free State	167	70 (41%)	16 (10%)	14 (9%)	14 (9%)	53 (31%)
Gauteng	428	142 (33%)	30 (7%)	44 (10%)	48 (12%)	164 (38%)
KZN	743	457 (61%)	66 (9%)	67 (9%)	64 (9%)	89 (12%)
Mpumalanga	256	177 (70%)	14 (5%)	16 (6%)	20 (8%)	29 (11%)
Northern Cape	44	4 (9%)	-	4 (9%)	5 (11%)	31 (71%)
Limpopo	659	475 (72%)	46 (7%)	45 (7%)	18 (3%)	75 (11%)
North West	196	101 (51%)	13 (7%)	17 (9%)	16 (8%)	49 (25%)
Western Cape	242	55 (22%)	16 (7%)	19 (8%)	24 (10%)	128 (53%)
Total	2 929	1 552 (54%)	211 (7%)	247 (8%)	218 (7%)	701 (24%)
Total Passes	18 515	1013 (5%)	719 (4%)	1 548 (8%)	3 666 (20%)	11 569 (63%)

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

Note: The total number of candidates passing is not exactly the same as that published by the NDoE, due to the exclusion of candidates with a condoned or conditional pass.

The implications of this table are somewhat different. In terms of schools it shows that:

- 24 per cent of schools nationally (701) are producing 63 per cent of all HG maths passes. This is an unacceptable concentration, and makes the country's supply of maths matriculants vulnerable to disruption. Yet it is heartening that 701 schools have succeeded in obtaining an HG maths pass rate of more than 80 per cent, and provide such a large proportion of passes. Without them, the country would be in even deeper trouble.
- There is a dramatic drop in schools in categories B, C, and D, and an extremely worrying indication that 54 per cent of all schools with HG candidates provide only 5 per cent of passes.

Provincial variations are extreme; however in nearly every province there is a 'core' of schools actually capable of significant performance in HG maths. Even in the provinces where only 10-12 per cent of schools are producing 80+ passes (KZN, Limpopo and Mpumalanga) there are nevertheless a number of excellent performing schools which can form the basis for further interventions.

Table 3.10 provides similar data in respect of physical science passes in 2000.

Table 3.10: Numbers of schools by pass rate in SC physical science by province, 2000

Province	Schools with physical science candidates	A 0% - 19%	B 20% - 39%	C 40% - 59%	D 60% - 79%	E 80% +	% of schools with 80%+ pass rate
Eastern Cape	773	69	107	153	157	287	32.6%
Free State	299	8	4	24	45	218	66.8%
Gauteng	598	26	40	79	107	346	55.0%
KZN	1025	104	97	179	204	441	33.8%
Mpumalanga	367	48	63	86	70	100	25.6%
Northern Cape	80	2	5	4	12	57	54.3%
Limpopo	1072	230	240	231	188	183	13.9%
North West	336	40	50	71	72	103	27.9%
Western Cape	340	2	3	9	21	305	81.8%
TOTAL	4890	529	609	836	876	2040	35.9%

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

Interestingly, the pattern of school performance in physical science is quite different. The overall pass rate is more than twice that in maths (35,9 per cent compared to 16,7 per cent); moreover, by far the largest single group of schools are those obtaining 80 per cent or more passes. Again, this shows that South Africa has a core of high-performing schools upon which efforts to improve the maths and science education subsystem can build. Provincial variations are once again extreme; there are more successful schools in physical science than in maths, and some provinces with very few performing schools.

Table 3.11 shows that:

- 58 per cent of successful candidates in HG physical science attend 662 schools (18 per cent of the total) which all achieve pass rates of 80 per cent or more.
- The percentages of these schools in the various provinces differ greatly, from a low of 3 per cent in Limpopo to a high of 63 per cent in the Western Cape. Considerably more schools fall into the next two bands (C and D).

The gap between category E and category A is not as marked as in HG maths, and there is an orderly progression of numbers of schools. However, the number of schools in category A is even larger than it is in maths (59 per cent compared to 54 per cent).

Table 3.11: Numbers of schools by pass rate category in HG physical science by province, 2000

Province	Schools with HG physical science candidates	A 0% - 19%	B 20% - 39%	C 40% - 59%	D 60% - 79%	E 80% +
Eastern Cape	273	171 (63%)	14 (5%)	20 (7%)	25 (9%)	43 (16%)
Free State	244	86 (35%)	33 (14%)	21 (9%)	13 (5%)	91 (37%)
Gauteng	491	189 (39%)	34 (7%)	61 (12%)	56 (11%)	151 (31%)
KZN	782	438 (56%)	86 (11%)	72 (9%)	78 (10%)	108 (14%)
Mpumalanga	317	236 (74%)	18 (6%)	21 (7%)	17 (5%)	25 (8%)
Northern Cape	52	11 (21%)	5 (10%)	6 (12%)	3 (5%)	27 (52%)
Limpopo	911	741 (81%)	85 (10%)	36 (4%)	12 (1%)	37 (3%)
North West	274	191 (70%)	23 (9%)	19 (7%)	15 (5%)	26 (11%)
Western Cape	245	38 (16%)	6 (2%)	20 (8%)	27 (11%)	154 (63%)
TOTAL	3 589	2 101 (59%)	304 (9%)	276 (8%)	246 (7%)	662 (18%)
Total passes	22 025	1 747 (8%)	1 173 (5%)	2 313 (11%)	4 097 (19%)	1 2695 (58%)

Note: The total number of candidates passing is not exactly the same as those published by the NDoE, due to the exclusion of candidates with a condoned or conditional pass.

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

All these findings point to huge variations between provinces, and within each province, which, in turn, confirm the need for focused interventions rather than generalised ones. Also, there are substantial numbers of schools which do not produce any passes at all.

CDE has been able to develop an index of school performance in maths and physical science, which enables any educational planner to identify the performance in maths and physical science of individual schools, and tailor strategies for them.

FACTORS AFFECTING INDIVIDUAL PERFORMANCE

We now turn to what the data can tell us about the characteristics of individual SC maths and physical science candidates. Using data for the years 1998 and 2000, performance in the SC as a whole was regressed against a number of variables. The analysis will not be reported here in detail, but the outcomes are:

Provincial variations

The influence of the province in which candidates write on individual results is unstable. One would expect provincial results to vary greatly, largely reflecting the legacy of the racially separate education departments of the apartheid era. Provinces that had to assimilate more 'homeland' and Department of Education and Training (DET) schools than other provinces could be expected to perform worst. The learners in departments under the former tricameral parliament were mainly assimilated into Gauteng, KwaZulu Natal, and the Western Cape, with the other six provinces being ‘disadvantaged’ to varying degrees.

However, these expectations are not substantiated by the regression results; rather, these indicate that the three best provinces in 1998 were Mpumalanga, North West, and the

Eastern Cape, and the three best in 2000 were Gauteng, Eastern Cape, and North West. This is because a number of variables that contribute to poor overall performance in the six provinces have been 'partialled out' by their inclusion in the regression. Thus the regression coefficients indicate the performance of provinces relative to the distribution of first language, number of subjects, gender, entry for mathematics and physical science, and whether SC is passed with or without endorsement.

The results show clearly that policies suited to one province may be unsuitable to or even counterproductive in another. The point to be made is that a straight comparison of provincial performance or participation in maths and physical science will fail to capture the characteristics of the provinces' pool of individual learners relative to the overall SC learner population. At the level of averages in 2000, for instance, the three 'advantaged' provinces provided 40,4 per cent of maths passes, but only 37,3 per cent of the candidates; and 55,6 per cent of all physical science passes, but only 46,7 per cent of the candidates.

First language

The results of candidates with different first languages varied enormously. In 1998 and 2000 African first-language candidates were 400 marks and 341 marks respectively behind Afrikaans first-language candidates. And the small number of very capable candidates who chose both English and Afrikaans as first languages were 405 and 379 marks ahead of candidates writing Afrikaans as a first language only.

Number of subjects

Candidates who wrote more than the required number of subjects obtained better results. There are two reasons for this. If more than six subjects are written, the weakest result is dropped from the aggregate, and writing more than six subjects is a choice typically made by better or more confident learners.

Gender

Overall, male candidates did slightly better that female candidates, but the variation is not significant.

Maths and physical science

Candidates who wrote both maths and physical science did better than those who wrote only one or neither subject. Next came candidates who wrote maths only.

Candidates who passed SC without endorsement received more than 150 marks less than candidates who passed SC with endorsement. This is the effect of selection; better learners will obtain the SC with endorsement.

Choosing or not choosing maths and physical science

Clearly, the number of SC candidates choosing to study maths and/or physical science has a decisive bearing on the number of passes each year. Numerous factors influence learners' decisions, ranging from a general perception that maths and physical science are difficult subjects which may lead to them failing the exams as a whole, to very specific career choices for which maths and/or physical science are required. Table 3.12 establishes the relationships between these factors in 1998 and 2000, thus aiding an understanding of why candidates choose or do not choose maths and/or physical science.

Table 3.12: Subject choice by endorsement and grade, 1998 and 2000

Endorsement	science not written	science SG	science HG
1998			
Endorsement			
Maths not written	203 065	489	485
Maths SG	78 316	44 336	34 059
Maths HG	14 945	8 131	35 881
Senior Certificate			
Maths not written	105 851	1 219	21
Maths SG	27 714	28 017	2 296
Maths HG	189	. 373	. 203
2000			
Endorsement			
Maths not written	106 223	682	295
Maths SG	65 498	43 928	27 984
Maths HG	7 540	5 197	24 981
Senior certificate			
Maths not written	129 984	1 942	24
Maths SG	48 000	52 500	1 720
Maths HG	*164*	*272*	*99*

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

As regards candidates who passed with endorsement (ie 'university entrance'):

- A significant proportion (48,4 per cent in 1998, and 37,6 per cent in 2000) did not write either mathematics or physical science.
- Very few (0,2 per cent in 1998, and 0,3 per cent in 2000) wrote physical science without writing mathematics.
- However, substantially more wrote mathematics without writing physical science (50,0 per cent in 1998 and 47,7 per cent in 2000 in respect of SG, and 25.3 per cent in 1998 and 20.0 per cent in 2000 in respect of HG).

As regards candidates who passed without endorsement:

- An even larger proportion (63, 8 per cent in 1998, and 55,4 per cent in 2000) did not write either mathematics or physical science.
- Again, very few (1,2 per cent in 1998, and 1,5 per cent in 2000) wrote physical science without writing mathematics.

- However, about the same proportions wrote mathematics without writing physical science (47,8 per cent in 1998 and 47,0 per cent in 2000 in respect of SG, and 25 per cent in 1998 and 31 per cent in 2000 in respect of HG).

Probability of writing maths and/or physical science

An ordered probity analysis (a specialised form of regression analysis) was carried out to establish this data. The results are not reported here in tabular form, but the conclusions are:

- The aggregate mark in SC clearly affects the probability of writing maths and physical science;
- However, entry for maths and physical science is only weakly related to endorsement level passes.
- All other things being equal, African and English language learners are more likely to enrol for maths and science than Afrikaans-language students;
- Learners taking seven or more subjects are more likely to enrol for maths and physical science than those taking six subjects;
- The probability of a learner entering maths and physical science is strongly influenced by the proportion of learners in the school entering for those subjects.
- Female learners are slightly less likely to enter than male learners.

THE ROLE OF GENDER

As regards gender, data for the period 1991-2002 reveals an interesting picture. Since 1994, South Africa has differed from many other developing countries in that more females than males have been enrolled in the state education system.

The latest figures indicate that female learners comprise 53 per cent of all learners. In 2001 female learners comprised 55,1 per cent of all SC candidates, and obtained 52,5 per cent of total passes. In 2002 female maths and physical science candidates comprised 53 per cent and 47 per cent respectively of all candidates in these subjects.

Figures 3.1 and 3.2 confirm that gender itself is not a primary determinant of participation in SC maths and physical science. The gender ‘performance gap’ is also narrow.

Figure 3.1: All maths candidates by gender

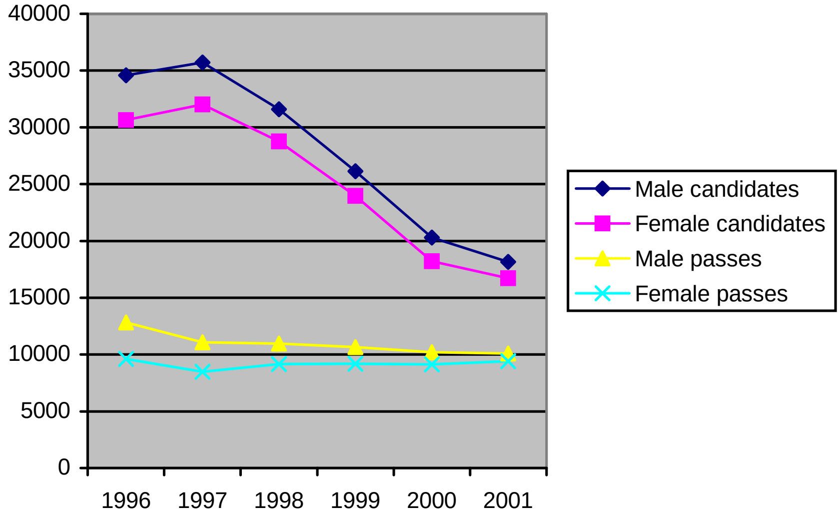
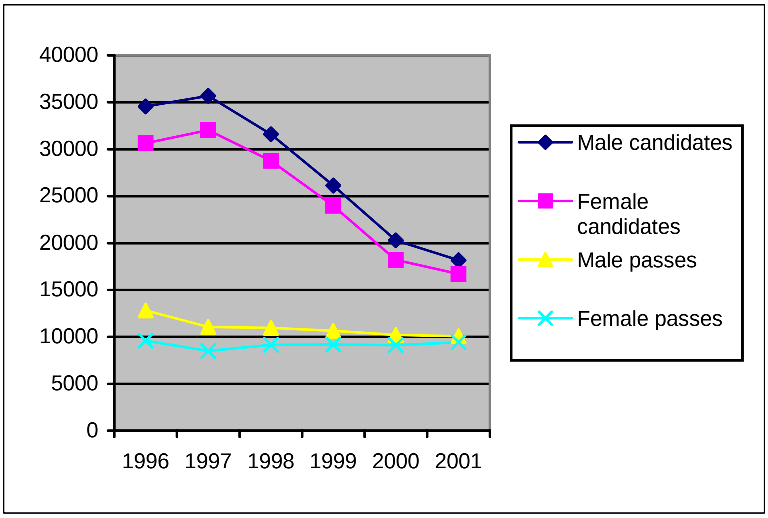


Figure 3.2: HG maths candidates by gender



Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Looking more closely at the data, however, two interesting trends emerge. In 2001 the pass rate of female SC candidates was 60,1 per cent, compared to 63,6 per cent of males. However, 53,6 per cent of all candidates who passed with endorsement (ie, obtained 'university' or 'exemption' passes) were female. In 2001 women were therefore slightly *over-represented* as a proportion of all SC candidates; fairly represented as a percentage of passes and of passes with exemption; and under-represented in terms of percentage pass rates of their own gender. Once again, the issue is not one of simple male/female differences, consistently displayed across the board. Closer analysis may show that some of these variations are not based on gender at all, but on other differences at the individual school level.

The second trend is that in 1996, the first year in which the gender of individual candidates was recorded, the traditional wisdom of female learners being underrepresented still seems to have been valid: fewer females were attempting SC maths and physical science, and fewer still were succeeding. In 1996, only 46,8 per cent of candidates in physical science were female, and only 54,4 per cent of those passed, compared to 65,9 per cent of males. While 50,2 per cent of all maths candidates were female, their pass rate was even worse: 38,2 per cent, compared to 47,3 per cent of males.

Since then, however, the performance of female candidates has improved steadily. In 1998, 53,2 per cent of all maths candidates were female, and 30,7 per cent passed (as against 37,1 per cent of males). By 2001 the proportion of female maths candidates had risen to 53,6 per cent, and their pass rate to 33,3 per cent (as against 41,2 per cent of males). As already indicated, at HG level the change was even more marked; by 2001 females constituted 47,9 per cent of all HG candidates, and 56,4 per cent of them passed (as against 55,5 per cent of male candidates). Therefore, in HG maths, females have effectively achieved parity in terms of numbers of candidates well as pass rates. Moreover, of those candidates who achieved more than 75 per cent in HG maths in 2000, no fewer than 49 per cent were female – higher than their overall participation rate of 47,3 per cent in this subject at this level.

The pattern repeats itself in physical science. Enrolment and pass rates of females are rising, and there are particularly sharp increases in quality at the upper levels. In 2001, 44,6 per cent of all physical science passes were female, and 47,8 per cent of all female HG candidates passed (as against 60 per cent of males). But between 1996 and 2001 the female pass rate improved from 31,9 per cent to 47,8 per cent, or by 15,9 percentage points (as against an 11,1 percentage point improvement for male candidates). Of those candidates who achieved more than 75 per cent in HG physical science in 2000, 45,3 per cent were female – about equal to their participation rate.

Race and gender

In 2002 the NDoE collected data on SC results by race for the first time since 1993. This data were made available to CDE in mid-2003. Once again, a disaggregation of the overall figures revealed separate trends. Table 3.13 displays the results in HG maths by race and gender:

Table 3.13: HG maths candidates and passes by race and gender, 2002

Race	Gender	No of candidates	% of total	Passes	Pass rate
African	Female	7 184	42.7%	1638	22.8%
	Male	9634	57.3%	2999	31.1%
	Total	16 818	100.0%	4637	27.6%
Coloured	Female	742	49.1%	511	68.9%
	Male	769	50.9%	556	72.3%
	Total	1 511	100.0%	1067	70.6%
Indian	Female	2231	52.9%	1614	72.3%
	Male	1987	47.1%	1421	71.5%
	Total	4218	100.0%	3035	72.0%
White	Female	6334	50.0%	5632	88.9%
	Male	6329	50.0%	5394	85.2%
	Total	12663	100.0%	11026	87.1%
Unknown	Female	31	45.6%	18	58.1%
	Male	37	54.4%	15	40.5%
	Total	68	100.0%	33	48.5%
Total	Female	16522	46.8%	9413	57.0%
	Male	18756	53.2%	10385	55.4%
	Total	35278	100.0%	19798	56.1%

Note: The total number of candidates and passes does not reflect exactly those figures published by the NDoE due to not including those candidates who gained a condoned pass.

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

It is immediately apparent that a major difference exists between African female candidates (overall pass rate 22,8 per cent) and all other female candidates. The pass rates for the other three races are: coloured, 68,9 per cent; Indian, 72,3 per cent; and white, 88,9 per cent. Thus the overall female pass rate (57,0 per cent), which is higher than the overall male pass rate (55,4 per cent), conceals a massive disparity between African females and others. Table 3.14 shows a similar pattern for physical science.

Table 3.14: HG physical science candidates and passes by race and gender, 2002

Race	Gender	No of candidates	% of total	Passes	Pass rate
African	Female	13319	44.2%	2654	19.9%
	Male	16837	55.8%	4475	26.6%
	Total	30156	100.0%	7129	23.6%
Coloured	Female	786	45.4%	570	72.5%
	Male	945	54.6%	681	72.1%
	Total	1731	100.0%	1251	72.3%
Indian	Female	2617	50.7%	1973	75.4%
	Male	2540	49.3%	1736	68.3%
	Total	5157	100.0%	3709	71.9%
White	Female	5815	43.0%	5098	87.7%
	Male	7706	57.0%	6206	80.5%
	Total	13521	100.0%	11304	83.6%
Unknown	Female	57	43.5%	17	29.8%
	Male	74	56.5%	24	32.4%
	Total	131	100.0%	41	31.3%
Total	Female	22594	44.6%	10312	45.6%
	Male	28102	55.4%	13122	46.7%
	Total	50696	100.0%	23434	46.2%

Note: The total number of candidates and passes does not reflect exactly those figures published by the NDoE due to not including those candidates who gained a condoned pass.

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

African female candidates achieved an even lower pass rate in physical science than in maths: 19,9 per cent, compared to 22,8 per cent. Once again, they were the least successful group of female candidates; coloured, Indian, and white female candidates achieved pass rates of 72,5 per cent, 75,4 per cent, and 87,7 per cent respectively.

Disturbed by these results, CDE decided to dig deeper and to disaggregate the national data to the provincial level. The results for maths are shown in table 3.15.

Table 3.15: HG maths candidates, number passing, and number converting to a SG pass by race, gender, and province, 2002

Province	Race	Gender	Candidate	Passes	Conversio	Pass rate
Eastern Cape	African	Female	349	163	78	46.7%
		Male	506	245	100	48.4%
	Coloured	Female	54	46	5	85.2%
		Male	75	62	9	82.7%
	Indian	Female	39	37	2	94.9%
		Male	24	22	2	91.7%
	White	Female	396	372	22	93.9%
		Male	383	348	29	90.9%
Free State	African	Female	190	90	49	47.4%
		Male	321	174	64	54.2%
	Coloured	Female	8	5	2	62.5%
		Male	9	6	3	66.7%
	Indian	Female	1	1	0	100.0%
		Male	0	0	0	0
	White	Female	495	461	28	93.1%
		Male	474	392	70	82.7%
	Unknown	Female	18	16	2	88.9%
		Male	16	12	4	75.0%
Gauteng	African	Female	1044	429	236	41.1%
		Male	1486	615	348	41.4%
	Coloured	Female	90	51	17	56.7%
		Male	71	43	20	60.6%
	Indian	Female	418	328	66	78.5%
		Male	345	254	53	73.6%
	White	Female	2526	2158	316	85.4%
		Male	2425	2000	340	82.5%
	Other	Female	13	2	1	15.4%
		Male	21	3	6	14.3%
KwaZulu/Nata	African	Female	2195	369	394	16.8%
		Male	2808	664	554	23.6%
	Coloured	Female	65	32	20	49.2%
		Male	75	43	20	57.3%
	Indian	Female	1631	1120	341	68.7%
		Male	1477	1013	291	68.6%
	White	Female	608	490	95	80.6%
		Male	766	588	116	76.8%
Mpumalanga	African	Female	368	61	69	16.6%
		Male	636	198	151	31.1%
	Coloured	Female	6	3	2	50.0%
		Male	4	3	1	75.0%
	Indian	Female	26	23	2	88.5%
		Male	29	28	0	96.6%
	White	Female	356	313	42	87.9%
		Male	303	265	31	87.5%
Northern	African	Female	30	11	12	36.7%
		Male	28	17	7	60.7%
	Coloured	Female	24	21	3	87.5%
		Male	20	19	1	95.0%
	Indian	Female	0	0	0	0
		Male	1	1	0	100.0%
	White	Female	142	137	4	96.5%
		Male	142	131	11	92.3%
Limpopo	African	Female	2544	296	348	11.6%

		Male	3191	733	616	23.0%
	Coloured	Female	2	1	1	50.0%
		Male	4	2	2	50.0%
	Indian	Female	10	6	3	60.0%
		Male	13	11	2	84.6%
	White	Female	181	162	17	89.5%
		Male	171	138	30	80.7%
North West	African	Female	334	136	90	40.7%
		Male	496	236	115	47.6%
	Coloured	Female	0	0	0	0%
		Male	12	9	2	75.0%
	Indian	Female	28	26	1	92.9%
		Male	23	21	2	91.3%
	White	Female	328	284	36	86.6%
		Male	310	253	48	81.6%
Western	African	Female	130	83	24	63.8%
		Male	162	117	23	72.2%
	Coloured	Female	493	352	91	71.4%
		Male	499	369	90	73.9%
	Indian	Female	78	73	1	93.6%
		Male	75	71	3	94.7%
	White	Female	1302	1255	44	96.4%
		Male	1355	1279	71	94.4%
Total	African	Female	7184	1638	1300	22.8%
		Male	9634	2999	1978	31.1%
	Coloured	Female	742	511	141	68.9%
		Male	769	556	148	72.3%
	Indian	Female	2231	1614	416	72.3%
		Male	1987	1421	353	71.5%
	White	Female	6334	5632	604	88.9%
		Male	6329	5394	746	85.2%
	Other/unk	Female	31	18	3	58.1%
		Male	37	15	10	40.5%
	Total	Female	16522	9413	2464	57.0%
		Male	18756	10385	3235	55.4%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Note: The total number of candidates and passes does not reflect exactly those figures published by the DOE due to not including those candidates who gained a conditional exemption.

This table shows that African candidates are the least successful group in all provinces. However, female African candidate are significantly less successful than their male counterparts in six provinces. In the Eastern Cape, Gauteng and Western Cape female performance is reasonable close or equal to male performance. Table 3.16 presents comparable data for physical science.

Table 3.16: HG physical science candidates, number passing and number converting to a SG pass by race, gender and province, 2002

Province	Race	Gender	Candidates	Pass	Convert to SG pass	Pass rate
Eastern Cape	African	F	409	153	157	37.4%
		M	568	265	179	46.7%
	Coloured	F	65	49	15	75.4%
		M	71	59	12	83.1%
	Indian	F	44	41	3	93.2%
		M	30	26	4	86.7%
	White	F	319	307	12	96.2%
		M	403	366	32	90.8%
Free State	African	F	671	151	269	22.5%
		M	1 071	337	451	31.5%
	Coloured	F	11	5	5	45.5%
		M	21	8	10	38.1%
	Indian	F	1	1	0	100.0%
		M	0	0	0	0
	White	F	543	461	76	84.9%
		M	680	490	161	72.1%
	Unknown	F	27	16	10	59.3%
		M	37	20	14	54.1%
Gauteng	African	F	1 507	501	639	33.2%
		M	2 029	721	765	35.5%
	Coloured	F	107	65	37	60.7%
		M	100	64	29	64.0%
	Indian	F	484	363	95	75.0%
		M	473	289	134	61.1%
	White	F	2 415	2035	349	84.3%
		M	2 916	2258	581	77.4%
	Other	F	30	1	10	3.3%
		M	37	4	11	10.8%
KwaZulu/Natal	African	F	3275	713	1315	21.8%
		M	4179	1031	1603	24.7%
	Coloured	F	63	45	15	71.4%
		M	91	52	26	57.1%
	Indian	F	1927	1434	415	74.4%
		M	1863	1288	448	69.1%
	White	F	499	445	47	89.2%
		M	970	756	202	77.9%
Mpumalanga	African	F	1134	144	373	12.7%
		M	1541	328	563	21.3%
	Coloured	F	12	3	8	25.0%
		M	9	5	3	55.6%
	Indian	F	33	26	6	78.8%
		M	35	28	7	80.0%
	White	F	385	322	56	83.6%
		M	414	321	88	77.5%
Northern Cape	African	F	11	5	3	45.5%
		M	35	24	9	68.6%
	Coloured	F	19	15	4	78.9%
		M	28	19	9	67.9%
	Indian	F	0	0	0	0
		M	1	1	0	100.0%
	White	F	102	96	4	94.1%
		M	163	140	22	85.9%
Limpopo	African	F	5068	641	2014	12.6%

Province	Race	Gender	Candidates	Pass	Convert to SG pass	Pass rate
		M	5980	1250	2406	20.9%
	Coloured	F	3	1	1	33.3%
		M	6	2	2	33.3%
	Indian	F	17	9	8	52.9%
		M	16	12	4	75.0%
	White	F	188	151	32	80.3%
		M	240	156	78	65.0%
North West	African	F	1115	268	446	24.0%
		M	1239	389	479	31.4%
	Coloured	F	7	2	4	28.6%
		M	17	8	4	47.1%
	Indian	F	22	21	1	95.5%
		M	26	21	5	80.8%
	White	F	337	290	42	86.1%
		M	420	348	69	82.9%
Western Cape	African	F	129	78	46	60.5%
		M	195	130	53	66.7%
	Coloured	F	499	385	98	77.2%
		M	602	464	118	77.1%
	Indian	F	89	78	10	87.6%
		M	96	71	21	74.0%
	White	F	1027	991	31	96.5%
		M	1500	1371	122	91.4%
Total	African	Female	13319	2654	5262	19.9%
		Male	16837	4475	6508	26.6%
	Coloured	Female	786	570	187	72.5%
		Male	945	681	213	72.1%
	Indian	Female	2617	1973	538	75.4%
		Male	2540	1736	623	68.3%
	White	Female	5815	5098	649	87.7%
		Male	7706	6206	1355	80.5%
	Other/unknow	Female	57	17	20	29.8%
		Male	74	24	25	32.4%
	Total	Female	22594	10312	6656	45.6%
		Male	28102	13122	8724	46.7%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

Note: The total number of candidates and passes does not reflect exactly those figures published by the NDoE due to not including those candidates who gained a conditional exemption.

The table shows that there are major differences between female and male African candidates in six provinces, but not in Gauteng, KwaZulu-Natal, and Western Cape.

The data in tables 3.13 to 3.16 are unlike any other data presented in this chapter because they have no dimension over time. It is simply not known whether these results can be used to identify a trend or not. Nevertheless, they are disturbing enough to take into account in the conclusions on gender.

Conclusion

At one level the data on gender are heartening. The general pass rate of female SC maths and physical science candidates at the higher grade is extremely high, and does not point to the need for programmes aimed specifically at female learners. However, once the data are disaggregated by race, gender, and province, there is no doubt that interventions aimed at increasing the success rates of female African candidates specifically are urgently required in six provinces in maths, and in six different provinces in physical science.

This exercise once again confirms the wisdom of taking data down to the lowest possible level; it has led to far more precise targets. Using the CDE database, it is possible to take the analysis down to the level of individual schools, and plan actions here. As the numbers of learners in the various provinces requiring attention vary from fewer than 200 to just more than 2 000, targeting them with specific interventions are not a daunting task.

THE LANGUAGE FACTOR

International and South African research has shown that language competence plays a decisive role in performance in maths and physical science. This is especially true in countries in which these subjects are taught in what is a second language for most learners.

In South Africa, SC maths and physical science are taught in one of two 'languages of learning and teaching' – ie, English or Afrikaans. This means that the vast majority of learners – 80 per cent in 2000 – are taught maths and physical science in a second language. It must be assumed that this influences their performance in these subjects.

This group was analysed in great detail, in order to try to establish useful correlations between variables. The following emerged:

- In 2000, no less than 61,6 per cent of African first-language candidates wrote both English and Afrikaans as second languages at the HG.
- A second substantial group (25,7 per cent) wrote English only as a second language at the HG.
- A much smaller number (4,9 per cent) did not write English or Afrikaans, while 4,7 per cent wrote English and Afrikaans as second languages at HG and SG respectively.
- The remaining 3,1 per cent wrote various combinations of Afrikaans and English at HG and SG.
- About 75 per cent of all secondary schools in the country use English as the medium of instruction.

This means that the most meaningful correlations between language competence and performance in maths and physical science must involve:

- performance in an African first language;
- performance in English as a second language, predominantly at the higher grade; and
- performance in maths and physical science.

Table 3.17 sets out the range of marks obtained by African first-language candidates in their own languages at the higher grade, and in English as a second language at the higher and standard grades. A fourth column, added for comparative purposes, records the marks of Afrikaans/English first-language candidates in their own languages at the higher grade.

Table 3.17: Marks in English of African first-language candidates

Distribution	African first-language candidates			English/Afrikaans first-language candidates
	First language, HG	English as second language, HG	English as second language, SG	English/Afrikaans as first language, HG
Maximum	400	300	300	400
10th percentile	164	79	94	153
25th percentile	189	96	115	180
Median	218	115	136	217
75th percentile	245	138	159	255
90th percentile	271	159	179	287
Mean	(54%) 217	(39%) 118	(46%) 137	(55%) 219
Standard deviation	42	32	33	52

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

The table shows that African first-language candidates perform roughly as well in their first language as English or Afrikaans first-language candidates in theirs. However, they perform far worse in English as a second language. Moreover, they do worse in HG English than in SG English.

Table 3.18 sets out the results of a regression analysis aimed at determining the correlation between maths and physical science results and language results; more specifically, what marks in English typically translate into a maths or physical science pass at both the higher and standard grades.

Table 3.18: Correlation between maths and physical science and language results, 2000

MATHEMATICS						
	Higher grade			Standard grade		
Constant	-104	-28	-39	-39	34	-27
African first language	0.425			0.375		
English second language	0.641	0.846		0.247	0.387	
English/Afrikaans first language			0.930			0.709
R squared	0.204	0.165	0.266	0.084	0.038	0.237
Number of observations	12,329	12,329	19,636	99,961	99,961	50,802
English mark required for a maths pass		222	214		171	179
SCIENCE						
	Higher grade			Standard grade		
Constant	-31	21	-36	24	66	38
African first language	0.283			0.211		
English second language	0.527	0.651		0.295	0.369	
English/Afrikaans first language			0.937			0.496
R squared	0.213	0.177	0.344	0.107	0.074	0.266
Number of observations	21,996	21,996	21,882	42,338	42,338	22,190
English mark required for a science pass		214	209		92	125

Source: Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000.

Note: All coefficients differ significantly from zero at the 5% level.

When interpreting the results of this table, we must take account of the effect of the different marks required in the 'language of learning and teaching' if the candidate is to succeed in maths or physical as well. First-language papers HG are marked out of 400, and second-language papers (HG or SG) out of 300. This means that, in order to gain the 214 marks in English associated with a HG maths pass, a student learning maths in his or her first language only requires a mark of 54 per cent (214/400) in that language. However, a student learning maths in his or her second language requires a mark of 71 per cent (214/300) in that language.

The other point to notice is that while the competence in English associated with passes in HG maths and physical science are roughly similar, there is a huge gap between the competence in English associated with passes in SG maths and SG physical science respectively. To pass SG maths, students whose first language is not the language of learning and teaching need a mark of 60 per cent in English. The SG physical science requirement is much lower.

These outcomes are very instructive. For African first-language candidates writing HG maths and physical science and SG physical science, the addition of one mark to their performance in HG English results in considerably more than one additional mark in maths and physical science. Also, increased language marks have an even stronger impact at HG than at SG. The chances of African first-language candidates performing better in maths and physical science would be dramatically improved by improving their performance in English.

While this calculation confirms common-sense perceptions, it gives them a firm quantitative dimension that is important for policy. Schools that wish to perform well in maths and physical science must pay equal attention to the language of learning and teaching, at least in the case of English.

In general, policies for improving performance in maths and physical science must pay more attention to improving candidates' abilities in English, particularly the terminology used to formulate maths and physical science word problems.

OTHER FACTORS INFLUENCING PERFORMANCE IN MATHS AND PHYSICAL SCIENCE

Data on the 1998 and 2000 SC examinations were also analysed to establish whether they provided yet more factors that influenced performance in maths and physical science.

The following variables were considered: the candidate's aggregate mark; the province in which the candidate studied; the candidate's first language; the number of subjects entered by the candidate; the candidate's gender; the proportion of candidates at a given examination centre writing the subject; and, in the case of physical science, whether the candidate also wrote maths, and at what level.

Of these seven variables, the aggregate mark turned out to be far more important than the rest. Using this indicator only, it emerges that:

- An aggregate mark of 1 238 in 1998 (1 243 in 2000) produced a pass (40 per cent) in HG maths. This is a high aggregate, achieved by fewer than 10 per cent of SC candidates.
- An aggregate mark of 983 or 946 in 1998 (996 or 950 in 2000) produced a pass (33,33 per cent) in SG maths, depending on whether maths was originally written at the higher or standard grade.
- An aggregate mark of 833 in 1998 (838 in 2000) produced a pass in LG maths.

By contrast:

- An aggregate mark of 1 113 in 1998 (1 156 in 2000) produced a pass (40 per cent) in HG physical science.
- An aggregate mark of 819 or 772 in 1998 (872 or 789 in 2000) produced a pass in SG physical science, depending on whether physical science was written in the higher or standard grade.
- An aggregate mark of 626 (646 in 2000) produced a pass in LG physical science.
- This information has a critical bearing on one of the system's main problems: Why do so few learners study maths and physical science and enter SC examinations? We explore this question in the following section.

COULD MORE CANDIDATES PASS SC MATHS AND/OR PHYSICAL SCIENCE?

All educational examination systems are based on the assumption that principals and educators know whether learners have the potential to pass a given examination, and act rationally on this knowledge. If candidates have little chance of succeeding at a higher level, they are advised or obliged to enter at a lower level (if this option exists at their school). If they have little chance of succeeding at the lower level, they are advised not to enter at all, or to try other subjects. Indeed, a few years ago, the NDoE instructed provincial departments to dissuade some learners from entering for maths and physical science SC examinations, especially at HG level, in a misguided attempt to inflate pass rates.

CDE data show conclusively that the answer to the question 'could more SC candidates pass maths and/or physical science?' in the South African system is 'Yes, they could'. This is a counter-intuitive finding that arises from a set of stereotypes and perverse incentives to which officials, principals, educators and learners are responding in positively turning away from SC maths and physical science.

A statistical analysis of the overall SC results in 1998 and 2000 shows that thousands of learners who could have succeeded in one or both subjects failed to study them or enter the exam or write. Indeed, the numbers of learners who could have succeeded in maths and physical science at both HG and SG but did not choose these subjects are sufficiently large to make it well worth while to identify this group.

Many learners are pressured by principals, educators, or parents not to study those subjects or to study them at SG, in order to maintain or improve the schools pass rate. This is obviously counterproductive for learners, their families, their schools, the education system, and the nation.

Given the strong correlations between aggregate marks and marks in maths and physical science, CDE decided to estimate the potential for additional mathematics and physical science passes. The exercise is based on the following assumptions:

- Learners can predict their aggregate mark when choosing their SC subjects.
- On the basis of that prediction, they can determine the probability distribution of their potential marks in mathematics and physical science. Based on this, they can also predict their probable/potential marks in maths and physical science.
- Learners only study mathematics and physical science if they expect to pass, at least at SG.
- Learners only enter at the HG if they expect to do as well as, or better than, they would if they entered at SG.

A calculation was made based on these assumptions involving candidates who wrote six or more subjects, in 1998 and 2000 and gained an aggregate of at least 710 marks.

The main findings for maths are:

- In 1998 41 per cent more SC maths learners could have passed maths HG than did so. In 2000 (after the NDoE issued its advice) 56 per cent more could have passed. This means that many learners are making unduly cautious decisions about taking HG mathematics, or are constrained by the options at their schools, or have been persuaded not to enter.

- In terms of numbers, among learners who did not write mathematics, 53 283 more learners potentially could have passed maths in 1998, and 49 439 104 in 2000. However, among this group the potential for extra HG passes was relatively small: 3 644 in 1998, and 3 728 in 2000.

The main findings for physical science are:

- In 1998, 35 per cent more SC physical science learners could have passed HG physical science, and in 2000 45 per cent more.
- Among the candidates who did not write physical science, there was the potential for 166 253 additional passes in 1998 and 161 595 additional passes in 2000. Among this group, the potential for HG passes was large: 15 956 in 1998 and 14 887 in 2000.

The results of this exercise should not be taken too literally. Talents for and interest in maths and physical science varies between candidates. These variations are not recorded in the dataset, and will affect choices and results. The estimate of potential passes in maths and physical science is therefore likely to be too high.

Nonetheless, the broad results point to a situation that requires urgent attention. Recent patterns of entry for maths and physical science have been far from optimal. A better pattern of entries could yield a considerably increased crop of passes in maths and science.

PERFORMANCE IN MATHS AND PHYSICAL SCIENCE RELATED TO SCHOOL FACILITIES AND LOCALITIES

As noted earlier, school facilities and the localities in which schools operate were also related to performance in maths and physical science. This has been achieved with data from three sources: The School Register of Needs of 1996; the Educational Management Information System (EMIS) of 1998; and the Census of 1996.

Now that the method for performing this analysis has been established, the exercise can be repeated when the data from Census 2001 becomes available.

As regards the data from the School Register of Needs, information on the general condition of the school, the availability of power, telecommunications, water, toilets, media centres, physical science laboratories, and textbooks were combined to produce a **facilities index**. This index records the facilities available at or to a school, ranging between zero and 70. It reveals that, on average, half of South African schools actually have the facilities they require to function in the 21st century.

A **minority index** was also calculated, reflecting estimates of the number of non-African learners at a given school. The rationale for this is that schools which originally fell under the previous department of education and training (DET) and 'homeland' departments of education suffer historical disadvantages. The Minority Index is a way of obtaining insight into the impact of these disadvantages on performance. It has been calculated from data in the EMIS 1998 that breaks down grade 12 learners by racial group. The Minority Index ranges between a value of 0.0, if the percentage of coloureds, Asians, and whites in grade 12 is less than 20 per cent of all learners, and a value of 1.0, if the minority groups constitute more than 20 per cent of learners. Further development of the index can test this scale.

The minority index is a relatively imprecise instrument, but it still raises several interesting issues. For instance, of the 3 927 schools for which information was available, 2 947 (75.0 per cent) had a minority index of 0.0, and 950 (25.0 per cent) a minority index of 1.0. In other words, only 25 per cent of schools in South Africa have more than 80 per cent non-African learners – there is clearly a threshold level for efforts to racially integrate South African schools.

Correlations show that 41,5 per cent of secondary schools had a physical science laboratory. However, only 36 per cent of schools with a minority index of 0.0 had a physical science laboratory, as against 86 per cent of schools with a minority index of 1.0. Similar disparities abound. However, the point is not simply to bemoan these facts, but to use the data to target interventions where they will have the maximum impact – at the school level.

A **school locality index** was also developed, using data from the 1996 census. Of 4 801 secondary schools offering SC maths and physical science, 2 174 (45,3 per cent) were in urban formal areas, 95 (2,0 per cent) in urban informal areas, 327 (6,8 per cent) in commercial farming areas, 2 038 (42,4 per cent) in tribal rural areas, 152 (3,2 per cent) in other rural areas, and 15 (0,3 per cent) in areas where no one settlement type was dominant. Some 2 354 were government schools (49 per cent of all schools); 1 789 (37,3 per cent) were community schools; 330 (6,9 per cent) were private schools; and the remainder were distributed over a number of other categories.

Once this data had been calculated, it was possible to relate the facilities index to provinces, dominant settlement types in the locality of the school, and the minority index thus allowing a comparative provincial analyses to be carried out on the 1996-8 data.

Provincial variations in the facilities index are substantial, with Free State, Mpumalanga, North West, and Western Cape best off, and the Eastern Cape worst off. Unsurprisingly, facilities are best in urban areas, and worst in tribal and rural areas. Schools with a minority index of 0.0 (completely or nearly completely African) had a facilities index 16 per cent lower than schools with a minority index of 1.0.

One specific aspect of dominant settlement type around a school is significantly related to performance. Census data allowed CDE to establish the average years of education of people older than 35 (i.e. probable parents of secondary school learners) in each of the localities. This analysis is reported in table 3.19.

Table 3.19: Average years of education of people aged 35 and older in localities with place names associated with schools

Settlement type	25th percentile	Median	75th percentile	Mean
Urban formal	7.6	8.8	11.6	9.2
Urban informal	5.0	5.8	6.7	6.1
Commercial farm	4.0	4.9	6.2	5.2
Tribal rural	2.2	3.1	4.3	3.4
Other rural		3.3	4.9	

Source: Charles Simkins, School and community determinants of mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000. CDE background research report, 2004.

This table shows that the average level of education among probable parents is considerably higher in urban formal areas than elsewhere. Schools are more likely to respond positively to reforms if they have a relatively better educated parent community. Level of education in a locality does have a positive influence on both maths and physical science enrolment and performance in schools in that locality.

THE EDUCATOR FACTOR

Two factors were used to establish correlations between educators and school performance. The first is simply the proportion of all qualified educators teaching maths and physical science in each school (the 'quantity factor'). The second is a combination of the average years of post-matriculation education of educators, combined with their average years of experience (the 'quality factor').

The EMIS data allowed values to be given to each factor. As regards the quantity factor, 187 schools reported that they had no educators qualified in mathematics. Results were calculated for each percentile of schools.

As regards the quality factor, educators qualified in mathematics had an average of 2,95 years of post-SC training, and those qualified in physical science 2,88 years. Percentile figures were calculated that show that many educators are underqualified. Ideally, secondary school educators should have an M+4 qualification in their subject(s). A mix of M+3 and M+4 educators in equal proportions (with an average of 3,5 post-matriculation years of training) would probably be adequate. However, only 14,7 per cent of schools report this average in mathematics, and only 16 per cent in physical science. On average, educators teaching mathematics had acceptable levels of 7,4 years of experience and educators teaching physical science 6,5 years.

EMIS records the proportion of all secondary school periods devoted to mathematics and physical science. This can be regarded as a further quantitative factor affecting performance in these subjects. Some 140 schools reported spending no time on mathematics. At the 25th percentile of the distribution of time spent, 8.3 per cent of all school periods were spent on mathematics; at the 50th percentile, 10,6 per cent; and at the 75th percentile, 13,0 per cent. A total of 236 schools reported spending no time on physical science. At the 25th percentile, 4,5 per cent of periods were spent on physical science; at the 50^{th} percentile, 6,6 per cent; and at the 75^{th} percentile, 9,0 per cent.

Maths and physical science periods were also related to total periods. In the case of mathematics:

- the proportion of periods rose with the proportion of educators qualified in mathematics;
- the proportion of periods was relatively high in Gauteng and relatively low in Western Cape, Northern Cape, and North West;
- the proportion was slightly lower in schools with fewer than 20 per cent minority learners.

In the case of physical science:

- the proportion of periods also rose with the proportion of educators qualified in physical science; and
- the proportion of periods was relatively high in Eastern Cape, Free State, and KwaZulu-Natal, and relatively low in North West.

In summary, then, the educator factor is significant, both in terms of quantity (numbers of educators) and quality (experience and qualifications). Many maths and physical science teachers are underqualified, with only 14 per cent of schools reporting an adequate average level of qualification in terms of their mathematics teachers. This leads logically to the next problem related to educators: the fact that insufficient teaching periods are devoted to mathematics and physical science if a school has poorly qualified maths and physical science teachers. The self-report data of TIMSS-R (see chapters 2 and 7) are conclusively confirmed by this completely independent data collection and analysis, thus giving us far more confidence in the TIMSS-R data as well.

SC PERFORMANCE IN MATHS AND PHYSICAL SCIENCE: A BROAD ANALYSIS

The following data were obtained by aggregating the results for each candidate within each school (examination centre); supplementary examination results are included.

General performance

- Proportion of candidates completing
- Proportion of completing candidates obtaining a SC pass
- Proportion of passing candidates obtaining a full or conditional endorsement
- The average aggregate mark per completing candidate
- The average aggregate mark per passing candidate

Performance in maths

- Proportion of candidates writing mathematics
- Proportion of candidates passing mathematics
- Proportion of candidates passing mathematics at the HG
- The average mark obtained by candidates writing mathematics
- The average mark obtained by candidates passing mathematics

Performance in physical science

- Proportion of candidates writing physical science
- Proportion of candidates passing physical science
- Proportion of candidates passing physical science at the HG
- The average mark obtained by candidates writing physical science
- The average mark obtained by candidates passing physical science

In order to reduce the number of variables in the analysis, the three clusters of variables were each put through a factor analysis. In each case a highly dominant first factor emerged, which can be regarded as indicating:

- the general quality of the sc outcome
- the quality of the mathematics outcome; and
- the quality of the physical science outcome.

The weight of the mathematics and physical science marks was much greater than all the other variables. Therefore, these marks were used as they stood in further analysis, and the other performance variables dropped.

A pairwise correlation matrix was calculated between the general performance factor, the mathematics mark, and the physical science mark. Table 3.20 displays the result.

Table 3.20: Correlation matrix

	General	Mathematics	Physical science
General	1,000		
Mathematics	0.871	1.000	
Physical science	0.717	0.763	1.000

Source: Charles Simkins, School and community determinants of mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000. CDE background research report, 2004.

The correlation coefficients are high between general performance, mathematics mark, and physical science mark. The correlation coefficient between the general outcome and the mathematics outcome is higher than the correlation coefficient between the general outcome and the physical science outcome.

This supports our earlier argument that the aggregate mark obtained by a candidate in the SC examination for all subjects remains the best general indicator of his or her mark in maths or physical science, should those subjects be written.

Table 3.21 relates choice of subject to some of the new socio-economic and school level variables.

Table 3.21: Results of analysis of the proportions of grade 12 learners studying HG mathematics, mathematics, HG physical science, and physical science

	Maths HG	All	Science HG	All
Constant	0.236	0.493	0.207	0.349
				Province
Western Cape	-0.134	-0.037	-0.104	-0.066
Eastern Cape	-0.089	-0.040	-0.063	-0.034
Northern Cape	-0.112	-0.082	-0.084	-0.091
KwaZulu Natal	0.018	0.023	-0.014	-0.051
North West	-0.053	0.000	0.019	-0.007
Gauteng	-0.024	0.065	0.023	0.083
Settlement type				
Urban formal	-0.056	-0.020	-0.044	-0.037
Urban informal	-0.044	-0.036	-0.041	-0.028
Commercial farm	-0.043	-0.009	-0.040	-0.018
Tribal rural	-0.015	0.013	0.000	-0.008
Minority index				
Less than 20% minority	-0.010	-0.054	-0.049	-0.056
No science lab			-0.016	-0.010
Educator quantity factor	0.061	0.117	0.064	0.104
Educator quality factor	-0.005	-0.001	0.014	-0.030
Average years of education of those aged > 35 in the community	0.0056	0.0081	0.0052	0.0056
R-squared	0.0536	0.1059	0.0752	0.1209
Number of observations	2428	2428	2427	2427

Source: Charles Simkins, School and community determinants of mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000. CDE background research report, 2004.

Notes: (1) The omitted categories are: Mpumalanga, other rural, more than 20% minority learners, science laboratory. (2) Free State and Limpopo Province omitted altogether for lack of data. (3) Coefficients in italics are not significant at the 5% level

This table confirms the data in the previous sections, and shows that:

- There are significant provincial variations.
- Settlement type generally does not exert a significant influence on subject choice.
- The lack of physical science laboratories appears to make no significant difference to the proportion of grade 12 physical science enrolments.
- The educator quantity factor (number of educators and proportion of periods devoted to the subject) is positively related to grade 12 enrolment rates in those subjects.
- The educator quality factor makes no significant difference to enrolments.

- The average education of the community within which the school is situated is positively related to the proportion of mathematics and physical science enrolments in Grade 12.

Table 3.22 sets out the results of a regression of the general SC performance factor, mathematics marks and physical science marks.

Table 3.22: Results of an analysis of the general SC performance factor, the mathematics factor, and the physical science factor

	General Factor	Mathematics Mark	Science mark
Constant	0.461	105	146
Province			
Western Cape	-0.596	-19	-17
Northern Cape	-0.525	4	-11
Free State	0.008		
Eastern Cape	-0.277	10	-4
KwaZulu-Natal	0.091	-6	19
Mpumalanga	0.167	-3	-4
Northern Province	-0.221	-33	
Gauteng	-0.332	0	-4
Average years of education 35+	0.039	2.1	1.6
Factors			
Mathematics teaching quantity		7.6	
Mathematics teaching quality		8.8	
Science teaching quantity			11.8
Science teaching quality			14.2
No science laboratory			-0.5
Facilities index	0.0077	0.39	0.40
Settlement type			
Urban formal	-0.203	-10	-9
Urban informal	-0.088	3	2
Commercial farm	0.093	12	1
Tribal rural	0.026	3	-2
Minority index			
Less than 20% minority	-1.062	-60	-63
Pupil-teacher ratio	-0.0085	-0.13	-0.15
Proportion of teachers with degrees	0.843		
Mathematics teacher with degree		4.6	
Science teacher with degree			0.3
R-squared	0.542	0.468	0.573
Number of observations	3226	2359	2157

Note: Coefficients in italics are not significantly different from zero at the 5% level.

Source: Charles Simkins, School and community determinants of mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000. CDE background research report, 2004.

From Table 3.22, we learn that:

- Three provinces do relatively better than the others in SC, once average years of education of people age 35 and above in the community, settlement type, the minority index and the learner-educator ratio have been taken into account. These provinces are: Mpumalanga, North West and KwaZulu Natal.

- The level of education of people age 35 and above near the school has a positive influence on the general performance factor
- Schools in which fewer than 20 per cent of the Grade 12 learners belong to the minority groups do considerably worse in SC.
- As one would expect, the learner-educator ratio influences SC performance: as it rises, performance falls
- General SC performance has a strong effect on mathematics and physical science performance. Also the variables which affect general performance will affect mathematics and physical science performance
- The mathematics teaching quality factor and the minority index have a specific effect on the mathematics performance factor.
- The physical science teaching quantity and quality factors, the absence of physical science laboratories, the facilities index more generally and the minority index have a specific effect on the physical science performance factor.

While the use of factors is helpful in reducing the dimensionality of the analytical problem, they are rather abstract constructs. Schools entering any mathematics and physical science candidates have therefore been divided into deciles by the mathematics and physical science marks respectively. The average value of underlying variables shown to be relevant is calculated in table 3.23.

Table 3.23: SC maths and physical science performance by decile

Mathematics											
Variable	Decile										*Mean*
	Top	2nd	3rd	4th	5th	6th	7th	8th	9th	Bottom	No mathematics
% of candidates completing	99.2	97.8	96.9	95.8	96.1	95.3	95.2	94.8	94.3	91.7	89.6
Pass rate for completing candidates	97.8	85.1	68.0	58.5	50.3	43.5	41.1	36.4	30.9	24.5	43.2
Proportion endorsements	62.0	38.4	27.4	23.7	20.6	18.4	18.2	16.5	14.9	13.0	17.6
Aggregate marks for candidates who passed	1256	1024	927	899	881	870	867	861	852	839	852
Mathematics entry rate	66.2	52.9	43.8	43.6	42.3	42.2	44.2	45.6	46.4	56.1	
Mathematics pass rate	96.8	84.0	65.2	50.9	39.7	29.8	22.7	16.3	10.1	4.2	
Proportion maths passes higher grade	32.0	10.8	4.5	2.6	1.8	1.2	1.0	0.7	0.3	0.1	
Average Mathematics mark for passes	201	150	133	125	121	120	118	116	113	110	
English second language higher grade	126	118	112	111	109	108	108	106	106	103	103
Percent schools with English second language HG entries	10	42	70	82	90	95	96	98	99	100	38
Facilities index	55	48	42	38	35	33	33	32	30	27	26
Percentage minorities in Grade 12	80.8	46.4	25.2	15.7	9.2	4.5	4.4	2.2	1.6	0.5	7.1
Learner/educator ratio	21.9	26.2	28.8	30.1	29.2	31.0	31.0	29.2	30.2	31.7	27.9
Average years of education: 35+	10.64	8.32	6.63	5.80	5.58	4.99	5.18	5.01	4.57	4.60	4.62
Percentage teachers qualified in maths	19.8	19.0	17.8	17.5	16.7	17.0	17.5	15.2	16.1	17.0	
Average years of post-matric maths training	2.99	3.06	3.05	3.01	2.99	2.97	2.86	2.83	2.84	2.73	
Percentage of periods in mathematics	11.6	11.4	10.3	10.2	10.4	10.3	10.7	10.1	10.8	11.2	
Average years of experience of maths teachers	11.1	9.0	7.6	7.2	7.0	6.6	6.5	6.6	6.4	6.3	
% with at least one degreed maths teacher	68.8	63.6	54.6	48.8	44.7	40.0	36.6	33.2	32.0	26.0	
Science											
Variable	Decile										*Mean*
	Top	2nd	3rd	4th	5th	6th	7th	8th	9th	Bottom	No science
% of candidates completing	99.2	98.3	97.1	96.6	96.1	95.3	95.3	94.8	94.4	91.0	94.0
Pass rate for completing candidates	96.3	88.4	72.2	60.5	53.7	46.8	40.7	35.1	31.9	22.9	44.3
Proportion endorsements	64.8	45.2	30.2	24.2	22.1	19.0	17.3	14.7	14.0	11.8	17.6
Aggregate marks for candidates who passed	1271	1079	945	904	886	873	864	855	849	834	864
Science entry rate	42.7	39.6	30.2	28.4	27.3	27.6	26.3	26.8	26.3	32.0	
Science pass rate	99.3	97.2	91.3	81.3	71.1	59.3	47.8	37.9	27.5	13.7	
Proportion maths passes higher grade	61.1	33.4	15.6	7.9	5.6	4.1	2.9	1.6	1.1	0.4	
Average Science mark for passes	220	173	146	133	126	121	119	115	112	108	
English second language higher grade	121	122	118	113	113	110	108	106	104	101	104
Percent schools with English second language HG entries	7	27	66	83	89	96	98	99	100	100	52
Facilities index	55	52	46	38	38	35	34	33	29	26	26
Percentage with laboratories	85	79	66	47	48	36	36	31	24	16	
Percentage minorities in Grade 12	83.4	56.1	25.8	14.8	8.6	5.0	1.0	1.0	0.3	0.6	9.4
Learner/educator ratio	22.2	25.7	28.8	29.8	30.0	31.8	29.7	29.5	30.4	30.2	29.7
Average years of education: 35+	10.49	9.17	6.98	6.14	5.93	5.47	5.12	4.87	4.66	4.51	4.51
Percentage teachers qualified in science	15.2	14.9	13.3	14.0	12.6	13.7	12.9	13.1	13.0	12.6	
Average years of post-matric science training	2.89	2.93	2.89	2.90	2.84	2.85	2.97	2.87	2.86	2.91	
Percentage of periods in science	7.4	7.3	7.4	7.4	6.9	7.4	7.0	7.2	7.5	7.8	
Average years of experience of science teachers	9.9	8.6	7.1	6.2	6.1	5.8	5.8	6.1	5.9	5.2	
% with at least one degreed science teacher	40.2	42.9	34.2	29.7	27.1	28.3	24.9	21.9	19.6	14.1	

Source: Charles Simkins, School and community determinants of mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000. CDE background research report, 2004.

Input variables that increase *dramatically* as the pass rate in mathematics increases are:

- The facilities index
- The average years of education of the school's surrounding community
- The average years of experience of mathematics educators

Input variables that increase *moderately* as the pass rate in mathematics increases are:

- Learner-educator ratio (from the fourth decile upwards)
- Percentage educators qualified in mathematics (from the fourth decile upwards)
- Average years of post-matric mathematics training

Input variables that increase dramatically as the pass rate in physical science increases are:

- The facilities index
- The proportion of schools with laboratories
- The average years of education of the community at the school's place name
- The average years of experience of physical science educators

The input variable that increases *moderately* as the pass rate in physical science increases is:

- Learner-educator ratio (from the fifth decile upwards)

INDEX OF SCHOOL PERFORMANCE IN MATHS AND PHYSICAL SCIENCE

As part of our study we developed an index of school performance that allows comparisons to be made along two dimensions:

- How does the performance of any one school compare with any other school and with all others?
- Is the performance of any one school improving, remaining stable, or deteriorating over time?

The index measures school performance along eight dimensions:

- total mathematics pass rate
- total physical science pass rate
- pass rate in HG mathematics
- pass rate in HG physical science
- mathematics candidates as a percentage of total candidates
- physical science candidates as a percentage of total candidates
- passes of female candidates in mathematics as a percentage of total female candidates
- passes of female candidates in physical science as a percentage of total female candidates

In the absence (as yet) of information required for useful differential weightings, each factor was weighted equally. Additional data will enable us to reassess the weightings.

BOX 3.1: METHOD USED TO PREPARE THE SCHOOLS INDEX

The index is based on data for each SC candidate recorded by the nine provincial departments of education. These databases are constantly updated, and archive the results of more than 700 000 candidates each year.

The databases are constructed from two main tables: full-time and part-time candidate's general information and full-time and part-time candidate information for each subject. These records can be linked to individual schools/examination centres. In essence the process of developing an index for each school entailed compiling the mathematics and physical science results for each full-time candidate including information on first language examination written and gender, and then summing up these results for each full-time examination centre. In general, a full-time examination centre coincides with a school; however, some full-time examination centres are adult centres, prisons and the like.

Problems were experienced with the 1998 data in terms of a number of duplicate candidates. Once it was ascertained that these were not valid candidates these duplicates were removed. Problems were also experienced with the subject coding lists in the 1998 database and the candidate subject codes could not be correctly linked to subject names. These were corrected and the analysis of this data completed. Problems were experienced with the examination centre numbers in the 1999 database which could not be correctly summed or linked to names until the correct centre numbers were forwarded by Phambili Information Technologies (the holder of the database). There were a number of centres with two codes and these had to be manually reconciled.

The weighting of the factors was discussed with the project management committee and it was decided to apply equal weighting for simplicity and transparency reasons. Equal weighting of the factors does not mean that these choices are devoid of policy implications. For example, not including a factor of HG participation somewhat equates the index of schools with a relatively large number of higher grade candidates compared to schools who may have the same higher grade pass rate but relatively few candidates actually writing the higher grade subjects. Similarly, including female passes as a percentage of female candidates only (as opposed to all candidates) is less punitive to those schools with naturally fewer female candidates but does not entirely reward schools who have a large proportion of female candidates who are achieving well in mathematics and physical science.

The problem with applying this index to schools with only male or only female candidates was overcome by calculating the index for these schools out of the first six factors and obtaining a index between 0 and 1 by dividing by 6. Schools with male and female candidates were calculated from all eight factors and divided by 8. This created indices on the same scale and for this exercise all schools were ranked together. Schools with male candidates only will still be slightly advantaged by this method of calculating the index.

CDE 2004

Table 3.24 lists the 20 best-performing schools in 2002, assessed according to the eight dimensions described above. Besides these dimensions, the percentage of African first-language candidates, the total number of candidates, and the total number of female candidates at a school are included in the table.

Table 3.24: Top 30 schools in maths and physical science, within prescribed parameters, 2002

				Factors used to calculate the index									
Prov	School	% African	Index	% maths pass	% science pass	% math HG pass	% science HG pass	% math candi-dates	% science candi-dates	% female maths pass	% fe-male science pass	Total candi-dates	Female candi-dates
FS	King's School Ficksburg		1.000	1.000	1.000	1.000	1.000	1.000	1.000			1	0
GT	Azaadville Muslim School		0.989	1.000	1.000	1.000	0.909	1.000	1.000	1.000	1.000	24	13
GT	Raucall Secondary School		0.987	1.000	1.000	1.000	0.898	1.000	1.000	1.000	1.000	70	35
GT	Yeshivath Torah Emeth College		0.967	1.000	1.000	1.000	1.000	1.000	0.800			5	0
WC	South African College School		0.950	0.969	1.000	0.984	0.913	1.000	0.833			162	0
NW	H T S Klerksdorp		0.947	0.964	1.000	0.923	0.688	1.000	1.000	1.000	1.000	112	23
NC	H T S Kimberley		0.947	1.000	1.000	0.824	0.750	1.000	1.000	1.000	1.000	42	1
NP	Mbilwi Sec School	94%	0.945	0.965	0.991	0.743	0.912	1.000	1.000	0.966	0.983	113	58
MP	Technical High School Ligbron		0.937	0.957	1.000	0.828	0.714	1.000	1.000	1.000	1.000	92	19
WC	Diocesan College		0.937	0.961	1.000	0.983	0.934	1.000	0.745			102	0
NW	H T S Rustenburg		0.935	0.985	1.000	0.906	0.919	1.000	0.868	1.000	0.800	68	5
WC	Rondebosch Boys' High School		0.926	0.993	1.000	0.986	0.926	0.959	0.694			147	0
EC	Newton Technical High School		0.923	0.988	0.965	1.000	0.429	1.000	1.000	1.000	1.000	85	1
WC	Bellville Technical High School		0.922	0.993	0.995	1.000	0.944	0.665	1.000	0.778	1.000	206	9
GT	Pretoria Boys' High School		0.921	0.967	0.990	0.875	0.951	0.939	0.805			261	0
GT	Central Islamic School		0.915	1.000	1.000	0.826	0.895	1.000	0.846	1.000	0.750	39	24
WC	Westerford High School		0.911	0.968	1.000	0.918	0.894	0.981	0.834	0.939	0.756	157	82
EC	Port Rex		0.911	0.990	0.984	0.826	0.714	0.772	1.000	1.000	1.000	127	2
KZ	Pinetown Boys' High School		0.909	0.981	0.975	0.765	0.733	1.000	1.000			161	0
FS	St Andrew's High School		0.904	0.964	1.000	1.000	1.000	0.846	0.615			65	0
EC	Theodor Herzl		0.903	1.000	1.000	1.000	0.923	0.929	0.750	0.938	0.688	28	16
GT	Parktown Boys' High School		0.903	1.000	1.000	0.830	1.000	0.836	0.750			128	0
GT	Crawford Schools Lonehill		0.902	1.000	1.000	1.000	1.000	1.000	0.658	1.000	0.556	38	18
EC	Ethembeni Enrichment Centre	100%	0.900	1.000	1.000	1.000	1.000	1.000	0.579	1.000	0.625	19	8
KZ	Durban High School		0.900	0.968	0.925	0.843	0.760	0.905	1.000			241	0
WC	Drostdy Technical High School		0.899	1.000	1.000	0.900	0.867	0.696	0.732	1.000	1.000	138	5
KZ	Westville Boys' High School		0.899	0.929	0.992	0.804	0.946	1.000	0.724			170	0
GT	Afrikaanse Hoër Seunskool		0.899	0.994	1.000	1.000	1.000	0.798	0.601			208	0
WC	Reddam House		0.898	1.000	1.000	0.889	0.900	1.000	0.769	1.000	0.625	13	8
GT	Springs Muslim School		0.898	0.882	0.971	0.643	0.684	1.000	1.000	1.000	1.000	34	14
WC	Herschel High School		0.896	1.000	1.000	0.964	1.000	0.949	0.654	0.949	0.654	78	78

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

IMPROVED SCHOOLS BETWEEN 1998 AND 2002

The school performance index was then used to establish the maths and physical science performance of all schools for each year from 1998 to 2002 inclusive. The annual change in the position of each school was calculated, and the overall improvement/deterioration over these four years calculated as the sum of the three annual changes. A list was then generated of the schools whose performance in maths and physical science had improved most dramatically.

Table 3.25: 30 most improved schools in maths and physical science, within prescribed parameters, 1998-2002

			2000			1999			1998			Improvement		
Prov	Description	% African	Index	Total candi-dates	Female candi-dates	Index	Total candi-dates	Female candi-dates	Index	Total candi-dates	Female candi-dates	Overall	98 - 99	99 - 2000
GT	Senaoane Secondary School	100%	0.859	25	13	0.115	253	146	0.210	233	143	0.648	-0.094	0.743
KZ	Enhlanhleni Combined	100%	0.732	44	14	0.445	38	13	0.148	43	18	0.584	0.297	0.287
KZ	Bonginhlanhla High School	100%	0.699	53	25	0.352	49	24	0.157	58	39	0.542	0.194	0.347
KZ	Siyaphakama High	100%	0.537	15	12	0	12	7				0.537	0	0.537
KZ	Emkhombe High	100%	0.513	20	9	0	14	6	0	12	7	0.513	0	0.513
EC	Sandi Senior Secondary School	100%	0.478	122	80	0.342	74	49	0	56	47	0.478	0.342	0.135
KZ	Seatides Secondary		0.693	24	16	0.657	33	16	0.223	27	7	0.470	0.434	0.036
KZ	Mabuthela High School	100%	0.547	44	14	0.557	16	5	0.077	94	43	0.470	0.480	-0.013
NP	Tshepho Secondary School	100%	0.615	11	10	0.260	6	4	0.15	5	2	0.465	0.110	0.354
KZ	Msimbu High School	100%	0.699	42	29	0.235	46	31	0.243	53	25	0.455	-0.008	0.463
GT	Allanridge Secondary School		0.610	43	15	0.244	25	12	0.163	36	20	0.447	0.081	0.365
EC	Solomon Mahlangu Sec School	100%	0.524	178	100	0.419	150	84	0.090	94	62	0.434	0.329	0.105
FS	S S Paki Sec School	100%	0.559	91	38	0.473	86	28	0.134	77	28	0.424	0.338	0.086
NW	Promosa Sekondêr		0.561	60	42	0.231	55	35	0.141	41	26	0.420	0.089	0.330
KZ	Galeni High School	98%	0.658	74	31	0.411	34	16	0.238	193	133	0.419	0.172	0.247
EC	Siyazakha S S School	100%	0.5	10	5	0.175	51	34	0.081	55	42	0.418	0.094	0.324
GT	Lee Rand Secondary School		0.628	8	5	0.281	21	12	0.211	22	10	0.416	0.069	0.347
EC	Mpingana Sen Sec School	100%	0.75	25	19	0.340	24	12				0.409	0	0.409
NW	Lighthouse Christian College		0.408	18	10	0	12	5				0.408	0	0.408
KZ	Carl Malcomess High School	98%	0.602	70	39	0.244	77	40	0.194	80	46	0.407	0.049	0.358
KZ	Langalibomvu High School	100%	0.508	26	7	0.061	35	21	0.110	52	35	0.398	-0.048	0.446
NP	Selebalo Sec School	100%	0.654	16	12	0.143	29	17	0.258	27	16	0.395	-0.114	0.510
NC	Hoërskool Richmond	20%	0.480	29	15	0.085	22	13	0.085	31	18	0.395	0	0.395
KZ	Nonkwenkwane High PMB	98%	0.392	84	46	0.196	58	39	0	73	43	0.392	0.196	0.195
KZ	Sea Cow Lake Sec School		0.438	60	43	0.269	105	53	0.046	107	67	0.391	0.222	0.168
KZ	Elwazi High School	100%	0.443	65	26	0.098	79	39	0.052	119	73	0.390	0.046	0.344
KZ	Mavumbuka High School	100%	0.444	80	52	0.178	74	51	0.055	89	63	0.388	0.123	0.265
KZ	Nhlungwane High School	100%	0.504	82	58	0.396	51	31	0.119	75	57	0.384	0.277	0.107
NP	Mokwane High School	100%	0.446	28	13	0.320	58	31	0.062	103	58	0.384	0.257	0.126
KZ	Sigqamise High School	100%	0.756	55	20	0.498	59	26	0.372	62	30	0.383	0.126	0.257

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination.

According to the CDE School Performance Index, between 1998 and 1999 the performance of 1 835 schools improved while the performance of 3 109 schools declined. However, between 1999 and 2000 this changed positively – in that period the performance of 3 878 schools improved, and the performance of only 1 428 schools declined. This reflects the overall improvement in SC results between 1999 and 2000. It is interesting to note that a core of 1 047 schools improved between 1998 and 1999 *and* maintained this improvement between 1999 and 2000. Clearly these schools need to be identified individually and helped to sustain their improvement.

A negative complicating factor is that the number of candidates at many of the schools on the list decreased significantly over the period in question. For example, the most improved school on the list, Senaoane Secondary School, experienced a drastic decrease in the number of candidates between 1998 and 2000. On closer inspection of the database it transpires that 166 full-time candidates registered for the SC examination, but only 25 finally wrote six or more subjects. Sometimes, this drop-out of weaker candidates is the main reason for an improvement of a school on the index.

This illustrates a problem revealed by all the statistics generated by CDE. Education officials and school principals have received the wrong message from the aggregate data on subject pass rates. Pass rates have been expressed as percentages of candidates entering. The easiest way to improve the percentage pass in any school is to exclude from the examination any candidates who appear even remotely likely to fail. Indeed, as previously noted, the NDoE has actually advised principals to do this. Other principals have gone further and excluded candidates on their own initiative. Anecdotes abound of school-going learners being obliged to enter as private candidates if the principal of their school believed that they might not pass.

This is a completely inappropriate approach. There is no record of any country resolving its problems with maths and physical science education by only educating candidates who are bound to pass on the basis of natural talents. This is in fact a complete negation of education itself which is intended to draw out the latent skills and aptitudes of learners, Policies and strategies must simultaneously increase the number of candidates *and* their success rate.

The other factor impacting on the improvement index is that of small schools where the improvement could be random from one year to the next, depending on only one or two candidates. Provinces and districts should be counselled to discount the influence of these schools when assessing performance.

Table 3.25 shows on a shaded background those schools in the 'top 30' in which there is a class size of over 30 and a less than 10% decrease in the number of candidates over the time period. Only 8 of the top 30 schools listed meet these criteria (and 25 of the first 100). Only one school has notably seen a significant increase in enrolment and an improvement in the maths and physical science performance index. This is the school that was reviewed as "a miracle" in the *Sunday Times.*[3]

SUMMARY AND CONCLUSIONS

The data set out in this chapter represent a major step forward in research related to the maths and physical science system in South African schools. There are two elements to this advance:

First, the data are now as reliable and comprehensive as the original sources permit. They are organised in ways that are of value to policy-makers, officials, principals, and other stakeholders. All of it is accessible by the most modern methods and technologies. It could be interrogated and manipulated to produce many more scenarios and insights.

Second, the database now extends over 12 years, and can now be easily extended and amplified year-on-year. A valuable time series of data from many sources is now available, and real long-term trends can now be identified and used to replace simple and often misleading year-on-year comparisons.

While the data is complex, and the whole chapter therefore needs to be carefully read, the main findings are as follows:

Our total schooling system is substantial by international standards, and very heterogeneous. Its size is related to the demographic profile of a developing country and to the success of the present government in extending access to schooling to all relevant age groups. We are unique among developing countries in the percentage of female participation. The heterogeneous nature of the system is the outcome of history, culture, and previous policies. Understandably, the emphasis to date has been on access and equity of provision. However the national need for human resources with a base in maths and physical science combined with ongoing low outputs in these areas makes increased specialisation and the pursuit of excellence in specialised subjects a national priority.

South Africa's education system for maths and physical science is performing very poorly. Conclusive and corroborating data, both international and national, in respect of grades 3, 4, 5, 6, 7, 9, 10 and 12 confirm this reality. Policies and programmes launched by public and private sectors have not had a measurable positive effect on actual learning outcomes at scale.

The general figures for SC mathematics and physical science conceal some alarming trends:

- While enrolment for SG maths and physical science is growing rapidly, pass rates are lagging.
- While pass rates for HG maths and physical science have improved significantly, enrolment is lagging – in fact, far fewer learners study HG maths today than in 1991.
- A significant proportion of SC candidates who do not enrol for mathematics or physical science could have done so successfully. Therefore, a major human resource is being wasted.

The immediate lesson to be drawn in respect of maths and physical science (and possibly other specialist subjects) is that the standards of provision need to be urgently improved. But the data in this chapter do not point towards large-scale, undifferentiated interventions. Rather, they point to, and provide the basis for, more closely targeted policies.

We now know what the ingredients are for success in respect of individual candidates, schools and provinces. We have new methods, and a new foundation of data, for measuring progress. In particular, we can now track trends relating to candidate performance by race, gender and language; school performance measured by an eight-factor index that compares schools, and also provides each school with a history of its own progress; the influence of school facilities on outcomes; the influence of the demographic composition of learners of schools and the locality of schools; and qualifications and experience of educators, and their relation to learning outcomes.

Proficiency in the language of instruction emerges as the single most crucial factor needed for success in maths and physical science, as well as the SC in general. The strong correlation between success in English and/or Afrikaans and success in maths and/or physical science is a clear pointer to how future policies and programmes should be prioritised.

The data also make it clear that advice given to parents and learners on the basis of inadequately researched and analysed information have often been counterproductive. The pressure to achieve a simple improved percentage pass rate in SC (aggregating HG, SG and LG) has led to dubious practices by schools, and has demotivated and deterred potentially successful maths and science candidates. The data on the number of candidates with a statistical chance of passing maths and physical science who do not even enter give cause for concern. Advice and counselling to principals, educators, and learners alike need to be improved.

Gender is not an issue that warrants overall national alarm. In general, female candidates and pass rates are at acceptable levels, and are actually improving more rapidly than the comparable figures for males. Indeed, coloured, Indian, and white females are already outperforming males in those categories. However, female African learners are performing very poorly, and should be targeted for specific interventions. The numbers are not so large as to put success out of reach.

Provinces that had to incorporate more former homeland and DET schools have generally struggled; yet some provinces in this category have performed well despite these difficulties. Again, detailed information on specific provinces is now available, and can be used to customise interventions.

In many schools, maths and physical science educators make up a small part of the teaching body, and are often underqualified. Together, these factors cause another major problem: insufficient teaching periods devoted to mathematics and physical science.

Our analysis of school performance reveals that there are reasonable numbers of high-performing schools – in fact, the number of schools achieving pass rates of 81–100 per cent is proportionately higher than might be expected. Conversely, the category immediately below this (60—80 per cent) contains fewer schools than might be expected. Positive action is possible here. This is a practical example of the way in which the data identify opportunities and provide information that is fine-grained enough to be the basis for action at the appropriate level.

In sum, CDE's quantitative work reveals a subsystem of maths and physical science education that has a complex but understandable nature. It is large, but not so massive as to be unmanageable. It has every chance of performing creditably. However, it is underperforming, and the reasons for this are now quite clear. Once the data generated by CDE's research are used to disaggregate problems, and approach them in a suitably flexible and focused way, many of the present strengths in the system can be exploited. However, the database needs to be maintained and updated. The steps needed to do this will feature in the recommendations.

ENDNOTES

[1] C Simkins, Mathematics and physical science results in the Senior Certificate examinations of 1998 and 2000, CDE background research report, 2003, p 12.

[2] 'Conditional endorsement' allows SC candidates who have just missed the endorsement level to enrol for bachelor's degrees at a university. If they obtain those degrees, they are also considered to have passed SC with endorsement.

[3] C Pretorius, Miracle Man, *Sunday Times*, 5 August 2000, p 1.

Chapter 4

FINDING FAULT OR FINDING VIRTUE (1): GOVERNMENT INITIATIVES, 1994-2003

In chapter 3 we provided quantitative data on maths and physical science education in South African schools. Worrying trends were identified in the quantity and quality of SC passes in these subjects. We could also point to extraordinary achievements in both quantitative and qualitative terms, even in some under-resourced and relatively disadvantaged schools. However, we found that the current system as a whole was underperforming, and that it could produce far more successful candidates, even with existing resources. Neither is the issue primarily one of a shortage of funds. We therefore need to examine the present public school system, and how maths and physical science are learnt and taught in the highest grades, for a qualitative understanding of the issues.

In this chapter we begin by examining the government's efforts since 1994 to transform the national education system. This has had far-reaching effects on the teaching of all subjects, including maths and physical science. Our first section outlines the reform process, and evaluates its impact on and implications for these subjects.

Secondly, the central government as well as provincial governments have introduced a number of special initiatives – including the innovative Dinaledi project – aimed at improving maths and physical science education. These are outlined and evaluated in section 2.

Many positive things can be found in all these efforts. Nevertheless, the worrying truth remains that, up to end 2003, there is no hard evidence that the initiatives dealt with in this chapter are having a positive effect. Accordingly, faults and shortcomings in the public school system also have to be identified. But before we do so, we have to trace the complex reform process under way since 1994.

THE TRANSFORMATION OF THE NATIONAL SCHOOL SYSTEM

Overview

The transformation of the national schooling system has been a complicated process. Therefore, to help orient the reader, we will start with a brief overview.

The public schooling system has been divided into two new bands: General Education and Training (GET), and Further Education and Training (FET). GET encompasses three phases: foundation (grades R-3), intermediate (grades 4-6), and senior (grades 7-9). Grade 9 marks the end of compulsory schooling, as well as GET; FET encompasses grades 10 to 12 in the schooling system, and N1 to N3 in the technical college system. The new grade 9 exit qualification is the General Education and Training Certificate (GETC); its implementation has been postponed twice. When finally introduced in 2008, the new grade 12 exit qualification will be the Further Education and Training Certificate (FETC).

As these names imply, these qualifications have been broadened to include other educational routes, including technical and vocational training. This aspect of the new system will be deal with in greater detail later.

In line with these changes, new curricula have been developed that move away from input-based to outcomes-based education (OBE) – ie, a change in orientation from content knowledge towards more useable knowledge and transferable skills. The first generation of the new curriculum was named Curriculum 2005 (C2005), after the year in which it was meant to be fully implemented: it was to have been phased in over eight years, beginning in 1998, and moving up year by year until reaching grade 12 in 2005, with the FETC replacing the SC in that year.[1]

C2005 was introduced in 1998, and did reach grade 9 in 2002. However, for various reasons, the introduction of the FET component of the curriculum has been delayed, which has disrupted the intended progression of OBE up to grade 12. OBE will now mark time at grade 9 level until 2005, and the SC curriculum for grades 10—12 will remain basically unchanged until that year, with the important proviso that continuous assessment will be introduced in this 'transition phase'.

The GETC, which was to have been awarded to the first generation of C2005 grade 9 learners in 2003, has also been delayed until 2005, due to what the NDoE has described as a lack of 'systems readiness'. This has undermined the standardisation of assessments in grade 9. In an attempt to minimise the problems caused by these discontinuities, the NDoE has introduced bridging mechanisms in grade 10, overlaying some elements of the outcomes-based approach on to the old-style SC curriculum. It now intends to progressively introduce a new FET curriculum from 2006 onwards, culminating in a FETC in Grade 12 in 2008.

To complicate matters even further, C2005 has been extensively revised. A revised Curriculum 2005 (RC2005) is being progressively introduced from this year (2004) onwards, and is due to reach grade 9 in 2008. Therefore, for the next few years, several curricula will continue to run simultaneously. The worst years are 2006 and 2007, when four different curricula will be in force. If the current plan is successfully implemented, the whole new schooling system will be stitched together for the first time in 2008.

This situation will make life very difficult for administrators, educators, and learners over the next few years. With several different curricula running simultaneously in the same schools, educators and learners will have to switch between different assessment mechanisms and curricula, depending on grade levels. In this context, it will be very difficult to standardise teaching, learning, and assessments, which will undoubtedly have a negative effect. The major impact is being felt in the transition to FET (grades 10-12), when learners who have become accustomed to OBE–type internal assessments have to revert to the old-style SC syllabus. FET educators also have to grapple with elements of OBE; they are now required to implement a significant continuous assessment component, but have received very little training in these new techniques. And once the new FET curriculum is in place, they will have to absorb significant new subject contents.

All these elements will now be reviewed in greater detail.

Curriculum 2005

The basic policy framework for the new education system was set out in the *White paper on education and training,*[2] released in March 1995. C2005 was originally conceived of as a unified curriculum stretching from grade R to grade 12. However, the development of curricula for the FET band was eventually separated from that for the GET band.

In April 1997 the NDoE released a discussion document entitled 'Curriculum 2005' which set out outcomes and assessment criteria for eight compulsory learning areas under GET. It summarised the work of a technical committee established early in 1997 to help the NDoE develop standards for this band.

A separate process was evolved to deal with FET, since this band was apparently more complicated than GET. Among the reasons cited was that, at this level, learners began to specialise, so a uniform curriculum for all learners was not appropriate. Another was that different types of FET could be offered by different types of providers, including general education offered by schools, general vocational education offered by technical colleges, and specific occupational FET offered at the workplace.

In 1996 and 1997, a ministerial national committee on further education (NCFE) investigated FET in depth.[3] Among other things, the committee examined existing providers, resources and infrastructure, curricula, human resource implications, funding, gender issues, database creation, counselling, and governance. Its report was released in August 1997. According to this document:

> The defining characteristic of the FET is that it allows for more specialisation than general education, and provides more context-based skills in preparing learners for higher education and the world of work.[4]

The report stated that, in order to implement the new curriculum, both material and human resources would have to be developed. On the need for the latter, it noted that:

> There are a range of human resource implications. In order for this system to be put in place, there is an urgent need for intensive capacity building for the different categories of staff in the institutions. It will be necessary to devise a re-training programme for all staff involved in the provision of FET as each existing institution has evolved its own tradition of teaching and learning. This will seriously affect the way in which a new FET system is implemented.[5]

In September 1998, the NDoE produced the *Education white paper 4: a programme for the transformation of further education and training,*[6] and, later in the same year, tabled the Further Education and Training Act (Act 98 of 1998). The act dealt with the establishment of both public and private FET institutions, the governance and funding of such institutions, and quality assurance, but not with curricula or qualifications.

In a foreword to the white paper, the then minister of education, Prof Sibusiso Bengu, outlined the aim of the new FET system as follows:

> When fully developed, the new FET system will provide access to high-quality education and training within a differentiated system that will offer a wide range of learning options to a diverse range of learners, including school-going young people, out-of-school youth, young adults and the larger adult population. A successful FET system will provide diversified programmes offering knowledge, skills, attitudes and values South Africans require as individuals and citizens, as lifelong learners, and as economically productive members of society. It will provide the vital intermediate to higher-level skills and competencies our country needs to chart its own course in the global competitive world of the 21st century.

He added that, although different types of institutions could provide education and training in the FET band, schools were especially important, since senior secondary schools (grades 10-12) account for 70 per cent of learners in this band. For at least the next five years, policy and targets for the senior secondary phase of schooling would be developed by provincial departments of education within the national policy framework, in the form of an aggregated plan that would be reviewed by provincial FET advisory bodies. The ministry had investigated the merits and practical implications of providing additional funding to at least some senior secondary schools to enable them to offer additional programmes beyond existing curricula, and greater opportunities for learners. Schools would be encouraged to introduce new programmes and curricula, and to develop collaborative relationships with one another.

As regards the qualifications obtainable in the FET band, the white paper stated that:

> The new FET curriculum will offer multiple entry and exit points and a diversity of learning programmes and qualifications to meet the varied needs of learners in different fields and at different stages of their lives. Learners who specialise early will be able to do so in the knowledge that this specialisation is neither too narrow nor deficient with respect to underpinning knowledge and values, and that further progression is possible. Learners who choose to specialise later will be assured that their programmes and qualifications provide adequate exposure to the realities and demands of social and economic life, as well as a meaningful foundation for future specialisation.

The key innovation was the introduction of flexibility in learning programmes and qualifications; learners' choices would be limited only 'by the need for coherence, adequate depth of learning, the requirements of further and higher learning, and work'. Credible exit qualifications would provide a reliable basis for HE programmes.

Bengu also outlined a process, beginning in 1999, that would culminate in the introduction of an integrated FET curriculum in grade 10 in 2003, with the first FETC being awarded to grade 12s in 2005. This timetable proved to be hopelessly overoptimistic.

Problems arose very early on. In May 1999, Bengu released a document entitled *National strategy for further education and training, 1999-2001*. It stated that new FET learning programmes and qualifications frameworks would be developed in 1999, and piloted in 2001. Although the document did not explicitly mention a timetable for actions beyond 2001, had the piloting taken place in 2001, it would have been possible to modify the programme in 2002 and introduce the new FET curriculum for grade 10 in 2003. The original target of introducing the new FETC in 2005 could then have been met.

In June 1999, following the second round of inclusive elections in South Africa, the new president, Thabo Mbeki, replaced Bengu with Prof Kader Asmalm e. On Tuesday 27 July 1999, the new minister announced the Tirisano Programme, a national initiative for transforming education and training. This was in response to his assessment that 'the educational condition of the majority of people in South Africa amounts to a national emergency'. One of the problems was that the 'number of young people who study mathematics with any degree of understanding and proficiency has declined, when it should have been increasingly rapidly. As a result, mathematical illiteracy is rife in our society, and the pool of recruits for further and higher education in the information and science-based professions is shrinking, a fact that has grave implications for our national future in the 21st century.'[7]

The minister identified nine priorities for the Tirisano Programme:

- 'We must make our provincial systems work by making co-operative government work;
- 'We must break the back of illiteracy among adults and youths in five years;
- 'Schools must become centres of community life;
- 'We must end conditions of physical degradation in South African schools
- 'We must develop the professional quality of our teaching force
- 'We must ensure the success of active learning through outcomes-based education
- 'We must create a vibrant further education and training system to equip youth and adults to meet the social and economic needs of the 21st century
- 'We must implement a rational, seamless higher education system that grasps the intellectual and professional challenges facing South Africans in the 21st century
- 'We must deal urgently and purposefully with the HIV/AIDS emergency in and through the education and training system.'

The NDoE's annual report for 1999 spelled out how these goals were to be realised. As regards FET, the new minister began to pursue two strategic objectives, which had the unfortunate (and probably unintended) effect of derailing Bengu's carefully structured programme for implementing an integrated OBE-based, C2005-aligned FET curriculum for grade 10s in 2003.

Asmal's first strategic objective was to 'review and modernise (RAM)' the existing FET programme, which was still based on the old curriculum. The ministry's intention was to establish new standards (expressed as learning outcomes) for each level of the FET band,and to design new FET learning programmes to achieve these. Programmes would also be launched to equip educators, managers, and officials with the skills and knowledge they would need to implement the new learning programmes. The RAM process was planned to take place between 1999 and 2003, when C2005 would be introduced in grade 10.

In May 2000 the NDoE released a 'Draft document – national curriculum framework for further education and training' for public comment. It identified four deficiencies in the existing system, along with proposed remedies, which are summarised in table 4.1.

Table 4.1: Deficiencies in the SC curriculum framework

Deficiencies	Proposed remedies
Separation of theory and practice	Integration of education and training
Poorly articulated FET programmes and qualifications for high schools and technical colleges	Articulation and accreditation agreements across programmes and institutions
Differences in the quality of provision, outcomes and curricula	Unit standards to be the basis for all FET programmes
Learners exiting the system and having to repeat passed subjects when they re-enter	Accumulation of credits achieved

The document proposed a single curriculum framework that would integrate both academic and vocational education. Flexible programmes would be developed by combining 'credits from nationally registered unit standards, leading towards nationally recognised qualifications'.[8] All FET programmes would be outcomes-based. Various constituencies, including provincial departments of education and FET institutions, would be responsible for programme development. It proposed that FET programmes should be co-ordinated by a national curriculum co-ordinating committee comprising a wide variety of stakeholders. As regards certification, the document stated that, at levels 2 and 3 (or grades 10 and 11), providers would issue credit-based certificates, accredited by provincial departments of education, while in grade 12 national certificates would be awarded in the form of FETCs, accredited by SAQA and awarded by the DoE.

However, at this point the minister began to realise that this framework could not be finalised unless his second strategic objective for FET of ensuring quality outcomes from C2004-aligned FET programmes could be assured. And this was when matters began to go awry.

One of the first things mal did when he assumed his new portfolio in 1999 was to initiate a revision of Curriculum 2005. According to the document entitled 'Phasing in OBE into the FET band – implementation strategies (2003-2006)', released in July 2002,

> When Professor Kader Asmal became the Minister of Education in 1999, Curriculum 2005 was in its second year of implementation. The Minister started a listening campaign to hear the views of society on progress made and the challenges that were experienced with the transformation of education. An overwhelming majority of views expressed frustration with the design and implementation of Curriculum 2005.[9]

In order to address these concerns, the minister set up a committee in February 2000 to review the implementation of Curriculum 2005. It presented its report on 31 May 2000. In November he appointed a new committee to manage the 'streamlining and strengthening' of C2005. Working groups were appointed to reduce and simplify the number of learning outcomes, and to provide more guidance on what should be taught and what assessment standards should be met at various grade levels. This process culminated in a revised *National Curriculum Statements for Grades R-9 (Schools),* which the cabinet approved on 20 March 2002.

The process of revising C2005 for the GET band was disastrous for the minister's first strategic goal of finalising new FET programmes. According to the document 'Phasing in OBE into the FET band – implementation strategies (2003-2006)':

> The process of developing a new curriculum for FET had to be put on hold pending the outcome of the streamlining and strengthening of Curriculum 2005. Up to the streamlining and strengthening of Curriculum 2005, the plan was to develop FET curricula based on the design of the GET curriculum that was defined by the 66 specific outcomes and associated features such as assessment criteria, range statements, performance indicators, [and] programme organisers.[10]

But by 2002 the original C2005 had reached grade 9. It was clearly impossible to get the new grade 10 FET curriculum in place for 2003, when these learners would be ready for the senior secondary schooling phase. As a result, the DoE staged workshops for teachers to help them manage the transition from the 'new' grade 9 to the 'old' grade 10 curricula, and layer the outcomes-based approach on top of the old curriculum. To aid this process, the department released a document entitled *Educator guide to phase OBE into FET, 2002-2005* in August 2002.

Asmal came under a great deal of pressure to ensure that the FET curriculum would be in place as soon as possible. On 9 June 2002, Cornia Pretorius, education reporter for the *Sunday Times*, wrote:

> A delay in the drafting of an outcomes-based curriculum for grades 10-12 will seriously hamper the academic progress of thousands of pupils who start their senior high school education next year. The delay means that grade 9 pupils, educated in line with the outcomes-based Curriculum 2005, will be ill-prepared when they switch back to the old grade 10 syllabus next year. ... Khetsi Lehoko, deputy director–general for further education and training, said that schools should carry on with grade 10 as it stands. He said that teachers must be 'sensitive for areas in which gaps exist in pupils' knowledge and not assume they learnt everything in Grade 9. ... Last week the Department of Education placed advertisements in Sunday newspapers to explain the delay, but the national and provincial departments' failure to communicate with schools earlier robbed them of valuable time to prepare their grade 9s.

In February 2002 a ministerial project committee was appointed to oversee the development of the national curriculum statements (NCSs) for grades 10-12 (FET). In April 2002 the Council of Education Ministers (CEM) – comprising the national and provincial ministers of education - decided that outcomes-based education should be expanded to grade 10 in 2004, and that the curriculum statements for grades 10-12 should be developed by March 2003.[11] A total of 25 core subjects were selected, and subject working groups were appointed in May 2002 to develop the curriculum for each subject.[12]

When, previously, the revised GET NCSs were released, educationist voiced serious concerns about their contents. As a result, they had to be substantially reworked, which caused the project to run over their March 2003 deadline. In order to avoid this problem in the case of FET, and also because the time frame for curriculum development was very short, field testing groups were established for each subject. The groups comprised a variety of stakeholders, including subject matter experts and educators.

The first drafts of the curriculum statements were sent to members of the field testing committees on 28 June 2002, and comments had to be returned by 10 July 2002 – a very short turnaround time. The comments were used to inform a second set of drafts, which was sent to the field testing committees on 7 August, with feedback required by 22 August. The working groups then produced what was meant to be their penultimate drafts, which were released for public comment on 28 October 2002, with a closing date on 31 January 2003. In terms of the NDoE's schedule, the final statements were to have been drafted in time for approval by the CEM at its meeting in March 2003, and implemented in 2004.

BOX 4.1: HOW THE FETC WILL DIFFER FROM THE SC

- To obtain an SC, learners have to study a minimum of six subjects. Each can be studied at a higher or standard grade, and some subjects at a lower grade.
- To obtain a FETC, learners will have to study a minimum of seven subjects. Grades will be abolished; learners will be differentiated on the basis of subject choice and performance alone.
- Following the SC examinations, a total score, or aggregate, is calculated for each learner. Furthermore, in order to obtain admission to higher education, a learner must obtain an SC with endorsement, which requires both certain subject combinations and certain marks.
- FETC marks will not be aggregated, and there will be no endorsement system.
- The FETC results will be presented as a list statement of the learners' performance in each of the subjects.
- Continuous assessment will contribute more than the present 25 per cent to learners' assessments.

CDE 2004

However, despite the field-testing process followed, a number of stakeholders still expressed serious concerns about the NCSs, with the result that the development and subsequent implementation of the new FET curriculum had to be further delayed.

It was unrealistic to expect that new curricula for the final years of schooling could be developed in half a year by practising educationists who had other full-time jobs and were having to fit this in with their other work. Moreover, the composition of the working groups was uneven; some groups lacked expertise in the subject concerned, and many lacked members. Even if it had been possible to develop the NCSs by March 2003, it would have been impossible to produce good quality textbooks and teacher guides and run adequate teacher development programmes during the rest of 2003 in order to be able to implement the new curriculum in 2004.

Ultimately, the new NCSs for FET were approved by the CEM in August 2003, and by the cabinet in September 2003**.** The new plan is to implement the new curricula for grade 10 in 2006, grade 11 in 2007, and grade 12 in 2008. The first FETC will therefore be awarded in the last-named year.

In the meantime, the revised C2005 for the GET band is due to be implemented in the foundation phase in 2004, intermediate phase in 2005, grade 7 in 2006, grade 8 in 2007, and grade 9 in 2008. Thus, until 2008 several curricula will run simultaneously, often in the same schools, placing enormous strain upon schools, educators, and learning support materials providers (see table 4.2).

Table 4.2: Implementation of the revised C2005 curriculum by grade level and year

GRADE	2003	2004	2005	2006	2007	2008
1	C2005	RC2005	RC2005	RC2005	RC2005	RC2005
2	C2005	RC2005	RC2005	RC2005	RC2005	RC2005
3	C2005	RC2005	RC2005	RC2005	RC2005	RC2005
4	C2005	C2005	RC2005	RC2005	RC2005	RC2005
5	C2005	C2005	RC2005	RC2005	RC2005	RC2005
6	C2005	C2005	RC2005	RC2005	RC2005	RC2005
7	C2005	C2005	C2005	RC2005	RC2005	RC2005
8	C2005	C2005	C2005	C2005	RC2005	RC2005
9	C2005	C2005	C2005	C2005	C2005	RC2005
10	SC	SC	SC	FET	FET	FET
11	SC	SC	SC	SC	FET	FET
12	SC	SC	SC	SC	SC	FET

Source: Diane Grayson, The Further Education and Training Certificate CDE background research report, 2003.

FET curriculum and maths and physical science learning and teaching

General

So far we have analysed problems surrounding the establishment of the new FET framework. However, analysts and educators have raised additional concerns about the impact of the new curriculum on the actual teaching of maths and physical science. These concerns fall into two categories: concerns about design, and concerns about implementation. Before we examine these, it is necessary to explain the proposed structure of the new FET curriculum, and the place of maths and physical science within it.

To recall, the NDoE in May 2000 proposed a new national curriculum framework for FET. According to the subsequent NCS, the primary purpose of the FETC (general) is to 'equip learners with knowledge, skills, values, and attitudes that will enable [them] to participate meaningfully in society'; provide 'a basis for continuing learning in Higher Education; lay a foundation for future careers; and develop learners to be productive and responsible citizens and lifelong learners'.

The ncs proposed that learners may follow any one of three routes to a FETC:

- FETC (general): offered at schools providing learners with a general education, based on a broad curriculum.
- FETC (general vocational): offered mainly by FET colleges (mostly former technical colleges), and intended to prepare learners for work and self-employment.
- FETC (trade, occupational, and professional): offered by colleges and industry-based providers.

In each of the three routes, learners would have to select subjects in three curriculum components:

1. A **fundamental component** comprising:
   - two languages selected from the 11 official languages, one a home language and the other either a home language or first additional language. One of the two languages must be the language of learning and teaching (LOLT; 20 credits x 2 = 40 credits);
   - mathematical literacy or mathematics (20 credits); and
   - life orientation (10 credits).
2. A **core learning component** comprising at least two subjects from one of the learning fields (20 credits x 2 = 40 credits).
3. An **elective learning component** comprising at least one subject selected from any learning field (20 credits).

NQF level 4 will be the only exit point where a national SAQA-accredited qualification will be issued. Learners exiting the FETC (general) route prior to NQF level 4 (grade 12) will receive a statement from the provincial education department indicating the exit-level learning outcomes and the grade-specific assessment standards attained from the school attended. But if they meet the relevant assessment criteria (a total of 130 credits) in grade 12, they will receive a national FETC qualification at the end of their academic year.

Each core and elective subject will be allocated a total of 150 teaching hours a year. However no provision has been made for additional time for subjects with a practical component, such as physical sciences.

The new NCS, which defines the core of subjects to be offered by the public schooling sector across the three FET curriculum components, now lists 35 subjects (versus the 124 subjects of the previous curriculum), of which 11 are the official languages. (Six foreign languages have subsequently been added).

SAQA is responsible for determining the standards to be met by any FETC qualification. According to SAQA, in order to qualify for any of the three FETCs, candidates must achieve:

- A total of at least 130 credits. At least 72 credits must be at or above level 4 on the NQF.
- 20 compulsory credits in language and communication at level 4 must be obtained in one of the 11 official languages provided for by the South African constitution of 1996.
- 20 credits in language and communication at a minimum of level 3 must be obtained in a second official language.
- 16 credits in mathematics must be obtained at level 4, but these may be obtained in different contexts.

One credit represents ten 'notional hours' of study. Notional hours are the time an 'average learner' would be expected to spend on study-related activities, including contact time with educators, time spent studying outside of formal classes, and time spent on assignments.

Our study focuses on the FETC (general) that will be offered in senior secondary public schools. The credit and time allocations for the FETC (general) are shown in the following table:

Table 4.3: Credit and time allocations for the FETC

Subject	Credits	Time allocation (hours per week)
Language 1 (LOLT)	20	4.5
Language 2	20	4.5
Mathematics or Mathematical Literacy	20	5
Life Orientation	10	2
Core Subjects	40	4.5 x 2
Elective Subject	20	4.5

Source: Grayson, The Further Education and Training Certificate.

To obtain the FETC (general), learners will have to obtain a total of 130 credits (six subjects worth 20 credits each, plus life orientation worth 10 credits). The following assessment scale will be used:

Table 4.4: FETC assessment scale

Rating code	Description of competence	Marks (%)
6	Outstanding	80-100
5	Meritorious	60-79
4	Satisfactory	50-59
3	Adequate	40-49
2	Partial	30-39
1	Inadequate	0-29

Source: Grayson, The Further Education and Training Certificate.

To meet the minimum requirements, at least 80 credits must be obtained at the ‘adequate’ achievement level (40-49 per cent, currently an E for the sc), and a maximum of 50 credits at the ‘partial’ achievement level (30-39 per cent, currently an F or FF for the sc).

Learners must show competence in the three fundamental subjects at the ‘adequate achievement’ level. An exception will be made in the case of mathematics or mathematical literacy until 2012, which will allow learners to obtain a FETC even if they receive a ‘partial achievement’ for these subjects.

It has been proposed that 25 per cent of learners’ marks will derive from school-based continuous assessments, while the rest will come from nationally determined assessments.

In recognition that the new FETC will demand a ‘highly skilled cadre of teachers, and well-prepared learning support materials’,[13] the NDoE has stated that there will be a transition period from 2008 to 2011 during which the ‘qualification design and composition’ of the FETC will be adjusted. During this period, the minimum requirement for a FETC will be 60 credits at the ‘adequate’ level, and no more than 80 credits at the ‘partial achievement’ level.

It should be pointed out that these standards are actually higher than those for the sc; it is currently possible to obtain a sc by passing six subjects at the standard grade with 33,3 per cent, which would correspond to all credits obtained at the ‘partial achievement’ level on the new FETC assessment scale. It is even possible to obtain a sc with endorsement by scoring 40 per cent in three subjects, and 33,3 per cent in the remaining three, two of which can be in the SG.

We can now turn to educators’ concerns about the new system.

Concerns about design

One of the biggest concerns centres on maths and mathematical literacy. It is widely accepted that all members of the school-leaving population should have a modicum of mathematical knowledge. However, maths educators from both the higher and secondary education sectors are concerned that the new subject ‘mathematics’ will be even more difficult than current HG mathematics, and that both learners and educators will therefore shy away from it, further reducing the number of high school-leavers studying maths and physical science at the HE level. Thus the South African Mathematical Society (SAMS) has stated:

> Our extreme concern that an already demoralised, underqualified, and shrinking body of teachers will be unable to cope with the new syllabus, so that instead of the envisaged increase in number of qualifications in FET mathematics from 2006 onwards, our country will instead suffer a decrease.[14]

There are also concerns that the new subject 'mathematical literacy' – a basic numeracy course for those not requiring a functional knowledge of mathematics – will be substituted for mathematics, which might result in learners who have an interest in maths but who are not seen as academically strong being encouraged to take Mathematical Literacy instead. Indeed, this does seem possible, given the following extract from the *Qualifications and assessment policy framework, grades 10-12:*

> Learners [at Level 3] may not change a combination of subjects once they have enrolled for the Grade 11 programme, except in the case of those learners who, having demonstrated capacity, may want to change from Mathematics to Mathematical Literacy.[15]

The Consolidated University Sector Response of 28 February 2003 produced by the South African Universities' Vice-Chancellors' Association (SAUVCA) raises the following concerns about mathematical literacy:

> One submission noted that a recent study shows that only 58,8 per cent of all senior certificate candidates (264 300 out of 449 371) wrote mathematics in 2001. Of these students registered for mathematics in 2001 senior certificate examinations, only 13 per cent wrote it on the higher grade. Of those who wrote HG mathematics, 56 per cent passed. That is, about 4 per cent of the total number of Senior Certificate candidates in 2001 passed mathematics on the higher grade. Of the 87 per cent of students who wrote mathematics on the standard grade, 57 per cent failed. This raises the question of how the 185 071 (41 per cent) of students who do not take mathematics at any level would be expected to fare if the mathematics literacy curriculum is pegged at approximately SG level. Certainly, if this happens, a significant amount of teacher upgrading and learning support material will be needed if we are to avoid very high levels of failure.
>
> Submissions on the mathematics literacy curriculum indicate lack of clarity on the level to be achieved. If mathematics literacy is not pegged at SG level and emerges in effect as a 'functional literacy course', those students who at present opt for and succeed at SG will be significantly underachieving, and many avenues of higher education will be closed to them. As another submission noted, the mathematics literacy curriculum as it stands 'falls very short of what would be required to study science or commerce at university, and students intending this degree track would need to take mathematics proper. However, because it will be easier for students to pass in mathematical literacy than in mathematics, many

> schools may opt for the former rather than the latter, thus reducing even further the already small number of students equipped to study science and commerce subjects at university.'[16]

Thus it appears that the FET curriculum may inadvertently diminish the number of learners who study maths at a level adequate for entering higher education. Under the SC, even though very few learners pass HG mathematics, it is at least possible for candidates who obtain high marks in SG mathematics to be admitted to higher education (see the discussion of the existing SC examinations and curriculum in chapter 5). SAUVCA has argued that an intermediate mathematics course is needed for learners who do not necessarily want to pursue math-related studies at the HE level but who do want to gain access to HE.

Numerous specific problems have been identified in respect of the mathematical literacy NCS. In its submission to the NDoE, the Association for Mathematics Education of South Africa (AMESA) has stated:

> Although mathematical literacy and mathematics are quite clearly related, they are also quite different. In the conceptualisation of mathematical literacy as presented in the subject statement it remains too much of a watered down version of mathematics. The outcomes are essentially the same as those of mathematics. It may be that this is done intentionally, to address matters of portability and mobility between mathematics and mathematical literacy, but we argue that the two subjects are so dissimilar in philosophy and purpose that such portability and mobility should not be a consideration.[17]

Educators, particularly at HE institutions, are also concerned about the abolition of standard and higher grade. This has been done because differentiation was perceived to be elitist; also, the NDoE argues that learners can be adequately differentiated in terms of subject choice and performance alone. However, other bodies, including SAUVCA, have argued that, under the current system, the SG versions of a given subject is not merely a watered-down version of the HG subject, but actually a different one, and that mathematical literacy is no substitute for SG maths. University mathematicians believe a D in HG maths is roughly equal to an A in SG maths, which seems to support this judgment, This line of thinking has led to proposals for introducing an intermediate maths course at the FETC level to cater for students on the new system who might fail to meet the more rigorous requirements for 'maths', but be able to attain the old requirements of SG mathematics.

Once the FETC is in place, one of the biggest problems facing HE institutions will be what criterion to use for selecting learners. Since there will be no HG and SG, no aggregate score, and no required combination of subjects, HE institutions will have to devise other means of assessing which learners are likely to succeed. One possibility is for HE institutions to develop entrance tests, but if one of the declared purposes of the FETC is to provide access to HE, and enable HE institutions to determine their school-leavers' capacity to enter HE, then one of the major arguments for introducing the new FETC appears to fall away.[18]

Concerns about implementation

A key concern here is the question of who will teach mathematics, and who will teach mathematical literacy. Since the new curriculum requires that every learner study one of these subjects, many more teachers with mathematical knowledge and skills will be needed. On the other hand, since the number of subjects offered at grade 12 level has been drastically reduced, many teachers specialising in these subjects will no longer have classes to teach. Thus either large numbers of teachers will have to be retrenched, and large numbers of mathematics teachers trained very quickly, or teachers whose subjects have become obsolete have to be retrained as maths teachers. Either course of action is fraught with difficulties, and will be expensive. As regards the latter option, the South African Mathematical Society has noted:

> That the proposed outcomes of mathematical literacy is at a level which would make it extremely difficult to retrain non-mathematical teachers sufficiently to guide learners to achieving these outcome, and that it will stretch the already insufficient number of trained teachers in the area to an unbearable level.[19]

All the policy documents on FET have stated that educators will have to be intensively developed if the new curriculum is to be successfully implemented. It remains to be seen exactly how this will be done, and whether enough time and material resources will be allocated to this process.

The issue of educator training was addressed in Asmal's Tirisano initiative, launched in 2001. In the NDoE's annual report for 2000–1, the director-general stated that the department had launched this project to train intermediate and senior phase mathematics and physical science educators in all provinces. Training would lead to a qualification, the Advanced Certificate in Education (ACE), or the National Professional Diploma in Education (NPDE).[20] Some 300 educators per province registered for this two-year programme, and 1 084 were expected to graduate at the end of 2002 with either of the two qualifications. It is too early for this initiative to have had a proper impact on the system, and therefore too early to assess it.

IMPACT OF OTHER GENERAL EDUCATION POLICIES

Further concerns have been expressed about the more general impact of educational policies and programmes on maths and physical science education in areas not directly related to the new national education framework. Though possibly as significant, these are more difficult to assess. In this section, we examine two such policies by means of case studies: the redeployment of educators carried out in 1995-7, and the financial policies applied in respect of 'poorer' schools.

The redeployment of educators

In its 1994 election manifesto, the ANC committed itself to 'open[ing] the doors of learning and culture to all'.[21] Two of the most important aspects of this were to establish one non-racial education department, and to equalise per capita spending on learners of all races. Since about 90 per cent of public expenditure on education was already being spent on personnel, the distribution of teaching posts was, as Fleisch has noted, 'inevitably going to be the main equity issue'.[22]

Following the transition, the new government strongly committed itself to maintaining fiscal discipline. This meant that, since the existing pool of educators could not be expanded, it would have to be redistributed. If all schools were to benefit from roughly equal learner: educator ratios, advantaged schools had to lose teaching posts, while disadvantaged schools would gain them.

Educators were to be redeployed by the provincial education departments, using lists of teachers provided by overstaffed schools, and of vacant posts by understaffed schools. Educators widely opposed this initiative. Schools strongly resisted naming teachers; extreme concern with due process dragged the redeployment out; teachers who were named registered grievances with the department, thus further delaying the process; and some understaffed schools were unwilling to accept redeployed teachers, perceiving them to be substandard, or at least unwilling. Poor information from the national as well as provincial governments further bedevilled the process.

Fleisch points out that 'the extent of the failure of redeployment and its consequences only began to emerge in 1997'.[23] Individuals named on lists of 'excess teachers' soon learnt that they could not be compelled to move to understaffed schools, and 'a special process was to be put in place to ensure that excess educators all had a fair chance to compete for the vacant posts'.[24] The process dragged on for months; as a result, it became clear that understaffed schools would have to fill their vacancies with temporary teachers. This created the problem of 'double parking', or two educators in one post: one excess educator in an overstaffed school, and one temporary educator in an understaffed school.

This was one cause of a budget crisis that made itself felt in the latter half of 1997. A number of explanations for this crisis have been advanced. The first was that the education budget for 1997/8 was unrealistic; it did not take into account all financial obligations to teachers, suppliers, and other contractual obligations. Also, attempts to cut costs and identify areas of wasted spending proved 'fruitless'.[25] The second was the redeployment programme; the programme's slow rollout meant that *more* money, not less, was being spent. Thousands of temporary teachers were hired to fill posts in understaffed schools, while thousands of teachers declared 'in excess' were still at their original schools. For example, the Gauteng department of education budgeted for an expenditure of R3,98 billion in 1997/8, but actually spent R4,9 billion.

Faced with the failure of the redeployment policy, the only mechanism left open to the education authorities to ensure an equal distribution of teaching posts and reduce expenditure was to allow large numbers of teachers to take voluntary severance packages.[26] According to one education expert, when this decision was taken, about one out of every ten teachers, including some of the most experienced school managers and science and mathematics teachers, exited the education system.[27]

Although the voluntary severance packages (VSPs) were designed to be most attractive to educators over 50, many younger teachers also opted for them. This was particularly true of teachers of maths, science, and commercial subjects who could easily find jobs in the private sector. As Fleisch highlights, ‘the real loss of experienced teachers was felt when inexperienced and unqualified teachers were left to teach mathematics and the natural sciences’.[28] The GDE received more than 4 000 applications for VSPs, representing some 9 per cent of educators in the province. A quarter of all principals applied; two thirds of them were younger than 55.[29]

The redeployment programme undoubtedly drained a great deal of expertise from the education system; it was an ill-conceived policy initiative that unnecessarily damaged the system. More specifically, it resulted in maths and physical science education being undermined in a very important period of transition.

The funding of schools

The educator redeployment crisis could perhaps be discounted as a failed policy of the past. However, there is an aspect of current policy which, while not specifically directed at maths and physical science education, is also having a significant negative impact: the financing of former Model C schools. The NDoE has done little to show that it is aware of this problem, or concerned about it.

Two points need to be made about former Model C schools. Firstly, they are a significant national resource, producing a disproportionate number of HG maths and physical science passes among African candidates. They are one of the virtues of our system that should be preserved and commended. Secondly, they illustrate that aspects of current education policy are based on outdated assumptions.

Almost all former Model C schools fell under the house of assembly in the pre-1994 tricameral parliament – ie, they were schools for white pupils only. However, since 1994 large numbers of learners from other races have begun to attend these schools, often travelling to and from former townships every day. Jane Hofmeyr, CEO of the Independent Schools Association of South Africa (ISASA), points out that ‘parents, realising the importance of education for the life chances of their children, are making huge sacrifices to taxi them to schools far from where they live, often spending more on taxi costs than school fees’.[30] As a result, while these schools are still located in relatively ‘wealthy’ areas, a far larger proportion of their learners now come from poorer households.

For a variety of reasons, these schools have, in recent years, produced a disproportionate percentage of African maths and physical science graduates. Table 4.5 shows that in 2002 the pass rate of African HG maths candidates was 20,4 per cent at former DET schools, but 68,7 per cent at former House of Assembly (white) schools; similarly, table 4.6 shows that the pass rate of African HG physical science candidates was 19,2 per cent at former DET schools, but 61,9 per cent at former House of Assembly schools. Many of these African learners do not to come from the relatively affluent neighbourhoods in which the schools are situated. As we show later, this is causing serious problems.

Table 4.5: Sources of African HG passes in maths, 2002

Former dept	No of schools	% of total schools	No of candidates	No of passes	% pass rate	% of total candidates	% of national passes
DET	2021	81.3%	14 161	2 889	20.4	84.2%	62%
HoR	43	1.7%	116	43	37.1	0.7%	0.9%
HoD	88	3.5%	276	148	53.6	1.6%	3.1%
HoA	335	13.5%	2 265	1 557	68.7	13.5%	34%
Total	2487	100%	16 818	4 637	-	100%	100%

Source: Helen Perry, Mathematics and physical science performance in the Senior Certificate examination , 1991-2003, CDE background research report, 2003.

Table 4.6: Sources of African HG passes in physical science, 2002

Former dept	No of schools	% of total schools	No of candidates	No of passes	% pass rate	% of total candidat-es	% of national passes
DET	2665	84.4%	26 804	5 154	19.2%	89%	72%
HoR	48	1.5%	199	80	40.2%	0.7%	1.2%
HoD	99	3.1%	404	192	47.5%	1.3%	2.8
HoA	346	10.9%	2 749	1 703	61.9%	9%	24%
Total	3158	100%	30 156	7 129	23.6%	100%	100%

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination , 1991-2003.

The second point to make regarding these schools concerns state funding. National funding policies are set out in the South African Schools Act (Act 26 of 1996) and the Funding Norms and Standards.[31] In terms of these policies, all state schools receive basic state funding calculated in terms of a standard teacher: pupil ratio. However, some schools receive additional funding which is weighted in terms of their area. This mechanism is a redistributive measure, aimed at redressing some of the gross inequities of the past.

Of course, it makes sense to direct additional funding to previously disadvantaged schools. However, these funding instruments are based on the assumption that state schools are essentially 'neighbourhood schools', and that most of their learners come from surrounding areas.

Learner migration has invalidated this assumption. Former Model C schools receive floods of applications from other areas – and indeed now accommodate many of those learners – as parents in poorer neighbourhoods prefer to send their children to what they perceive to be better schools. For example, a recent survey of parents of learners at the Parktown High School for Girls in Johannesburg showed that learners came from 181 different suburbs, and parents' income levels ranged from less than R1 500 to R20 000 and more a month.[32]

This clearly poses a range of problems for the schools concerned. It also poses problems for the education departments working to evaluate those schools' needs. Many former Model C schools feel they receive too little government funding. Also, while many of them are still well-resourced – because of their previous stock of resources, as well as additional funding by parents – many others now have predominantly African and poorer learners.

These schools now represent a significant national resource. It is quite apparent that the present funding norms are based on an outdated understanding of the composition of the body of learners in many of these schools. Of course there are exceptions, but such schools can be identified and steps taken to address entry policies. In chapter 3 we show that these schools represent a 'virtue' in the system, and should be supported as such. Without such action, South Africa is in danger of financially starving the small number of schools that actually produce good maths and physical science results, under an inflexible policy that fails to realise that their learners no longer have the same socio-economic profiles as the suburbs in which those schools are located. Inflexibility and a lack of suitable data lie at the base of this.

GOVERNMENT INITIATIVES TO IMPROVE MATHS AND PHYSICAL SCIENCE EDUCATION

National initiatives

The state has launched two major national maths and physical science initiatives since 1994: the Students and Youth in Science, Technology and Mathematics (SYSTEM) programme, and the National Strategy for Mathematics, Technology and Science Education. Moreover, provinces have introduced their own maths and physical science initiatives. In this section we first examine the two major national initiatives (including the '102 schools' or Dinaledi programme), before concluding with an account of provincial initiatives.

SYSTEM 1 and 2

The first national initiative, now terminated, was the programme known as Students and Youth in Science Technology and Mathematics. This had two components, initially known as SYSTEM 1 and SYSTEM 2.[33]

SYSTEM 1 was intended to be a second-chance, or recovery, programme for learners who had studied SC maths and physical science but had failed or performed too poorly to qualify for higher education. SYSTEM 2 was intended to increase the pool of well-qualified maths and physical science educators and to place them in schools more quickly by offering a four-year 'sandwich' programme. This would comprise alternating years of college-based training (years 1 and 3) and school-based training (years 2 and 4), with the latter allowing trainee educators to begin teaching productively after only one year's training.

SYSTEM was to have been funded by the central government, and was intended to involve 9 000 learners a year (later changed to 10 000 a year). It would have run in each province and made use of existing underutilised facilities, including some technical colleges and colleges of education.

A three-person task team spent most of 1994 involved in 'intense policy development, advocacy and lobbying', culminating in a formal submission accepted in 1995 by the interim committee of heads of provincial education departments.[34] In the same year the task team raised funds from donors for appointing specific teams to develop curricula and to take the process of implementation further. Efforts were also made to draw on existing expertise in the country in the area of university-based maths and science foundation programmes.

Up to this point, it could be argued that SYSTEM was not a government initiative, except for the fact that the work of the task team was carried out on behalf of the government. However, in November 1995 a SYSTEM national task team was appointed within the NDoE comprising a national co-ordinator and one co-ordinator for each curriculum; staff and student selection; and finance and logistics. At this point, SYSTEM became a formal government initiative.

It requires substantial professional development and repeated efforts over an extended period to create a shared vision of a project of this scale, and the capacity needed to manage it. This was especially the case because SYSTEM was premised on a fundamentally different vision of education from that known or experienced by the officials and educators responsible for implementing it. The approach to teaching and learning in both components of SYSTEM was based on discovery learning and problem-solving, focusing on a real understanding of content, and the development of lasting skills. The diploma was accredited with existing universities, which differed from province to province. The novelty of the method and the variety of accrediting bodies created further implementation problems.

Three other factors contributed to these difficulties. Provincial SYSTEM administrators were appointed on short-term contracts, so the posts did not attract top candidates. In some provinces, positions could not be filled. Appointment criteria were applied differently in different provinces. Furthermore, although the original project documents had indicated that staff development would be needed, there was minimal professional support after the initial programme of staff development. This was largely as a result of budgetary constraints imposed by the NDoE. These categories of problems – overambitious targets, short-term horizons, and budget constraints – appear regularly as factors undermining government educational policy initiatives during the period under review.

SYSTEM 1 ran from 1997 to 1999 in all nine provinces. Some 750 students participated in 1997, 534 in 1998, and 308 in 1999, a far cry from the originally envisaged 10 000 a year. The pass rates were disappointingly low, as indicated in table 4.7.

Table 4.7: SYSTEM 1 pass rates

Year	Physical science pass rate	Mathematics pass rate
1997	14% (106/750)	15% (109/750)
1998	8% (42/534)	9% (50/534)
1999	4% (12/308)	6% (17/308)

Source: Diane Grayson, Government initiatives to improve mathematics and physical science education, CDE background research report, 2002.

However, it should be noted that the pass mark for SYSTEM subjects was set at 50 per cent, compared with the SC pass mark of 33 per cent. This 'discriminated' against the SYSTEM candidates by making their pass rates seem lower than they actually were. Again, arbitrary variances in standards undermined the credibility of the initiative.

SYSTEM 2 ran from 1998 to 2001 in five provinces. Of the 122 students who began the programme in 1998, 114 passed. In one college each in Limpopo and Free State, SYSTEM students completed their diplomas in 2002. That marked the end of the SYSTEM project.

In terms of funding, the NDoE allocated R20 million to the project, and a further R11,3 million was obtained from donors – mainly the French government.

The later phases of SYSTEM coincided with the NDoE's decision to rationalise colleges of education, and, later, to incorporate them into universities and technikons. By 2001 all colleges of education had been merged into other higher education institutions. Thus, although the teacher education component of SYSTEM seemed promising, it did not really have any chance to make the intended impact. This is a classic example of policy contradiction and discontinuity: the NDoE was funding an initiative that depended on teacher training colleges at the same time that it was closing these colleges down. Further examples of policy discontinuity abound in the initiatives of national and local government.

BOX 4.2: POLICY DISCONTINUITY IN LIMPOPO[35]

Limpopo, formerly Northern Province, has probably had the most extreme set of provincial circumstances to deal with over the past ten years. It not only had to merge previously racially based education departments, but had to integrate three homeland education departments as well. The MEC for education, Dr Aaron Motsoaledi, has stated that the province was '... poisoned three times by Bantu education: Venda, Gazankulu and Lebowa'.36 In 1995 it was recognised that only 9 per cent of teachers in the province were qualified, and that only 5 per cent were trained in maths and physical science. Not surprisingly, pass rates in hg maths and physical science were well below the national average – 6 per cent for hg maths, and 13,6 per cent for hg physical science.

Given the history of education in the region, improving the situation would not be easy. In the 1970s many schools did not offer maths or physical science in standards 9 and 10, due to the severe shortage of qualified teachers. In some cases educators who were teaching in these standards were actually learning the syllabus and writing the exams at the same time as their students. An already untenable situation became worse during the 1980s when a number of high schools were converted to educational colleges, resulting in 22 colleges of education in a province of just over 5 million people. This created an oversupply of 'teachers', very few of whom were qualified to teach maths or physical science as they had not taken it at a high school level.

Dr Motsoaledi, who had grown up in the province, became its first post-apartheid MEC of education. He had experienced the dysfunctionalities of the education system at first hand, and believed that the real reason for the creation of so many colleges of education during the 1980s was the misguided conception that, if people could get a teaching qualification, they would find work. Traditional leaders accordingly encouraged the conversion of these schools. According to Dr Motsoaledi, by 1994 the 22 colleges had produced an excess of 30 000 teachers in the province – yet matriculants were still clamouring for admission.[37] As a result, he commissioned a study of the colleges, and, in 1995, closed all but seven of them. Realising that this would disappoint many of the learners, Motsoaledi sent personal letters to all matriculants, explaining his reasons for closing the colleges.

Following this first initiative, two important new education programmes were launched. The first was the Science and Mathematics Bridging Project (SMBP), and the second the Maths, Science and Technology Education Colleges (MASTEC). Introduced in 1997, the SMBP was a forerunner of system. Basically, it was a recovery programme which allowed students who had studied maths and physical science in matric and failed, or wished to improve their marks, to retake the courses and rewrite the examinations. Students were given extra classes, with better equipment and improved learning material. The programme was funded from the culture of learning budget under the Reconstruction and Development Programme which gave it resources of more than R10 million. Unfortunately, much of the money spent on science equipment was wasted – many teachers and students did not know how to use the equipment, and the programme made no provision for training. Motsoaledi commented that '... it was like giving a Rolls Royce to someone who does not know how to drive'.[38]

MASTEC emanated from a 1995 conference on science, mathematics, and technology education policy, held in Polokwane. The colleges were initially conceived of as maths, science, and technology education facilities, which would train educators in these subjects and offer them continued support. The project was funded by DFID, to the tune of £2 million, and the Open Society, to the tune of a further R4,5 million. Therefore, initially at least, the project was adequately funded.

Certain schools were selected to form part of the project. It was from these schools that teachers were drawn for the project and where participants would complete the practical components of their course. The first year of MASTEC was considered a success; curricula were developed, teachers were trained, and more schools joined the project, bringing the total to 45.[39]

A number of implementation problems developed. Differences between old and new teaching methods led to tensions between older staff and MASTEC teachers. The former also feared that they would become redundant, and believed MASTEC teachers were receiving preferential treatment. This situation was made worse by the fact that MASTEC's headquarters were based at a college that was being decommissioned, creating a situation of intense rivalry and jealousy. The reporting structures between MASTEC and the MEC's office were new and untested, which meant that communication between the two was often difficult or ineffective.

At a political level, MASTEC was not strongly endorsed by national government, and what little there was disappeared when Motsoaledi was removed from office. Added to this, Limpopo's education department realised that it was spending 90 per cent of its budget on teachers' salaries, which was unsustainable; it therefore decided to rationalise schools, and decrease the number of teachers. As a result, new teachers were fired, the MASTEC colleges were closed, and existing students enrolled at the University of the North.

Despite all its sponsorship and planning, MASTEC lacked political endorsement and a sustainable infrastructure. It produced very few graduates, most of whom have not found employment in Limpopo. It would seem as if one person's passion is not sufficient to sustain a project of this nature in the face of adverse political agendas and the economic realities in the contemporary educational arena.

CDE 2004

National Strategy for Mathematics, Technology, and Science Education

This second national initiative was launched in July 2000, when 46 maths and physical science educators from across South Africa attended a 'workshop on developing a strategy to improve science, mathematics and technology education'. It was organised by the National Research Foundation (NRF) under the auspices of the NDoE. Participants were drawn from universities, provincial and national education departments, NGOs, parastatal bodies, and professional organisations. Most of the workshop was devoted to group discussions and feedback, and focused primarily on developing short-term strategies for improving the output of maths and physical science students.

Based on ideas developed at this workshop, a draft strategy was prepared that formed the basis for a consultative conference held in September 2000 under the joint auspices of the NDoE, the National Science and Technology Forum (NSTF), DACST, and the NRF.

Inputs and discussions centred on four issues, namely curricula; human resource development; learning support materials; and physical science, mathematics, and technology literacy. Three major thrusts were identified:

- **Thrust One (**'to the future'): providing a high-quality physical science, mathematics and technology education (SMTE) for all FETC and GETC learners.
- **Thrust Two (**'attend to the immediate'): improving the participation of learners from previously disadvantaged communities in SC physical science and mathematics, and improving their performance.
- **Thrust Three (**'People are our resource'): increasing the human resource capacity to deliver quality SMTE.

In June 2001 the NDoE released a document entitled 'National strategy for mathematics, science, and technology education in general and further education and training' which currently guides the national government's work in this area. It identifies three goals, namely:

- improving the participation and performance of historically disadvantaged learners in SC maths and physical science;
- providing high-quality mathematics, physical science, and technology education for all learners studying for GETC and FETC; and

- increasing and enhancing the human resource capacity to deliver quality mathematics, physical science, and technology education.

According to the document, the first goal had four subcomponents, namely creating dedicated mathematics and physical science schools; improving competence in the language of learning and teaching; providing adequate learning support materials; and increasing participation and performance of girls. Only the first is worded as a clear set of actions. It is not clear what the other three subcomponents might mean in practice. The first involves the selection of and special support for 100 (later changed to 102) dedicated mathematics and physical science schools. This programme is now named Dinaledi, and is discussed below.

As regards the second subcomponent, the document states that it is 'important to strengthen the teaching of English second language'. As regards the third, it states that the strategy will 'support the Tirisano programme on learning support materials procurement, delivery and retrieval'. As regards the fourth subcomponent, it is even less specific in that it says the strategy 'will consider' various possible initiatives to 'increase the participation and performance by girls'.

The second 'action item' is not broken down into subcomponents. This section in the document is primarily devoted to a discussion of the National Curriculum Framework (NCF) developed for the GET phase. It does not discuss specific actions to be undertaken, but does state that 'All learners who graduate with a General Education and Training Certificate in Grade 9 must be competent in mathematics, physical science, and technology.'

The third action item is nominally divided into three subcomponents, but in fact only two are mentioned: increasing the pool of new mathematics and physical science educators, and improving the capacity of existing ones. The document states: 'There is a need to develop strategies for attracting, recruiting and selecting learners that have obtained good marks in mathematics and physical science to train as educators.' As an incentive, it suggests that students could be provided with bursaries and then be required to teach for an agreed time in an agreed place. This, in effect, would mark a return to the practice common in many education departments prior to the new dispensation, so can hardly be regarded as a new strategy.

A further problem with this strategy is that it assumes that teaching posts will be available for newly qualified teachers. This is not necessarily the case. Our case study on Limpopo illustrates this. A Mathematics, Science, and Technology Education College (MASTEC) was created, only to find that its first cohort of graduates had no jobs to go to. Present practices regarding the appointment of new teachers make it impossible for a school to employ a qualified maths teacher, say, to replace a history teacher who has been drafted into teaching maths while no maths teacher was available. So the school remains with an unqualified 'maths' teacher, and the newly qualified maths teacher is lost to the system.

For practising teachers, the strategy indicates that there are some educators teaching maths, physical science, or technology who are underqualified or unqualified. The document states that 'An upgrading programme that focuses on both subject content knowledge and teaching skills will be introduced as a matter of urgency'. A third subcomponent is suggested, but is hidden by the format of the document: it relates to increasing the pool of good maths and physical science educators by enticing retrenched or retired educators to return to teaching. This is a controversial but desirable move. It is also suggested that educator trainers from other countries could be recruited to 'complement the current teaching corps'.

In these cases, and as shown in the Limpopo case study, undifferentiated and generalised policies have negative effects. While it is necessary to increase the non-personnel component of education budgets, simply imposing a blanket ban on the employment of any additional educators is too crude. Indeed, it is vital to create new maths and physical science posts, and to fill them with well-qualified educators.

The national strategy initially fell directly under the then deputy minister of education, Prof M Shabane Manganyi. In October 2001 a full-time project manager was appointed to oversee its implementation. It is fair to say that, at present, only the Dinaledi initiative is being implemented as part of the national strategy.

The Dinaledi programme

This project is the most clearly articulated and penetrating of all activities initiated by the government as part of the national strategy. Indeed, it appears to have become the central component of the strategy, a fact that is very significant for this report. For these reasons, we will examine the project in some detail.

In May 2001 The National Strategy for Maths, Science and Technology Education (NSMST) was launched. It was the culmination of a consultative process begun two years earlier with teachers, educators, NGOs, and academics. The aim of Dinaledi (which means 'stars') is to ensure that '… every school increases the numbers of those who are registered for higher grade in mathematics and physical science by 10 per cent each year'.[40] A total of 102 schools were chosen as dedicated schools for maths and science. In theory at least, each school had to meet one of two criteria: the first was that they either had to be 'under-resourced and well-performing schools', which meant that they already offered maths and science in the higher grade and had classes with more than 20 learners who were being educated by competent teachers. The second was that they had to have the 'potential to improve participation and performance'; offering maths and science at the standard grade by teachers who were competent, or had the potential to become competent. Both types of schools had to be located within presidential nodes, and display basic levels of functionality. The intention of Dinaledi was to improve maths and science education within these schools. In addition, they were to act as facilitative centres for other schools in surrounding communities.

The NdoE soon found that many of the participating schools lacked basic amenities and services; for example, 45 schools had no water or very poor water supplies; 29 lacked electricity. More than half did not have a general science laboratory, or if they did, some laboratories did not have water and electricity, thus rendering them ineffective. Therefore, a range of issues needed to be addressed before even the most basic Dinaledi 'targets' could be tackled; from a lack of teaching resources, including textbooks, equipment, and knowledge, to more fundamental physical requirements such as classrooms, laboratories, water, and electricity.

The NdoE sought ways of addressing these needs in conjunction with aid organisations and NGOs, including USAID/South Africa, the Thintana Project, the Phambili Education Project, and the Council for Educational Opportunities, as well as a number of private and state-owned corporations, namely Multichoice, Sasol, Somerset MicroScience, and Telkom. Each of the partners has provided the Dinaledi schools with services or equipment – Sasol, for example, has bought textbooks, and the Thintana Project has supplied computers and training. Somerset MicroScience has provided science kits, teacher training on their use, and ongoing support for educators. Phambili Projects has provided teacher materials in the form of lesson plans, work sheets and transparencies, as well as overhead projectors, screens, and calculators for learners and educators.

The NdoE, together with the Department of Public Works, is establishing water and electricity supplies to all Dinaledi schools. It has also staged a series of autumn workshops for maths and physical science educators, and developed an 'on the ground' training programme, the latter with the assistance of USAID, ASME, and PROTEC.

Over the period 2001-2003, the number of candidates writing HG SC maths increased by 105 per cent, and those writing physical science by 75 per cent.

BOX 4.3: GOVERNMENT REVIEWS THE DINALEDI PROGRAMME

In 2004 the NDoE offered the following general assessment of the results of the NMSTE strategy:

Achievements

- raising maths and science participation and performance in the 102 dedicated maths and science schools;
- a 'steady increase in the number of learners' and pass rates; and
- 'encouraging' improvements in African maths and science participation and performance.

Limitations

- poor output of maths and science graduates in grade 12 – particularly at the HG level;
- underqualified and unqualified maths and science teachers, manifested as a 'vicious cycle of low- quality teaching, poor learner performance, and a constant undersupply of quality teachers'';
- a lack of adequate facilities and resources for effective teaching and learning; and
- insufficient financial and other forms of support for talented students.

The report expressed particular concern about the following limitations:

- 'the output at HG level is still disturbingly low';
- 'a slight decrease in enrolments' in physical science;
- the fact that ten times more African learners passed SG maths (38,9 per cent) than HG maths (3,48 per cent)'; and

- ‘girl learner participation and performance remains a concern’.

In September 2004 the deputy minister of education, Enver Surty, stated that the NdoE had learned the following lessons from the first phase of activity in 2001-2003:

‘We learned that support for the implementation of the first phase ... was affected by minimal professional support given by district offices, educators not employed on a first-time basis, some overcrowded classrooms, and investments that do no match performance. Furthermore, optimal use of the resources given to schools is yet to be achieved.’ [41]

Second phase of the NMSTE strategy, 2005-2009

According to the NdoE, the challenge for the next phase of the NMSTE strategy for the period 2005-2009 is to ‘sustain the improved participation and performance across the system’ by ‘maximising outputs within the existing capacities’ and establishing ‘national norms’ for maths and science learning and teaching in participating schools.

The new implementation plan was aimed at achieving the following goals within five years:

- systemic ‘covering [of] all the different levels, from reception level to higher education’;
- integrating technology into teaching, learning, and management, and improving the language of teaching and learning;
- improve accountability between all levels in the system; and
- ‘schools will be expected to produce results to match the resources and level of attention invested’.

Evidently, the government and the NdoE are committed to expanding the original aims and goals of the NMSTE strategy. The minister of education, Naledi Pandor, has stated that: ‘We will consolidate the efforts made thus far in improving the teaching of mathematics, science and technology in our schools. Not only will we continue supporting the 102 mathematics and science focus schools; we will provide the resources necessary for the proper teaching and learning of these subjects in many more schools, both at primary and secondary level.’

CDE 2004

The performance of the Dinaledi schools is monitored on an annual basis. On-site evaluation tools have been developed, aimed at testing implementation of the Dinaledi strategy against its original goals. The evaluations are carried out by district subject advisors, who visit the schools at regular intervals.

Evaluation

Although the NDoE goes to some lengths to avoid using this term, Dinaledi is in fact a ‘special schools’ programme, similar to those in many other countries. Even the requirement that special schools become a resource to other schools in the area and to the local community is found in other systems.

Be that as it may, Dinaledi is a very welcome development. It is the first attempt to concentrate resources on an underperforming component of the education system. It provides highly targeted assistance on a significant scale, and in ways that can be monitored and evaluated. This is not to say, however, that all aspects of Dinaledi have been optimally planned or implemented.

Public–private co-operation

This aspect of Dinaledi is another positive development in principle. National and provincial government resources have been combined with those of a foreign government, expertise from an American consultancy, financial resources and donations in kind from several South African companies, and the expertise of no fewer than six non-government maths and science organisations. The project shows a willingness on the part of the NDoE to involve multiple stakeholders, thus combining the expertise or resources that can be contributed by each. This flexibility on the part of the NDoE is commendable. Dinaledi is much closer than any other government project studied to the participative model of educational reform identified in the international literature. Nevertheless, participation by a reasonably large number of institutions has created problems that will be discussed below. Our research shows, however, that the mix of state and private resources is not optimal, and that the management system is not functioning very well. A new management structure seems to be required. Once again, there are important international examples. In several countries, separate authorities have been created to oversee special schools. They have a legal obligation to the public sector, but develop their own managerial structures (see chapter 7).

The selection of schools

The selection of school has not been optimal. It has not been systematically based on the two criteria outlined in the original project documents, namely participation and performance in maths and physical science.

The following table provides a general picture of the performance of Dinaledi schools on CDE's schools performance index (first described in chapter 3):

Table 4.8: Performance of Dinaledi schools on the CDE schools performance index, 2002

Ranges on CDE maths/science school performance index (maximum 1)	No of Dinaledi schools
0,75 – 1	10
0,50 – 0,74	39
0,30 – 0,49	37
Below 0,3	16

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination , 1991-2003.

The table shows that participating Dinaledi schools range from the most effective in maths and science in the country to some of the very weakest. In table 4.9 the 2001 SC results of Dinaledi schools are analysed in greater detail (data drawn from the CDE index).

Table 4.9: Dinaledi schools by SC results in maths and science, 2001

Indicators / provinces	Eastern Cape (15 schools) (iv)	Free State (6 schools)	Gauteng (11 schools)	KwaZulu Natal (23 schools)
National ranking (i)	279, 427, 626, 723, 956, 1051, 1320, 1323, 1545, 1715, 1976, 2806, 2841, 2952, 3037	6, 490, 691, 1246, 1640, 2795	2, 561, 876, 1131, 1442, 1562, 1659, 2351, 2496, 4118, 4644	349, 393, 608, 671, 676, 937, 973, 1449, 1453, 1799, 1997, 2081, 2213, 2288, 2461, 2827, 3110, 3320, 3360, 4802, 4802, 5256, 5400
Provincial ranking (ii)	25, 38, 59, 70, 90, 98, 125, 126, 146, 166, 198, 322, 330, 355, 368	1, 30, 50, 87, 113, 183	2, 146, 210, 253, 306, 317, 332, 400, 419, 567, 594	50, 57, 106, 120, 121, 196, 208, 344, 346, 439, 500, 524, 556, 574, 617, 707, 778, 834, 847, 1157, 1157, 1259, 1286
% African language speakers (iii)	12 schools: 100%; 1 school 75%; 1 school 41%; 1 school 3%	5 schools 100%; 1 school 87%	All schools 100%	All schools 100%
No of maths candidates (% of all candidates)	34 :152 (38% : 97%)	9 : 100 (19% : 100%)	21 : 237 (26% : 100%)	12 : 193 (35% : 100%)
No science candidates (% of all candidates)	11 : 112 (21% : 73%)	9 : 100 (19% : 100%)	11 : 132 (9% : 100%)	0 : 94 (0% : 72%)
% maths pass (female pass rate)	15% : 78% (6% : 54%)	27% : 93% (4% : 100%)	10% : 100% (3% : 100%)	0% : 85% (0% : 76%)
% science pass (female pass rate)	26% : 94% (9% : 53%)	48% : 89% (4% : 100%)	34% : 100% (4% : 100%)	0% : 100% (0% : 63%)
Maths HG pass rate	0% : 75%	0% : 100%	0% : 100%	0% : 100%
Science HG pass rate	0% : 100%	0% : 100%	0% : 100%	0% : 100%

Indicators / provinces	Limpopo (15 schools)	Mpumalanga (7 schools)	N Cape (4 schools)	North West (7 schools)	Western Cape (5 schools)
National rank	8, 50, 99, 189, 511, 653, 967, 1048, 1315, 1445, 1483, 1484, 1632, 1786, 1854, 1913, 1919, 2686, 2894, 3167, 3424, 4190, 4732	752, 1036, 1284, 1761, 1819, 2330, 2529	703, 1497, 1865, 1921	351, 583, 666, 898, 997, 1029, 1681	317, 991, 1125, 1129, 1410
Provincial rank	1, 4, 6, 9, 20, 31, 47, 51, 82, 103, 107, 108, 122, 149, 159, 172, 173, 310, 347, 411, 469, 704, 911	43, 55, 67, 90, 94, 120, 137	23, 42, 47, 50	21, 31, 37, 54, 61, 64, 100	63, 163, 179, 181, 197
% African language speakers	13 schools 100%; 1 school 94%; 1 unknown	6 schools 100%; 1 school 98%	1 school 100%; 3 unknown	6 schools 100%; 1 school 98%	1 school 100%; 4 unknown
No. maths candidates (% of all candidates)	12 : 193 (25% : 100%)	42 : 171 (25% : 66%)	42 : 56 (26% : 76%)	85 : 341 (38% : 100%)	21 : 91 (19% : 100%)
No. science candidates (% of all candidates)	0 : 94 (0% : 72%)	21 : 59 (14% : 45%)	12 : 33 (20% : 21%)	41 : 201 (36%: 100%)	21 : 75 (13% : 100%)
% maths pass (female pass rate)	0% : 83% (0% : 22%)	16% : 100% (2% : 33%)	21% : 87% (13% : 27%)	15% : 99% (14% : 76%)	56% : 100% (2% : 100%)
% physical science pass (female pass rate)	0 : 84 (0% : 47%)	18% : 95% (2% : 19%)	33% : 97% (3% : 16%)	32% : 100% (16% : 58%)	38% : 100% (5% : 100%)
Maths HG pass rate	0% : 100%	0% : 100%	0% : 100%	0% : 100%	33% : 100%
Physical Science HG pass rate	0% : 100%	7% : 89%	0% : 100%	0% : 100%	0% : 100%

(i) Calculated from the CDE School Index (see chapter 3); (ii) Calculated from the CDE School Performance Index (see chapter 3); (iii) Lowest and highest school percentages shown in this and all succeeding columns; (iv) Numbers indicate the ranking of each individual school in the Dinaledi initiative.

Source: Perry, Mathematics and physical science performance in the Senior Certificate examination , 1991-2003.

The table shows massive variations between Dinaledi schools in the initial year of implementation (2001). The schools ranged from the second-best maths and physical science school in the country to one ranked 5 400th out of 5 789. Within provinces, the narrowest range was 23rd to 50th, but the widest was 1st to 911th.

Our tables show that in 2001 some Dinaledi schools actually did not offer maths and physical science in grade 12; nor did they have any maths and physical science educators. The numbers of maths candidates in different schools ranged from a tiny class of nine to many classes totalling 341. SC maths candidates comprised 19 to 38 per cent of total SC candidates at Dinaledi schools in each province, and SC physical science candidates 0 per cent to 21 per cent. African language-speakers studying maths and physical science, ranged from 3 per cent of all learners at Dinaledi schools to 100 per cent. Most worryingly, pass rates in HG maths and science ranged from 0 per cent to 100 per cent in almost all provinces.

We are aware of the tensions between the NDoE and provincial departments over the selection of Dinaledi schools, and the pressures brought to bear on provincial departments by local interest groups that wish to have a prestige Dinaledi school in their area. We are also aware of the requirement that a certain number of Dinaledi schools have to be located in presidential development nodes. Nevertheless, the selection of schools under the project is clearly a classic case of:

- Policy confusion, with educational policy being arbitrarily linked to geographic development policy;
- Delegation of key aspects of implementation to the provincial level, potentially undermining the project as a whole;
- The assertion of local political interests in a way that must ultimately be self-defeating for the schools involved since success is hardly assured or even likely for many; and
- An inability on the part of the NDoE to ensure that its own guidelines are adhered to.

The upshot is that 102 schools that are much closer to a random cross-section of schools rather than a focused selection of potential special schools are now asked to participate in a well-conceived project for which some are not suitable. This situation must be urgently addressed. If not, there is a real chance that the whole concept of special schools will be discredited in South Africa, with long-term negative impacts.

Content knowledge and teaching skills

When Dinaledi was launched, its planners assumed that educators already had satisfactory levels of content knowledge, and therefore concentrated on teaching skills. However, all the research gathered in the course of this project indicates that this assumption is incorrect. Indeed, even in the United States most successful development programmes for educators now start with content (see the analysis of the Discovery programme in chapter 7). Dinaledi has swiftly discovered this truth. Workshops and training courses aimed at improving educators' teaching skills had to be converted on an ad hoc basis to lessons in content, and during the 2003 Autumn Workshop the content component had to be upgraded to 40 per cent. Unrealistic expectations and policies based on these have had a negative impact.

Ideological conflict

There is a danger that Dinaledi will become a victim of ideological disputes about the nature of education, essentially between those who support 'learner-centred' education and those who support 'teacher-centred' education. The NDoE needs to provide clear guidance on this topic, in order to prevent future sniping from adversely affecting Dinaledi's outcomes. This topic is also discussed in chapter 7.

Future development

A revised version of Dinaledi needs to become a permanent feature of the South African education system. The present three-year time scale is irrelevant. If Dinaledi is seen as a permanent venture, it is not too late to make positive changes that are consistent with the original ethos of the programme. CDE will make proposals in this regard in chapter 10.

PROVINCIAL INITIATIVES

We gathered data on provincial maths and physical science initiatives by asking education MECs for the following:

1. A list of what they considered to be the most important initiatives undertaken in their province since 1994 to improve maths and physical science education at the secondary school level.
2. Copies of all documents dealing with these initiatives, particularly those dealing with their impact or success.

Responses were initially received from four provinces only. Information on the other provinces has been compiled from other public sources. In all provinces there are numerous projects related not only to maths and physical science but also to technology education, often in collaboration with various donors and NGOs. Given space constraints, we do not intend to treat each provincial initiative in detail. We will rather give an overall sense of what is being achieved in the provinces through an overview of the more innovative programmes.

The largest GED project is Gauteng Online. Funded by the Gauteng department of education to the tune of R500 million over three years,[42] it is aimed at providing every school in the province with 25 computers and internet access, and training educators how to use them in order to enhance learning in other subjects as well.

Another large project involving all the provinces is the Thintana Maths, Science and Technology Project, in terms of which R30 million has been committed over two years for establishing 18 centres of excellence serving 200 historically disadvantaged schools across the country. These centres will be provided with appropriate equipment by Thintana in co-operation with the NDoE and the Centre for Educational Technology and Distance Education (CETDE).[43] Thintana is a foreign consortium, comprising Telkom's equity partners Telkom Malaysia and SBC International, and thus cannot be said to be a truly South African initiative.[44]

The GED is also budgeting for other in-service educator training courses, and additional maths and physical science teaching posts. These posts will be allocated to disadvantaged schools where a need to expand the curriculum offerings in subjects such as mathematics, physical science, and economic sciences has been identified.

A detailed historical survey of initiatives in Limpopo has already been presented in box 4.2, in order to convey the very real problems of politics and policy discontinuity that undermine many provincial initiatives, sometimes fatally so.

Gauteng, the Western Cape, and Free State have each produced their own provincial strategies for math, physical science, and technology (MST) education.

The Western Cape mathematics, physical science, and technology strategy for 2002 outlines three 'thrusts' aimed at delivering 'quality MST education' in the province:

3. Participation: to raise learner interest, participation and achievement;
4. Teachers: to increase the number of capable teachers able to offer effective MST education, including the assessment of key MST concepts
5. Resources and Learner Support Materials (LSM): to provide adequate support and resources including ICT to provide high quality mathematics, physical science and technology education for all learners.[45]

The Western Cape department of education has created four additional Dinaledi schools, besides the six already selected in the province. The department has also established the Cape Academy of Mathematics, Physical Science, and Technology 'to provide specialised schooling for learners with the potential to excel in these subjects in the SC examinations'.[46] The school will cater for day scholars and boarders from grades 10 to 12, starting with grade 10 in 2004.[47]

The Western Cape department has also outlined specific desired outcomes in respect of mathematics for each of the education bands. The desired outcome for the GET band is to 'increase learners' interest in mathematics and physical science, so that they will choose the sciences as a subject area in the FET band'.[48] The desired outcome for the FET band is to increase the numbers of learners studying these subjects and obtaining their SCs, particularly at the higher grade.[49]

The *Gauteng strategy for mathematics, science, and technology education, 2002-6* spells out two goals:

Goal #1: To increase and enhance the human resource capacity to deliver quality maths, physical science, and technology education for all learners in the GET and FET bands.

Goal#2: To increase the participation and performance of learners in maths, physical science, and technology in the GET and FET bands, giving special attention to black learners, female learners, and learners with special educational needs.[50]

The document states: 'Achieving these goals will require a comprehensive battery of strategies that cover curriculum, professional development, provision of resources, learners, research and administrative and community support.'[51] It lists nine specific strategies for achieving goal 1, and four for achieving goal 2.

The *Free State three-year strategy for science, mathematics and technology (SMT) 2001-2003* rests on four pillars:

- Develop a positive approach towards maths and physical science teaching;
- Do quality INSET in the maths and physical science learning area and subject content training from grades R to 12;
- Provide basic infrastructure – furniture, labs, quality LSM, and other resources – and teach educators how to manage and use this equipment.
- Provide quality, effective support for the implementation of C2005 and maintaining support for the NATED 550 curriculum (SC) in these subjects.

Many of the maths and physical science initiatives of the KwaZulu-Natal department of education are structured as public–private partnerships. A three-year technology education partnership between Zenex Foundation, PROTEC, and the department targeting 15 schools in two districts ran between 1999 and 2002. Since 2001, more than 500 'new curriculum transformation posts' have been made available to 'previously disadvantaged' schools in order to address past imbalances, and to introduce maths, physical science, technology, and commerce education.[52] We are unable to assess if, whether indeed, these initiatives have had the effects intended.

SUMMARY AND CONCLUSIONS

We begin this chapter by examining the major efforts of the government since 1994 to transform the national education system, and establish a new education framework. Our first section outlines the reform process, and evaluates its impact on and implications for maths and physical science. We concluded that these have had far-reaching effects on the teaching of all subjects, including maths and physical science. The situation as regards current curriculum reforms and particularly their implementation in the secondary schooling phase is clearly a major concern, and a significant current challenge: it also has potentially disastrous implications for maths and physical science learning and teaching in the senior secondary phase. CDE began its research on the premise that the SC examination – or a modified but equivalent examination, based on a similarly specialised curriculum – would remain in place to maintain the performance of learners exiting from the schooling system. It became evident that the NDoE was proceeding on a different assumption, and new research had to be commissioned at a late hour to take these curriculum proposals for the FET band into account.

Our research all along has been based on a determination to identify both the virtues and the faults in the current maths and physical science education subsystem: however, having stated this aim, it is evident that the new educational framework and the curriculum and assessment criteria which drive it have not been bedded down; without this happening in the immediate future all present and future interventions will matter very little whatever potential they posses.

What conclusions can be reached about the effect of the many national and provincial government initiatives to improve maths and physical science education? The first conclusion is clear. When it comes to developing policies, strategies, and plans, there is no lack of enthusiasm and energy. The issues at hand are exhaustively studied. Seminars, conferences, and workshops are held. Documents are drafted, circulated, commented on, amended, and published. Programs are implemented with much initial political support and significant financial backing by both national and provincial government ministers and the private sector. Yet the key issue is whether such initiatives ranging from the most comprehensive to the more focussed interventions have had the effect of improving results at participating schools. As noted earlier, despite the resources brought to bear on these programmes, no clear monitoring and evaluation mechanisms appear to be in place that enables this question to be answered.

Obviously, major problems are still occurring at the level of implementation, and so, as the Limpopo case study suggests, is a lack of stable political commitment. Political discontinuities, budget constraints, and a lack of implementation skills and capacity undermine good policies. We have to ask why this is so. One reason may be the absence of a common national goal as regards maths and physical science education that transcends more parochial political or education priorities. Another may be the absence of firm political leadership.

However having argued that actual implementation has and is undermining many initiatives which clearly have the potential to make a significant difference, it remains to be said that there have been and are a number of bad education policies for which the NDoE planners are responsible that have pervasive negative impact on many aspects of schooling, even the special programmes.

Part of the answer for this lies with the overambitious nature of the policy changes. Until very recently, government planners have attempted to change the whole system, or large parts of it, all at once. All the international research consulted by CDE shows that this is a futile and counterproductive strategy, especially as it results in scepticism and demotivation when the inevitable failure to achieve the initial goals occurs. This approach has undermined even those few schools that have continued to achieve even under circumstances that are anything but propitious: it is important to state that this category includes both former ‘Model C’ schools as well as former DET schools; whatever their provenance, both are been currently undermined in the present circumstances.

Secondly, new policies often depart from or abruptly replace previous initiatives launched by the same department. One example of a policy discontinuity is to start up new programmes for teacher education based on teacher training colleges at the same time that colleges of education are being rationalised and absorbed into higher education institutions. Another is to encourage new maths and physical science entrants to the teaching profession at a time when provincial education departments are expected to cut their personnel budgets, thereby making it impossible for schools to employ new maths and physical science educators. Who would want to be trained as an educator if there is no prospect of being employed as one? In the case of the Dinaledi project, the issues of learner-centred or teacher-centred training were not resolved in advance, leading to conflict among project personnel. The NDoE and some provinces are involved in upgrading educators teaching and content skills in these subjects, and providing bursaries for aspiring teachers: the question will be whether qualification criteria will be applied to assuming maths and physical science teaching posts in the schools.

A third problem is a persistent refusal (probably under pressure from certain stakeholders) to adopt differential policies and strategies. By this we refer to policies based on the self-evident truth that an education system is composed of different subsystems, and that results in some cases can only be achieved through policies that differentiate among subsystems, even benefiting some more than others. It is not wise always to deal with every component of the education system in exactly the same way. Crucial subjects such as maths and physical science are treated as if they are no more important than, say, religious instruction or history. By contrast, abundant modern experience shows that it is both valuable and feasible to prioritise various aspects of an education system at different times. An absolutist attitude flies in the face of national needs, and once again causes a loss of credibility in the system.

A fourth problem arises from what CDE is beginning to identify as a reluctance amongst education officials to admit that their attempts to create an entirely new national education system has become derailed in the critical areas of curriculum development, with now real negative educational consequences looming for the country and the present learner cohorts entering the FET band, particularly those in disadvantaged, weaker schools. They cannot, for fear of the political consequences for the minister and the government, continue not admitting to the extent of the problem facing the country now in our schools. They must bite the bullet and take the bold steps needed to stabilise the system to the extent this is still possible, whatever the potential political fall-out. There are many examples here – one is the negative impact of school selection and provincial inadequacies on the potentially significant Dinaledi initiative. A further example arises in respect of the FET and the fiasco surrounding its implementation. Another is the development of the FET curriculum that is currently 'still under construction'. The option of an intensive science stream for example has not even been raised, because of pressure to make room in the curriculum for other, more 'politically correct' subjects. Compulsory Mathematics or Maths Literacy in the new curriculum likewise pose their own problems as is indicated in this chapter.

A fifth problem relates to educators. There is as yet no agreed upon mechanism for testing maths and physical science teachers' content knowledge or for positively requiring professional development where it is found to be lacking. Whatever the cause of this situation it must be overcome and soon as the new curriculum proposals (RC2005) are implemented. Any education reform initiative can only be successful to the extent that the very people entrusted with the process of development itself are fully behind the process: the educators.

A sixth issue is a lack of attention to the process by which change is brought about in education systems. Michael Fullan, probably the best known international expert in educational change, notes: 'Neglect of the phenomenology of change - that is, how people actually experience change as distinct from how it was intended - is at the heart of the spectacular lack of success of most social reform.'[53] As we will see in chapter 5, efforts of almost all South African education departments to lead change (as opposed to the need for sensible new policies) are negatively regarded by principals and educators.

A seventh issue is the large amount of time required to change a system meaningfully. Unless more attention is paid to the process aspects of educational change, and not only to the desired outcomes, this problem is likely to emerge again when the new FET curricula are implemented. Not enough time was initially allowed to acquire necessary resources, develop materials, build capacity, and create a shared vision among those involved in implementing them. With the FET curriculum in particular, the initial government requirement that a new curriculum should be produced by the end of 2002 for implementation in 2003 meant that it would be impossible to provide resources to educators, learners, and schools in time. Given the large number of underqualified and unqualified teachers in South Africa, it is deeply worrying that educational authorities are not providing sufficient time for innovations to be thoroughly planned, resources mobilised, and genuine capacity built. Whilst the FETC deadline has been extended by three years, an 'interim' curriculum to 'phase OBE into the FET' has been implemented in grades 10-12 which is having severe negative impacts not only on learners but on increasingly disillusioned educators particularly maths and physical science educators as we shall see in chapter 5.

To summarise, national and provincial governments have come up with some interesting and innovative policies for improving maths and physical science education in secondary schools. To make these policies more effective, careful attention now needs to be paid to policy alignment, capacity-building, time frames for implementation, and the process aspects of educational change. How this is to happen, what the precise objectives are, and where key responsibilities lie are crucial challenges that will be addressed in depth later in this report.

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Chapter 5

FINDING FAULT OR FINDING VIRTUE (2): CDE'S QUALITATIVE RESEARCH

INTRODUCTION

The quantitative research on maths and physical science education outlined in chapter three was amplified by qualitative research, recording and drawing on the views of professionals actually involved in administering, teaching, and assessing these subjects.

More specifically, CDE researchers:

- interviewed educators, education officials, and researchers involved in maths and physical science education;
- held workshops involving examiners, moderators, markers, and educators involved in SC examinations in these subjects; and
- studied the delivery of maths and physical science education in a number of selected schools.

In each case we tried to record, and learn from, the experiences of practitioners who are immersed in the school-based maths and physical science education system, and identify its 'faults' and 'virtues' as experienced by them at first hand.

THE MATHS AND PHYSICAL SCIENCE EDUCATION COMMUNITY

CDE researchers conducted 40 structured interviews with people who had experience, knowledge, and/or research data on maths and physical science education, and could contribute valuable insights into successful maths and physical science education implementation strategies.[1]

The main feature of the interviews with educators, education officials, and researchers was the prominence given to good – or bad – policy-making. Much of this was encapsulated by a teacher in the Western Cape who stated: 'There is policy fatigue … 101 policies are being imposed … Let's be [more] realistic.[2] Immediately we are plunged into a world far removed from confident national policy statements, one populated by professionals who experience policy changes at the point of implementation.

First, interviewees were asked to comment in general on the present state of maths and physical science education in secondary schools. Almost without exception, they said that, despite some remarkable achievements, the system was in a bad state, and deteriorating further. Negative features mentioned included:

- low levels of enrolment by learners in these subjects;
- poor performances by those who did enrol;

- a shortage of properly qualified educators;
- too few new educators;
- inadequate in-service training in content knowledge and/or teaching skills;
- a shortage of learning and teaching resources;
- inadequate English skills among grade 10 learners in maths and physical science;
- too few provincial subject advisers, and too many schools to assist (for example, there is one physical science adviser to 105 schools in Mpumalanga, 34 of which are secondary schools); and
- overly large classes.

These factors correlate closely with the results of our quantitative study. We believe these members of the maths and physical science education community have a good and realistic understanding of the system, its shortcomings, and the challenges it faces. The only issue on which the opinions of interviewees were not confirmed by quantitative research is gender participation: all the respondents stated that, since 1994, girls had not performed as well as boys, while our quantitative research shows that this is incorrect.

As regards qualitative issues, the responses were remarkably consistent, and interviewees confirmed many of the conclusions suggested by the quantitative research. They said the multiple and disparate systems of education prior to 1994 had left the following legacy:

- a negative attitude by learners to maths and physical science;
- a perception among learners that maths and physical science are irrelevant;
- a poorly qualified educator corps;
- poorly resourced schools, especially in rural areas and poor urban areas;
- a deficient culture of learning, caused by apartheid but exacerbated in the post-apartheid period by inadequate policies on school management;
- communities that were insufficiently educated or motivated or simply too poor to support learners and their schools;
- similar weaknesses in parental support; and
- an inability by parents to act as 'educated consumers' of education, and insist on improvements.

All the interviewees were questioned about their experiences of attempts to improve the maths and physical science education system. They unanimously stated that the ultimate responsibility for improving it rested with the central government. They perceived central government as the source of policy change, and provincial departments as implementers.

Almost all interviewees stated that too many policy initiatives had been introduced; that these were not properly co-ordinated or prioritised; and that many of the policies implemented had had negative consequences. This included the redeployment and retrenchment of qualified and experienced educators, whom, interviewees believed, should, and might have to, be recalled.

They also responded negatively to the introduction of 'continuous assessment' of learners, and the way in which it was being implemented; this will be dealt with in greater detail later in this chapter.

Due to the large number of new policies they had been expected to implement, members of all the groups expressed a loss of interest in yet more policy changes or new initiatives.

The interviews show that educators still appreciate the need for reform, but are suffering from 'policy fatigue' as a result of too many changes being introduced by the NDoE and provincial education departments. They also complained that policy changes were often haphazard and inadequately prepared; and poorly implemented.

The most important issue raised by the interviewees was the quality of the educators themselves. Here, a paradox emerged. Interviewees agreed that the relatively low quality (and the shortage) of educators was a prime cause of current problems surrounding maths and physical science education; at the same time, they all agreed that educators were also central to any solution of these problems. Thus a teacher in the Western Cape stated:

> The only people in the classroom today are those who were there yesterday, and they are the only ones who will be there tomorrow. The teachers who are the cause of today's situation must be the solution to tomorrow's.[3]

In the final stage of the interviews, respondents were asked to suggest what practical steps could be taken to improve maths and physical science education.

At the provincial department and school district level, they identified improved monitoring and support by curriculum advisers and officials, in-service training, and a far more personalised and less bureaucratic approach towards educators and learners.

At the school level, teachers argued for stronger leadership, better management, a result-orientated culture, reasonable class sizes, confident educators, a supportive environment for learners, better and earlier diagnostic assessment, and greater parental and community support.

At the classroom level, educators maintained that the proper planning and pacing of work, an emphasis on the relevance of both subjects to daily life, more personal contact with learners, and access to additional materials and courses would vastly improve maths and physical science education.

BOX 5.2: COMMENTS BY INTERVIEWEES

'The performance of learners in maths and science is a tall, thin pyramid. We have the normal amount of learners who do very well, and a number who are coping at the matric level, but the overwhelming majority don't have any confidence in their competence in maths and science.' – **Expert in school-based maths, science, and technology education.**

'It is much easier to send a spaceship into space than to fix maths education.' – **Ed Beagle, American expert on maths education, quoted by expert, Gauteng.**

'The hurried implementation of curriculum 2005 created a crisis on top of a crisis' – **Expert, Gauteng.**

'Teachers don't have enough time to gather their thoughts on a particular process before being thrown into something new'. – **Educator, Gauteng.**

'We can't continue to throw money into a bottomless pit. We have to have strategies in place which ensure that money is spent the best possible way ... there's no point in allocating money for science equipment when there's no secure place to keep it ... there's no stock control, and no commitment to stock control ... you have to change people ... At some schools, science equipment is stacked in the principal's office; the teachers have never seen it.' – **NAPTOSA official.**

'The department's responsibility is to be seen as being supportive of schools. That's not coming across at the moment … we view them as a meddlesome interference, and largely incompetent in what they are doing. We are struggling to survive in spite of them.' – **Educator, KwaZulu Natal.**

On the NDoE: 'They walk in here to scrutinise. There never seems to be enough time when they come in. They never gather a few teachers together to talk about the problems they are having in a friendly way. It's always bureaucratic and official.' – **Educator, Western Cape.**

CDE 2004

Conclusions from the interviews

When we considered the aggregated views of the respondents, it was clear to that we were dealing with a knowledgeable and experienced group of individuals with a key role to play in reforming the education system in general, and the maths and physical science education system in particular. This is a huge virtue for the country.

However, their enthusiasm for additional reforms has been dampened by what they perceive to be failed or botched policy changes in the past, incompetent implementation, and additional unresolved problems. The result is that many of them have become disillusioned. Any proposals for reforming the system will have to take this factor into account, and include steps to rekindle the earlier optimism of educators while utilising the strengths and abilities that they have to offer in overcoming the present faults and problems.

THE MATHS AND PHYSICAL SCIENCE EXAMINATION COMMUNITY

In 2002 CDE held four workshops, two with school-level experts in maths and physical science, and two with higher education experts in these subjects, at which participants assessed the standards and appropriateness of SC maths and physical science exam papers.[4]

The SC examination is the only objective assessment of the knowledge, skills, and ability of South African learners after 12 years of schooling. Like all public examinations, it serves as a summative evaluation of previous learning, and a formative evaluation of those candidates seeking to continue their education in various ways. In recent years, it has also become a means of informally assessing the quality of individual educators, in the absence of any other method. We asked ourselves: Can the examination itself be contributing to poor results in these subjects?

This issue has become even more important that it was when we conducted our interviews, because, given the postponement in introducing the FETC, the SC examination will be written until 2007. The key question now is whether the SC examination will add to the problems surrounding maths and physical science education in this intervening period. Rather unexpectedly, our research shows that it will not.

The two school-level groups were first asked to consider the following basic question: 'Do the exam papers under discussion effectively assess the knowledge and skills specified in the SC curriculum?'

All the members of both groups concerned with mathematics agreed that the exams did test the knowledge and skills specified in the curricula. Participants in the physical science groups were more equivocal: they agreed that the exams were testing the curricula in a literal sense, as they were set out in curricula statements, but did not test them in the sense in which they were described in the preambles to those statements.

These responses are very significant. They mean that, by and large, participants believed that the level of failures in SC maths and physical science examinations could not be attributed to the nature of the examination itself, its moderation, or, with some reservations, variations in marking.

Next, participants were asked to discuss the effect of continuous assessment (CA) on candidates' SC results. CA comprises 25 per cent of the mark achieved by each candidate, and involves the assessment of knowledge and skills over the course of the school year by means of alternative assessment mechanisms than that of the formal end-of-year exam. Participants reported that CA was unevenly implemented across the provinces, and that it appeared to place significant additional demands on educators in terms of preparation and time. Finally, they felt that, in some schools and provinces, CA marks were being allocated in an arbitrary manner. While they could not cite specific instances, they felt that these marks could therefore be distorting the results of SC candidates.

Participants in all four workshops expressed concern about the degree to which educators were focusing on training or coaching candidates for their examinations, rather than on inculcating a real understanding of maths and physical science. Members of all four groups stated that the current exams did not adequately test higher levels of ability and knowledge. More specifically, they expressed two concerns. First, they felt that exam questions could too often be answered with purely memorised knowledge. Second, they felt that the way in which questions were structured and formulated (apparently for ease and accuracy of marking) often reduced their assessment of candidates' skills.

The last, and most important, aspect of exam questions discussed by all groups was 'word problems'. Most participants agreed that setting questions in words in both maths and physical science was essential if important goals of the curriculum, including contextualisation and the application of learning to real-life situations, were to be tested.

Therefore, 'word problems' were desirable, but, as the maths and physical science exams are set in English and Afrikaans only, simple linguistic comprehension became an issue for any candidate with a first language other than these two. All the participants agreed that word problems should be retained, but that language and cultural experts should be used to reduce the possibility of candidates being prejudiced by an inferior ability in languages other than their own.

Conclusions

The most important point to emerge from these workshops is that current failure rates in these subjects cannot be attributed to examination papers that are too difficult, or 'unfair', in the sense of confronting candidates with unfamiliar questions. If anything, the participants felt that papers did not contain enough difficult questions, which would allow the more talented and capable candidates to be identified.

In general, though, examiners and moderators were given a clear vote of confidence, especially as regards coverage of the knowledge and skills specified in the current curricula.

Participants regarded CA as potentially valuable, but currently unreliable because of the way it was being implemented. If this system is to be continued, it must be strengthened, the assessment criteria made more transparent, and educators properly taught how to conduct and moderate it.

When interpreted in an international perspective, the data gained from the workshops point to the conclusion that the assessment component of maths and physical science education in South Africa is not part of the problem, and therefore not an area requiring wholesale crisis intervention. As noted earlier, this is an unexpected finding, given reported widespread dissatisfaction amongst educators, parents, and politicians with the 'old' apartheid' SC syllabus. Be that as it may, it should be seen as a 'virtue' that can be built on in the short term, up to 2007, by which time the NDoE and the education community at large should have addressed the concerns about the FET maths and physical science curricula alluded to in chapter 4.

THE SCHOOLS COMMUNITY

This component of the research programme was aimed at determining exactly what was happening in schools that were maintaining high levels of learner performance, or consistently improving previously low levels of learner performance. Similar studies have been undertaken in the past, but were hampered by a lack of resources that limited the numbers and geographical spread of the schools that could be studied. Also, researchers undertaking those studies could not apply the latest case study techniques because too few researcher-days were available for each school. By contrast, given greater resources, CDE was able to study 13 schools in six provinces, involving more than 160 researcher-days at the schools themselves, and subsequently to synthesise these into a composite report.[7]

Research questions

The research questions underpinning the 13 case studies were formulated as follows:

- Why do learners at the schools under review consistently achieve higher than average marks in SC maths and physical science examinations, or why do their marks show a consistent year-on-year improvement?
- Which specific practices in those schools contribute to their success and / or improvement in maths and physical science?
- Which of these factors are in-school, and which out-of-school?
- What strategies are administrators and educators at these schools using to achieve these levels of performance?
- How do these schools characterise their own ethos and educational environment beyond the features common to all secondary schools?
- What practical conclusions can be drawn from these case studies?

The selected schools were diverse in terms of origin, history, locality, length of establishment, the socio-economic background of learners, resources, funding, and other factors. All they had in common were a principal, some classrooms, some educators, and some learners. Yet schools 1-7 consistently performed far better than the national average in maths and physical science, and schools 8-13 were performing far better than they had in the past, and somewhat better than the national average (see table xx). We will examine each of the following aspects of these schools in turn:

- results achieved;
- physical setting;
- internal cultures;
- guidance in subject choice;
- the quality and experience of educators;
- the learning and teaching resources at their disposal;
- parental and community involvement; and
- the relations of these schools with provincial and national education authorities.

Some of the information gathered during the studies is set out in the table below.

Table 5.1: Background information on the schools studied

SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4	SCHOOL 5	SCHOOL 6	SCHOOL 7
LOCATION						
North West; located 45 km west of Pretoria; peri-urban setting; running water and electricity supply; tarred road with 1 km dirt road to school; area marked by poverty and high unemployment.	Gauteng; located in Centurion, an affluent middle class suburb on the outskirts of Pretoria. Easily accessible. Electricity and water supply.	KwaZulu-Natal; located 4km from the rural town of Nongoma. Electricity and water supply. Accessible by tarred road. Very poor community.	Gauteng; located in Orange Farm, vast informal settlement 50km south of Johannesburg. Area marked by poverty and high unemployment.	Gauteng; located in Lenasia Ext.1, an area originally developed for Asians 45 km south west of Johannesburg, borders the south of Soweto. Poor community .Electricity and water supply.	Gauteng; located in the central business district of Boksburg, 30 km from Johannesburg. Easily accessible by road. Electricity and water supply. Middle class community.	KwaZulu-Natal; located in deep rural Egazeni Reserve, 34km on a narrow dirt road from nearest town. Electricity and water supply. Very poor community.
HISTORY						
Established in 1975 as a semi-autonomous religious school with a distinct Catholic ethos. Initial intake of 71 grades 8 and 9 learners and 4 staff. Today, 26 staff for grades 7-12. Now a state school	Established in 1959 as an Afrikaans school to offer quality education. Since 1994 has reverted to a State school, without changing its ethos/culture. Grade range: 8-12	Established in the 1960s as a KZN Empowerment Project that was well resourced. Now a State school and poorly resourced. Grade range: 8-12	Established in 1993 by the DET for grades 10 &11, then in two buildings 2km apart. Today in new buildings. Grade range 8-12	Established by the DET in 1953 as the first secondary school in Lenasia. Now under Gauteng DOE. School's demography has since changed. Grade range 8-12	Established as East Rand Training Centre in 1920, became a high school in 1925 under the name it presently uses. A typical former white suburban school, now multi-racial. Grade range 8-12	Established in 1990 with 26 grade 8 learners. Founded by a primary teacher, the school began with only one classroom built from donations and the help of the community and parents. Grade range 8-12
SOCIO-ECONOMIC STATUS						
65% of learners come from township, 35% from rural and informal settlements.	100% of learners come from the suburbs, fairly affluent middleclass families, mostly Afrikaans speaking.	90% are boarders. Others live in rural and peri-urban neighbourhood; 60% in towns and 35% in rural and informal settlements.	84% of learners reside in informal settlement; 13% in townships and the remaining 2% in the suburbs.	80% of learners come from disadvantaged backgrounds within the surrounding township; 20% reside in informal settlements.	60% of learners come from suburbs, 40% reside in neighbouring urban townships.	100% of learners come from rural settings; mainly a farming community with few social amenities.

SCHOOL TYPE						
Consistent high performing school, 98% African enrolment, rural religious/state school.	Consistent high performing school, 100% Afrikaans enrolment, white, urban school	Consistent high performing school, 100% African, special ex-homeland initiative school	Consistent high performing school, 99% African learners, informal settlement/township school.	Consistent high performing Indian school, with significant numbers of African learners, urban intake.	Consistent high performing school, former white suburban school, now multiracial in enrolment.	Consistent high performing school, 100% African, ordinary ex-homeland rural school.
RANKING BY SCHOOL TYPE						
181	25	218	127	274	141	162
ENROLMENT, 2001						
708 Male 256 Female 452	1340 633 707	832 349 483	1314 535 779	1160 568 592	1335 628 707	707 346 361
NO. OF MATRIC CANDIDATES IN 2000						
118	227	97	92	170	226	78
SCHOOL MANAGEMENT						
PRINCIPAL 1 VICE 0 HOD 4 EDUCATOR 21 NON TEACHING 3 —————- STATE employed 26 SGB employed 3	1 2 10 54 7 ———— 56 18	1 1 3 23 26 ———— 46 8	1 1 6 32 6 ———— 46 0	1 2 5 31 3 ————- 36 6	1 2 7 46 12 ———— 49 19	1 1 2 14 1 ————- 19 1

FACILITIES						
Offices Yes *Staff room* Yes *Library* Yes *Classrooms* 15 *Science Lab* Yes (2) *Storerooms* Yes *Computer* *Laboratory* Yes *School Hall* No *Electricity* Yes *Water supply* Yes *Playing/Sports* *Field* Yes *Well-resourced* Yes	Yes Yes Yes 48 Yes (7) Yes Yes Yes Yes Yes Yes Yes	Yes Yes Yes 25 Yes (2) Yes Yes No Yes Yes, Erratic No Fairly	Yes Yes Yes 35 Yes (3) No Yes No Yes Yes No Fairly/Poor	Yes Yes Yes 49 Yes No Yes Yes Yes Yes Yes Fair	Yes Yes Yes 36 Yes (7) Yes Yes Yes Yes Yes Yes Yes	Yes Yes No 14 No No No No Yes Yes, Irregular Yes Poor
FUNDING						
Fees: R120 p.a.; A once-off R250 fee for computer fund; Substantial financial support from an Education Trust fund and the corporate sector/ embassies	Fees: R3600 5% of running costs by donation, 15% by State, and 80% by school fees	R3996, for boarders; R905 for day; State pays salaries. Major part of revenue from fees.	Fees: R80 p.a. School's main source of income is the DOE.	Fees:R600 p.a. Major part of revenue from the State; PTA helps to raise funds	Fees: R3750 for Juniors. R4250 for Seniors. Income from fees 95%; State 1.2%; others 3.8%	Fees:R90 Major funding from the State.
EDUCATOR TURNOVER						
2 in the past five years	3 in the past two years	8 in the past five years	No data	No data	No data	None since the school's inception

SCHOOL 8	SCHOOL 9	SCHOOL 10	SCHOOL 11	SCHOOL 12	SCHOOL 13
LOCATION					
Western Cape Province; located 30 km from Cape Town city centre in the township of Khayelitsha. Urban setting. Access by tarred road to school. Very disadvantaged community.	Gauteng Province; located 45km north of Pretoria in an urban township with a long history of educational involvement. It is easily accessible by road. Very poor community.	Eastern Cape Province; located 30km from East London city centre in Mdantsane township. An informal settlement is adjacent to the school. An area of high crime and unemployment.	KwaZulu-Natal Province; located in Inanda township, about 25km north of Durban city centre. Very high unemployment. High level of family strife, drug abuse and violent crime.	Gauteng Province; located 20km from Johannesburg city centre, in Orlando West, a suburb of Soweto. Easily accessible by road. Poor, but well-established community.	Western Cape Province; located in Mitchell's Plain, on the Cape flats. Surrounded by some of the most notorious criminal areas on the Flats. Poor community. Easily accessible by road.
HISTORY					
Established in 1980s. It is now a state funded school with a history of vandalism. Grade range 8-12	Established in 1985 as a Junior secondary school for grades 8-10 only. Today it is a fully-fledged high school for grades 10-12 only. Has links with Atherly Primary School in England	Established in 1983 in then Ciskei homeland. The school was originally named after a local businessman who fell out of favour and the school was later renamed in the 1990s after a political activist. Grade range:8-12	Established in 1990 and admitted its first learners in 1991(grade8) Presented its first matric candidates in 1994 and had a 98% matric pass rate. The school has had a history of politically instigated violence right on its doorstep. Grade range 8-12	Established by the DET in 1957 as a Junior Secondary school. Steeped in the struggle politics of the 70s and 80s. In 1994, became a Senior Secondary school. In 2001 was placed under the Education Action Zone as a dysfunctional school.	Established in 1984 for grades 8-10. Initially built for 800 but has since expanded to hold 1300 learners. Became a 'struggle school' during apartheid. Grade range 8-12
SOCIO-ECONOMIC STATUS					
95% of learners come from informal settlements and 5% from formal townships; high unemployment and poverty.	99% of learners reside in neighbouring townships with only 1% from informal settlements. High unemployment rate and poverty. About 20% of parents exempted from fee payment.	60% of learners come from townships, 20% from informal settlements, 10% from rural areas and 10% from suburbs. High unemployment. School is marked by vandalism.	95% of learners live in informal settlements, 3% in formal townships and 2% in rural areas. Very deprived community.	95% of learners come from the surrounding township; 2% from informal settlements and 3% reside in city high rise flats.	90% of learners come from formal townships, 5% from informal settlements and 5% from the suburbs or low density flats.
SCHOOL TYPE					
Significantly improved school; 98% African enrolment, conventional township school.	Significantly improved school; 99% African enrolment, township school.	Significantly improved school; 100% African enrolment, conventional township school	Significantly improved school, 99% African enrolment, conventional township school	Significantly improved school, 100% African enrolment, conventional township school.	Significantly improved school, Coloured urban large school.
RANKING BY SCHOOL TYPE					
40 (improving schools)	78 (improving schools)	14 (improving schools)	90 (improving schools)	96 (improving schools)	22 (improving schools)

TOTAL ENROLMENT Year 2001					
1498 Male 673 Female 825	1188 435 753	867 413 454	1158 552 606	634 311 323	1260 550 710
NO OF MATRIC CANDIDATES IN 2000					
110	212	178	93	104	134
SCHOOL MANAGEMENT					
PRINCIPAL 1 VICE/DPTY 2 HOD 4 EDUCATOR 21 NON TEACHG 3 ——————- STATE employed 26 SGB employed 3	1 2 5 22 2 ——————— 32 0	1 1 3 20 1 ———————— 25 1	1 1 5 28 2 ————————- 37 3	1 1 3 17 6 ———————- 28 0	1 2 6 28 6 ———————- 43 0
FACILITIES					
Offices Yes *Staff room* Yes *Library* Yes *Classrooms* 34 *Science Lab* Yes 3 *Storerooms* No *Computer* *Laboratory* No *School Hall* No *Electricity* Yes *Water supply* Yes *Playing/Sports* *Field* No *Well-resourced?* No	Yes Makeshift Makeshift (?) Yes (1) No No Yes Yes Yes No No	Yes Yes Disused 14 1 disused No No Disused Yes Yes No No	Yes Yes Yes (no books) 29 Yes (5) Yes Yes No Yes Yes Yes Fair	Yes Yes Poorly resourced 38 3 (unfurnished) No Yes Yes Yes Yes Yes Fair/Poor	Yes Yes Yes 28 5 (poorly resourced) Yes Yes No Yes Yes Yes Fairly well

FUNDING					
Fees: R120 p.a. 50% of parents can pay. Main source of income from State.	Fees: R200 p.a. 25% of school income from State, 65% from fees; 5% from donations.	Fees: R50 p.a. State pays all salaries. Major part of revenue from fees (90%) and 10% from donations.	Fees: R230 p.a. Paid by less than 10% of pupils. State pays staff salaries. Grant of R46000 from state; R130000 from fees. No other revenue source. .	Fees: R70 p.a. 70% of school income is from the State; 30% from school fees.	Fees: R300 p.a. 40% of school income is from the State; 40% from fees; 20% from an innovative scheme that involves buying and selling exercise books to neighbouring schools at marginal profit.
EDUCATOR TURNOVER					
No data	No data	No data	2 in the last year	No data	No data

Note: The 13 schools reflected in this table did not wish to be named.

Source: Gilbert Onwu, Review of case study results of 13 performing maths and science secondary schools across urban and rural South Africa, CDE background research report, 2003. **

Results in SC maths and physical science, 1996-2001

CDE asked the schools under review to provide their SC results for 1996—2001. Four schools were unable to provide this data, and where possible we added data from our own database. The composite data are displayed in table 5.2.

Table 5.2: Results in SC mathematics and physical science, 1996-2000/1

	MATHEMATICS					PHYSICAL SCIENCE				
School	Total learners	HG pass	SG pass	Fail	Pass rate (%)	Total learners	HG pass	SG pass	Fail	*Pass rate (%)*
1	405	146	253	6	98.5	199	140	59	-	*100*
2	323	146	177	-	100	249	159	90	-	*100*
3	445	199	150	96	785	288	285	0	3	*99*
4	263	10	210	43	81	152	18	116	18	*88*
5	558	134	254	170	70	515	215	258	42	*92*
6	638	131	450	57	81	453	173	261	19	*96*
7	160	28	84	48	68	141	74	67	10	*94*
8	177	1	41	135	25.5	94	4	53	38	*61*
9	461	-	355	46	77	291	5	171	67	*61*
10	217	-	144	37	66	293	11	195	46	*70*
11	540	116	230	-	44	171	31	40	-	*42*
12	124	4	17	98	18	47	2	29	6	*66*
13	*292*	*7*	*215*	*70*	*76*	*115*	*9*	*104*	*2*	98

Source: Gilbert Onwu, Review of case study results of 13 performing maths and science secondary schools across urban and rural South Africa, CDE background research report, 2003.

Physical settings

The researchers did not expect to establish a firm link between the educational quality of an institution and its physical condition, such as the age of the buildings, and their standard of maintenance. Nevertheless, the research team felt that untidy classrooms or unkempt grounds could point to poor management in other areas as well.

The physical condition of the schools surveyed varied considerably, as did their policies for attending to those conditions. Some of the schools, especially those located in rural settings or surrounded by informal settlements (schools 4, 8, 11 and 12) were desperately poor, and could give little attention to aesthetics. The grounds of three of those schools in particular were very untidy; litter was visible, and lawns were overgrown. However, this did not affect their performance. The quality and condition of buildings also varied significantly. Nevertheless, in all schools under review the essentials for effective teaching were in place. These included chalkboards, dusters, chalk, enough chairs and desks, wall charts, and additional teaching aids. Personnel at all the poorly resourced schools understood the importance of an attractive physical learning environment, but were struggling to achieve this.

Schools that had experienced repeated burglaries and other criminal activities (4, 8, 11 and 12) were fitted with fences, gates, and burglar bars. Only one school was completely unsecured (school 12).

A pattern could be seen regarding security. Most of the improving schools had once been unsafe and insecure, and had not achieved good SC results in that time. The surrounding neighbourhoods were also unsafe. Eventually, the principals of all those schools (supported by parents) decided to make their schools safer and more secure, as they believed that improved security would lead to improved attendance, and improved teaching and learning. This was done by means of fencing, burglar-proofing, the employment of guards, and police patrols. As security improved, their principals believe, so did their SC results.

These case studies enabled us to identify the following factors that invariably accompany good or steadily improving performance:

- The school is fitted with clear signage, which helps visitors to find their way to and around the school. This is a common indicator of efficient school management.
- The school is decorated with learners' artwork, and displays other academic and sporting achievements, such as trophies and certificates of merit that inspire present learners.
- Classrooms, special subject rooms, and laboratories are well maintained.
- The school has clear policies on maintaining grounds and buildings, and on tidiness and cleanliness, which every stakeholder in the school helps to achieve. Some schools (eg schools 1 and 2) had environmental committees (consisting of staff and learners) that oversaw environmental matters.
- High levels of safety and security are maintained, turning the school into a 'safe haven', even when there are high levels of crime in the surrounding neighbourhood.

School cultures

The research showed that all the schools had evolved their own distinctive cultures, and that these impacted significantly on their educational performance. These cultures were commonly influenced by factors such as the schools' physical setting, the resources available to them, the personality and role of the principal, the approaches and practices of administrative staff, and the approaches of the educators. Not surprisingly, the cultures of the 13 schools under review differed markedly though underpinned by very general shared features, namely a clear vision and professional ethos; strong discipline; strong academic leadership; clearly defined academic programmes; effective delivery of those programmes; high levels of parental and community involvement; and effective school governance.

At all 13 schools the school governing bodies (SGBs) and principals had formulated a vision for the school which served as an overarching framework for all aspects of school management, and also helped to create the ethos of a particular school. Principals are ultimately responsible for the quality of their schools; however, they cannot succeed on the basis of their personal standing alone. Thus teamwork was a major feature of the ethos of all the successful schools. Other stakeholders (administrative personnel, educators, and learners) are also vital players in these schools' success stories. As the head of the maths department of a highly successful peri-urban school department put it: 'We are a team … a family that is kept going by the school vision … we want to keep our school at the top.'[9]

In most of the consistently performing schools, learners had as much insight as educators and administrative personnel into the reasons for their schools' superior performance. This reflects the pervasiveness of collective effort at those schools. Learners consistently mentioned such factors as:[10]

- 'The maths and science results are satisfactory because the teachers teaching these subjects have good knowledge of their subjects';
- 'They are committed and dedicated';
- 'They rarely miss a lesson, and if they do, they always make it up';
- 'They work hard';
- 'I chose this school because there is discipline here and it has a great reputation for success.'

All the schools under review were marked by strong discipline, which was accepted by educators as well as learners. It would therefore not be too much to state that a positive correlation was found between discipline and improved maths and physical science results. Discipline is a personal and social value, but is most important in a school when it is linked to a state of order that does not need to be continuously enforced.

Although all 13 schools had written disciplinary rules, we discovered that principals were solely responsible for drawing up the rules in eight schools; at four schools, principals drew up these rules in conjunction with the SGB, or, at one, with the students' representative council. Issues addressed include learners coming late, absenteeism, untidy or improper clothing, loitering between classes, and other misdemeanours. School management carefully implemented and monitored these rules; in six schools, however, there was a disciplinary committee consisting of staff members and learners.

Interviewees in each of the 13 schools attributed their successes in SC maths and physical science to discipline. When asked what was responsible for good physical science and mathematics results, one principal's response was typical:

'The teachers are committed, and know their subject. Year after year, they complete the syllabi in each grade. They are highly disciplined. I have never had to ask the matric science or maths students what stage they are in their syllabus… the teachers' absenteeism is almost 0 per cent. Parents are very keen for their children to do maths and science, hence the learners are disciplined and motivated to study their subjects, even at home.'[11]

A common theme was the importance of what principals and educators referred to as strong academic leadership. Academic leadership can be formally defined as the leadership provided by the principal and staff 'for the immediate purpose of enhancing learning and teaching. It is not only intellectual leadership, but includes also pedagogical leadership and leadership in respect of the proper administration required for effective learning and teaching.'[5]

Whilst seldom conforming to this comprehensive definition, 10 of the 13 schools had **clearly defined rules and agreements** in the area of academic leadership. The following are some of the indicators of quality characterising academic leadership in these schools:

- The principal delegates authority for academic and administrative decision-making to various committees that involve staff and learners.
- The principal delegates individual responsibilities in consultation with the staff.
- The principal and/or other members of the senior management staff develop an academic year plan or a calendar of main activities so that everyone is aware of the important academic deadlines, such as examinations, etc.
- The principal gives high priority to contact with educators and learners, and provide them with easy access; in this way, the principal maintains independent lines of communication with learners and educators, and stays in touch with learning and teaching in the school.
- The principal is aware of all educators' formal and informal qualifications, respects their professionalism, and encourages them to upgrade their qualifications and attend content-specific in-service training courses.
- The principal keeps in touch with the day-to-day activities in the school by being highly visible and by interacting with learners and teachers outside the office and in daily school activities.
- Staff and learners acknowledge and respect the leadership qualities of the principal.
- Each head of the department that includes physical science and mathematics compiles an academic year plan for each subject, and ensures that it is implemented.
- A daily system for conveying information is in place so as to ensure the smooth running of the school. Avoiding the cancellation of lessons is a high priority.

In all 13 schools we found clear **policies** on matters such as language, discipline, non-academic activities, and the academic subjects on offer. However, our research plainly shows that it is the **implementation of policy** that makes the difference. Schools were implementing the following strategies to achieve success in physical science and mathematics:

- *Language policy*. In almost all the schools surveyed, English was the language of instruction, although code switching took place during classes and outside the classrooms. Personnel generally recognised that a lack of proficiency in the language of instruction invariably had a negative impact on maths and science results. The teaching staff also encourage the use of the language of instruction outside the classroom. This is based on the understanding that using a language for informal communication strengthens its use in the classroom.
- In seven consistently successful schools, academic activities and events outside of formal classes are on offer nearly every week.
- *High behavioural expectations and social etiquette*: In the seven most successful schools, learners and staff are expected to observe certain social conventions, including greeting each other, regularly attending classes, and taking part in extramural activities. The 'social traffic regulations' that apply inside and outside the classrooms were identified as important elements of success.
- *Time usage:* These schools optimise their usage of time to focus on academic activities, maximising the opportunity of the school calendar and the timetable. Educators very rarely miss classes, and when they do, they make up for it.
- *Regular assessment of learners, and feedback about their performance.* Assessment policies played an important role in the academic achievement of the consistently performing and some of the improved schools. While all government schools are required to perform continuous assessments, many do not do this consistently. However, at the schools surveyed continuous assessments were regularly performed in all grades, and competition among learners and with learners at other schools was encouraged. Educators monitor exercise books, and review the performances of all learners. Regular meetings are held where parents are informed about their children's progress.
- *Guidance and counselling.* All the schools had clear policies on counselling learners in respect of further study in maths and physical science, based on assessments of learners throughout the academic year.

In all the schools under review, parents played a supportive role; however, levels of parental involvement and support were higher at some schools, particularly at fee-paying schools where parents donated extra funds to the school despite their poor financial status, or donated their skills/services for building or other purposes.

All the schools under review had well-functioning SGBs. At several schools, SGBs employ extra teaching or support staff. At school 2, where there is a very close working relationship between the school and its SGB, the latter employs 13 additional educators and five additional support staff, thus adding significantly to its managerial and teaching capacity. However, despite playing these important roles, the SGBs at these schools do not involve themselves in the every-day running of the schools, and do not cut across the authority of the principals.

Whilst each of the 13 schools constitutes a distinctive learning community with a distinct culture, the factors underpinning their success are familiar ones of effective organisation and management. Principals pay attention to the maintenance of interpersonal relations based on trust and discipline. They take great care to maximise opportunities for positive support of learners by educators in and out the classroom. Clear lines of discipline and control, managed by the principal with the support of heads of department, maintain the common team effort of the school.

The selection and guidance of learners

There are two points in the careers of learners who want to study maths and physical science at which selection and guidance are crucial. The first is when learners move up to secondary school. Not all secondary schools offer maths and physical science, and parents who want their children to study these subjects have to ensure that they apply to schools that do.

The second point is when learners enter grades 10 and 11, when they need to decide whether they should continue with maths and physical science, and whether or not they should study those subjects in the higher grade.

On this score, the principal of one school had this to say:

> At the end of grade 11, learners are promoted based on their year mark and their performance in the end of year exams. If we find they are not ready for grade 12, we advise them to repeat, provided we feel they would benefit. We also advise them on which subject to drop going into grade 12, and help them to choose the subjects according to their choice of career and potential.[12]

Through this filtering process, success rates in external examinations are increased.

The principal of one of the improving schools (school 11) attributed its success to its previous admission policy:

> We were very selective when we first started. The school had an admission policy of pre-entry or entrance examinations to be taken by prospective candidates. So only the good candidates were admitted.[13]

Selective admission policy and pressure for achievement are typical elements of a successful school's culture, as well as important components of its success. There is no point in avoiding this issue. Maths and physical science can be mastered up to grade 10 by almost everyone who can reach that level of schooling. However, beyond that, some learners will have a greater aptitude for these subjects. The key to increasing the number of those who pass is to identify them early, ensure that they attend the correct schools, and provide them with good teaching and guidance.

Maths and physical science educators

Our case studies confirmed that the single most important element in maths and physical science education is what happens in the classroom: if educators are suitably qualified, well-trained, experienced, well-organised, and strongly motivated, they will make a major difference to learners' experience of education, and indeed their educational performance.

All the physical science and mathematics educators in the 13 schools studied had a degree, a Secondary Teacher's Diploma (STD), a Further Diploma in Education (FDE), or both. Most had taught at the same school for 10 years or more; however, as might be expected, the experience of maths and science teachers did vary from 1 to 22 years. The total numbers of qualified male and female teachers were roughly equal, but the ratios at individual schools varied considerably.

In 10 of the 13 schools (the exceptions were among the significantly improving schools), grade 12 physical science and mathematics educators were deeply involved in general school management.

Again in 10 of the 13 schools, we found a profound respect for the professionalism of the maths and physical science educators. The principal of school 1 attributed its excellent results in these subjects largely to the dedication and work ethic of its educators:

> The mathematics and the science educators always do the things that contribute to our success, because we share a common vision ... They exchange ideas among themselves, talk about individual learners, and (where applicable) give individual attention to learners that perform poorly... Colleagues with special expertise help out with 'tips' in the teaching of topics that are difficult to learn.[14]

These educators acknowledged that their professionalism was reinforced by the fact that their pupils were successful, and that their achievements were recognised by others.

At the same time, educators at three schools whose professionalism was not acknowledged expressed negative attitudes to their work, and profound disillusionment. A researcher at one of these schools observed:

> The educators appear uncommitted, and do not seem to care whether learners understand what they teach. Nevertheless, they seem to have a good command of the content of what they teach. They are high on absenteeism (three or four had not reported after the COSATU strike) and on tardiness, since it is common for them to arrive late at school for morning assemblies, or turn up 10 to 15 minutes late for each class[15].

However, when we asked educators why their schools performed well in maths and physical science, they concurred with their colleagues at the other schools in identifying the following factors as important: discipline, leadership by the principal, motivated learners, collegiality among educators, and a love of their subject and their learners.

It was difficult to separate the factors that educators perceived as important for their success from those that 'really' influenced their success. When asked what the characteristics of good educators were, educators at all 13 schools listed the following:

- They have a good understanding of their subjects, retain an intellectual interest in them, and are enthusiastic communicators.
- They are involved with and attentive to learners, even outside the classroom.
- They co-operate closely with their colleagues.
- They have high expectations of their learners.
- They are proud of their schools' achievements, and determined to maintain those standards.
- They have a strong work ethic, and are strongly committed to education.

Teaching methods

Teaching methods used at the schools under review were overwhelmingly traditional. They were educator-centred and textbook-based, and involved whole class teaching at all the schools. Was this simply a practical response to large classes – often of more than 50 learners – in crowded classrooms? Or was it a response to learner expectations?

Either way, the interviews clearly showed that the educator-centred approach was the preferred method of imparting knowledge.

Observation of the methods used by mathematics educators yielded interesting results. Except for chalkboards, hardly any teaching aids were used. Questions and answers made up most of the lessons, supplemented by lecturing. Recitations and the chanting of rules and definitions were common, especially in the lower grades. When asked about chorus-answering, a learner said: 'It helps us to remember the rules and equations to use when solving problems or doing exercises.' In HG classes, question and answer sessions and periods during which learners copy notes are complemented by individual work. Learners are often asked to come up to the blackboard to solve problems, or present ideas arising from group work..

Nearly all the mathematics educators we observed effectively controlled the pace of their lessons. Their classroom management skills seemed aimed at instilling a sense of 'learning together'.

The methods used by physical science educators were generally similar to those used for maths. Only a few physical science classes were taught in laboratories. Of those, most still involved educator demonstrations. Besides this, the 'telling method' was commonly used. Lessons usually started with a practical demonstration by the educator, followed by a short lecture on theory. Learners recorded the results of the demonstrations in exercise books. Educators then asked guiding questions, and learners were given the opportunity to raise issues or problems. Laboratory reports were written up in class if there was enough time, or taken home to be completed as homework assignments.

Resources for learning and teaching

Table 5.3 presents the results of a survey of resources for learners in eight of the schools studied which are both consistent and improving. Grades 9, 10, and 11 physical science and maths classes were studied.

Table 5.3: Resource profile of learners by school (8 selected schools)

Resource available (%)	School 1	School 2	School 3	School 7	School 10	School 11	School 12	School 13
Science textbooks	100	100	5	27	46	12	50	100 /57
Maths textbooks	95	100	24	19	71	29	52	73/57
Calculators	100	100	92	42	74	78	40	76
Study at home	100	100	96	96	95	90	85	86
Convenient to study at home	85	95	84	68	78	57	68	72
Quiet place to study at home	80	98	82	79	73	67	61	67
Study at home alone	80	82	73	50	69	64	69	69
Revision materials at home	90	77	93	56	78	51	31	69
Communication								
Use English at home	35	8	10	87	5	8	4	45
No problem with English	90	Examined in Afrikaans	90	57	80	37	72	27
Prefer to study science and maths in mother tongue	20	92 (which they do)	43	66	56	55	52	83
Additional aids								
TV science and maths programme	80	27	73	62	66	58	50	55
Newspaper supplement (Yes)	60	24	56	56	62	50	46	59
Study group	30	6	73	86	55	54	37	7
Help from family	65	63	78	72	84	73	69	34
Extra lessons	60	40	79	43	57	39	30	45
Winter school	10	5	70	35	12	30	20	32
Science club	40	3	39	40	13	31	15	14
Saturday classes	40	3	51	51	21	26	36	52

Source: Gilbert Onwu, Review of case study results of 13 performing maths and science secondary schools across urban and rural South Africa, CDE background research report, 2003.

Key results

Access to textbooks varied widely, from as little as 5 per cent of learners to the expected 100 per cent. At school 3, the head of the physical science and mathematics department said so few learners had textbooks because 'the school has not had a supply of textbooks for some time now. Six to seven learners are sharing physical science textbooks, and three to four learners [are] sharing mathematics textbooks. Most of the[se] textbooks are provided by the state.'

A high proportion (79–100 per cent) of learners studied at home, and most of these (57-100 per cent) found it convenient to do so. Relatively few learners attended winter schools or extra lessons.

Only seven schools provided additional resources such as television learning sessions, video cassettes, and newspaper supplements. These were funded by donors or SGBs.

A large proportion of learners received academic help from family members. This largely consisted of elder brothers or sisters tutoring them, or helping them with their homework.

These results clearly show that success in maths and physical science as presently taught and examined does not depend on sophisticated physical resources; in fact, most of the schools studied were under-resourced even by developing country standards. Also, some of them were located in very poor communities. The positive conclusion from this part of the study is that a paucity of resources can be overcome in the short and medium term. The key factors are well-educated, well-trained and strongly motivated educators, a well-organised school, appreciation of success, a charismatic principal, and good discipline. Moreover, the evidence shows that educators and learners are aware of this, and respond positively to strategies designed to improve these core aspects of learning and teaching.

Language skills

In all but two of the 13 schools the language of learning and teaching was English (in the other two, it was Afrikaans). Two of these schools (1 and 2) had programmes for improving learners' proficiency in English, since English was not the mother tongue of the majority of learners. Learners at these schools did not seem to experience problems with English as the medium of instruction in maths and physical science, and were the two best performing schools in HG maths and science in our sample. School 13 was an anomaly: it is an improving school, whose learners are largely drawn from coloured communities. Some 93 per cent of learners interviewed said they would prefer to be taught maths and physical science in their mother tongue (Afrikaans), but were obliged to study in English. To confuse matters further, from grade 10 onwards, learners at the school are exposed to dual-medium instruction in all subjects, with the result that all the maths and physical science classes are presented with constant code-switching between Afrikaans and English.

Parental support

Throughout the world, parental and community support play a key role in eliciting good performances from schools. In the case of parents, the connection is obvious. Attendance by learners, discipline, study at home, and attitudes to schooling are strongly influenced by the behaviour of parents, and they are also obviously responsible for paying fees and making occasional donations. The last two are by no means trivial sacrifices for poor parents to make.

School governing bodies

Another avenue for parental involvement is the school governing bodies (SGBs), which have come to play an increasingly important role in the life of schools. Parents constitute about 50 per cent of the membership of SGBs. Through them, communities have become a major source of material and management support, especially for more successful schools. Personnel at the schools under review stated that SGBs should be given even greater powers, and that the education system was not giving them enough support.

Community support

We were not surprised by the importance of the role played by parents – but we were surprised by the strength of our findings on the importance of communities as a support system. All the schools that performed consistently well, and most of the improving schools, benefited from high levels of community support, beyond that of parents of learners currently at the school.

Relations with the government

In the South African education system, 'government' impacts on public schools in ways that are vital to the level of quality those schools can achieve. For all but a small minority of schools in affluent communities, the greatest part of a school's financial resources come directly from 'government', in the form of educators' salaries, text books, building grants, equipment, and the like. The national government specifies class sizes and educator qualifications, and lays down other parameters. Provincial governments employ educators in the schools and supervisory and advisory staff in district offices, provide in-service training, and organise public examinations.

The researchers were surprised and dismayed by the widespread negative attitudes towards 'government'. Indeed, personnel at all the schools that relied on government to a significant extent felt that there was little, if any, positive input from either national or provincial education departments.

Personnel at all the schools felt they were 'on their own'. Indeed, a number of principals expressed the belief that schools should be more autonomous so that they could deal with problems that government officials were failing to address. Maths and physical science educators complained that even basic documentation such as syllabi, exam results, and examiners' reports were not received regularly or on time, and sometimes not at all.

However, the most frequent criticisms centred on government policies and regulations. Personnel complained that the government made it difficult for schools to provide good education because of what one principal described as 'unnecessary legislation'. Some changes in policy, such as those affecting promotion, retrenchment, and the redeployment of staff, were seen to have had negative consequences. The implementation of Curriculum 2005 had already caused confusion when the case studies were carried out in 2001.

Principals and educators noted that the government had organised workshops on new policies and programmes, and that there had been some positive responses to these. However, on the whole, the workshops were part of the problem, as they were often facilitated by people who had not mastered their topics. As a result, the workshops were often taken over and run by the educators themselves, as this was the only way in which they believed they could get any value out of the meetings.

Educators at poorer schools consistently complained about a lack of laboratories, learning materials, and libraries.

Our researchers observed that educators and principals considered neither the national nor provincial departments of education as part of the answer for better maths and physical science education. The preferred option was for individual schools or groups of schools to take charge of their own affairs.

Findings

The findings of the study of 13 schools can be summarised under five headings: school factors; educator factors; classroom factors; learner factors; and factors outside the school.

School factors

- The central factor at the school level is the **principal,** who creates and sustains the culture and ethos of the school. The principal realises that these values have to be communicated to and internalised by everyone else at the school. After proper communication and acceptance, these values become the school's understanding of itself.
- The key to the process of communication is **participation** by a wide group in formulating a **vision** and putting it into practice through agreed **policies and procedures**.
- Clarity of **rules** is vital, after the need for them has been agreed. Rules, as embodied in time tables, dress codes, homework obligations, and many other features, provide the certainty needed about behaviour that enables attention to be focused on the goal of learning.
- There is constant pressure to **achieve**.

- Feedback is given to learners so that they can assess their own progress and take steps with the staff to remedy weaknesses. In time, regular high achievement becomes a history or **culture of success**.
- The principal practises **delegation** of authority as the school becomes larger. The best-performing schools invariably have a vice-principal and some heads of departments, providing levels of management between the principal and the detail of what happens in the classroom.
- Successful maths and physical science schools have a clear policy on **language**. They promote the informal use of the language of instruction and examination (if this is not the learners' home language) in order to improve fluency in and the confident use of that language.
- **Physical resources** are important at the basic level of classrooms of a sufficient size, desks, a chalkboard, some textbooks, and writing paper. However, we observed quality work taking place at hugely different levels of resource provision.
- **SGBs** are important. They function better in schools with better results, as part of the virtuous cycle.

Educator factors

- The confidence of the educator stems from his/her **content knowledge**. If the educator does not understand certain aspects of the curriculum, this will inevitably filter down to learners.
- **Sound professional training** is vital, and is enhanced by experience. Educators at the schools surveyed had nine years' experience on average. Theoretically, the in-service upgrading of skills is freely available, which is not the case in respect of content knowledge. However, personnel at the schools surveyed had reservations about the quality and relevance of in-service training; as a result, stable employment at a successful school was regarded as more valuable.
- **Commitment** by educators takes many forms: punctuality; preparation; planning; team spirit; a willingness to work additional hours tutoring learners; and others.

Classroom factors

- Classrooms have to be in a certain minimum physical condition, but this level is quite low. The survey clearly showed that what counts is not the equipment a classroom contains, but what happens inside it.
- The first aspect of what goes on in the classroom might be called the 'yes'. Maths and physical science are difficult subjects; choosing to study them is risky, and the results are hard to predict. This could result in a learning atmosphere characterised by anxiety and concern. However, learners at all the schools surveyed identified the class-

room environment as non-threatening, high on cohesiveness and satisfaction, and low on friction and difficulty.

- The second key aspect in respects of classrooms is **orderliness**, not in physical terms, or even in terms of learners' behaviour, but in the way material is presented and mastered. Successful educators supply learners with clear time tables, world out clear goals for each lesson, sequence their lessons properly, logically order concepts, relate new concepts to those already learnt, review material already covered, and provide learners with feedback on tasks or homework.
- Instruction is **educator-centred**, with dynamics almost always flowing from the educator to the learners. There is considerable textbook-based classroom work as well. Whole class teaching is the norm, and group work rare, but learners often do individual desk-work, solving problems set by the educator.
- At some schools, educators also undertake some team teaching in the more senior grades.
- **Drill and practice** is common, but takes place especially after the SC syllabus has been covered and material with a bearing on the final examination is revised.
- **Homework** is regularly given and marked.
- In physical science classes, individual practical work is almost unknown. At best, physical science educators give demonstrations and guide learners' observations of these by means of questions and explanations.

Learner factors

- Learners studying SC maths and physical science represent an elite learning group. Researchers found them to be intelligent, motivated, and committed. They have a strong **will to succeed,** usually related to continuing the school's good record, or starting such a record. They have **aspirations** to study at the tertiary level, and to embark on successful careers.
- The vast majority of those learners report that they support **discipline and order** in the school. They share in maintaining this through their own behaviour, by representing the school at extracurricular events, including maths and physical science competitions, by tutoring weaker learners, and by voting for and serving on students' representative councils.
- As far as the researchers could establish, these learners are committed to **hard work**, especially in the classroom. Classrooms were almost always well-disciplined.
- Maths and physical science learners at the schools under review appeared to have above-average **language skills**.

Factors outside the school

- Personnel at the schools surveyed perceived themselves as receiving little or no assistance from education departments. In fact, they felt hindered by theoretical interventions, badly managed workshops, and the like. The NdoE and provincial departments of education should be concerned about this.
- Trade unions, including SADTU, played a negligible role in the affairs of the schools under review.
- **Community and parental support** are highly correlated with the success rates of the schools under review. As previously indicated, these schools achieve a virtuous cycle in which improved results push up applications, making it possible to increase fees, invest in additional educators and facilities, thus improving results, and so on.
- **Public acknowledgement** plays a crucial role in these schools. This applies within the school, as well as outside the school, the government, parents, the community, and the private sector. Given that schools struggle continuously to perform well under difficult conditions, systems of public recognition are vital.

SUMMARY AND CONCLUSIONS

The material reflected in this chapter was gathered in the field by means of established techniques of qualitative research. While the samples were relatively small, levels of agreement were so high that CDE believes the studies provide a realistic account of the actual conditions under which maths and physical science are being taught in South African schools.

The conclusions are unequivocal. The maths and physical science education system as a whole is not performing well. The reasons cited for this are hardly surprising – indeed, they are well known to everyone associated with the system. Our quantitative research in chapter three has identified many of these factors, and in chapter four we considered factors specific to government initiatives.

Other reasons are clearly specific to maths and physical science education. This chapter has considered these aspects in some detail, focusing on the SC examination itself, the perception of individuals who are professionally involved with school-based maths and physical science learning and teaching, and finally through in-depth case studies of conditions at 13 South African schools. Though hardly perfect, the schools studied show how each of the negative factors are being overcome by applying well-known and tried and tested approaches.

There are ‘pockets of excellence’ throughout the system, and they all display the same characteristics that set them apart from parts of the system that are not working. However, none of these ‘success factors’ involves a radical new approach to maths and physical science education. Rather, they show higher levels of application of traditionally successful approaches which everyone we interviewed appears to be guided by.

These successful approaches were present at all of the well-performing schools, regardless of differences in physical setting, resources, and other apparently important factors. Those same factors were absent to varying degrees at all the improving schools; however, to state the obverse, elements of some of those success factors were present at each improving school, and the more there were, the greater the improvement.

Those factors are so well known that it would hardly have been worthwhile researching them if it were not for the fact that schools all over the country are failing hopelessly to achieve them.

The **success factors** are:

- principals with strong leadership and managerial abilities;
- educators equipped with sound content knowledge and traditional teaching skills;
- school administrations marked by good planning, strong discipline, and good order;
- starting or maintaining a tradition of success in maths and physical science;
- strong parental and community support;
- low levels of departmental intervention, unless these can be substantially improved in quality; and
- time (probably five to seven years) for changes to bed down, without the targets for success being moved yet again by outside intervention, a new curriculum introduced, new forms of assessment experimented with, or perverse incentives applied.

These success factors are present in schools operating in very poor conditions (our case study schools included eight such cases). Therefore, our research (confirmed by that of others) has made it quite clear how the principals and educators at these relatively successful schools overcome poor conditions. None of their methods seem to require major expenditure. Rather, improvements are related to school culture and management, the qualifications and professionalism of educators, and parental and community support. In fact, these qualities have been associated with good schools, good teaching and learning, and high learner motivation for many years. Our research convinces us that these capacities are latent throughout our system; the key is to bring them out.

Our research into the views of the maths and physical science education community shows that its members will support this kind of approach provided they are provided with rational explanations and leadership. They have been alienated and demotivated by a multiplicity of policy initiatives, some of them contradictory and discontinuous, which have, as a result, not been effectively implemented. They will welcome reasonable, achievable targets for quantifiable improvements in a stable system.

In general, then, our research shows that the maths and physical science education system at public schools have many virtues, some of them latent, and also many faults. But all of them are well-known to people actually working in the system. There is an indisputable will to do better. The country certainly has something to build on. But how? This question will be pursued in the chapters that follow. Meanwhile, in chapter 6, we turn to an overview of the role that private initiatives have played in improving maths and physical science education.

ENDNOTES

1 The information contained in this section has been drawn from J Smith, Interview component, CDE background research report, 2001.

2 Ibid, p 2.

3 Ibid, p 14.

4 The information in this section has been drawn from R Lee, Report on four workshops held to discuss matric examination papers in mathematics and physical science, CDE background research report, 2003.

6 Ibid, pp 6-7.

7 The information in this section has been drawn from G Onwu, Review of case study results of 13 performing maths and science secondary schools across urban and rural South Africa, CDE background research report, 2003.

8 Ibid, pp 10-14.

9 Ibid, p 36.

10 Ibid.

11 Ibid, p 37.

12 Ibid, p 33.

13 Ibid, p 34.

14 Ibid, p 43.

15 Ibid.

Chapter 6

WHO'S ALSO HELPING?: PRIVATE SECTOR INITIATIVES TO IMPROVE MATHS AND PHYSICAL SCIENCE EDUCATION, 1994–2003

INTRODUCTION

The South African business sector has mounted a number of individual and collective initiatives to change the public schooling system. It has sought and developed partnerships with government, focused on the shared needs of business and of national development. In common with government, most of the businesses supporting these initiatives have aimed at improving school-based maths and physical science education. There have been some successes, and some failures. These lessons have been learned by corporates in the 'school of hard knocks' in the course of some 30 years of investment and involvement in public education.

The activities of the Urban Foundation (UF) in education represented the first common effort by the business community to channel resources into this sector. The UF was active between 1976 and 1994, largely in opposition to the apartheid government's policies in various sectors, including education. It was closed down following the transition to democracy. New organisations emerged, funded by the private sector, which supported the education sector. Among them was the Joint Education Trust (JET), which has aligned itself with the new government's education goals.

The National Business Initiative (NBI), which also emerged after the demise of the UF, channels corporate donations directly to education initiatives. The Business Trust (BT), established in 2000 with corporate funding of R1 billion over five years, is the business sector's most recent collaborative initiative in education, and directly partners government.

As South Africa enters its second decade of democracy, the business sector needs to determine how it should structure its next collective effort in education. Whatever it decides, it is clear that this effort should be undertaken in partnership with government, focus on the needs of both the private sector and of national development, and aim at increasing the number of learners who are eligible to study maths and science at the tertiary level.

The role of the business sector in supporting independent initiatives in education has arguably become more important since foreign governments, multilateral organisations, and NGOs began making large financial contributions directly to the government from the mid-1990s onwards.

BOX 6.1: WHAT THE PRIVATE SECTOR SHOULD KNOW ABOUT EFFECTIVE INTERVENTIONS

- Understand that the private sector is a relatively small player in education when compared with the state and international agencies, and that its contributions are less sustainable.
- Spending money in the right place, and for the right reasons, are more important than how much is spent.
- Ensure that resources are going where they are really required, and where they can make a difference.
- Base interventions on research which shows where the gaps and opportunities are.
- Supporting research can also support improvements in maths and physical science learning and teaching.
- Spend money on finding out where in the system success is being achieved, and on building up a better understanding of the education field.
- Accountability is essential – without it, reform initiatives will be ad hoc, unsystematic, and will probably not succeed.
- Demand for quality education represents an opportunity for private sector involvement.
- The system cannot be changed through unrelated individual inputs such as providing a classroom in one place, educational material in another, and so on. Although these inputs may well be just what a particular school needs, unless individual initiatives take place in a common framework of priorities, they will not make the systemic difference needed.
- Interventions need to be aligned to or form part of a properly designed reform programme, based on sound research and analysis, and differentiated to the appropriate level, and should include clearly specified and measurable outputs.
- Bursaries and scholarships are an important private sector contribution. Find ways to use these inputs as effectively as possible to support more, and more talented, maths and physical science learners.

CDE 2004

THE SCOPE AND SCALE OF PRIVATE SECTOR INVOLVEMENT

As part of the research for this project, CDE compiled a database of private sector initiatives in maths and physical science education in 2001; 323 initiatives were identified, including those falling under JET, the NBI, and the BT.[1] They encompassed educator as well as learner support and development, and included so-called ‘second-chance’ opportunities for SC drop-outs or failures, and for learners preparing to write SC. They provided materials for use in classrooms, backing for resource centres, in-school ‘apprentice’ teacher training, and support for talented student programmes, programmes linking schools with the ‘world of work’, and various education media projects and programmes.

Besides these initiatives, many private companies commit funds to educational initiatives in response to personal approaches. They act on their perceptions of need as opposed to concrete knowledge of what is actually required, and do not clearly appreciate what should be done in which priority areas in order to make a systemic difference.

BOX 6.2: THE JOINT EDUCATION TRUST

JET is a partnership of 15 of South Africa's largest private sector companies and nine community-based organisations in the fields of politics, labour, education, and business development.

It was established as a partnership that would co-ordinate the efforts of different sectors of society to change the education and training system.

Its formation in 1992 was spearheaded by the Private Sector Initiative (PSI), a consortium of 20 leading corporations, which committed R500 million to the trust over five years.

It adopted a sectoral approach to grant-making, characterised by quality assurance mechanisms for grantees within each sector, and periodic sector-wide evaluations. Its chosen sectors are teacher development, early childhood development, adult basic education, and youth development. Since 1992 it has managed the disbursement of R400 million to 400 NGOS and CBOs active in these sectors.

Since the transition to democracy of 1994, JET also offers project management services to large donors, generally in partnership with the national and provincial departments of education.

Funds under management on behalf of overseas donors currently total R650 million.

JET has developed a model for success which is based on five elements:

1. Interventions will not have the required impact unless they help the government to implement its own agenda – projects should be owned and driven by government officials.
2. Both supply ('push') and demand ('pull') factors are important.
3. Learning is improved in schools and classrooms, and these should be the targets of support.
4. School management capacity is crucial to making reforms 'stick'.
5. Sustainable reforms are only possible if management capacity is created at all levels of the public schooling system.

CDE 2004

These private sector initiatives are generally aimed at rectifying perceived shortages, or a lack of resources or services. Since the late 1990s, systemic reform programmes have become increasingly important, and constitute a third phase of intervention. These initiatives typically combine supply-side elements ('whole school' support) with demand-side ones: better outputs, improved standards, and greater accountability to donors, learners, and parents (these aspects are examined later in this chapter).

How much is the private sector spending on maths and physical science education? CDE was unable to determine this figure; however, according to the most recent *Corporate Social investment handbook* (2002), the top 100 corporates spent R1 842 million on CSI in 2001. Of this, R865 740 million (47 per cent) was spent on education and training, which made this by far the most strongly supported sector.[2] According to research commissioned by CDE, the private sector was spending about R100–R200 million a year at that time directly on maths and physical science programmes. However, the bulk of the expenditure was in the form of contributions to large-scale school reform programmes, such as the BT's Quality Learning Programme (QLP), the NBI's CCF initiative, and READ's 1 000 Schools programme, that include maths and physical science as elements of larger school improvement programmes. (Our research did not consider contributions made to HE, such as bridging and foundation programmes.)

Therefore, while the corporate sector does prioritise education, it is not prioritising maths and science. Also, while total CSI expenditure on education is considerable, it is still far less than that of the government, and the private sector should therefore ensure that these funds are applied as strategically as possible.

As regards the spread of expenditure, CDE's research showed that only 62 South African corporations supported a maths and physical science initiative in 2001. It was not possible to obtain credible aggregate data on these interventions. Annual spending by individual companies also probably varied widely; indeed, the *CSI handbook* reported that less than a third of the top 100 companies contributed more than 80 per cent of total private sector funds for education and training.[3] Corporate spending ranged from R100 000 to individual amounts of more than R20 million a year (the average contribution is R3,2 million).[4] Therefore, in contrast to the majority, a few major companies are clearly committed to significant expenditure on education.

Another interesting finding is that, prior to 1994, most private sector programmes were undertaken in isolation from, and in opposition to, the apartheid government's education policy. Since that time, the objectives of business and the government have converged. The CDE database shows that many initiatives now involve some kind of partnership among business, the NGO sector, and national and/or provincial governments.

Market forces have also driven the government and the private sector towards joint ventures in this field. Individual companies now offer resources directly to the government, initiate their own projects, or outsource programme management to an NGO or commercially inclined service provider in joint ventures with government.

Companies now seem to be considering that there are other gains to be made from entering into partnerships with government:

- they may gain political endorsement from being seen to back the government's social development policies, and following its 'footprint';
- project resources can be substantially augmented when government comes in as a 'partner', while the company's own contributions remain relatively modest;
- partnership in projects can improve co-operation with the government in other areas, including better personal and professional networking with influential government contacts, and much goodwill; and
- private sector initiatives can empower government officials to run the projects concerned in the long term, thus providing the company with an exit strategy after laying the appropriate foundation in the early years.

But there are also some downsides to partnering. Private sector partners – which generally provide funding, as well as managerial support – are often restricted by the complexity of partnering with government, which has numerous and other conflicting constituencies to consider. Government officials sometimes lack appropriate experience and project management and financial skills, and take time to learn these. Being in partnership with government also means that technological and administrative skills are often outdated, and project implementation and administration may be hampered by complex bureaucratic demands.

On the other hand, partnering holds many advantages for government that are often appreciated and acknowledged: apart from funding and management and financial resources, companies also have experience in translating pilot projects into models that are workable at scale. Because business often has greater freedom to experiment, with the capacity to draw on different expertise and widely divergent skills sets, partnering with the private sector enhances the efficiency of joint projects, and helps government managers to move beyond outmoded conventions and paradigms.

While corporations say they are serious about partnering government, our research shows that they have a lot of room for expanding their involvement with the public sector. Over 50 per cent of the top 100 companies involve government in less than 25 per cent of their CSI programmes; 13 per cent (largely parastatals and the very large corporates) engage with government in the course of more than 75 per cent of their CSI efforts.[5]

Each corporation partners with the government in its own unique way, which is to be expected: the consequence is that it is difficult to describe an 'ideal' partnership, given the many different ways of partnering that have emerged, depending on the type of project, the area of focus, and the CSI objective.

Partnerships with government are therefore complex; there is no definite formula for success, and each partnership will have its own unique 'mix'. As a result, there are many partnerships models in South African education, ranging from the passive (providing funding and EQUIPment) to the active and engaged. Examples include:

- providing computer EQUIPment to a provincial department for distribution to schools;
- initiating programmes that seek to comply with the government's education policies;
- playing an initiating role in flagship projects, in partnership with government; or
- leveraging a project idea by supporting a pilot initiative with the aim of persuading a government department to roll it out in the medium term (known as 'exemplar' projects).[6] Many see this role as the most promising form of public–private partnerships.

It is obvious that not all private sector companies have the resources to enter into a partnership with a government department: managing such partnerships is a time-consuming and resource-intensive affair, which can be very frustrating, and demand great patience and perseverance. ONGOing challenges abound; they include building and maintaining trust between the partners, establishing and maintaining a mutual commitment, addressing technical administration and funding issues, identifying and working with key role players, clarifying decision-making processes and powers, resolving conflicting responsibilities, and so on.

Partnerships thus 'mask a complex interaction between a range of role players'.[7] Nevertheless, 'the partnership imperative is compelling', concludes the most comprehensive current analysis of public–private partnerships, 'for by engaging government strategically, corporates can make project plans a reality and can develop exemplar models for widespread adoption by other corporates and state administrations'.[8]

However, many companies are not clear on 'how to get involved, how to open doors, how best to structure partnering arrangements'.[9] As a result, when contemplating engaging with government, 'many corporates simply don't know and see only bureaucracy and obstruction. So they're often guilty of taking the easy route by offering only CSI cheque hand-outs.'

Nevertheless, there is little doubt that much is being achieved in terms of supporting individual learners from mainly poorer schools, and providing them with resources. Indeed, many programmes are specifically directed at the poorest, most disadvantaged learners, which is often a condition for partnering with government. Our research in 2001 showed that private sector initiatives listed in our directory were directly reaching some 15 000 learners every year.[10] Many more benefited indirectly. However, this seems relatively insignificant when we recall that there were 263 945 mathematics and 153 847 physical science SC candidates in 2001. It may be significant when related to the 19 504 HG mathematics passes in 2001, but it is not known how many of these passes resulted from these interventions.

BOX 6.3: A SUMMARY OF PROJECTS AND SPECIALIST ORGANISATIONS MENTIONED IN THIS CHAPTER

Business Trust (BT). The Business Trust is an initiative of 145 companies in South Africa working in partnership with government. It undertakes targeted job creation and capacity building programmes. The Trust's strategy to achieve this includes job creation via a focus on tourism and to concentrate on schooling as a means of national capacity building. Programmes supported by the Trust within the above categories are many, in the field of education they include the Quality Learning Project (see below) at the secondary school level, a R153 million collaborative venture with read at primary school level, and the Colleges Collaborative Fund at tertiary education level.

The Centre for the Advancement of Science and Mathematics Education (CASME). Located at the University of Natal, Durban, and established in 1985, it concentrates on educator professional development, as well as running winter schools and Saturday classes for grade 10, 11 and 12 learners. It also provides teaching aids, resource centres for educators in remote communities, and science kits.

The District Development and Support Project (DDSP) is a school development programme of the Joint Education Trust (see below). It works in 469 primary schools in four of our poorest provinces: EC, KZN, NC and LP. It approximates Imbewu in its model of school development, although it does not work at the provincial head office level – a major focus for Imbewu – and its modus operandi is very different.

Education Development Trusts are typically partnerships between large corporate donors. Their objective is generally to tackle government priorities, with a particular focus on skills enhancement and building projects. They also provides a vehicle through which contributions towards education can be channelled and expedited, and funds can be generated.

EQUIP is an programme of the National Business Initiative. It is a large project in multiple provinces aimed at systemic change, concentrating on the school level. It has since 2001 included a concentration on maths and science specifically.

Imbewu aims at improving the quality of primary education in the EC Province. It aims to do this through 5 outputs: transforming the capacity of the provincial DoE through improved planning, budgeting and financial management, human resource management, and monitoring and evaluation.; improved management capacity and performance of 500 primary school principals; quality of teaching and learning improved in 500 primary schools; quality and availability of appropriate teaching and learning materials in schools; enhanced community involvement in primary education.

The Institute for Mathematics and Science Teaching (IMSTUS) at the University of Stellenbosch offers professional development opportunities for educators in the former of the Advanced Certificate in Education (ace). The Physical Science, Biology and Computer Studies programmes are taught on campus, while the maths specialisation is a distance learning programme, with an enrolment of around 400 educators.

The Independent Schools Association of South Africa (ISASA) provides a maths and science programme with three components: 1) a short term learner strategy to increase the very small pool of African matriculants with hg passes in maths and science; 2) a medium term teacher strategy focusing on training/retraining of African teachers in maths and science through school-based teacher internships; and 3) a long term-school strategy using outreach programmes and partnerships to improve the maths and science capacity of clusters of disadvantaged schools.

The Joint Education Trust (JET) is a partnership between 15 of South Africa's largest private sector companies and nine community-based organisations. Established in 1992 to administer a R500-million contribution to education development by the corporate partners, is today a development and project management agency, managing funds from a variety of local and offshore, and projects in the fields of school development, further education, adult education and workforce development, higher education, and youth development. The Quality Learning Project (see below) is the largest JET project. Others include in the area of schools development Mahlahle (see below), Imbewu, DDSP, and Siyathuthuka (see below).

The Kgatelopele Initiative is an educator support and development strategy (funded by the Royal Netherlands Embassy) that was introduced in the North West Department of Education (nwed) with the aim of enhancing professional and quality teaching and learning guidance in the foundation and intermediate phases. Five education centres known as Education Development Support Centres (edsc's) have been identified in five regions wherein subject advisors, college lecturers and field consultants would work jointly to fulfil the aims of the strategy.

The Khanya Project. The main purpose of the Khanya technology in education project is to deliver and support the curriculum, and to assist in improving the quality of teaching and learning in all schools of the Western Cape using information, communication, and audio-visual technologies.

The Mahlahle Project is a four-year district development partnership project between JET and the Limpopo DoE. The purpose of the project is to improve the quality of learning and teaching in the get phase by developing capacity and systems at several levels. Activities include the development and implementation of management, administration and governance systems at Regional, District and school levels; provision of curriculum support to educators between grades 4 and 9, in the areas of Maths, Science and Language (English); review of service provider contracts; and the conducting of baseline studies and follow up reviews.

The Mathematics Centre (formerly MCPT, The Mathematics Centre for Professional Teachers) is an educator training programme operating in seven provinces. The aim of the Key Teacher Development Programme is to enhance the knowledge and skills base of the targeted educators.

The National Business Initiative (NBI), a consortium of South African businesses. Together with the Black Business Council, the NBI facilitated the establishment of the Business Trust. While they have no access to Trust funds, they do manage the implementation of Business Trust Projects. Equip is the NBI's most high profile education project.

The Programme for Leader Educators Senior phase Mathematics Education (PLESME) was a two-year programme managed by RADMASTE (see below).

The Project for Technology Education (PROTEC) is a national non-profit educational service provider. It provides training and support for educators (concentrating on OBE teaching methods, curriculum management, and school-based educator mentorship). It also provides curriculum materials, including textbooks, science kits, and other materials (concentrating on English, mathematics and science).[11]

The Quality Learning Project (QLP) is a five-year school improvement project that commenced in 2000. Funded by the Business Trust, the project is being implemented by a consortium led by JET and the NBI under the guidance of the NDoE. It is intended to facilitate educational change in South Africa by working with district officials, school management teams and educators. The specific project aim is to improve learner performance in mathematics and the language of instruction in grades 8 to 12 in some 523 schools across 17 districts in all nine provinces.

The Centre for Research and Development in Mathematics, Science and Technology Education (RADMASTE) at the University of the Witwatersrand targets educator development from grades 1 to 12 as well as those at Colleges of Education through an annual operating budget of some R10 million.[12] It also provides educator aids (such as worksheets and EQUIPment and kits).

READ operates countrywide. It is a non-profit donor-funded professional organisation that aims to improve educational attainments of African pupils by assisting under-performing schools transform themselves into centres of successful learning through community-based educational interventions with sustainable long-term effects.

The Rhodes University Mathematics Education Project (RUMEP) is an NGO-linked to the University which aims at assisting educators in disadvantaged schools. Is does so through the provision of workshops for educators; programmes of in-class support; materials research & development; and formal diploma courses for educators wishing to develop their teaching skills.

The Science Education Project is an NGO linked to the University of Pretoria's Centre for Science Education. It develops science education materials and provides educator support through teacher in-service training (inset) programmes. It also provides science kits, educator handbooks, and learner workbooks for schools in the region.

CDE 2004

CATEGORIES OF PRIVATE SECTOR INITIATIVES

Private sector interventions in SC maths and physical science can typically be divided into four primary categories, each with a subset of associated activities, as outlined below:[13]

1. Educator support and development

a. Formal programmes (ie, programmes that lead to a formal qualification, attached to a HE institution, usually a university)

b. Informal educator programmes, usually leading to the award of a certificate of attendance

2. Learner support and development

a. Second-chance opportunities

b. Support for learners preparing to write SC

3. Materials support and development

4. Other initiatives

a. Resource centres

b. In-school teacher training

c. Talented student programmes

d. Media projects and programmes

For the sake of brevity, this section will only describe a few examples from each category.

1. Educator support and development

Educator support and development can be divided into formal programmes (ie, those programmes which lead to a formal qualification), and informal programmes, which lead to a certificate of attendance.

Before the Further Diploma in Education (FDE) and similar courses were introduced in 1996, almost all educator support and development took place via informal programmes, and most educator intervention is still informal. An important development is that, before 1996, informal programmes were typically once-off in-service afternoon workshops, often presented in an ad hoc manner. Today, most stakeholders have realised that there are few benefits to be gained from this type of intervention.

CDE's research identified a lack of contract between facilitator and participant as an important reason for the failure of these programmes. The facilitator or provider has no guarantee that the targeted participant will attend, or that he or she will apply the knowledge or skills gained. This, combined with the inherent inefficiency of once-off programmes, has resulted in longer programmes of two or three years in duration, with participating educators and their schools committing themselves to attending training sessions for several hours a week, and also attend weekend and holiday courses. Many of these require the commitment of all the mathematics or physical science educators at a given school.

Providers, usually NGOs, typically offer a pedagogic framework for the course, in-service training, study materials and other resources, and, sometimes, complementary support in the form of extra lessons.

After 1994, informal educator programmes mainly took the form of in-service training (INSET). Some still survive, while others have evolved into FDEs. However, most are now conducted in the context of whole school reform, as planners began to realise that, while this was a prerequisite for improving the quality of schooling, working with individual teachers could not in itself change the way in which educational institutions function. Principals, school management teams, school governing bodies, representative councils of learners, and the district officials are often also involved.

Since the late 1990s educator programmes have been taken up into systemic school reform projects such as the QLP, Imbewu, DDSP, and Mahlalahle, all of which have large school and even district development components.

CDE examined PLESME, the PROTEC model, the SAILI model, the EQUIP proposal, and the MCPT Key Teacher Development Programme. It appears that success varies tremendously, and it is difficult to pinpoint the reasons why. In some cases – among them PLESME – the personality of the person driving the project plays a key role. In others, the location of the project within a whole school development or systemic reform programme appears to be crucial.

PLESME

Sixteen maths teachers from nine secondary schools in Soweto and Eldorado Park (Gauteng) participated in the Programme for Leader Educators in the Senior Phase Education Programme (PLESME) managed by the University of the Witwatersrand's Centre for Research and Development in Mathematics, Science and Technology Education (RADMASTE), and run over two years, namely 1999-2000. Participating teachers engaged in a range of activities that included (total time per teacher in brackets):

- weekly workshops (180 hours);
- structured reflection (20 hours);
- classroom-based assignments, video reflection, discussion, and write-up (45 hours);
- additional practical assignments (80 hours);
- written assignments (25 hours);
- Conference and field trips (8 days—60 hours);
- preparation for conference presentation (20 hours);
- networking and organisation (leader teacher roles; 90 hours); and
- reading relevant mathematics education documents and literature (80 hours)[14]

Very high demands were placed on participants in a non-accreditation environment – ie, one in which participation would not lead to the award of an accredited qualification.

Evaluators regarded PLESME as a major success, crucial to which was the facilitator and the role she played in managing the project — one facilitator for 16 teachers. It was her passion and drive more than any other factor that kept the programme going. The costs involved (thought to be in excess of R500 000) and the reliance on this highly motivated facilitator may prohibit reproduction on a large scale. Also, while PLESME was an important intervention in the lives of the 16 teachers involved, it was also a research programme of RADMASTE and the facilitator, which makes repetition of the conditions for success unlikely.

PROTEC

One of the programmes offered by PROTEC (the Project for Technology Education) is intended to improve the quality of teaching and learning in maths and physical science, the capacity of schools to deliver quality maths and physical science education, and, ultimately, improve maths and physical science SC results. Micro science kits, teachers' handbooks, and students' notes are provided, and after-school support is also given. Recognising that an intervention is unlikely to make a significant impact on a grade 12 cohort in only one year, the PROTEC intervention typically focuses on grades 10 and 11 in year one, expanding to grade 12 in year two.

SAILI

SAILI (the Scientific and Industrial Leadership Initiative) works at various levels, from whole school development in primary schools to providing support for engineering students at the tertiary level. The stated aim of the project is to 'increase the numbers of previously disadvantaged people in leadership positions in science and industry in such a way as to benefit the economy and thereby the well-being of South Africa'.[15] The major maths and physical science initiative of the project is at high school level, and is described here. SAILI's initial work at this level was a direct classroom intervention involving daily classroom visits to teachers by project workers to improve teaching itself. However, this initial intervention failed to halt continued declines in HG maths and physical science participation at those schools. SAILI began working directly with students, and also supporting teachers. Students, not teachers, are now the locus of the intervention. Support to teachers (of schools whose students are involved in the SAILI student programme) is now provided through quarterly workshops.

The SAILI experience is an example of visible results governing the nature of the programme. Wanting to see improved matriculation results by students in a short period of time, the organisation changed its focus from teachers to students in the secondary school. While continuing to offer quarterly meetings for teachers (and certificates to those who attended 100 per cent of these), the organisation shifted its attention to the students.

EQUIP

This NBI programme focuses on developing the capacity of districts and schools to implement the government education reform initiatives, but also seeks to ensure that these initiatives result in quality educational experiences for the individual learner. It is a three-year programme implemented in 100 high schools in three provinces from 2001.

The mathematics and science component is targeted at district officials (subject advisers for mathematics and science), and two teachers per school.

Teachers attend workshops, and receive follow-up support in the form of school visits and school-based seminars. Teachers choose modules based on their identified strengths and weaknesses. Each participating school will qualify for a number of modules that are equivalent to two teachers attending for the full year. Teachers completing the full programme qualify for a Further Diploma in Mathematics or Science Education. 'For teachers that already have these diplomas ... a Master Teachers Training programme will be available.'[16]

The Maths Centre (formerly MCPT)

The Maths Centre (formerly known as the Maths Centre for Professional Teachers) runs an educator training programme in primary schools in seven provinces. The aim of this Key Teacher Development Programme is to 'speedily enhance the knowledge and skills base of the teacher'.[17] Teachers receive intensive training (in a co-operative environment) for about two days a week for one term, after which contact is maintained through workshops and classroom visits. Work with schools and teachers in the MCPT programmes is complemented by a very wide range of materials that have been developed by the centre expressly for South African teachers and their classroom context. These materials range from manipulatives in the form of 'maths kits' to resource books for teachers, and a textbook series. The Maths Centre is also involved in the QLP, which is analysed later.

2. Learner support and development

Private sector support for learners is typically supplied in two main forms: second-chance opportunities (for those why have already written the SC examinations but failed, or achieved results which are too poor to give them access to their desired tertiary education programme); and secondly, support for learners preparing to write matric (generally concentrating on grades 10 to 12).

Support for learners in grade 12 typically comes in the form of Saturday classes and winter, or holiday, schools. Some programmes are extensive, and are in contact with learners for more than 150 hours a year. This is impressive, when one considers that the most contact hours a well-functioning high school can hope for are 140 contact hours a year in grades eight to 11, and 100 hours in grade 12.

Most, if not all, universities and technikons in South Africa now offer bridging or foundation courses for disadvantaged (and often underprepared) students beginning a degree in the sciences.

CDE identified some 19 universities and 12 technikons across the country that offer a course of this kind.

An interesting private sector programme has been the development of science and technology centres. These offer an interactive environment where learners from disadvantaged schools, schools that are often without electricity and running water, are able to see at first hand how scientific experiments work. They are generally staffed by well-trained facilitators who run interactive programmes, help learners with career guidance, and train educators.

There are 34 such centres, which are affiliated to the Southern African Association of Science and Technology Centres (SAASTEC). Thirty-three are located in South Africa, and one in Botswana. Eighteen of these are in Gauteng, five in the Western Cape, three in Limpopo, two in KwaZulu-Natal, two in the Free State and one each in the Eastern Cape, Mpumalanga, and Northern Cape.[18]

All centres emphasise interactive learning. They are typically started by people who are passionate about science and who have seen that the model works, either overseas (there are 1 185 centres worldwide) or locally. The first two centres (at the University of Zululand and the University of Pretoria) were both established by physics professors at those institutions. Each centre caters for the needs of its immediate community, and centres can differ quite markedly in terms of the standard of facilities and programmes on offer. Centres are usually responsible for organising their own funding.[19]

At the Giyani Centre in Limpopo, learners are able to observe experiments, and receive enrichment lessons in physical science and maths. Facilities at Giyani include a 300-seater lecture theatre, computer rooms, physical science laboratory, electronics laboratory, and a library.[20] The Giyani Centre is primarily aimed at disadvantaged children, and entrance is free, thanks largely to funding from the Limpopo department of education, which provides the centre with 80 per cent of its funds.[21] An estimated 20 000 learners visit the centre each year, usually more than once, and its mobile laboratory visits about 50 learners each week.[22]

The MTN Science Centre at Century City in Cape Town has advanced facilities, and offers a multitude of programmes designed to complement the school curriculum. It receives 120 000 visitors a year, and generates about R1,5 million in revenue. This is supplemented by core funding from MTN as well as ad hoc grants from other corporate sponsors. About 72 000 of the visitors to the centre are learners, with about 40 per cent (28 800) of those from disadvantaged communities. Disadvantaged schools usually obtain corporate sponsorship to cover the R15 per learner entrance fee.[23]

Most science centres operate without constant state funding, and rely on ad hoc grants as well as donations from sponsors. According to Derek Fish, a member of the SAASTEC Council and head of the Unizul (University of Zululand) Centre in KwaZulu-Natal, a proposal has been put forward for a more formalised funding structure. It is envisaged that monies will flow from the Department of Science and Technology to a flagship science centre in each province that will be responsible for other satellite centres in the province.[24]

Derek Fish points to anecdotal evidence that highlights the success of the Unizul Centre, such as the number of schools that support the centre, support from industry (six nearby industries contribute funding to the Unizul Centre) and the winning of National Science and Technology Foundation (NSTF) awards. Some 25 000 learners are expected to visit the Unizul centre in 2003; besides this, staff members of the centre will visit some 20 000 learners and an additional 10 000 matrics in their schools, and train 400 educators. Some 95 per cent of these learners are from disadvantaged backgrounds.[25]

It is difficult to assess the tangible benefits of science centres, as the overall performance of maths and physical science candidates remains unsatisfactory. However, as Fish points out, the situation would undoubtedly be worse without science centres.[26] Perhaps the benefits of the centres will be felt more widely and deeply when each centre is able to count on a steady stream of state funding.

3. Materials support and development

A large number of organisations surveyed provide (and in many cases even develop) materials to support their work in educator and learner development. These materials typically come in four varieties (included in parentheses are a selection of organisations identified by CDE that provide the particular variety of materials; there may be others):

- Resource books and materials for teachers (CASME, IMSTUS, SMATE, RADMASTE, RUMEP, SDU, MCPT, PROTEC, SAILI);
- Resource kits for use by students in the classroom (SMATE, MCPT);
- Support materials for students (IMSTUS, RADMASTE, PROTEC, SAILI); and
- Textbook series (SDU, RADMASTE, MCPT)

In the case of physical science, there is a need for laboratory EQUIPment. While this is not a pre-requisite or even a precondition for success, there can be no doubt that appropriate EQUIPment facilitates learner understanding and is an aid to effective teaching. At least four major providers – RADMASTE, PROTEC, SMATE, and SEDIBA – produce and distribute science kits. Science kits are an important development; they enable learners to gain the benefits of practical observation and experience without a laboratory having to be built. Building a lab may be far beyond the means of many schools, but with practical micro science kits many of the benefits of a lab can be accrued.

Materials support also occasionally links with media interventions in that print media are sometimes used to distribute basic exercises and exam preparation information.

It is at this point that our descriptive categories for maths and physical science initiatives begin to merge with a range of interventions that can only be described as ‘other’. At the risk of passing over many fine programmes we have elected to highlight only example which falls into this ‘other’ category since it includes elements from each of the above categories, as well as having original dimensions of its own. This is the Liberty Foundation's media intervention, Mindset Network, which is a multimedia satellite television network launched in July 2003. Its aim is to provide easily accessible education resources for learners in all grades. It is a large project of approximately R225 million, with a number of corporate backers.

Hosted on the satellite TV channel, DSTV, it broadcasts across Southern Africa daily programmes on maths, science and English. The channel's programmes are also televised to at least 100 million learners in 17 other African countries, including neighbouring states, as well as more distant countries such as Ethiopia, Ghana and Nigeria.

Supporting published material is made available via the internet and in the print media. Complementing such initiatives is The Liberty Learning Channel, televised for 700 hours a year by the SABC. The channel delivers core curriculum material for grade 11 and 12 learners in biology, chemistry, mathematics, physics, and English. A number of schools countrywide have integrated the Liberty Learning Channel's two hours a day into their routine teaching environment, encouraging the development of Mindset Network.

Also sponsored by the Liberty Foundation is one of the Internet's most well-supported educational websites, www.learn.co.za. The site covers the curriculum for grades 8 to 12. The website not only allows learners to use interactive teaching and learning facilities, but also to receive free, downloadable textbooks. In addition www.teach.co.za will provide support for teachers in the form of lesson plans, OBE guidelines, marking memoranda, and more. It is reported that participating schools are provided with service and education support.

EVALUATING PRIVATE SECTOR INITIATIVES

In the previous section we described various private sector-funded maths and physical science education initiatives. The data was requested from the organisations by our researchers. In this section we turn to the difficult issue of assessing their impact. The difficulties associated with such a task are immense, and well-documented. They include the following factors:

1. Each programme is structured uniquely.
2. Project design and programme elements differ, and can't be directly compared with others.
3. Programmes operate in different parts of the country, and at different levels of the public school system.
4. The schools involved within programmes vary considerably according to resources, district-level support, locality, and the socio-economic composition of staff, learners, and parents.

Almost without exception, all programmes claim to have effected positive change in the education system. CDE's research, however, indicated that monitoring and evaluation was a general weakness. Naturally there are a number of highly significant exceptions, many of which are referred to in this chapter. However, considering that, according to one source. 'It has been estimated that there are funded interventions in about 10 per cent of all schools in the country', the data is fairly thin on the ground.[27]

Experts in the field have also commented on how, even when properly evaluated, private initiatives fail to circulate such evaluations publicly:

> Donor-driven research and evaluation reports have almost without exception remained in the private domain, and of restricted circulation. The majority of these studies are mimeos and some are quoted verbally so often that they have attained a quasi-mythical status. Names like Imbewu, DDSP, Mahlahle, GTZ, and so on are now practically speaking part of public educational discourse, but the reports themselves are rarely seen, and the writers usually too busy to write them up for peer review and publication in respected public journals, with some important exceptions.... The result is that the developing pool of researchers and evaluators rarely refer to one another and the educational knowledge base in the country proliferates but hardly accumulates or grows.[28]

Given CDE's limited resources and the poor response rate, it was therefore not possible to evaluate the success of each and every programme in all the aspects which matter, let alone to compare programmes on a case-by-case basis in terms of key inputs and, more importantly for our project, outputs.

More importantly, many of the private sector initiatives in our inventory on examination turned out to be highly localised, once-off interventions, with little interest paid to achieving systematic effects. However it is these systemic impacts which are of interest in this project. We therefore adopted a different approach, which is to proceed on the basis of a general description of a few singular interventions aimed at achieving large scale systemic changes in the schooling system. In this way we could build a profile of the general principles and impacts of intervention sponsored by such activity.

CDE's analysis concurred with the most comprehensive and up-to-date review of school development programmes in South Africa, undertaken by JET, and published in 2003.

The JET study points out that that the best of South Africa's current school development programmes parallel 'best practice' internationally, which is 'convergence around the importance of linking classroom instruction to an external accountability system':

> There is a general understanding that, without an explicit focus on schools and classrooms, improved learning is very difficult if not impossible to achieve. And without attention to capacity building in higher levels of the system, change cannot be directed and monitored effectively, nor is it likely to be sustained beyond the life of the project, or to be replicated in non-project schools.[29]

This finding thus represents the understanding that there are two key elements common to successful systemic reform. The first is a focus on schools, including initiatives to improve the organisational culture of schools (shared values, vision, and teamwork), classroom instruction, and other competence-based activities. The second is accountability, linked to a performance-based pedagogy.

BOX 6.5: ST MARY'S OUTREACH PROJECT

In terms of this project, extramural classes are offered to learners from schools in Alexandra, north of Johannesburg, at St Mary's School for Girls in Waverley, Johannesburg. The project has been operating since 1990. When the project started, 75 learners in grades 5 and 6 attended classes for four and a half hours a week. Today, nearly 150 learners in grades 9 to 12 from five Alexandra schools, attend classes for a minimum of eight and a half hours a week. They receive tuition in mathematics, science, accounting, English, and computer literacy. They also receive career guidance and hiv and aids awareness education, and attend life skills camps.[30] The project is currently being funded by Fasset and Nedcor.[31]

Learners are selected on the basis of an assessment and an interview. Age, academic performance, commitment, school attendance, and family support are all considered when selecting a candidate.[32] While most students are selected on merit and their likelihood of succeeding, learners who appear particularly committed may also be chosen.[33]

Success rates vary from year to year, but somewhere between 85 and 96 per cent of St Mary's outreach students pass matric maths each year.[34] In 2002, Outreach learners achieved an average of 54 per cent in sg sc maths. The two top sg maths students at Alexandra High School were Outreach students, and both achieved a 'B' for mathematics. Outreach students achieved all five distinctions for maths at East Bank High School; both distinctions for sg maths at Minerva High School; and the top four marks for sg maths at Realogile High School.[35] At KwaBhekilanga High School, an Outreach learner achieved the only hg pass.[36]

According to Marion Joseph, the programme's academic planner, Outreach learners are encouraged to write the hg exam if they feel they can cope, but few feel confident enough to do so. Some of the schools do not allow learners to write the hg exam, as they are afraid that their possible failure will affect the overall pass rate. Another problem is that most of the teachers in Alexandra are not EQUIPped to teach hg maths.[37]

Outreach learners achieved a similar success rate in physical science. Out of the five schools, 160 learners wrote sg science, and 18 of the 54 passes were achieved by Outreach learners. Eighteen learners in total wrote hg science. Only six passed, all of whom were Outreach learners.[38]

These statistics show that the top learners at Alexandra schools are those enrolled for the St Mary's Outreach project. However, they do not adequately demonstrate the benefits of the programme, since these students were likely to achieve the best results in any case, given that they are selected for their potential to succeed. Individual improvement is a good indicator of the benefits of the programme. One student was failing sg maths, but managed to achieve a pass mark of 92 per cent after attending the project.[39]

Marion Joseph says the programme's success can be put down to a number of factors:

- The amount of time students spend on their work. Students work four afternoons a week and sometimes work on Saturdays and through the holidays.
- The commitment and co-operation of learners' parents.
- A small educator-to-learner ratio.
- Matric classes receive an additional four hours a week over and above the usual St Mary's tutoring.
- Learners are treated as 'whole beings', ie, educators work through the students' problems outside the classroom and ensure that each student is getting enough food.[40]

> Learners in disadvantaged communities do not have to be seen as a 'lost cause'. The success of the St Mary's Outreach Project is very encouraging, and offers a model of supplementary teaching that can, and should, be emulated. There is no reason why similar initiatives set up with the aid of the private sector should not achieve the same level of success elsewhere.
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> **CDE 2004**

The lesson from successful large-scale systemic reform internationally is that any support must be aligned with acountability measures.

According to JET, the vast majority of school development programmes in South Africa initiated by the private sector 'lean towards the inside-out approach', with one or two important (best practice) exceptions which we shall deal with later.[41] The tendency is *more towards support than towards accountability.*

For these and other reasons, the private sector's continuing support for school-based learning and teaching initiatives in maths and physical science has not had the systemic impact that was initially hoped for. However, the analysis that follows of South Africa's largest and most systemic school improvement programme shows just how difficult it is, even given willing partners, and even when accountability measures are built into the project from its conception, to manage such an initiative.

THE QUALITY LEARNING PROJECT

The QLP is a five-year school improvement project started in 2000. Funded by the BT, the project is being implemented by a consortium led by JET under the guidance of the NDoE. It is intended to facilitate educational change by working with district officials, school management teams, and educators. The specific objective of the project is to improve the performace of learners in mathematics and the language of instruction in grades 8 to 12 in 523 schools, across 17 districts, in all nine provinces.

The QLP has five main programmes:

Programme 1 is focused on district development, and concentrates on human resource and financial management as well as school monitoring and support.

Programme 2 concentrates on school management issues, including instructional leadership, curriculum management, school governance, and financial management.

Programme 3 concentrates on learning outcomes and assessment practices.

Programme 4 involves educator development, aimed at enhancing teachers' content knowledge and improving classroom management.

Programme 5 relates to the monitoring and evaluation of the QLP conducted by the HSRC.

QLP's baseline study found that many of the issues that have derailed whole-school 'inside out' programmes in the past are evident in the 525 sample schools. These include:

- Poor reading and mathematics skills.

- Low levels of teaching days –all the schools surveyed lost about 40 teaching days a year.[42]
- Poor time management by educators, and teacher and learner absenteeism.
- Low levels of curriculum planning are endemic in both primary and secondary schools.[43]
- Poor support by school districts: only seven out of 17 (41 per cent) of districts had staff organograms;[44] only two (12 per cent) had staff job descriptions;[45] only one of 17 district managers had drafted a three-year strategic plan; only one of 17 district manager has plans for improving mathematics. No district was able to provide a financial year plan.[46]
- 39 per cent of the teachers surveyed reported that they had not attended any district-run workshops in the past year.
- Teachers stated that principals were unable to monitor and assess their curriculum planning or classroom practices, as they were unfamiliar with new curricula.[47]
- Only one district had an improvement plan for mathematics, while seven had improvement plans for English.[48]

Progress made by the QLP

The QLP's annual report for 2002 (that is, for year two of the five-year programme) details progress made in the following areas:[49]

District development

The project implementation teams succeeded in setting up organograms, job descriptions, education management information systems, and financial management systems in all districts (a;though further assistance would be needed in 2003 and 2004).

School development

The project implementation teams had conducted various training programmes at all 524 project schools. Some 1 500 members of schools management teams had been trained in curriculum leadership, school administration, and financial management.

Teacher development and assessment

The project team had given content training to all available maths teachers at the project schools. These project teams had also helped districts to organise additional spring and winter classes for matric learners.

Outcomes[50]

The most important measure of the project's success (or lack thereof) is the matric examination. An analysis conducted by the QLP of the 2002 matric exam revealed that the project had begun to deliver measurable improvement; project schools performed better on average than the national average. Specifically, the QLP schools exceeded the national increase in:

- the number of matric passes by 3,3 percentage points;
- the number of exemptions by 8,8 percentage points
- the number of HG maths passes by 20,8 percentage points;
- the number of SG maths passes by 19,4 percentage points; and
- the pass rate by 3,9 percentage points.

The project has increased the number of learners at project schools obtaining matric exemptions from 7,7 per cent in 2001 to 9,8 per cent in 2002. Maths SG pass rates improved from 26 per cent in 2001 to 48,5 per cent in 2002, and HG pass rates from 42,5 per cent in 2001 to 47,1 per cent in 2002. The number of schools recording a pass rate lower than 40 per cent were reduced from 172 in 2001 to 120 in 2002.

Observations on the QLP to date

According to an unpublished internal review on 'The sustainability of the QLP', there are three major threats to the QLP 'model': monitoring practices, restructuring, and an absence of basic teaching materials.

Monitoring practices in public schooling in South Africa are fixed in a supply-side mode. Demand drivers, in the form of outcome targets, monitoring systems, and management practices are in short supply, and emerging very sluggishly. The slow development of demand-side policies and systems in the public sector is one of the biggest threats to the full implementation of the QLP model, and hence its sustainability. QLP can do little on its own to improve productivity, apart from exerting pressure via the public debate. The problem is not a lack of policy, but poor implementation. There has been agreement on a school monitoring system – Whole School Evaluation – for some three years but it has still not been implemented. Similarly, a policy on Systemic Evaluation – ie, testing samples of learners across the country in key grades – was adopted in 1998, but the grade 3 test was only piloted in grade 3 in 2001, and the report, which was only released 18 months later, raised a number of fundamental questions about the programme's design.

The restructuring of the official school district system is the second great threat to the QLP model. In the first two years of the project, work at district level was severely hampered in six of the nine provinces due to extensive restructuring. Restructuring is now beginning in the remaining three provinces unaffected until now, with a number of QLP schools being moved between districts, and most district offices being entirely reconstituted. According to JET, this has 'potentially grave consequences for the QLP'.[51] It is also a public management issue over which QLP has no control.

The third threat to the QLP is the lack of basic teaching and learning resources in the schools in which it is working. One of the principles behind the selection of districts and schools for inclusion in the programme was that each would have the basic resources to ensure effective teaching. However, in general, provinces allocated their worst-performing rural or township schools to the project. In rural areas, it has proven difficult to attract better qualified and more experienced teachers to remote schools. As a result, there is a concentration of unqualified teachers in these schools. The majority of QLP schools are now in this situation, leading to the need for greater INSET teacher training at those schools.

Even more seriously, the supply of textbooks to schools remains a major impediment to systemic teaching. While the situation is improving markedly each year, 'there is a long way to go before all children have direct access to copies of even the most basic texts. The magnitude of the problem is way beyond the resources of the project, although efforts have been made at supplying the poorest schools with textbooks and calculators.'[52]

Over the past decade, enormous strides have been made in reforming the public schooling system, restructuring it away from race-based policies, and redistributing resources towards the poorest. However, in the absence of effective monitoring systems, there is no way of tracking the performance of schools, and thus of making them more accountable. The most recent government report acknowledges this, and that, while demand-pull measures are slowly being put in place, 'these are likely to come to fruition too late for the QLP to benefit maximally'.[53] The project is likely therefore to register two achievements: to improve the performance of QLP schools relative to those of other schools; and to establish a model of best practice in respect of the systems of accountability required to complement school supply-side measures.[54] However, the full implementation of the programme has been hampered by the three factors described above, which are all beyond the control of the QLP.[55]

SUMMARY AND CONCLUSIONS

In this conclusion, we try to draw out what has been learned in very broad terms. We do so in terms of four major themes:

- the benefits of acting collectively;
- establishing successful mutually beneficial partnerships with government;
- priorities for intervention; and
- the need for a strategic approach.

There is clearly a tension between the business sector acting collectively to achieve systemic changes on the one hand, and businesses acting individually for whatever reason on the other. Private initiative has therefore resulted in a myriad of teacher and, to a lesser extent, learner-centred interventions impacting on all levels of the school system. Besides the collective initiatives, there are literally hundreds of 'once-off' support or single-input projects which have provided crucial resources to many individual public schools. Consequently, the level and commitment, resources, and duration of involvement consequently varies tremendously by initiative and project. Neverthelss, each one represents a contribution to resource equity within the new schooling system, although it is impossible to systematically evaluate these contributions. They are often based on a subjective assessment of need, are not systematically recorded in any source, do not occur within an explicit 'framework of engagement' and often fail to reflect clear priorities in terms the results envisaged.

For many in the business sector, 'making a difference' is therefore still often seen as an aggregation of these small, individual, initiatives. Although each initiative has undoubtedly helped individual participants, amounting to possibly tens of thousands of learners and thousands of teachers and principals, they do not add up to a education system that is anywhere near adequate in terms of performance or quality. Many approaches have been tried, among them Saturday schools, cluster schools, teacher training, community outreach, teacher materials, family maths, teacher colleges, whole school development, larger systemic interventions – the list is substantial. However, we simply don't know how many passes result from which interventions, or if or indeed when the need for such interventions may have passed as sufficient expertise and capacity enters the public system itself. Whilst the number of evaluations is growing, as is the industry of designing research instruments for assessing 'before' (and 'after') baseline pupil competency via an independent measure, resulting in better data sets which now include learner achievement scores, this generally remains an important weakness, and an areas of concern.

Many private initiatives have concentrated on providing inputs (resources of various kinds) as discrete elements of 'school development' programmes in partnership with the government. No doubt the aim is to improve the quality of maths and physical science learning and teaching in the classroom. According to the most recent assessment of these programmes, it is now more widely realised that a combination of support and measures to improve accountability are required to make them more successful, internationally and in South Africa.

The jury is still out on whether business acting collectively can achieve sufficient levels of aggregation to sustain large-scale long-term systemic reforms. (The Business Trust is funding five or six large projects other than the QLP.) However, such considerations may be less important than success in establishing a model for intervention in school-based maths and physical science education which government can take to scale, which is the intention of the Business Trust projects. This becomes clear when we consider that it is the government which has the resources to sustain systemic change in the long term.

The projects analysed in this chapter show that it plays a crucial role in large-scale reform, if only because of the difficulties surrounding the relationship. But only the government can align and integrate accountability and support measures at the levels required so that they operate in tandem, pushing and pulling the schooling system to higher levels of performance. According to the JET study, government needs to address the following shortcomings: more effective monitoring of day-to-day activities in schools and classrooms, an agreed upon and clear curriculum with adequate assessment of learner performance in common examinations, and a standard set of school performance and management-related measures. The QLP is a good example of a large-scale, long-term, systemic reform initiative collectively supported by the business sector, in partnership with government. The project has apparently begun to deliver measurable improvements. However, according to JET, its implementation has been affected by the inadequacies in the educational regulatory environment, particularly the scarcity of monitoring mechanisms in the school system, the destabilising effects of institutional restructuring, the scarcity of trained teachers, and the inadequate supplies of textbooks in affected schools. This is hampering the full implementation of the programme, and threatens its sustainability.

On its own, corporate investment is a drop in the development ocean. It falls well short of the development quantum South Africa requires annually. However, having said that, the corporate sector appears to be comparatively undercommitted to maths and physical science in relation both to its own education and training 'spend' and to that of government and foreign donors. Only a little more than half (62) of the top 100 South African corporates currently support maths and physical science initiatives, and their contributions also vary considerably.[56] To have the positive impact on education that it would apparently like to have, the business sector needs to both increase the proportion of its education funding committed to maths and physical science as well as think more strategically about how the funds are disbursed.

The resources available from the South African private sector for driving large-scale change in education are limited (relative to the size of the government's resources, or in gross CSI terms). Partnering with government is the most realistic way of effecting *system-wide change*, so attention must be given to structuring such partnerships for maximum benefit. Companies gain in many ways from entering into partnerships with government, but there are also downsides to this arrangement: different levels of government often make conflicting demands on the private sector; the public service is sometimes unable to form effective partnerships due to poor human resource capacity, knowledge and skills; the public service and the education authorities may rely on dated technology and administrative skills; and implementation may be shackled by a tendency to approach project management in a very bureaucratic way.

Translating partnerships into workable models or programmes is therefore a very complex challenge. But here business can help, because it has greater freedom to experiment, generally has greater capacity, can draw on a variety of expertise and skill sets, and can work outside of old conventions and paradigm. There is no definite formula for success, and each partnership has its own unique 'mix'. Managing business–government partnerships is time-consuming and resource-intensive. Attention to key issues such as the budget, core funding, project objectives and motivations, and staffing is crucial. ONGOing challenges such as building trust between the partners, establishing mutual commitment, addressing technical administration and funding issues, identifying and working with key role players, establishing effective decision-making processes and powers, and effectively resolving conflicting responsibilities occur on day-by-day basis.

However there are many partnerships models that do work. Exemplar projects – ie, pilot projects which have the potential to go to scale should they win the support of a government department – are seen by many as having the most significant potential of all private–public partnerships. By engaging government strategically, corporates can make project plans a reality, and can develop models for widespread adoption by other corporates and government departments. However, many companies are not clear on how to get involved, how to open doors, or how best to structure partnering arrangements. Many simply don't know how to form partnerships, and see only bureaucracy and obstruction. So they take the easy route by offering once-off 'hand-outs'.

'Partnerships' are simply not a guarantee of success: the crucial questions soon become strategic ones of 'bolting on' or 'bolting in', acknowledging the realities of the schooling system in different places, adjusting programme engagement to government strengths and weaknesses, realistically assessing goals and outcomes in the prevailing socio-economic and policy environment, and so on. Embarking on a partnership is a journey, not an end point, and a crucial aspect is having good 'maps' to follow, and to effectively analyse the state of the schooling system before, during, and after departure. The importance of sound data to project design and strategic decision-making along the way cannot be overstressed.

The private sector has already made substantial and sustained investments in the education system over many years, yet its impact on maths and physical science results overall is unknown, and, in the absence of demand drivers (and monitoring systems in particular) cannot be known. Our research reflected in chapter 4 shows that one of the crucial variables is schools that hold teachers and learners accountable for results: consideration of the mechanisms for accountability in schools as well as other output measures is therefore crucial. Their absence is hampering many current initiatives. It seems clear that any large-scale intervention has to take account of the issue of accountability, either by designing certain outcome measures into the project from the outset (establishing an objective performance measure, for example school performance in the SC exam), or by requiring participating schools to meet certain prior minimum criteria before funding is made available. The QLP also shows the effects of poor school selection: initiatives have to be correctly targeted, in order to boost maths and physical science learning and teaching in schools that have demonstrated the willingness and capacity to help themselves.

One of the investments on which the private sector has always had a positive return is the provision of competitive, self-selecting, voluntary scholarships and bursaries to learners, teachers, and even schools with obvious and particular talents and records in maths and physical science. Providing appropriately structured incentives should form part of all private sector initiatives.

This chapter has stressed the difficulty of determining precisely which maths and physical science programmes are most likely to succeed. Our research clearly showed that, at this stage, educator support and development is the single most important area for intervention; yet the landscape of maths and physical science is still characterised by underqualified and unqualified educators. The problem is more complex than simply improving the skills and knowledge of educators; however, this is a vital component. Clearly, a combination of formal and informal educator support and development is called for.

Formal programmes, particularly those attached to universities, have been very successful. The FDE and ACE qualifications are particularly noteworthy because they are designed to enable existing educators who only hold diplomas to obtain a university qualification. In the process, help to upgrade educators' content and didactic knowledge. However, the classroom practices of educators participating in these programmes must be modified in such a way that the study of maths or physical science will improve. FDEs have been offered since 1996, with enrolment increasing annually.

However, if six major providers have graduated fewer than 2 000 educators with FDEs in six years, how long will it take for a critical mass of such educators to emerge? The country will continue to rely on informal educator interventions for some time. Before 1996 informal programmes were typically once-off afternoon in-service workshops, often presented in an *ad hoc* manner. Today, most stakeholders have realised that there are few benefits to be gained from this type of intervention. This, combined with the inherent inefficiency of 'once-off' programmes, has resulted in longer programmes of two or three years, involving a commitment by the participating educators and schools. Most informal educator programmes are now run in the context of whole school reform, as the key players realised that working with individual teachers, while a prerequisite for improving the quality of schooling, could not on its own change the way in which institutions function. Informal educator programmes have now been taken up into systemic school reform projects, all of which have large school and even district development components. However informal programmes still vary greatly in the detail. It appears that success varies tremendously, and it is difficult to pinpoint causal factors. The results must be measured in terms of learner outcomes, in order to maximise the investments made, and hold service providers and participants accountable.

Private sector support for learners is typically supplied in two main forms: second-chance opportunities, and support for learners preparing to write matric. Support for learners in grade 12 typically comes in the form of Saturday classes and winter, or holiday, schools. Most, if not all, universities and technikons now offer bridging or foundation courses for disadvantaged (and often underprepared) students starting a degree in the sciences. Many businesses directly involved in maths and physical science interventions choose to support learners who are preparing to write the SC examinations. A point which emerges very clearly is that businesses seem to be becoming more conscious of the need to be selective regarding their intervention. There is a desire to spend their money where it will see the greatest return. In particular, many companies seek schools that are reasonably well-governed, and have a culture of rewarding learning and academic achievement.

Working with government is the 'only game in town'. Transformation is taking longer than anticipated, particularly mechanisms that improve accountability and key elements of the system, demand drivers in particular, are proving to be difficult to establish. Whatever initiative is proposed or supported, the capacity of system 'change agents' to positively support such an initiative is very important. The private sector also has to think about centring its support and interventions on existing 'virtues' in the system – successful and improving schools which are already proving that they have a recipe for excellence under the present constrained conditions, as we argue in chapters 2 and 4.

In the past, many NGOs were influential enough to 'change thinking', and drove a great deal of institutional change. Many have subsequently died, quite a few have metamorphosed along with changing conditions, and new ones have arisen to complement the new activities of the government and the private sector, primarily as service providers. Which of these organisations the private sector should turn to for objective and realistic assessments of the challenges, and how best to support such objectives and forms of policy research aligned to its aims and objectives has to be thought through very carefully.

It is clear that the private sector will not 'act as one.' But large companies will support a broad national effort, particularly in areas where national issues coincide with their 'own interests'. The current shortage of HG maths and physical science SC candidates is an issue which is exercising all of business.

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Chapter 7

INTERNATIONAL PERSPECTIVES ON EDUCATIONAL REFORM

In this chapter we review current research on successful attempts to change educational systems in general, and maths and physical science education subsystems in particular. We have selected material that is particularly relevant to developing countries, and thus to South Africa.

International comparisons should not be dismissed. First, they correlate closely with research findings in South Africa, thus reinforcing the latter's veracity. Second, a primary reason for improving maths and physical science education in this country is to improve its international economic competitiveness. Competitiveness is intrinsically a comparative measure, and it is therefore important to establish how our education system shapes up against those of other countries, as well as against standards derived from international research and best practice. Proficiency in maths and physical science is a key building block of modern knowledge-based economies. Therefore, the hard truth is that South Africa cannot become internationally competitive without a competitive schooling system.

In the first section of this chapter, we assess contemporary research about effective ways to change educational systems in general and maths and physical science education subsystems in particular. In the second, we assess research on educational change in developing countries. In the third, we assess work done on the supply and development of educators ('teachers', in the international literature) in developed and developing countries.

In the next three sections, we discuss three types of initiatives undertaken internationally that seem especially relevant to South Africa. They are:

- providing differentiated incentives for maths and physical science educators;
- creating secondary schools specialising in maths and physical science; and
- stimulating the demand side of maths and physical science education by providing assistance to learners who wish to study maths and science, and to their parents.

In a concluding section, we draw out a few key points emerging from the international review that are especially relevant to our study.

MODERN VIEWS ON THE NATURE OF EDUCATIONAL CHANGE

Developed countries have been preoccupied with ways of changing their public education systems since these began to emerge some 150 years ago. A huge amount of research has been done on this topic; however, there are analysts who provide reliable guides to the voluminous literature, among them Michael Fullan. In his major work entitled *Change forces: probing the depths of education reform* (1993), Fullan outlines more than 50 years of attempts to reform education systems, but focuses more closely on major trends from the 1960s to the 1990s. Referring to the 1960s, he notes:

> We [developed countries] started naively in the 1960s pouring scads of money into large-scale national curriculum efforts, open-plan schools, individualized instruction, and the like. It was assumed, but not planned for, that something was bound to come of it. We have never really recovered from the profound disappointment experienced when our expectations turned out to be so far removed from the realities of implementation. Indeed, the term 'implementation' was not even used in the 1960s, not even contemplated as a problem.[1]

Fullan then describes how, in the 1970s, implementation studies began to reveal that the new initiatives were beset with problems. These studies led to a crisis of confidence among educators over whether educational systems could be changed, and whether this would make a difference; inter alia, a perception took hold that, given deepening societal problems, reforming the educational system was merely a form of tinkering. Only minor successes were reported.

The 1980s saw large-scale, top-down public interventions implemented once more in many western countries. Fullan writes:

> Now we were engaged in large-scale tinkering. In the United States, state curricula were specified and mandated, competencies for students and teachers were detailed and tested, salaries of teachers (woefully low at the time) were raised, leadership competencies were listed and trained.[2]

In Great Britain, the Educational Reform Act of 1988 introduced – heretically for that country – a national curriculum. Overlapping these top-down regulatory efforts was another movement, called 'restructuring' in the United States, which emphasised school-based management, enhanced roles for principals and teachers, and other decentralised components.

In the 1990s, things changed again, creating a situation which Fullan describes as a combination of 'bifurcation and confusion'. On the one hand, 'centralists' believed the answer lay in enhanced top-down control over education. On the other, 'restructionists' believes the answer lay in giving more autonomy to teachers and other school-based-educators. Clearly, these are conflicting positions. What is needed, Fullan suggests, is a new mindset about education:

> Without such a shift of mind the insurmountable basic problem is the juxtaposition of a continuous change theme with a continuous conservative system. On the one hand, we have the constant and ever expanding presence of educational innovation and reform. It is no exaggeration to say that dealing with change is endemic to post-modern society. On the other hand, however, we have an educational system which is fundamentally conservative. The way that teachers are trained, the ways that schools are organized, the way that the educational hierarchy operates, and the way that education is treated by political decision-makers result in a system that is more likely to retain the status quo than to change.

> When change is attempted under such circumstances it results in defensiveness, superficiality or at best short-lived pockets of success.
>
> To put it differently, the answer does not lie in designing better reform strategies. No amount of sophistication in strategizing for particular innovations or policies will ever work. It is simply unrealistic to expect that introducing reforms one by one, even major ones, in a situation which is basically not organized to engage in change will do anything but give reform a bad name. You cannot have an educational environment in which change is continuously expected, alongside a conservative system and expect anything but constant aggravation.[3]

As an alternative, Fullan suggests that the educational system itself should become a learning organisation which is 'expert at dealing with change as a normal part of its work, not just in relation to the latest policy, but as a way of life'.[4]The reason why the educational system should develop such capacity for change is that is has a moral purpose: 'to make a difference in the lives of students regardless of background, and to help produce citizens who can live and work productively in increasingly dynamically complex societies'.[5]

Thus the first important insight arising from the international research is that, rather than being subjected to successive reform strategies, **education systems themselves should develop the capacity for continuous change**.

In a more recent book, Fullan deals with a topic that is especially relevant to South Africa: the problems encountered when reform- or transformation-oriented governments try to rapidly change an (inherently conservative) schooling system. He presents a balanced view: governments do have a role, but they have to realise that there are limits to this. Governments can do certain useful things, but other types of intervention will alienate people. Time scales for change in education are much longer than political ones.

According to Fullan, governments have three viable roles, namely to:

- increase accountability within the education system, and between the system and society;
- provide incentives for ensuring that certain kinds of change do happen; and
- build capacity. Crucially, he points out that 'we need capacity to build capacity'; ie, any major system, such as a public education system, can only be reformed by utilising its internal capacity. Should this be lacking, or, as in South Africa's maths and physical science education system, be severely constrained, some basic capacity must first be built before substantive reform can proceed.

The third role is by far the most important, as it brings changes that are 'deep' and permanent. Accountability and incentives are helpful, but not decisive:

> [Newmann and colleagues] found that some schools had high capacity for reform, defined as individual skill and knowledge of teachers, professional learning communities, program coherence, availability of resources, and a school principal who helped develop the previ-

> ous four factors. Of interest here, they also asked whether external assistance and external policy coordination at the district and state levels had contributed to the high capacity schools. Essentially they found a weak relationship using *the standard of high capacity*, that is, external assistance and policy sometimes made partial contributions (and sometimes made matters worse) but were not formulated in a way that could help with comprehensive, school wide reform. Policy support thus remains at best potentially helpful (*emphasis in original*).[6]

Fullan also discusses an element of change that is certainly available in the South African maths and physical science system: the mobilisation of 'existing unfocused capacity' by means of effective policies and strategies acceptable to educators themselves.[7] Our research reflected in chapter 5 shows that such capacity exists in abundance at various levels of the South African system, and should indeed be mobilised.

Fullan sums up his current position as follows:

> What is needed now, I think, is a two-phased process that starts with accountability and incentives as phase 1, and adds capacity-building in phase two. The criterion of success is *large-scale reform*, which makes a *deep difference* (emphasis in original).[8]

Accordingly, the second key insight arising from the international literature is that **education reforms must be embedded, via appropriate capacity-building, in those systems themselves.** National policies and strategies significantly affect levels of motivation and accountability in the education system. This is important, but will not in itself change the system deeply. The slow and unglamorous task of capacity-building makes the difference between lasting success and failure.

Educational systems need several different kinds of capacity. The most important is capacity in respect of educators. Fullan's strategy has two dimensions: enough educators are needed, and they need to be adequately trained. Achieving lasting change requires educators who are skilled change agents. Thus the development of educators is the key to effective educational change. As Fullan notes:

> Teacher education ... has the honour of being the best solution and the worst problem in education today. Despite the rhetoric, society has not yet seriously tried to use teacher education as a tool for improvement. ... the problem of productive change simply cannot be addressed unless we treat continuous teacher education- pre-service and in-service- as the major vehicles for producing teachers as moral change agents. [9]

Jane Butler Kahle, director of Discovery, the highly successful initiative to reform maths and science education in Ohio in the United States, reports that 'teacher professional development has been both the starting point and the central focus of the initiative' (see box 7.1). She has stated:

Schools are only as good as their teachers, regardless of how high their standards, how up-to-date their technology, or how innovative their programs. But if teachers are not given adequate opportunities to learn through sustained professional development experiences, they have little chance of meeting the ever-increasing demands of our technological society. For this reason, professional development for teachers is a critical component of improving schools and our nation's teachers.[10]

BOX 7.1: THE DISCOVERY INITIATIVE[11]

Imagine an initiative that, over a period of 10 years, greatly improves the content knowledge and teaching skills of 13 000 maths and physical science educators, who then pass on their new skills to another 5 400 of their colleagues. More than 350 principals and other senior administrators learn how to create the conditions under which these educators can succeed. Ultimately, more than 19 000 learners and educators in 420 schools participate in the initiative. Over five years, eighth-grade learners educated by teachers benefiting from the programme increase their average scores in standardised maths tests from 57 per cent to 70 per cent, and in physical science tests from 54 per cent to 73 per cent.

This is the record of Discovery, an initiative for reforming maths and physical science education at state/public schools in Ohio in the United States. It is funded by the National Science Foundation (NSF), and supported by the Ohio department of education and the Ohio state parliament. The objective of this broad-based intervention is to improve learners' performance in maths and physical science, and seeks these improvements across ethnic, gender, geographic, and socio-economic lines. The strategy is simple: to '… increase teacher knowledge and skills, thereby improving classroom practice in order to raise student achievement levels and narrow the gaps among various demographic groups'.[12]

The Discovery strategy (now also followed in nine other American states) has two major components, which aid in its success: a technical strategy, for achieving the desired changes in teaching and learning; and a political strategy, for establishing a 'supportive context for reform'.[13] Together, according to a formal evaluation study, they amount to a 'strategic systemic reform initiative' (SSRI) which 'establish the capacity or means for reform, and the will or opportunity to accomplish a vision for high-quality mathematics and physical science teaching and learning for all'.[14]

Developing educators

The initiative develops educators in three ways. First and foremost, it concentrates on improving teachers' content knowledge, focused on current curricula so that this is immediately useful in the classroom.

Second, it improves their enquiry and problem-solving abilities. This is based on the conviction that the methods used to develop teachers should model those they use in the classroom; thus the educators learn through the same methods which they will use to teach..[15] They are required to assess their own teaching styles, and to record changes in learners' performances.

Third, it exposes educators to sustained professional experiences. Teachers are trained for a minimum of 140 hours over several weeks; visit other classes; and are counselled on implementation.

They also serve as interns at businesses and research institutions in order to increase their awareness of how maths and physical science are applied in the workplace. Language proficiency is highlighted throughout, even though the vast majority of educators in Ohio are native English-speakers. Units of instruction are as long as school classes, so that learning practices may be easily transferred from educators' learning to learners' learning.

Strategies for change

According to Discovery, the following components are crucial for success:

Broad-based research: This is used to establish baseline standards for educators and principals, and identify areas that are lacking on which the facilitation programmes should focus. It identifies which demographic or social groups need special attention, and in which schools. Finally, it is used to monitor progress, which allows the project to be continuously refined and improved.

Identifying the status quo: Planners establish where the initial effort should be focused along the continuum of the schooling years (K–grade 12). Thus general and special target groups, such as female learners, are identified, and a profile built up of teachers' existing knowledge. Discovery also identifies existing initiatives in order to co-ordinate their activities.

The involvement of educators: Discovery's managers have found that their initiatives work best if they involve a critical mass of educators (preferably all) at a school (learners' scores in standardised maths and physical science tests have improved by 17,5 per cent and 9,2 per cent respectively in schools where more than 51 per cent of educators have benefited from Discovery, but have declined by 11,3 per cent and 3,3 per cent respectively in schools where fewer than 25 per cent of educators have utilised the programme). Also, educators become more motivated if local institutions of higher education give them credits for completed Discovery courses.

Institutional support: The programme is also aimed at aligning formal education policies, and capturing professional, political, and public support.[16] Assessing the existing policy environment in respect of maths and physical science education, and then aligning with it or minimising opposition from it are seen as crucial. Also important is stimulating an understanding of the reform initiative itself in political and professional groupings, and creating stakeholder support. In her discussions with CDE, Butler Kahle emphasised the need to find a single entry point into the system, and use this to establish a 'wedge' from which a cycle of implementation could be created, following the incremental pathway of design, implementation, evaluation/research, and redesign.[17]

Communication: Communication and implementation are most effective if focused on 'visible units of reform',[18] such as positive progress in a grade or a group of schools, or implementation across an entire school.

Scale: The programme distinguishes between 'going to scale' and 'scaling up'. Going to scale generally occurs when the approach used for a small pilot project is applied to a larger venture, without significant structural changes to the strategy. 'Scaling up' means initiating changes in a part of the system, assessing these, expanding further in range or depth or both, and repeating the process until real impact at scale is achieved. On balance, Discovery's managers believe 'scaling up' is far more effective than 'going to scale'.

Evaluation

Discovery's sustainability depends almost entirely on positive results. Therefore, the initiative itself continuously tests learners, over and above any routine testing forming part of the education system. However, the former are only convincing if they correlate closely with the latter, and this has been achieved (r=0.98 in physical science, and 0.97 in math).[19]

In the end, the only outcome that counts is improved learner performance. Evidence of improvement must be related to the performance of learners who do not as yet have access to the initiative. Data is also collected and presented in respect of targeted subgroups; for example, in 1995-7 the average test scores in maths of white Discovery learners improved from 62 per cent to 82 per cent, and those of African American learners from 52 per cent to 75 per cent. This 'narrowing of the gap' did not occur among non-Discovery learners over the same period – in fact, it widened from 10 per cent to 15 per cent.[20] The system's results were worsening, while Discovery's were improving.

Additional initiatives

Discovery has not limited itself to what South Africans would call 'in-service education and training'. Obviously, such a systemic reform initiative can never succeed entirely if inadequately prepared teachers keep entering the system after graduating. Thus a 'reach back' into pre-service is inevitable, and should be consistent with the in-service component. In 1996, five years into the initiative, Discovery also launched Project SUSTAIN, which focuses on the preparation of maths and physical science teachers at colleges and universities. Many learners will be motivated to improve maths and physical science scores if this raises their chance of better-paid and more interesting jobs. Liaison with potential employers is vital, especially in technology-based fields. This is achieved through an initiative known as TECH PREP, which brings together high schools, tertiary institutions, business, and industry 'to prepare students for the technology occupations of the future'.

CDE 2004

While Discovery's efforts began with teachers, other aspects of the system were eventually addressed as well. When the programme began in 1991, it only developed 'middle-school' educators, believing that this was the age group which would benefit most from the programme. However, it was later broadened to include educators in all other school grades as well as principals and other administrators. In 1997 institutes were developed to help school principals and other administrators increase their understanding of maths and physical science reform; facilitate school-wide reform; improve the college education of all educators; and build networks among various schools and universities. In 1999 Discovery began to create 'model schools', which are used as training grounds for teams of educators and administrators who then train staff and educators at other schools in those districts.[21]

Discovery's planners did not try to address all aspects of the system simultaneously. Instead, they first set out to strengthen teachers – whom they perceived to be the key element of any reform strategy – and to do so sustainably. Additional elements of the system were slowly targeted over a period of years. Thus the third key lesson from the international research is that **reform must begin with maths and physical science educators.** Several recommendations will be made in this respect.

Both Fullan and Kahle are concerned with giving systems the capacity they need to change themselves when external circumstances require. The next influential research on which we focus out attention is also preoccupied with systemic change. In their book *Changing the subject* (1996), Black and Atkin synthesise the results of 23 case studies related to maths, science, and technology education in 13 OECD countries. They write that:

> '...one meaning of the term [systemic reform] defines a reform that addresses *all* the key elements of a whole educational system. Those who use it tend to believe that reform must be systemic to succeed, and that the most effective strategies must encompass not only new curricula, but new forms of teaching and teacher education, new approaches to student assessment, and new instructional materials. And they believe that every aspect of a reform must be directed towards the same ends. A systemic reform may also be defined as reaching beyond the education system itself, to include all the people and institutions which have any stake in the quality of education.[22].

Many others, including the National Science Foundation in the United States (which has a special program for systemic initiatives), now recognise the importance of addressing other necessary and directly related components of the education system in order to bring about lasting change. The emerging consensus, as described by Black and Atkin, is that systemic reform must address all the key elements of a whole education system:

> Curriculum relates to instructional materials which relates to student assessment, which relates to teacher education, which relates to the provision of resources, which relates to the role of business and industry in the schools, which relates to support from the community, which relates to wider social services and so on and on. There is a 'system', organised or not, and projects for educational change have to acknowledge and work with (or around) it.[23]

But reality often intervenes. In practice, it is never possible to change all the aspects of even a simple system at once, and so there are different perspectives on *how many* aspects should be addressed simultaneously. Most analysts believe that prospective educational reformers should quickly try to gain an understanding of the dynamics of the whole system, but not try to change too many aspects at once. However, it is also self-defeating to attempt too little. Savage paints a graphic picture of the effects of *not* addressing different parts of the system at the same time. Referring to Africa, he writes:

> Teachers can only change in environments that permit change, and the environment of schools is a complexity of many interrelated factors that has considerable momentum. Yet governments, funders, educational planners, and the like expect changing one of the many factors to lead to some magical domino effect – and expect change to be cheap. ... Governments, funders, and so on also frequently send conflicting messages to teachers. They expect dedicated service, yet pay teachers so little that they are forced to seek other ways to supplement their incomes. Governments expect schools to give children income-earning skills when neither markets nor job opportunities exist. They expect teachers to use child-centred methods of learning and add content to already overcrowded syllabuses without

> removing anything. They expect teachers to promote thinking skills, yet set examinations that test only rote memory. Governments expect teachers to make countless, instant decisions to help children, yet do not consult them on major policy decisions affecting classrooms. The litany is endless. Is it any wonder that schools have not changed?[24]

Clearly, then, reformers could err on the side of changing too few aspects of the system, leaving educators and others with the task of reconciling the resultant contradictions. This observation leads to the fourth key lesson arising from the international research: **the entire system under review must be well understood before any changes are made**. The scale of the changes must be a considered balance between 'everything at once' and 'too little to make a difference'. Change must be significant but manageable, and must be consolidated before more changes are introduced.

While there are obvious benefits to adopting a systemic approach to reform, Black and Atkin highlight two possible limitations, not so much of the approach itself as of the way in which it has often been implemented. They refer to the first as 'the privileged view of those farthest from the actual provision of services to children':

> Most current systemic views are through the telephoto lens. How do the schools look from the national capital? From the office of a provincial or regional governor? From the ministry? The vantage point makes a difference. The long-distance view tends to fortify the powers and prerogatives of those with the most general responsibilities, and weaken the prerogatives of those closest to the sites where educational services are actually provided.[25]

In other words, responsibility for change is often located in the wrong place; it should be as close to the point of implementation as possible. Clearly, provincial and national governments should provide direction, but if principals are not motivated and trained, little will happen.

The second limitation is the assumption of a general failure of the schools referred to in chapter 4 – the 'all too-ready assumption abroad that all past endeavours to improve schools have failed'.[26] The result is 'solutions' that challenge too many of the foundations of the public education system at once.

If policy-makers do not learn from the past, educational reform could actually have a negative effect. Black and Atkin advocate policy that is directed towards finding virtue rather than finding fault; in other words, we must look for what is valuable in the existing system, and build on that:

> Where ... policy-makers assume that previous efforts to improve the schools have been at least partially successful, they may be led to different sorts of strategy: to identifying strengths and trying to build on them. Where does the curriculum seem attractive? Which school districts seem to retain their best teachers? Which universities educate the most sought-after teachers?[27]

They provide numerous examples of reforms that have worked by building on existing strengths. These included a programme in Ireland in terms of which the expertise of the best teachers serves as a model for others, and the Urban Mathematics Collaboratives (UMCS) and Precalculus Reforms in the United States that supported the collaborative efforts of teachers which were already evident in desired area of reforms. Black and Atkin go on to say:

> When a country capitalizes on the accomplishments of the most able professionals in its education system and on their work, it creates the impetus for more improvement. People are motivated when their accomplishments are recognized. Building on existing strength may serve to steal the wind of destructive reforms, those that follow one another at breakneck speed because priorities cannot be allowed to stand or new shortcomings are perceived every day. Such initiatives never recognize present merit and assume that everything is in steep decline. In the quest for new programmes and structures they are inattentive to history, unmindful of those who are still trying valiantly to meet the demands of the last round of reform.[28]

In 1996 the National Research Council (NRC) in the United States, at the behest of the National Academy of Sciences, published a set of guidelines entitled N*ational Science Education Standards which* contained a useful checklist of the features of good policy (see box 7.2) The standards are formulated for physical science education, but are clearly applicable to maths education as well. Besides the standards themselves, the document spells out a number of criteria for implementing them; among these are that potential reformers should gain an understanding of the system as a whole,

> … in terms of interacting component subsystems, boundaries, inputs and outputs, feedback, and relationships. In the education system, the school is the central institution for public education. The school includes many components that interact, for example, teaching, administration, and finance. The school is a component subsystem of a local district, which is a subsystem of a state educational system.[29]

BOX 7.2: THE US NATIONAL RESEARCH COUNCIL'S NATIONAL PHYSICAL SCIENCE EDUCATION STANDARDS

- Policies that influence the practice of physical science education must be congruent with the existing programme, teaching, professional development, assessment, and content standards, while allowing for adaptation to local circumstances.
- Policies that influence physical science education should be co-ordinated within and across agencies, institutions, and organisations.
- Policies need to be sustained over sufficient time to provide the continuity necessary to bring about the changes required by the *Standards*.
- Policies must be supported with resources.

- Physical science education policies must be equitable.
- All policy instruments must be reviewed for possible unintended effects on the classroom practice of physical science education.
- Responsible individuals must take the opportunity afforded by the standards-based reform movement to achieve the new vision of physical science education portrayed in the standards.

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This brings us to the fifth key insight arising from the international research: **successful change must identify and build on the existing virtues of the system in question.** South Africa's current educational system has many virtues, including relatively good performance under very difficult circumstances. These should be rewarded and enhanced.

The sixth key insight is the general point that **educational change, far from being a single event, is a continuous process, and exceedingly complex**. Neglect of what Fullan calls the 'phenomenology of change' – that is, how people actually experience change, as distinct from how it was intended – 'is at the heart of the spectacular lack of success of most social reform'.[30]

Furthermore, educational change should be seen as a process of continuous improvement – called *kaizen* by the Japanese – both at the level of individuals (teachers and administrators) and at the level of schools. At its core, productive educational change is

> ... not the capacity to implement the latest policy, but rather the ability to survive the vicissitudes of planned and unplanned change while growing and developing.[31]

In summary, although change is complex, there are a few simple lessons that, if heeded, are likely to lead to effective change. Fullan has summarised these colloquially as the 'eight basic lessons of the new paradigm of change' (see box 7.3).

BOX 7.3: THE EIGHT BASIC LESSONS OF THE NEW PARADIGM OF CHANGE[32]

1. You can't mandate what matters – the more complex the change, the less you can force it.
2. Change is journey, not a blueprint – it is non-linear, loaded with uncertainty and excitement, and sometimes perverse.
3. Problems are our friends – they are inevitable, and you can't learn without them.
4. Vision and strategic planning come later – premature visions and planning blind.
5. Individualism and collectivism must have equal power – there are no one-sided solutions to isolation and group-think.
6. Neither centralisation nor decentralisation works – both top-down and bottom-up strategies are necessary.
7. Connection with the wider environment is crucial for success – the best organisations learn externally as well as internally.
8. Every person is a change agent – change is too important to leave to the experts. Personal mindset and mastery is the ultimate protection.

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Given these insights, it is clear that educational change can only be lasting and effective if it is viewed as a complex, non-linear process, and not an endpoint. It involves many voices, and requires learning continuously from experiences along the way. It is based on research; it is pragmatic; it builds on strengths; and it is sustained over time by clear goals.

EDUCATIONAL CHANGE IN DEVELOPING COUNTRIES

Many developing countries lack capacity in various areas, and at various levels. In the field of education, shortages of managerial skills and experience are common. This has undermined the impact of the billions of dollars spent by agencies such as the World Bank to strengthen education in those countries. This is why Rondinelli, Middleton, and Verspoor (1990) propose a 'contingency approach' to planning educational initiatives in developing countries (see box 7.5).

BOX 7.4: CONTINGENCY ANALYSIS IN PROJECT DESIGN

Rondinelli et al propose a four-stage process for applying contingency analysis to project design:

1. Assess the management requirements of the project in terms of environmental uncertainty, task innovativeness, and the management process, value orientations, and the organisational structures required to implement it effectively.
2. Assess the implementing organisation's capacity in terms of these variables.
3. Compare the two; if large discrepancies are found, the design must be modified, or the management capacity of the implementing organisation must be expanded.
4. Formulate action plans to develop more management capacity, redesign the project so that it can be implemented with existing capacity, or both.

CDE 2004

This approach assumes that the

> ... level of innovation in project tasks and the degrees of uncertainty in the environment in which they must be carried out are the primary determinants of an appropriate management strategy. Education projects – especially those promoting innovation and change – can be more successful when planners select a management strategy that reduces the gap between the project's *management requirements* and the *managerial capacity* of education institutions to adopt innovations and cope with environmental turbulence.[33]

As projects become more ambitious, the gap widens between the proposed reforms and the ability to implement them. There is a great deal of literature on this. In a review of 17 education projects funded by the World Bank, Middleton argues that the 'high degree of innovation and uncertainty in government education policies increase[s] the complexity of projects and their management requirements'.[34] Thus, in circumstances where management capacity is limited, innovations are likely to be more effective if they are not too ambitious, and if innovations are not introduced too quickly one after another.

Similarly, Verspoor, in an analysis of 21 World Bank projects, finds that

> ... successful implementation depended on designing a program that introduced innovations at a rate appropriate for environmental conditions and on supporting them with effective organisation development programs and staff training. [35]

An important aspect of selecting an appropriate management strategy also involves understanding that strategies that are effective for managing innovative projects are different from those that are effective for managing an existing, stable schooling system.

Another problem with many educational reforms in developing countries is inappropriate project design. Rondinelli *et al* ask why the projects they studied were so frequently plagued with problems. The answer, they suggest, 'lies primarily in the process by which projects are planned and carried out':[36]

> Conventional processes of project design attempt to create a comprehensive blueprint for actions, to which managers are expected to adhere and deviations from which are often defined as bad management. Although such a blueprint approach may be appropriate for physical construction and routine service delivery improvement projects, a comprehensive and detailed 'blueprint' is not necessarily appropriate for managing innovative education reforms. Projects designed to change education systems require a different form of planning. It is usually difficult for planners to formulate a detailed prospectus for innovative projects to which managers can faithfully adhere. Any project design should give some description of objectives, size, scale, location timing, the technical package, cost estimates, and a desired implementation schedule. But for innovative projects planners can only suggest an appropriate management strategy and leave tactical details of implementation to those who will be managing them.[37]

'Blueprint planning' is not effective for education reform because educational planners and administrators cannot predict the future; they can only anticipate some of the problems that might arise during implementation. 'Thus, planners must design projects so that they are flexible, and can be changed as managers learn from experience.' [38]

This is why contingency analysis has been suggested as a useful tool for educational reforms, since it involves the recognition that 'adjustments in tasks, organisational structure, and management processes must evolve incrementally from learning and experimentation'. This approach joins 'learning with action to move incrementally toward effective and efficient implementation, based on knowledge and experience gained through interaction with participants and beneficiaries'.[39]

Rondinelli *et al* suggest that the chances of successful implementation are increased if the three major issues outlined below are addressed at the design stage.

Simplicity versus complexity

> Although the education problems and needs of most developing countries are serious and complex, overly ambitious designs – manifested in multiple objectives, rapid change, substantial requirements for human and financial resources, and complicated processes of coordination– create equally serious problems in implementing education reform projects. These problems are exacerbated by political and organisational instability in many developing countries. ... The World Bank's long experience in the education sector suggests that ensuring simplicity in project design by choosing a dominant project objective is an essential first step toward successful implementation, particularly where the political and organisational environments are unstable. Such an objective should be clearly defined and operationally feasible, that is, progress toward it should be measurable. [40]

It is not always possible to limit a project to a single objective, as a drastic narrowing of focus may not sufficiently improve the quality of education. The value, then, of contingency analysis is that it can help project designers to balance the level of complexity needed to achieve meaningful change against the management capacity available among those who will implement the project.

Feasibility versus the need for change

Rondinelli *et al* also point out that, while projects must be economically and technically feasible, achieving meaningful change often requires that people break with what they have done in the past and step out into the unknown. Doing so is risky; nonetheless, it can be very beneficial.

One example is the common practice of erecting prefabricated school buildings in rural areas. This is an 'easy response' to the need in those areas, but an expensive one, and technically inappropriate in the longer term; according to Rondinelli *et al*, this tried and tested approach may 'inhibit the search for less expensive, labour-intensive construction techniques that make use of local materials and are better adapted to local conditions'.[41]

At this juncture it is worth stating the seventh key insight arising from the international research: **the capacity of people in developing countries to implement complex reform programmes must be realistically assessed.** There should be fewer targets rather than more, and a means of revising the programme should it prove difficult to implement.

Mobilising support for change

Interventions should be designed in such a way that they elicit the commitment and support of intended beneficiaries. If the project is meant to promote change, however, it may be necessary to mobilise support during implementation rather than prior to it. Project design should include strategies for enlisting the support of implementers, such as teachers and administrators, and intended beneficiaries, such as students.

In a developing world context, say Rondinelli et al, teachers are particularly important:

> Teachers must always be convinced of the feasibility and usefulness of innovations, especially when changes require deviations from existing classroom practices or extra uncompensated work. [42]

> Teachers, administrators, and community and political leaders should be involved in the design process to assure that the proposed innovations fit with local conditions and to motivate teachers to try new approaches.[43]

Most important of all is to secure the participation of individuals and groups whose actions could seriously affect implementation, or who are likely to be seriously affected by the project. Their participation should begin during proposal preparation and project design, and continue through implementation. Each group that participates can be expected to have a different perspective on the problems and issues that the project will address, and on the most effective means of solving them, alleviating them, or coping with them. However, each group can be expected to bring its own knowledge, experience, understanding, and resources to bear on achieving the project's objectives.

Thus the eighth key insight from the international literature is that **educational change is fundamentally about changing people**:

> [The] success of 'people-centred' development programs, including education] depends on the ability of planners and administrators to tailor services to the particular needs of different groups of people and on changing people's behaviour so that they can more effectively help themselves.[44]

The literature shows that there is widespread agreement on this. For example, Keith Lewin writes:

> Our basic value stance is that change is for the benefit of the clients of education systems (students, parents, employers, communities) and those who work in them (teachers, administrators, planners and policy-makers). Our judgement of the research literature, including that reviewed here, is that the weight of evidence on effective change supports the view that innovations where consultation with clients is marginalised and their interests and motivations are not recognised rarely lead to durable change which is recognised positively by clients.[45]

Lewin warns that attempted change in developing countries is generally 'too much , too quickly'. He writes:

> High rates of change can, however, penalise those parts of the system that most need its benefits. In many educational systems in developing countries the losers in the change process are those clients on the margins of the existing system. Rural children and teachers in isolated, under-resourced, and neglected schools, with many unqualified teachers and little access to information, are those least prepared for change. This is interpreted by some as rural 'conservatism'. In reality it may be ignorance of alternatives and lack of understanding of the purposes the changes are directed to. These are linked to lack of capability and confidence in implementing change. High rates of change in these systems are disruptive of fragile delivery systems that at best succeed in enrolling most children for most of the time and make as much use as they can of whatever teachers are available.[46]

He consequently advocates an evolutionary rather than a revolutionary approach to change, particularly in developing countries, where both exogenous factors, such as global trade and recession, and indigenous ones, such as population growth and distribution, have 'unpredictable knock-on effects on education'.[47] An evolutionary approach provides some stability in an otherwise unstable environment.

Furthermore, he argues, an evolutionary approach is likely to be especially beneficial to the most disadvantaged members of society:

> If the concern of the innovator is to improve the quality of an educational service to those most disadvantaged by existing structures, the larger and more frequent the innovations the less the infrastructure in place will be able to cope. This argues in favour of evolutionary approaches with continuity and sensitive phasing sympathetic to the absorptive capacity of institutions and individuals for change.[48]

Thus the ninth key insight arising from the international literature is that those attempting to reform educational systems must **avoid the common trap of doing too much too quickly**. Very sober assessments must be made of what is possible. This is especially the case because the 'cost' of a failed change is not simply the opportunity cost of its potential success plus the cost of implementing the failure; there is also a much larger 'cost' in disillusionment and lack of enthusiasm for further change on the part of those involved in the failure.

Another important concept in planning for change in developing countries is what Lewin calls the 'planner's paradox', which he describes as follows: '... innovation is needed in education systems which fail to deliver equitably an acceptable quality of service. But innovation is disruptive, resource-consuming, and often unevenly implemented. As a result, it is likely to adversely affect the equitable delivery of service at an acceptable level of quality.'[49]

According to him, it is difficult 'to avoid the short-term consequences of the planner's paradox for the marginalised,' but in some situations it is a necessary short-term cost.[50] Nonetheless, awareness of the planner's paradox is helpful for planners who do not wish to lose sight of the 'needs of the most vulnerable groups as a whole, rather than those segments identified as the target group of special intervention programmes which are transient and often not generalisable'.[51]

Thus the tenth key insight from the international literature is that innovations may attract resources out of the existing system, leading to a reduction in equity and/or quality in parts of the system that are not even involved in the change. Failure exacts a much higher price than we think.

BOX 7.5: MATHS AND PHYSICAL SCIENCE EDUCATION IN DEVELOPING COUNTRIES

Developing countries experience the same kinds of problems as developed countries in respect of maths and physical science education. However, the problems in those countries are invariably far worse in quantitative terms, which create new problems in turn.

For example, if teachers are in short supply, as they invariably are, class sizes can be enormous. This problem is compounded when initiatives to increase access to education result in a sudden increase in student enrolment. Thus Onwu writes:

'After the adoption of the principle of universal primary education, the 1970s and 1980s saw an unprecedented expansion of student enrolment in African countries. As a consequence, class sizes have increased dramatically, with a concomitant decrease in the quality and quantity of resources.'[52]

Teachers' salaries may be so low that they take on part-time jobs after hours which take them away from extra-curricular activities, or reduce the time they have to spend on preparing lessons and marking homework or tests.

Learner assessments which place too much emphasis on the recall of information, rather than application or comprehension – common in sub-Saharan Africa – exacerbate the often poor content knowledge of the very few maths and physical science teachers actually in the education system. The results are teaching approaches that stress rote learning rather than the development of higher-order cognitive skills.[53]

Education systems in developing countries also tend to suffer from a lack of management capacity as well as resources, ranging from laboratories, textbooks and teacher' guides to desks and chairs, electricity, and running water.

On the basis of a study of physical science education in 12 developing countries, conducted under the auspices of the International Institute for Educational Planning, Caillods et al recommend four major cost-effective approaches to physical science education, which are summarised below.[54]

Special science schools

One cost-effective option for increasing the number of high school physical science graduates is to create special science schools, as has been done in Nigeria and Malaysia. In both countries, these schools have improved the quality and quantity of passes. For example, in Kano State in Nigeria, science schools achieved pass rates of 55–70 per cent, compared with 5-14 per cent at normal schools.

Caillods *et al* put forward four arguments for special science schools as cost-effective alternatives:

- Good physical science teaching is expensive, and the necessary resources (competent teachers, well-equipped laboratories, up-to-date libraries) are scarce. Providing quality physical science education to a smaller number of selected students at special institutions is therefore justifiable.
- Developing societies urgently need scientists and technicians. They are more likely to be produced by concentrating on the best physical science students at special institutions than by a diluted effort across the whole school system.
- It is sometimes argued that the best way to develop those scarce students with a talent for physical science is to start teaching them at an early stage. Scientific thinking may be more difficult to impart to older students.
- Special science-focused institutions with special admissions policies may be needed to increase the participation of historically marginalised groups in science and technology-based education and employment.[55]

To be most cost-effective, specialised science schools must have valid and reliable means of selecting able students, attract well-qualified teachers, implement innovative curricula, employ effective teaching approaches, and include challenging and intellectually demanding assessment tasks. Such schools most also have enough teachers, laboratories, equipment, and students' and teachers' resource materials. Other arguments in favour of special schools, and their successful introduction at scale in England, are discussed later.

Physical science laboratories and science kits

Laboratory costs are often unnecessarily high, largely as a result of 'local preferences for standards of provision found in the best schools, and the availability of external finance for high-cost facilities'.[56] There is no convincing link between the costs of laboratory facilities and levels of achievement. As an alternative, Caillods *et al* advocate science rooms rather than science laboratories, fitted with basic amenities such as electricity and water, but not for every student, together with simple equipment. Such rooms cost as much to build as ordinary classrooms, with modest additional costs for suitable furniture. According to the authors, data from Botswana show that such science rooms can be provided as about one third of the cost of a fully equipped laboratory.

A number of developing countries have devised science kits for use at schools without laboratories, or whose science rooms or laboratories are poorly equipped or inadequately maintained. One of the challenges of kits is to reduce the imported component and expensive consumables in order to keep the costs down. Caillods *et al* say that, for the benefits of kits to be realised, several conditions need to be met, namely:[57]

- they need to be closely integrated with curricula;
- they must suit conditions in typical schools;
- teachers must be taught how to use them properly;
- practical examinations require appropriate material, in the form of a kit or otherwise;
- materials must be easy and cheap to replenish, and the kits easy and cheap to repair; and
- the use of the kits must be evaluated, in order to adapt them to changing demands.

The third and fourth points are particularly important. Often, teachers are not trained to use the kits at all, or are only trained when the kits arrive at their schools. Less well-qualified teachers and teachers who join schools after kits have been introduced need more training. Similarly, the replenishment and repair of kits are often neglected. A system is needed for replenishing consumables, and repairing or replacing broken equipment.

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THE SUPPLY AND DEVELOPMENT OF EDUCATORS

As noted earlier, planners have increasingly recognised that educators are central to any attempt to change educational systems. The key question then becomes how this potential should be maximised. This falls out into two issues: adequate supply, and professional development.

Supply

If good teachers are the *sine qua non* of effective education, then clearly the first element in any strategy for creating a sound maths and physical science education subsystem must be to recruit and retain good maths and physical science teachers.

The literature shows that there is a shortage of well-qualified maths and physical science teachers throughout the world, particularly in secondary schools. The Glenn report stated that the demand for qualified maths and physical science teachers in the United States was far outpacing the supply; it reported that in 1993–4 (the most recent data available when the report was written) 20 per cent of maths and physical science teacher were uncertified. Similarly, the British Institute of Physics reports:

> There is a crisis in the teaching of physics in schools. The critical shortage of physics teachers in schools and colleges is the greatest threat to the future supply of skilled scientists and engineers. Only those with confidence and competence can teach their subject well, engaging and enthusing pupils and motivating them to pursue careers in science and engineering. Teaching is not an attractive career option for physics graduates, and the number entering is at an all-time low.[58]

The decreasing number of entrants to maths and physical science teaching can be linked to a decline in teachers' status and salary relative to other professionals. Interestingly, this is not a problem in Japan, where teachers are paid almost as much as university lecturers, and earn more as they grow older. Furthermore, in Japan the number of children is decreasing as people live longer and young people opt to marry later and have fewer children. As a result, there is growing competition for places in pre-service teacher training programmes, which means that high-quality candidates can be selected.[59] Thus salary and status are not as problematic in Japan that they are in many western and developing countries, and there is no shortage of qualified teachers. If anything, there is an oversupply, even though the requirements for being a teacher are rigorous, especially at the secondary level, requiring not only a professional qualification in the subject(s) to be taught but also passing a battery of prefectural examinations.

In line with the principle of building on what is good in existing systems, the Glenn report recommends that exemplary programmes for teacher preparation should be identified, and ways found to multiply their success. Once they have been identified, the report proposes that incentives be provided to attract three groups of potential candidates:

- university graduates in maths and physical science who have either recently graduated or are in mid-career could be offered prestigious one-year fellowships leading to certification as teachers;
- university students could be offered student loans which will be written off if they commit themselves to teaching for five years in districts with a shortage of maths and physical science teachers; and
- a small number of senior high school students could be given full scholarships to study at one of the exemplary teacher education institutions.

All these incentives would require the students to commit themselves to teaching in districts with a shortage of maths and physical science teachers for a period of five years. The report also suggests that a new kind of teacher preparation programme is needed, based at mathematics and physical science teaching academies which would build on existing institutions, but bring them together into a new configuration. Each academy should comprise at least one higher education institution, neighbouring school districts, and business partners.

As regards the retention of good teachers, the report recommends an induction programme for new teachers, career paths that allow good teachers to advance without having to leave the classroom (for instance, having to become a principal or district manager simply to improve their incomes), and better salaries.

Interestingly, all the recommended measures already form part of the Japanese educational system. In Japan all teachers are required to participate in a formal induction programme during their first year of teaching. This typically consists of at least 60 days of in-school, mentor-based training and 30 days of out-of-school training, usually at a prefectural education centre. There is a widely held belief that

> ... early teaching practices and the school where beginning teachers first teach have a life-long impact on teachers' development. Given this assumption, the importance of the in-school or site-based mentor programme cannot be overemphasized.[60]

When a local board of education appoints a new teacher, it is also responsible for ensuring that the teacher concerned has a mentor in the school to which he/she has been assigned. Collinson and Ono spell out the mentor's role:

> Mentors have release time to work with beginning teachers. For example, they are released to observe the new teacher each week and to allow the beginning teacher time to observe in other teachers' classrooms. Mentoring takes various formats: lecture, exchange of ideas, reflection notes, interviews, individual coaching after observation of a lesson, examination of a lesson plan in a grade teachers meeting, participation in developing handouts for students, and planning a school activity as members of a school management committee meeting. Beginning teachers' daily reflections on their teaching are turned in to the head of the grade level on Saturday when teachers leave the school. All members of the team try to respond to the reflections with some comments.[61]

The British Institute of Physics suggests the following four strategies for addressing the shortage of physics teachers:

- Parliament should investigate the crisis in teaching and address the five major deterrents: pay, working conditions, status, workload, and technical resources in schools.
- The government should accept and respond to market forces that dictate differential salaries for teachers according to their subjects.
- The government should set targets for the proportion of physical science classes taught to learners aged 14—19 by specialised teachers, and collaborate with educational and scientific bodies on implementing policies designed to meet the new targets.

- University physics departments must forge closer links with schools and teachers, offering support, advice, and access to equipment, and must receive due credit for doing so. The Institute of Physics should support and encourage this.[62]

Thus the 11th key insight arising from the international research is that to improve the supply of quality educators in a specialised area of need – such as maths and physical science – a well-rounded special government programme that acknowledges the professional needs of teachers in the specific area of need is required. This commitment must bringing various elements or aspects of reform together in such a way that the professional outcomes for these educators is greater than the simple sum of the inputs.

Professional development

Besides ensuring an adequate supply of talented teachers, educational experts also increasingly believe that they need special training. In its report entitled *Before it's too late* (2000), the National Commission on Mathematics and Science Teaching for the 21st Century in the United States, chaired by the former astronaut John Glenn, makes the point that teachers cannot effectively play their role as change agents in improving maths and physical science education without continuing development. The report argues that:

> If high-quality teaching is the leverage point for improving mathematics and science education, and if professional development is a prerequisite for a well-qualified and effective teaching force, then teachers need a focused support system and enough time to grow as professionals. ... Many people erroneously believe that teachers are not working unless they are standing in front of a classroom. In fact, preparation time and individual study time, as well as time for peer contact and joint lesson planning, are vital sources of both competence and nourishment for all teachers.[63]

While the elements referred to in the last sentence do not typically form part of the experience of American teachers, they do – once again – form part of the experience of teachers in Japan. In the latter country, collaboration among teachers is the norm. In particular, Japanese teachers regularly engage in 'lesson studies'[64] or 'research lessons'[65] in which one teacher presents a lesson, and several others attend. After the lesson, the teacher who presented and his or her colleagues discuss the lesson, the good and bad points, what did and did not go according to plan, and what could be improved. In this way, teachers are involved in a process of continuous development, in line with the broader Japanese concept of *kaizen*, or 'continuous improvement'. In addition, each prefecture has a teacher development centre, and Japanese teachers are required to participate in formal development programmes during their first year of teaching, and again after five, ten, and 20 years of teaching. Exemplary teachers are seconded to teacher centres. Prefectures also offer a variety of voluntary development programmes, often at little or no expense to the teachers. Furthermore, a limited number of teachers can apply for paid leave in order to undergo advanced training at universities that will equip them to become teacher consultants.[66]

The spirit of the recommendations of the Glenn report is consonant with the Japanese model of professional development. In the Glenn report, professional development means:

> a collaborative, educational process of continuous improvement for teachers that helps them to do five things: (1) deepen their knowledge of the subject(s) they are teaching; (2) sharpen their teaching skills in the classroom; (3) keep up with developments in their fields, and in education generally; (4) generate and contribute new knowledge to the profession; and (5) increase their ability to monitor students' work, so they can provide constructive feedback to students and appropriately redirect their own teaching.[67]

In the literature, traditional in-service programmes for teachers are often criticised as being too superficial and short-term. Kahle, for example, describes the usual forms of teacher development as 'a mile wide and an inch deep'.[68] These programmes typically follow a particular training paradigm of short-term, standardised sessions designed to impart discrete skills and/or techniques. However, such short-term, finite programmes (popularly described as 'make-and-take' or 'spray-and-pray' workshops) do not improve teachers' content knowledge, change teaching practices, or improve performance by students. Regrettably, these observations apply to many of the teacher development initiatives funded by the South African private sector.

A growing body of evidence now exists about what type of professional development does improve both learning and teaching. For example, if teachers' content knowledge is improved, they do change their teaching practices. Therefore, professional development experiences that enhance teachers' knowledge of their subjects and expand their range of teaching practices are likely to improve the achievement of their students. Besides this, reformers have learnt that professional development will only be effective if it is undertaken over a relatively long period. By contrast, time spent in short workshops on special topics or issues do not result in changed practices.

Kahle recommends that development experiences for physical science and maths teachers should:

- be sustained, content-based, and use new teaching methods;
- provide for follow-up experiences so that teachers have opportunities to test, discuss, and analyse new teaching strategies;
- include leadership opportunities, and model strategies that teachers will use with their students;
- provide time for teachers to reflect on and practice what has been learnt;
- provide incentives (such as graduate credits) and be tied to career goals, including differential staffing and teacher career ladders; and
- be accountable, including research to assess changes in teaching practices and student learning.

Box 7.6 contains a set of guidelines for the development of maths and physical science teachers, based on experience gained in the course of the Discovery programme.

BOX 7.6: DISCOVERY'S GUIDELINES FOR TEACHER DEVELOPMENT

Content focus

Enhancement of content knowledge

Professional development experiences should focus on enhancing teachers' knowledge of physical science and mathematics. The content recommended is found in Ohio's Model Curricula, and in the standards of the National Council of Teachers of Mathematics and the National Research Council.

Standards-based curricula

Standards-based physical science and mathematics curricula should form the basis of teacher development. (See OSI-Discovery's website for links to reviews of K-12 curricula.)

Link to curriculum

Professional development experiences should be linked to implementing local curricular frameworks that are aligned with state and national standards in order to improve the teaching of physical science and mathematics.

Enquiry and problem-solving

Modelling of enquiry

Professional development activities should model instructional strategies, such as enquiry, problem-solving, and co-operative grouping that teachers will use with their students. Opportunities to reflect upon and connect with other teachers' experiences as part of learning communities are recommended.

In-depth coverage

Professional development experiences should emphasise the need to challenge students to construct in-depth understandings of core concepts. They should be designed around the research concerning effective learning and teaching.

Assessment of experiences

Assessment should be integrated into the professional development experience. Assessment should include documenting changes in teaching practice and in student learning.

Sustained experiences

Substantive experiences

Professional development experiences need to be sustained over a period of several weeks with significant contact hours (a minimum of 40 hours is recommended). These experiences may include visits to other teachers' classrooms and should always include follow-up activities such as school-based seminars and/or reflection groups.

Tailored to teachers

Professional development experiences should connect with the professional responsibilities of teachers and be tailored to their level of knowledge, skills, and needs. Choices about the design and content of professional development should draw upon teachers' expertise and knowledge.

> *Internships*
>
> When appropriate, professional development experiences may include internships in business, industry, or research laboratories that will enhance teachers' understanding of mathematical and scientific applications.
>
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Besides the National Science Education Standards referred to earlier, the National Research Council (NRC) in the United States has produced a complementary set of standards for the professional development of physical science teachers.[69] Like the Glenn report, the NRC views professional development as a continuous process:

> Professional development for teachers should be analogous to professional development for other professionals. Becoming an effective science teacher is a continuous process that stretches from pre-service experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability. Teachers also must have opportunities to develop understanding of how students with diverse interests, abilities, and experiences make sense of scientific ideas and what a teacher does to support and guide all students. And teachers require the opportunity to study and engage in research on science teaching and learning, and to share with colleagues what they have learnt.[70]

Another important aspect of professional development is that it must provide teachers with the opportunity to experience good maths and physical science teaching practices for themselves; ie, professional development programmes must model sound teaching approaches. For instance, teachers cannot be expected to implement enquiry approaches to teaching if all they themselves have ever experienced is lecture-based teaching.

The NRC standards summarise these aspects of professional development as 'learning science, learning to teach physical science, and learning to learn'.[71]

INCENTIVES FOR EDUCATORS

Internationally, increasing attention has been focused on using incentives as a means of recruiting and retaining adequately educated and trained educators. Incentives have largely emerged as a practical response to the widespread shortage of maths and physical science educators. However, the case for educator incentives needs to be made more comprehensively, so that the gains South Africa can reap by applying the lessons learned elsewhere are not foregone.

Incentives and employment

Incentives are a major feature of the modern workplace. Conditions of service, contracts, and agreements commonly contain provisions aimed at motivating employees to achieve higher levels of performance, or achieve other goals. These arrangements are so pervasive that one commentator has stated: 'Incentives are the essence of economics.'[72] This is because there is seldom a perfect alignment between the self-interest of buyers or employers on the one hand, and the self-interest of sellers or employees on the other. Incentives are offered to bridge the gap between the two sets of interests.

Box 7.7: The theoretical basis of incentives

There are four main theories about incentives. The first is agency theory, which explains the behavioural basis of incentives. In the language of this theory, an individual agrees to carry out certain activities as an agent of an organisation or institution, and is offered appropriate incentives to do this. Educators are 'agents' of the education system, in the same way that miners or managers or secretaries are 'agents' of specific companies, or officials in a state bureaucracy of the government. As agents, all employees, including educators, accept and operate within an incentive system.

The second is contingency theory, which focuses on the goals to be achieved through incentives:

'Contingency theory postulates that compensation and incentive programs work when they fit well with the basic strategies and characteristics of the large organisation, including, more specifically, its human resources practices. The more closely the design elements of the incentive plan match the key strategies and overall vision of the organisation, the more effective the incentive plan is at motivating employees and increasing productivity.'73

Most importantly, contingency theory cautions against any ad hoc use of incentives that may lead to patterns of behaviour that are short term and self-seeking, rather than to patterns that benefit the longer- term, positive goals of the organisation.

The third is expectancy theory, which explains why some incentives succeed and others fail. It focuses on the elements of incentives that appeal to specific sets of employees:

'Expectancy theory postulates that people will respond favourably to an incentive program if three conditions are met … First, people must believe that they can accomplish the goal embodied in the incentive plan and that doing so is substantially within their control; that is, successful goal accomplishment must be seen as realistic, and workers must believe they have the ability, skills, competencies and authorities to accomplish the task being rewarded. This is called expectancy. Second, employees must perceive a connection between their individual effort and receipt of a reward. This is called line of sight. Third, employees must value the reward itself enough to put forth the effort to achieve it. This is called valence. Expectancy (theory) includes having sufficient resources (time, energy, peer support) to achieve higher performance – that is, workers having sufficient control over their work environment to mobilise their efforts towards goal attainment.'74

The fourth is participative management theory. This 'suggests that if employees, particularly highly educated employees, have a voice in important decisions on both organisational objectives and job-specific duties, they are more likely to be motivated to work, and to be committed to the organisation'. 75 For the purposes of this study this is the most important kind of incentive, as it harmonises with the participative change model described in chapter 2 and in this chapter.

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The implementation of incentives

Our research shows that a sound theoretical basis exists for using incentives to improve the supply, recruitment, development, and retention of maths and physical science educators. However, research also cautions that much depends on implementation. Five issues are at stake:

Firstly, we have to take into account the vexed issue of **differential incentives –** ie, offering more pay or other rewards to people in certain categories, with certain skills, or with certain qualifications. This is especially problematic in the education profession, which has traditionally related individual rewards almost exclusively to formal qualifications and length of service. Also, whatever differential incentives do exist have invariably been attached to positions rather than persons. Thus a principal is always paid more than a head of department, but an excellent principal with a short period of service is paid less than an average principal with long service.

However sophisticated the package, differential incentives will always mean that some educators will receive greater rewards than others for educating the same learners for the same period of time.

Second, we have to take account of the differences between **intrinsic and extrinsic incentives**: that is, incentives that satisfy the inner sense of achievement and worth of the educator on the one hand, and those that provide concrete rewards such as money or material advancement on the other.

Third, we have to take into account the **appropriateness** of incentives during different stages in an educator's career, from potential educators still attending high school to those approaching retirement.

Fourth, we have to consider any incentives to educators in the context of the broader education system, so as to ensure that incentives do not create **unintended consequences** or stimulate actions by recipients that are inconsistent with the aims of the system as a whole.

And, fifth, we have to consider the criteria that will determine **eligibility** for any incentives introduced into the existing system. The main concern here is that educators will focus specifically on satisfying the criteria rather than improving their knowledge or broadening their skills in the desired manner.

Differential incentives

This is the most controversial aspect of incentives for educators in South Africa. It is dealt with at length in the international research. Differential incentives are controversial since they are often added to an existing system of incentives to attract or retain a particular group of employees, and usually result in at least temporary additional benefits to some. The outcomes are regarded as 'unfair', or as raising the status of one discipline over others. This outcome has been resisted (at least initially) by all the organised associations representing educators in all the countries surveyed. In many cases, however, a perception of the greater good to be achieved has diminished this opposition, or converted it into tacit acceptance and even open support. For instance, educator unions in countries that offer incentives to educators to relocate to rural schools have come to realise that this approach makes it less likely that unwilling educators will simply be assigned to rural schools, and reduces pressures on the whole educator force to behave in a ‘patriotic’ way and accept a stint at a rural school.

According to the literature, differential incentives have been opposed for three main reasons. The first is a general one, and may be described as an issue of ‘solidarity’. Educator representatives maintain (with some validity internationally, but not in South Africa, as Crouch has shown[76]) that educators are already undervalued and underpaid. Therefore, they argue, the struggle should be aimed at increasing remuneration for all educators. They argue (or at least claim) that the struggle is diluted and solidarity undermined if certain categories of educators are differentially rewarded.

The second relates to differential incentives based on performance, such as merit pay. A typical response is the following:

> New York mayor Rudolph Giuliani proposed an individual merit pay program [in 2000], drawing the ire of United Federation of Teachers / New York president Randi Weingarten. She says Giuliani's plan would worsen potential teacher shortages. ‘Classrooms aren't factories, and teachers don't do piecework’, she says. ‘To do their work well, educators need to collaborate – not compete – with their colleagues.’ [77]

Educators argue (with some validity) that there is no objective method of assessing the performance of educators. Still less can educator performance be linked to learner performance, as so many variables can intervene between the educator's contact with the learner and the assessment of the learner's knowledge and skills in the examination. As a result, they argue, incentives based on merit or performance are awarded on a subjective basis, are often unfair, and may even be used by superiors to build networks of educators who are beholden to them, and punish other educators they do not like.

The third reason for opposing differential incentives is related to the ‘market scarcity’ argument in favour, which goes as follows: from time to time, employers look for more graduates in particular fields than others. Increased demand drives up levels of remuneration, and creates scarcity. At present the market scarcity is in maths, physical science, and technology. Therefore, educators with these qualifications must be paid more than others to ensure that the education system gets at least a reasonable share of the available talent. Against this, educator representatives argue (with some validity) that this form of differential incentive implies that some subjects are intrinsically more valuable than others. As one writer puts it: ‘After all, who is to say that teaching physical science and mathematics is more important than teaching history, English, or a foreign language?’[78] Moreover, different sets of knowledge and skills become scarce at different times, and it will be difficult to remove the incentives of some educators and give them to others.

Each of these arguments is partly valid. Nevertheless, on balance, opposition to incentives derives from an outdated conception of work and motivation. The private sector demonstrates that differential incentives are perfectly consistent with superior personal performance *and* effective teamwork, and evidence exists that reasonable incentives can be effective in the public sector as well. Competition for incentives does not seem to diminish people's capacity for collaboration in order to get a job done. There is little reason to doubt that appropriate competitive incentives would work in the education system. Conversely, uniform incentives are likely to lead to uniform performance at the level of the lowest common denominator.

Almost all analysts agree that incentives are essential for improving the supply and performance of maths and physical science educators, and that the concerns of educator representatives should be regarded as practical hurdles to be overcome in the course of implementation. However, even at this level they still constitute a major negative dynamic in many countries. In others, agreements have been reached which offer South Africa a number of valuable lessons.

Intrinsic and extrinsic incentives

Other aspects of incentives are much easier to understand, and generally more acceptable. Intrinsic incentives are those that meet the intangible or internal needs of an individual educator. Extrinsic incentives are those that offer external and material rewards for changed educator behaviour. Each will be appropriate under different circumstances.

The appropriateness of incentives

There is a less substantial research base for determining the appropriateness of incentives offered to particular educators at particular points in their careers in particular education systems. However, it has proved to be quite feasible to design a comprehensive system of incentives for specific groups of educators that include appropriate types of incentives at different stages of their careers.

System considerations

Incentives also need to be located within a given system of education. Here the classic conflict between the centralisation and decentralisation of education systems emerges once again; while the centre may supply the financial resources, and formulate guidelines, the system would have to be administered and monitored at the school level, which could create innumerable problems. The issue is analysed in detail in a background research report, resulting in the conclusion that creating incentives for educators poses one of the most difficult of all educational reform challenges. In South Africa, the report suggests, this would require a sophisticated advocacy and negotiation programme, pilot or trial programmes in selected areas, and a phased national introduction after assessment of the trials. Again, this task is quite possible once in-principle support for an incentive system has been acknowledged.[79]

Possible criteria

According to the research, possible incentives range from easily quantifiable factors to more problematic qualitative ones (the example of measuring classroom performance has already been discussed). At this stage, therefore, attention should initially be focused on incentives that can be objectively verified (for example, whether educators' content knowledge has improved). It would be premature to link an educator incentive programme to learner performance in maths and physical science.

In all of this, the attitude of the educator unions is crucial. The literature shows that these bodies may initially resist differential incentives as a matter of principle. Major resources will have to be committed to programmes aimed at persuading educator representatives to appreciate the logic of national need, personal educator development, and systemic reform associated with the introduction of incentives. Both the state and the private sector will need to invest in advocacy programmes aimed at persuading unions to adopt more flexible approaches.

Findings

The background research report concludes that well-focused educator incentives, offered by the South African government and the private, should be a crucial component of reforming the maths and physical science education system in this country.

It may be most sensible to focus initially on limited targets. The most obvious would be to:

- provide financial support to learners at schools with the potential to meet the academic requirements of formal teacher training courses in higher education;
- provide bursaries for school leavers to become maths and physical science educators;
- provide graduate maths and physical science graduates with incentives to actually start teaching;
- provide beginner teachers with further incentives to teach for at least five years; and
- provide maths and physical science educators with bursaries for further study throughout their careers.

Such a programme should have clear goals, and its components should be accurately costed and evaluated; the results could then feed into the design of more substantial interventions. It is also vital to work with the large number of existing teachers who are in the system but not sufficiently skilled or knowledgeable, and to keep those teachers who are skilled in the system by providing career paths that do not take teachers away from teaching. A study by the Centre for the Improvement of Mathematics, Science and Technology Education of the University of South Africa (UNISA)[80] has shown that there is a sharp drop in the number of maths and physical science teachers after age 40. For such a educator incentive system to work efficiently, the returns to individuals choosing to participate must be linked to an appropriate and fair system of assessment. As noted above, these would initially be more easily quantifiable outcomes; over time a more qualitative, performance-linked assessment system would be more appropriate.

To summarise, incentives for educators are a contested initiative. Worldwide, more theoretical justifications exist than actual successful programmes. However, incentive programmes for maths and physical science educators do offer a concrete means of attracting and retaining suitably qualified educators in these key subjects.

THE POTENTIAL OF SPECIAL SCHOOLS FOR MATHS AND PHYSICAL SCIENCE

Another strategy adopted in some countries to boost maths and physical science education has been to create a subset of schools that specialise in teaching these subjects. It is important to recall our earlier discussion of the cost–benefits of special schools in developing countries. In this section, however, we attempt to gain a fuller understanding of the complex set of relationships implied by the concept of special schools. In order to do so, this section largely deals with the English model, but also refers to the Malaysian and Nigerian systems. Dealing with this broader spectrum is important, because some analysts with an incomplete knowledge of special schools initiatives have alleged that special schools are inherently elitist, and an expression of favouritism. It is also important because it points the way to beneficial changes that could be made to the Dinaledi project.

The starting point is the obvious fact that in any reasonably developed society it is both necessary and advantageous to allow a degree of specialisation at the higher levels of the schooling system. Behind this notion lies an understanding that educated people have varied attributes and aptitudes, and that it is in the interests of individuals and society that this variety is acknowledged and developed.

Clearly, response to individual needs should not be at the expense of all commonality of interest and purpose. But in many education systems the pursuit of uniform school systems has gone too far. Regrettably, these systems have emphasised the value of commonality over that of diversity. This is understandable when the society in question faces grave backlogs in providing even basic education. But once that problem has been overcome – which has largely happened in South Africa – attention has to be paid to developing special individual abilities.

The development of higher-order aptitudes and abilities requires levels of expertise and individual attention to learners that have not yet been developed in our education system. Educators who are struggling with classes of 50 learners can hardly be expected to cope with the demands of a few learners who have highly developed aptitudes and preferences. Specific arrangements have to be made to make this possible.

The third starting point for understanding special schools is the realisation that modern societies and economies rely on highly educated and specialised individuals. Accordingly, there is a huge demand for school-leavers with maths and physical science. Once again, the implication is that the education system has to make a special effort to identify, educate, develop, and use people with specific abilities.

Special schools in developing countries

Research shows that physical science is one of the most expensive subjects to teach at secondary schools. It follows that if (as is the case in many developing countries) access to high-quality facilities cannot be provided to all learners, some specialisation and selection need to occur if optimum outputs are to be achieved.

Given this, numerous developed and developing countries have elected to create special science schools; Malaysia and Nigeria are two examples in the latter category that are particularly relevant to South Africa. Among the arguments in favour of this approach is that special institutions with special admissions policies are needed to increase the participation of historically marginalised groups in science-based education and employment.

According to Caillods *et al,* [81] the results in Malaysia and Nigeria have largely been positive. In Malaysia a range of schools have been established for previously marginalised groups, (ie ethnic Malays and other indigenous people), and rural communities. The participation and achievement of the targeted groups have improved substantially.

In Nigeria the rationale for special science schools has been the almost universal inadequacy of resources and facilities, which has led to a concentration of resources at particular schools with a record of excellence. An often-quoted example is that of Kano State, whose special science schools have attracted some of the best physical science teachers from other secondary schools. This has reduced the chance of physical science being effectively taught at regular schools; however, the facilities and track records of outlying schools were so modest (or non-existent) that even excellent teachers were extremely constrained in what they could achieve, and were unlikely to remain in the profession for long.

In both countries, the number of physical science graduates from previously disadvantaged groups has increased substantially. In Nigeria, the output of science-school graduates has increased to such an extent that there are now enough physical science graduates to fill many previously vacant science-based posts.

Britain's specialist schools

Special schools have also been introduced in highly developed countries – notably in England. In terms of a system regulated by the national department of education, state schools may specialise in one of the following areas: technology; maths and physical science; modern languages; physical education and sport; and performance, visual, and media arts.

The Specialist Schools Programme has become increasingly popular and successful since its inception in 1994. In September 2002 there were 992 specialist schools, comprising 443 technology colleges, four engineering colleges, 12 maths and computing colleges, 24 science colleges, 157 language colleges, 173 arts colleges, and 161 sports colleges. They are located under 150 local education authorities in both urban and rural areas. In 2003 there were 1 686 specialist schools, representing 54 per cent of all secondary schools and teaching more than 1,5 million pupils – half of all pupils attending secondary schools.[82]

According to our background research report, specialist schools strive to:

- diversify the educational opportunities in a particular area;

- develop the specific aptitudes of individual pupils without abandoning a basic curriculum shared by all;
- extend the range of opportunities available to pupils which best meet their needs and interests;
- raise standards of teaching and learning in the subjects in question;
- raise standards of achievement for all their pupils of all abilities;
- develop characteristics which signal their changed identity, and which reflect the school's aims;
- benefit other schools and the wider community in the area; and
- strengthen the links between schools and private and charitable sponsors.

The vision of schools specialising in technology, maths and physical science (confusingly also known as 'technology colleges') has been defined as follows:

> Technology colleges will raise standards of achievement in technology, science and mathematics for all students across the ability range, leading to whole school improvement in performance. They will be active partners in a learning society with their local families of schools and their communities, sharing resources and developing and sharing good practice. Colleges will promote an educational culture which is scientific, technological, enterprising and vocational. They will raise the post-16 participation rate in the specialist subject area, and provide young people with the skills needed to progress into employment, further training or higher education according to their individual abilities, aptitudes and ambitions.[83]

The programme is entirely voluntary. Specialist schools are not designated by the national department or local education authorities; instead, individual schools apply to an independent authority (one for each area of specialisation) for designation. Only about half succeed.

Only state schools may participate in the programme. They retain their existing legal status (maintained, community, foundation, etc) and add a new identity by virtue of the specialisation.

Applications have to meet certain criteria laid down by the national department. They should show good or steadily improving results in the subject concerned. However, there is a 'fresh start' category for schools producing poor results which believe that becoming a specialised school will help them to improve. There is even provision for very weak schools participating in the Education Action Zone programme to apply as part of working their way out of this category. The finances of applicants should be sound, and they should demonstrate an ability to raise private funds. Applicants also have to present a four-year development plan containing specific targets and performance indicators against which success can be judged.

The focus is exclusively on 14–16 year olds – that is, the upper end of the British school system. Schools that wish to involve learners outside this age range cannot do so themselves, but can enter into partnerships with schools catering for younger or older learners.

Successful applicants receive a once-off capital grant and additional funding over three years. Schools that achieve their targets, or make good progress, may apply for support for further three-year periods. When doing so, they have to submit a fresh development plan, and new targets. The national department monitors progress made by all designated schools.

Specialist schools are expected to assist non-specialised schools in their area, and to allow the surrounding community to use their facilities. According to a report entitled *Educational outcomes of specialist schools for the year 1999,* published by the Technology Colleges Trust, half of all specialist schools are located in the 100 most deprived areas of the country.

The research on specialist schools shows that:

- This is not primarily a middle-class programme. The department for education and employment maintains a register of needy schools, known as the Additional Educational Needs Index, which operates on a scale of 0–3, from absolutely needy (by British standards) to marginally needy. The vast majority of specialist schools are rated between 0,5 and 1, 5 (that is, from very needy to quite needy).
- The proportion of minority ethnic groups in 327 specialist schools evaluated is broadly similar to the national average in all schools.
- Some 29 per cent of learners at specialist schools receive free school lunches (a proxy for the lowest socio-economic class of learners), compared with only 18 per cent in all secondary schools.
- Attendance at specialist schools is better than the national mean. At 80 per cent of the specialist schools, attendance rose over the first three years. Half of the remaining schools already had high attendance figures, and maintained these. Attendance at the rest was at least equal to the national average.
- A study by Jesson shows that specialist schools that do not select learners perform better and add more value to education than standard non-selective secondary schools, especially in poorer areas: '… many [specialist schools] are sited in inner city areas and other areas of relative or absolute social disadvantage. The success of these schools, sometimes described as 'against the odds', is very encouraging, and offers 'signs of hope' for other schools similarly placed.'[84]

In summary, specialist schools in England have succeeded in providing the specialised learning and teaching required by learners with special aptitudes and expecting to follow careers in maths and physical science, including teaching, without losing a local geographical base, a broad choice of subjects at school-leaving level, and responsiveness to deprived groups. We believe this programme holds important lessons for educational reform in South Africa.

THE DEMAND SIDE OF EDUCATION

Historical reviews of the provision of education in Western Europe and North America reveal three broad phases. The first was an extremely long period, from time immemorial to the mid-19th century, during which the provision of education was driven by demand from individuals. The demand was met by private supply; individual learners found individual teachers. If enough learners were looking for a particular teacher, classes were formed and institutions – initially churches, and then secular, voluntary bodies – came into existence to organise both learners and teachers. Both religious and secular bodies became the forerunners of all higher education institutions.

During the second phase, starting in about 1850, the provision of education began to move into a supply-side mode; notably, the state began to supply education to learners on an unprecedented scale. Learners initially responded voluntarily, but as ‘universal’ provision became dominant, increasing degrees of persuasion were applied to ensure that learners took up the supply on offer. Compulsory schooling gradually became the norm, and by the late 20th century virtually every country in the world compelled all learners under a certain age to consume the education supplied.

The consequences were predictable. Provision for large numbers of learners favoured a mass production approach to teaching. Huge education organisations became more concerned with the interests of employees (officials and teachers) than those of learners. Attendance became unappealing. Offerings were often irrelevant to learners’ needs. And the education system always changed more slowly than the society it was supposed to prepare the learners for. The whole emphasis shifted from attracting learners to compelling them to attend, and policing non-attendance.

Increasingly, the late 20th and early 21st centuries have seen a retreat from the total domination of compulsory state education. However, the state system has remained powerful, and there is no immediate prospect of a reversal of its dynamics. Rather, change is being achieved through various smaller opportunities.

Throughout these developments, private schooling has remained available in most countries. The existence of ‘free’ state systems inevitably drove private education upmarket, but it never disappeared. Now, around the world, it is making a comeback, and it is no longer the more expensive option.

Private education – not just for the rich

There is a widely held view that privately provided education is both inherently superior and significantly more expensive than that provided by the state. It is also common currency that private education is elitist, and enhances greater social and economic inequality. However, research undertaken for this study seems to refute this. Two factors were examined: the variety and scope of private education, and the number of learners and scale of expenditure on private education globally, particularly in the developing world. Many think of private education (particularly in developing countries) in terms of high quality and expensive private schools catering predominantly for the children of the elite.

The real picture is rather different. As Tooley writes: 'Unnoticed and not applauded in the media, not initiated by governments nor international development agencies, there are important developments taking place in private education in developing countries.'[85]

In many developing countries, educational entrepreneurs are able to satisfy demand by creating educational opportunities that are profitable, totally (or almost totally) financed from students' fees, and charge comparatively modest fees, making them accessible to many socio-economic groups, not just the elite.

These entrepreneurs have created education companies running 'chains' of schools, colleges, and universities, sometimes on a franchise basis. Benefiting from economies of scale, investment in research and development, and strict quality control, consumers are provided with the 'informational benefits' of brand names. According to Tooley, such benefits significantly reduce consumer risk when investing in a private education company's product – a factor especially important for poor and disadvantaged customers.[86] These big education companies are active in Zimbabwe (Speciss College), South Africa (Educor), India (NIIT), Peru (TECSUP), and Brazil (COC, Objetivo/UNIP, Pitágoras, and Radial Brazil).

Our survey shows that the private education market is booming in all the countries surveyed, namely Argentina, Brazil, Colombia, India, Indonesia, Peru, Romania, Russia, South Africa, Thailand, Turkey, the United States, and Zimbabwe. The sector offers a range of products at every level, ranging from degree courses in Argentina down to primary school maths education in Brazil.

While no overall figure was calculated, spending on private education is clearly high, based on the enrolment figures below. Attendance figures are astounding: no less than 54 per cent of learners at secondary schools in Indonesia are studying at private schools. Other figures are: India, 42 per cent; Colombia, 40 per cent; Argentina, 30 per cent; and Cote d'Ivoire, 27 per cent.[87] In South Africa, it is 2 per cent.

These figures show conclusively that parents in many countries, including some of the world's poorest, are willing and able to send their children to private schools, and that private schools can cater for a mass market. South Africa is no exception to this widespread process though overall numbers are low by international standards (see box 7.8). Finally, schools have emerged that are publicly funded but privately managed, as exemplified by the 'charter schools' in the United States.

BOX 7.8: MATHS AND SCIENCE DEVELOPMENT PROJECTS IN INDEPENDENT SCHOOLS

The independent schools sector has changed dramatically since 1990, according to a study conducted by the Human Sciences Research Council (HSRC) in 2002—3. Far from being 'white, affluent, and exclusive' (the dominant public perception), 58 per cent of learners in independent schools are now black, and most schools charge less than R6 000 a year. The sector has also grown rapidly, from about 550 schools in 1990 to 1 800 in 2002. Enrolment has also increased to 3,2 per cent of the total schoolgoing population.

Most importantly, the HSRC study also showed that the grade 12 pass rate was higher at independent than public schools, with a notably higher number of university exemptions (37,5 per cent versus 15,1 per cent). The average pass rate in mathematics and science was also higher at independent schools (62,7 per cent versus 58,4 per cent), and proportionately more learners, including black learners, in the sector wrote these subjects at HG level.

This finding highlights the important contribution that independent schools can make to increasing the pool of maths and science matriculants in the country. As a first step in this direction, the Independent Schools Association of Southern Africa (ISASA) has established a Maths and Science Partnership Project at the FET level, to address the shortage of African maths and science matriculants in particular.

Grade 10 African learners with maths and science potential are identified, and placed in independent schools. Private donors provide a portion of the funding, and schools absorb the balance. The goal is for as many of these learners as possible to matriculate with good passes in HG maths and science.

This component of the project has been piloted at low- and high-fee independent schools, and has achieved impressive results. At Sekolo Sa Borokgo, a low-fee school in Johannesburg, 25 children from mainly disadvantaged educational backgrounds in townships and informal settlements were placed on an intensive bridging programme in all subjects but with a particular emphasis on maths, science, and English. In the 2003 SC examination, 16 out of 17 passed HG maths, 12 out of 13 passed HG science and all 25 passed English as a first language. Nineteen out of 25 qualified for university entrance, and the group achieved seven distinctions, including three for maths.

High-fee schools are also participating. Durban Girls' College is concentrating on developing the maths and science skills of black girls. Kearsney College in KwaZulu-Natal is achieving very good results with black pupils originally from farm schools. Diocesan College (Bishops) in Cape Town has recently established a 'School of Excellence', a maths and science programme aimed at township learners in Cape Town, with the support of the Western Cape department of education.

The second component of the project involves partnerships between well-resourced independent schools and less-resourced schools (independent and public) in the same geographic area. The well-resourced schools undertake, over time, to help improve the quality of teaching and learning at the partner schools.

Many ISASA-affiliated schools have already implemented programmes of this kind. Penryn College in Nelspruit operates the very successful Penreach project that involves tens of thousands of learners, and includes a significant maths and science component. Other independent school associations, notably the Catholic Institute for Education, have implemented their own development partnerships.

The third component of training and retraining African teachers in these subjects has been tackled through learnerships in independent schools. Other initiatives are being explored to increase competence in practice of qualified black teachers through a mentored year in independent schools.

Significantly, the strategies adopted by ISASA schools to address the maths and science crisis are in keeping with the recommendations of this report. While the ISASA project was always envisaged as a joint endeavour among schools, business, and government, provincial education departments have been slow to participate, as have corporations. It seems a great pity that the valuable expertise, resources, and commitment of independent schools are not being harnessed more effectively.

CDE 2004

Charter schools

In South Africa it is commonly assumed that parents face two basic choices: they can send their children to a regular state school, or (if they can afford it) they can send them to a private school where they will get a better education.

In the United States, the charter school movement has drawn a line through this bipolar model. The central idea behind this movement is to expand parental choice to schools that are privately managed, but benefit from state financial support. In the 1990s many states adopted laws enabling the establishment of 'charter schools', and they now exist across two thirds of the United States.

Under this system, private organisations enter into agreements (charters) with state education authorities to provide education of an acceptable quality on their behalf. Whatever the state would have spent on learners at public schools are now paid to the charter school.

The charters serve three functions:

- they allow the managers of charter schools to gain clarity about their mission, and how they will carry them out;
- they allow state governments to hold charter schools accountable for their actions in educating citizens; and
- they serve as barriers to arbitrary, officious, or untimely interference by the state in the operation of the charter schools.

Charter schools are controversial, largely because views about them are generally divided along party-political lines. Significantly, however, they are highly popular among black and Latino communities in inner cities, which feel that state schools are failing them.

Education vouchers

Education vouchers are a relatively recent innovation also aimed at erasing the distinction between public and private schooling.[88] In the United States the object is improved educational outcomes, especially among disadvantaged, mainly 'inner-city', minority neighbourhoods. Under these programmes, state agencies provide parents with vouchers worth the full value of state expenditure on an individual learner, which they can redeem at any state of private school of their choice. Clearly, this gives parents a spectrum of choices that cut across the traditional public–private divide.

Proponents of this system have been encouraged by the successful use of vouchers in the course of other public welfare programmes, including housing, child care, and food relief initiatives. The reasons for the success of voucher programmes are practical rather than ideological. Vouchers give poorer people an opportunity to make decisions based on personal preference rather than the ideology of public agencies. This enhances personal responsibility, and improves the efficiency of the public agencies involved. Vouchers also encourage the emergence of new kinds of service providers which are more closely attuned to the needs of poorer clients.

BOX 7.9: USING SCHOOL VOUCHERS TO GIVE POORER PEOPLE A BROADER CHOICE

Ideally, all private, religious, and specialist schools should be so heavily subsidised that they are able to accept even the poorest children. But this is not practical, even in the United States. What can be done, however, is to start school voucher programmes that will give at least some poorer parents a broader choice of schools for their children.

A voucher is simply a certificate that can be used instead of money to pay for particular goods or services. Food vouchers, for example, can only be used to buy food. Some believe they are preferable to ordinary money grants as an instrument of poverty relief because they can only be used to buy food and not, say, alcohol or tobacco. Similarly, a school voucher is a form of government grant that can only be used to pay for schooling provided by approved schools.

Vouchers are an attractive instrument for reformers frustrated by the slow pace of improvement in American public schools, despite massive increases in funding. While they are still being run on a relatively small scale, school voucher programmes in that country have already shown encouraging results: in the 1999-2000 school year, nearly 50 000 students participated in 68 privately funded voucher programmes, and another 12 000 or more in three publicly funded ones.

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Findings

The charter school and educational voucher movements are attempts to stimulate the demand side of education. This contrasts with the exclusively supply-side approach of public schooling systems. These movements have many positive features. They are more in accord with modern social thought that favours demand-driven systems. They empower parents, learners, and individual schools. They are also more responsive to local needs, and make state resources go further.

However, South African schooling remains trapped in the second historical phase. More than 95 per cent of all learners attend public schools in their neighbourhoods, regardless of their own aptitudes or the wishes of their parents. This remains the case despite a long-standing tradition of private schools in this country, and the recent emergence of other schooling options.

Our review of international research shows clearly that stimulating demand factors – and introducing more flexible supply – have a vital role to play in improving maths and physical science education.

SUMMARY AND CONCLUSIONS

The 13 observations listed above are all based on extensive research. There are examples of successful implementation of every proposal in many countries. They help us to identify the main drivers of successful systemic change, and specific components of this change that can be implemented in South Africa without overambitious planning.

Crucially, they confirm our finding that, rather than attempting to change the entire system at once, we need to improve parts of it in ways that will show relatively quick results, and will produce the outputs required to improve the rest of the system over time. In the words of Michael Fullan, we are in the phase in which we 'need capacity to build capacity'.[89] We need more HG maths and physical science matriculants to provide more competent (preferably graduate) teachers, before we can build more capacity into the system as a whole.

Thus the key lesson confirmed by the international literature is that we need to improve the existing system in an incremental way, using the gains we make as the basis for more advances. In due course we can improve the subsystem of maths and physical science education as a whole.

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Chapter 8

CONCLUSIONS FROM THE RESEARCH, AND THEIR IMPLICATIONS FOR EDUCATION REFORM

This chapter draws conclusions from all the external research material available to CDE as well as our own research over the past three years, as reflected in the preceding seven chapters. It restates the problem or challenge facing South Africa in respect of school-based maths and science education in the framework of the greater understanding developed in the course of this report. The education system is not producing enough school-leavers with HG maths and/or science to meet the needs of the education system itself, let alone the needs of the economy. As a result, there is a shortage of teachers capable of teaching these subjects in grades 10 to 12. Moreover, the shortage of matriculants in these subjects is constraining the country's economic growth, particularly in those sectors interacting with the global economy. However, we cannot even contemplate trying to improve the entire system all at once.

We then recall the conclusions reached by quantitative analysis. The first outcome is that we now know the scale of the challenge, based on the most reliable data from both public and private systems. Second, we now have a reliable time series, so that trends can be confidently identified. Third, we can look behind the obvious year-on-year percentage pass rate for trends that go into making up that (often misleading) figure. Fourth, we now have the analytical tools to selectively target key parts of the system. They make it possible to develop targeted strategies for achieving two specific results: getting more learners to do better at SC maths and physical science, and building the capacity we need to reform the whole system over time.

From our qualitative research we learn that maths and science educators widely agree about what needs to be done to improve results in these subjects. Above all, our detailed school case studies concur with several other studies about what really works in schools in South Africa.

Our analysis of private sector contributions shows that the private sector is already substantially engaged, but remains a small player in financial terms, and that its contributions are not always sustainable. Nevertheless, distinct 'virtues' have been identified in the continuing efforts of corporations and other private sector players that can be built on in a framework of engagement with learners, parents, schools, and education authorities.

Finally, our review of the international literature and of successful projects worldwide provides several approaches that can work here as well.

The chapter concludes by noting that the research confirms many things which experts already suspected were true but were unable to demonstrate, as well as dispelling a much smaller number of 'truths' that were simply unfounded. When all is said and done our overriding impression is many South African's already know what the major problems are and share these insights in common with key stakeholders in government and the private sector. The issue then becomes one of how best to approach these problems, and the actions which flow from such an orientation. It is clear to CDE that a new approach is required if our schools are going to deliver in this vital area. Determining the components of this new approach is often determined less by the facts that the research has confirmed, than by the insights we have developed during the course of research. It is these insights which are explored in the chapter which follows.

CONFIRMING THAT A PROBLEM EXISTS

CDE's research has confirmed that, even by developing country standards, South Africa has a serious problem in the vital maths and science component of its education system. In an international comparison at grade 4 level with 12 comparable developing countries, it scored lowest in numeracy, and second lowest in literacy in English, a factor crucial to success in maths and science. In a second, related, study at grade 9 level, its scores were significantly worse than those of ten comparable developing countries – in fact, South African learners achieved the worst scores in both subjects. CDE's own research shows that the number of HG SC graduates in maths and physical science have increased by fewer than 3 000 each over the past 12 years. Ever fewer SC graduates are enrolling for higher education courses leading to teaching qualifications in maths and science; thus the pool of newly qualified maths and science educators is not even keeping pace with retirements, retrenchments and loss to other sectors, never mind actually increasing the resources available. In 2000, the number of students at teacher training colleges were 56 per cent less than in 1994 (since then, teacher training colleges have been amalgamated with universities). And, between 1996 and 2000, the number of education degrees awarded at universities and technikons declined by 5,4 per cent.

These trends become more significant when we recall that maths and physical science are increasingly important to modern economies. Also, government policy in many areas (HIV/AIDS, infrastructure, water resources, information technology, and others) must be explicable to the citizens of a democracy. To achieve this, citizens themselves need to be technologically literate.

The international evidence, the opinion of domestic experts and practitioners, and the views of learners and parents all confirm that maths and science education is the area of our education system that needs to be most urgently reformed. Given that the private sector has committed substantial resources to maths and physical science projects for a number of years, it clearly shares this view as well. While it has achieved considerable success at the level of individual projects, it has not had the critical mass to significantly change the system itself. As yet, only a few ways have been found to co-operate with government at scale.

South Africa's maths and science challenge has very specific origins related to the country's history of apartheid education. These are discussed in chapter 3, insofar as they have affected the performance of new provincial departments. However, the problems surrounding these subjects are not restricted to this country alone: CDE's international research identified very few countries that are satisfied with their achievements in maths and science education. Nevertheless, we have to acknowledge that, once all allowances have been made, available comparative data indicate that South Africa is in a worse position, objectively speaking, than many comparable developing countries. (Of course, there may be countries that have not participated in comparative studies which have less effective systems than ours.)

South Africa performed worst of all 38 countries included in the Third International Maths and Science Study (TIMSS-R) of 1998–9, involving a standardised test administered to grade 8 learners. When, drawing on data from the TIMSS-R study, CDE compared South Africa to ten participating developing countries similar to ourselves, this country's grade 8's still performed worst*,* even though they were, on average, 1,1 years older than the participants from the other countries. Our learners obtained mean scores that were consistently the lowest of all countries concerned: Chile, Czech Republic, Indonesia, Korea, Malaysia, Morocco, Philippines, Thailand, Tunisia, and Turkey. Most of these countries have similar educational problems to ours, such as a multiplicity of languages, massive income differentials, sharp urban–rural divisions, and histories of recent conflict. The factors that have cited as reasons for our poor performance are not, in our view, unique disadvantages under which we alone struggle. Therefore, in our view, this study is a valid comparison.

The TIMSS-R study has turned up some possible reasons for our poor performance. Our school year is substantially shorter than those of all other participating countries. We have the highest absentee rates for educators and learners. The time devoted to instruction in maths and science is the shortest of all countries. Maths and science educators and learners spend significantly more of this time on repetition and homework than their peers, as opposed to clarifying key concepts or making steady progress through a systematic learning curriculum or programme. Many schools are badly managed. The effective utilisation of available resources is well below the average of comparable countries. Countries with maths and science class sizes similar to our own perform significantly better than us; indeed, some are classified as high performers.

In brief, South Africa faces a major challenge in bringing its maths and science education system up to acceptable international standards.

UNDERSTANDING THE CHALLENGE QUANTITATIVELY

CDE's quantitative research has made it possible to measure and analyse the outcomes of the school-based maths and physical science education system. Our work represents an advance over previous research in the following ways:

- The official database of SC results have been checked and improved as much as is possible, starting in 1991. It is now as reliable for each year as the sources themselves permit, and certainly reliable enough to sustain detailed analysis over time, with the exception of two years for which key data are missing.
- Methods have been developed to interpret the data in several new ways, thus allowing key variables affecting SC performance to be identified.

- A comparative index has been developed which displays the performance of individual schools in maths and science, and allows them to be compared to and ranked against others.

In short, CDE has established a reliable database over time and across all provinces, which includes the IEB, and reaches down into the system, not only to the school level but to the level of individual candidates. Various government agencies helped us to collect the data, which is highly appreciated. Researchers then spent months cleaning up the mass of information, removing incorrect and duplicated statistics, considering whether or not to use dubious data, and consolidating many thousands of small corrections. Following this, we have, for the first time, a really reliable time-series of data in respect of performance in SC maths and physical science. CDE intends to place this data in the public domain (see box 8.1).

BOX 8.1: OUTPUTS OF CDE'S QUANTITATIVE RESEARCH

CDE's quantitative research does not only create a new dataset. A number of important methods have been pioneered, tested, and approved by external experts. These will make it possible for researchers at CDE and elsewhere to continue adding the database, and using it in future. These methods include the following:

- The national data on SC results and the IEB data on matric results have been verified, corrected, and consolidated into a new database, to which new data can be easily and quickly added every year.
- A school performance index has been created, which can also easily be easily updated every year, and allows sophisticated comparisons of the performance of individual schools year on year, as well as their performance relative to other schools on the index.
- A method has been created for relating school performance to the composition of candidates by community of origin.
- A method has been established to relate school performance to school facilities. Once again, this method can be easily and quickly applied to annual results and to the two-yearly Register of School Needs. It allows the creation of a record of facilities which can easily be updated, and can be correlated with results in individual schools, schools by province, or types of schools nationally.
- A method has been established for relating school performance to socio-economic conditions in surrounding communities, as reflected in the Census figures every five years. This too can become an ongoing database.
- A method has been pioneered for comparing the performance of South African learners in grades 8-9 with that of learners in ten other countries, each of which is at a comparable developmental stage to South Africa. This has been done through TIMSS-R, and can be easily updated when a further round of data is collected internationally. This is a primary source of comparative international data, telling us whether we are performing better or worse than other countries, and why.

CDE 2004

Our quantitative work has yielded the following insights:

1. Very different trends emerge once the analysis goes beyond the simple pass/fail rates provided annually by the NDoE, and debated in the media. Indeed, these figures have concealed the fact that, while enrolment for SG maths and science has grown significantly, the pass rates in these subjects are lagging, and that, while the pass rates of HG maths and physical science have improved, enrolment has plummeted, even in absolute terms.

2. Provincial variances are also significant, with the provinces that had to integrate several of the previous education departments (especially 'homeland' departments) being most disadvantaged. It soon became clear that, even in these two subjects, we are dealing with a heterogeneous system. Different policies and strategies will be required in different provinces, different regions within provinces, and even in different schools. Single, national policy prescriptions have little chance of success.

3. Further disaggregation of results down to individual magisterial district and then to individual schools confirmed how heterogeneous the system actually is. However, the creation of the maths and science school performance index now makes it possible to tailor interventions at the school level.

4. Further analysis of the data has produced many detailed insights. However, three key variables have emerged as crucial to determining success in SC maths and science:

    a. The most important variable is the educational qualifications (content knowledge) of educators, the pre- and in-service development of their teaching skills, and their length of experience. These factors correlate closely with results, thus indicating that any initiative to improve learner's performance in maths and physical must include a major intervention directed at educators. This is urgently needed, as only 14 per cent of secondary schools report that their maths and science educators have the minimum qualifications laid down by the education authorities (SC plus 3,5 years of higher education). In the absence of specialist educators, fewer periods are allocated to these subjects, further compounding the problem.

    b. The next major variable is competence in the languages used for examination purposes – in most cases, English rather than Afrikaans. Our research shows that there is a significant correlation between marks achieved in an examination language (usually English), and achievement in maths and science. Our case studies of schools confirm this, and the expert examiners, moderators, and markers who participated in our workshops concur. This evidence is so strong that CDE will be proposing not simply maths and science reforms, but maths, science and language reforms. Such an approach will have major consequences for existing projects such as Dinaledi.

    c. The third significant variable is the characteristics of SC examination centres (almost always schools). A specific set of school characteristics emerge very clearly as a factor for success. This finding has several dimensions. Statistically, the greater the number of candidates in maths and science at a given examination centre (almost always a school), the better the success rate. Peer pressure and team work obviously help. But school management, levels of discipline and orderliness (both physical and psychological), educator commitment, and other factors all come into play.

5. A surprisingly large number of potentially successful maths and science candidates do not enrol for these subjects, or enrol for SG when their overall marks show that they might succeed at HG. Whatever the reasons for this, the country cannot afford this waste of potential. This issue can be addressed by assessing learners at earlier stages of the system, and conducting a voluntary maths and science aptitude assessment in grade 9, in order to identify learners likely to succeed in grades 10—12. This should be accompanied by counselling and financial support.
6. Less than 20 per cent of schools offering SC maths and science are achieving pass rates of over 80 per cent. This reflects positively on the schools concerned, but also means that the system is unbalanced, and vulnerable to any problems that may arise in this small number of schools. Resources can now be directed to those schools individually to ensure that they continue to deliver. At the same time, schools with pass rates of 60–79 per cent can now be identified and resources directed to them in order to move them into the 80 per cent-plus pass rate category.
7. Finally, the quantitative data has helped us to identify areas in which no action is needed. For example, there is no general problem with gender at the SC level, either in terms of numbers of candidates or in terms of success rates; therefore, a national programme to increase female participation in maths and science is not indicated. However, the more necessary interventions that might be needed in provinces, regions, or schools, can now be identified. For example, the data clearly shows that in some provinces, African female learners are lagging behind: a programme to address this specific issue where it manifests can now be developed and applied. Similarly, access to a science laboratory is not correlated with consistently high levels of success. This is not to say that this resource is not ultimately desirable, but rather that investment will be more immediately productive if it goes towards more and better educators and more textbooks.

Potential uses of the quantitative research

The results of CDE's quantitative research confirms its value, and demonstrates how sound data can be used to inform reform policies and strategies. The research confirms our hypothesis that our education system requires differentiated reform strategies aimed at clearly identified problems, and that these would be more effective than generalised, one-size-fits-all policy prescriptions. Importantly, the research can also help us to formulate such differentiated strategies. This is strikingly illustrated by the index of school performance in maths and physical science for 2000 and 2001. For example, it reveals that:

- A total of 948 (17 per cent) of schools achieved a pass rate of over 80 per cent in the 2000 and 2001 SC maths exams. These schools can be identified and studied for guidelines to other schools, especially as high performance has often been achieved under adverse circumstances. In addition, these schools can be given special support to sustain and further their success rates.

- Far fewer candidates than expected show up in the 60–79 per cent range, but there is a strong showing in the 40-59 per cent range. This means that, once individual schools at the top of the latter range are identified, they could easily be pushed up into the next range, which would represent an effective use of resources.

Interestingly, performance patterns in SC physical science are quite different, and this only becomes evident once the results are analysed in greater detail. Not only is the overall pass rate more than twice that in maths (35,9 per cent compared to 16,7 per cent); also, by far the largest group of schools is that in the 80 per cent or more category. There is a strong provincial variation: for example, 82 per cent of Western Cape schools achieve pass rates of close to 80 per cent, while only 13,9 per cent of Eastern Cape schools do so. Again, the point is that differentiated strategies are called for at all levels. This can best be based on provinces; examples of this are provided in chapter 3, and in the detailed research paper on which this part of the report is based.

Even *within* provinces, data on individual schools could be used for designing even more closely targeted interventions. For example, our tables show that 12,3 per cent of schools produce 62,5 per cent of successful HG maths candidates. These schools can now be identified, and steps taken to ensure that they maintain and further improve their performance. Lower down the scale, a total of 674 schools produced 20–79 per cent of successful candidates. These schools require to be analysed individually, and resources applied in appropriate ways. The fact that 54 per cent of all schools produce only 0-19 per cent of HG maths passes points to major basic problems. Perhaps these schools (or at least those which consistently fail to achieve any HG passes) should not be assisted at this stage, and should cease to offer this subjects until trained educators and proper facilities can be supplied. Talented individuals in maths and science could rather be accommodated at successful schools, thereby increasing their chances of success.

Alternatively, an attempt might be made to move the top 20 per cent of the weakest schools in each province up to the next category. Again, there might be provincial variables that require differentiated strategies. For example, table 3.10 shows there are only four schools in the Northern Cape in the category 0–19 per cent, and none in the next highest category (20–39 per cent). A specific strategy could be evolved to help these four schools improve their performance.

Many schools do not have the capacity and resources to adequately teach maths and physical science; however, a generalised support strategy for all schools is not called for. There is a core of well-performing and now improving schools (many, as we have shown, located in disadvantaged areas) that have always managed to generate significant numbers of HG passes. Such schools should be supported in order to maintain their performance – which may include incentives to retain their educators – while others that are on the brink of success can be identified for targeted interventions based on meeting certain achievable goals. In both cases, building on 'virtues' identified in the system will produce better results more quickly, and give much-needed momentum to reforming the system more broadly.

Once we start to consider actual, targeted reforms, we also need to distinguish between maths and physical science. The latter is more accessible to learners than maths, and there are fewer physical science than maths students. A suitable programme could involve specifically targeting physical science educators (who may or may not also be maths educators) for professional development; ensuring adequate supplies of text books; motivating learners by assessing aptitude and capability, and providing proper counselling; and, where feasible, creating opportunities for experimental laboratory work. The language of instruction and examination is very important since physical science is learnt through descriptions, supplemented by observations. However, the members of our panels responsible for foundation programmes at higher education institutions stated that, if other elements could be improved, and candidates in HG SC physical science could achieve a C symbol, they had a very good chance of managing the transition to tertiary study, and making up for the lack of practical laboratory work at school.

Clearly, the small numbers of HG passes produced in these two subjects is a priority issue, and needs to be urgently addressed. This view is supported by the government, the private sector, and parents of learners. There is a strong correlation between learner's performances in maths and physical science with competency in the language of learning and teaching. Therefore a strategy purely aimed at improving performance in these two subjects will fail if it is not accompanied by a programme to improve learners' competence in the language of instruction.

Our research also suggests that there are resource constraints throughout the system. Again, choices will have to be made, the first priority should be to build and retain an effective corps of maths, physical science, and other educators who have a firm grasp of the language of learning and teaching, which under the present system is (mainly) English. Secondly, priority should be given to ensuring access to textbooks, before any large sums are spent on additional teaching materials, laboratories, distance education programmes, or complex computer systems.

Finally, the research shows that improving maths and physical science SC performance, particularly at the HG level, will be more effective if approaches are more focused. This indicates that scarce resources should first target those learners who can succeed, rather than indiscriminate targeting of all learners.

BOX 8.2: INSIGHTS FROM THE QUANTITATIVE ANALYSIS

- Overall percentage pass/fail rates in maths and science are not very helpful. They actually conceal more important trends, and have acted as misleading incentives to officials, principals and educators.
- The maths and science education system is extremely heterogeneous – even more so than the schooling system as a whole. It cannot be improved by applying undifferentiated, nationally prescribed policies and strategies.

- The database is now sound enough to allow every education authority to customise interventions down to the individual school level. We do not need and should not use 'one-size-fits-all' interventions.
- Statistically three key variables are associated with success in maths and science at the SC level: educators; language competence in English or Afrikaans; school effectiveness.
- Large numbers of potentially successful candidates never study maths and science and/or never enter the SC examination in these subjects.
- Passes achieved come from fewer than 20 per cent of schools entering candidates. Such a skewed system is vulnerable and its long term effects unhealthy.
- There is no general problem regarding gender. Indeed, Indian and white females are statistically the top performers. However, in most provinces there is a serious problem regarding African female learners that requires appropriate action.
- There is a core of ongoing successful schools and another of improving schools. Both can be built on to increase to increase the numbers of successful candidates rapidly. These schools can also act as support to less successful schools in their area.
- Even the shorthand concept 'maths and science education' CDE has used is misleading at the level of interventions. Physical science can be improved more rapidly and need not be always linked to maths, certainly in terms of educators.
- Both maths and physical science are highly language-dependent, and no strategy to improve maths and science education should leave out a language component.

CDE 2004

QUALITATIVE RESEARCH

Our qualitative research had four main components, each of which will be summarised below.

Government initiatives

Government initiatives since 1994 to improve maths and physical science were considered. We found that the government has displayed considerable concern over this issue, and has made a significant effort, in financial and other terms, to remedy it. However, its efforts have not yielded satisfactory results. Some of the reasons are listed in box 8.3. We are convinced that these aspects can be improved upon, without losing the gains that have already been made.

BOX 8.3: COMMENT ON GOVERNMENT INITIATIVES, 1994-2003

In general government initiatives have been characterised by:

1. **Grandiose policies**: Attempts to change the whole system, or large parts of it, all at once. Every piece of international research consulted by CDE shows that this is a futile and ultimately counterproductive strategy.
2. **Policy discontinuity**: New policies conflict with, diverge from or abruptly discontinue initiatives already launched, sometimes by the same department!
3. **Undifferentiated strategies**: Important subjects such as maths and physical science are treated as if their context and national importance are exactly comparable to all other subjects, provinces are treated as if they are all the same and differentiated approaches as regards educators and funding are positively discouraged.
4. **Lack of political will**: government has to establish what its priority areas are in maths and physical science education and stick to its guns. For example, local political considerations in selecting participating Dinaledi schools will undermine the successes achieved and lead to demoralisation and apathy.
5. **Inattention to maths and science educators as a specific group**: Real quality improvements in learning and teaching have been slow in coming because of the absence of a mechanism for testing educators' maths and physical science content knowledge and requiring educators to undergo on-going professional development. Also, space must be created for new entrants to the profession in these subjects despite a general control on personnel costs, and consideration given to ways of attracting and retaining newly qualified teachers.
6. **Inability to generate professional pride and motivation**: Reforms must pay attention to the phenomenology of change, i.e. the people affected by change (educators) should actually experience the change as being something important and making a difference to their lives as professionals and be motivated by incentives to enter and remain in the profession
7. **Poorly planned, too rapid implementation**: Sufficient time must be made available for maths and physical science innovations to take effect with clear and achievable outcomes identified beforehand, ongoing progress towards targets, and with excellent planning and sufficient resources allocated.

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Experts' opinions

CDE's interviews with educators, education officials, and researchers revealed a high degree of consensus on the state of maths and physical science education, the problems surrounding it, and what needs to be done to improve it. Interviewees stated their belief that the government should take the lead in this field, and had in fact done so. They also acknowledged that some progress had been made. In fact, most of all believed that too much was being attempted at once, leading to what one interviewee described as 'policy fatigue'. Fewer and more focused initiatives, based on the existing strengths in the system, would be more appropriate, as these would be easier to implement, and their outcomes could be properly assessed before further changes were made.

Respondents unanimously commended the government for initiating the National Strategy for Mathematics, Technology, and Science Education. However, they also stated that there were simply too many policy initiatives; that these were not properly co-ordinated or prioritised; and that many – such as the educator redeployment and retrenchment policy – had had unexpected negative consequences. They expressed grave concerns about the proliferation of curricula, and also about the implementation of continuous assessment.

They agreed that the shortage of properly qualified and trained educators was one of the most important causes of the current problems surrounding this subsystem. Yet all agreed that educators were also the key to dealing with these problems. Producing more and better educators would take a long time, and it would be difficult to retain them. The system could not be improved more quickly than this issue could be resolved. Reasons cited for the present situation included: most educators in these subjects had been trained at colleges instead of universities; a failure to introduce differential salaries for specialised maths and science teachers, thus increasing the risk of them leaving the profession for more lucrative jobs elsewhere; the fact that remuneration was only based on general qualifications and years of experience; poor working conditions; a shortage of learning resources; and pressures to produce 'SC results'. Instead, incentives should be offered that will help to procure and retain specialised educators in these subjects without adding to the education salary bill as a whole.

Finally, interviewees were asked what practical steps should be taken to improve maths and science education. At the provincial department and school district level, they identified improved monitoring and support by curriculum advisors and officials, improved in-service training, and a more personalised and less bureaucratic approach by officials. At the school level, they identified strong school leadership, good school management, a results-oriented culture in schools, reasonable class sizes, confident educators, a supportive environment for learners, better and earlier diagnostic assessment, and stronger parental and community support. In the classroom itself, they identified proper planning and pacing of work, stressing the relevance of both subjects to careers and daily life, more personalised contact with learners, and the provision of extra materials and courses.

The responses of interviewees led us to identify a further 'virtue' in the present system: a high level of concern among people involved in this subsystem that South Africa should do better, and a conviction that it can do better. Appropriate reform initiatives will certainly be well received among in this community.

The Senior Certificate examination

School-based maths and science education current culminates in the SC examination (or its equivalent). Does this exam, and the dynamics surrounding it, add to the problems surrounding these two subjects, or not?

In order to find an answer to this question, CDE researchers closely examined ongoing research in this area, as well as the current NDoE initiative to benchmark examinations in these and other subjects against those set by the Scottish education authority. We then sought the views of those at the 'coalface' on whether existing policies and practices at this point of exit from the school system are having a positive or negative effect.

Our four workshops with examiners, moderators, markers, and educators involved in SC examinations in these subjects confirmed that there were numerous 'virtues' in the current system. They confirm that the SC examinations were playing a valuable role, and did not require immediate intervention. The current system could be improved, and an opportune moment for doing so would be when the FETC is introduced. However, given that many other aspects of the system did need urgent attention, they believed it would be wiser to keep the current examination system as stable as possible.

These experts concurred that the 'matric' exam was important because it was the only objective, summative assessment of the knowledge, skills, and ability of learners after 12 years of schooling. It served as a target for work during the lower grades, and as a reference for higher education.

While the workshop participants did have some reservations about aspects of the exams, it emerged quite clearly that the level of failures in SC maths and physical science is not attributable to the nature or standard of the examination itself, its moderation, or, with some reservations, variations in marking.

Therefore, CDE has concluded that the SC exam does not contribute to the problems surrounding maths and physical science education, and is not a priority area for wholesale intervention. The present system can be improved. Where necessary, curricula should be systematically upgraded and modernised, and assessment considered at the same time to ensure that future exam papers are of the highest possible standard in terms of coverage, levels of difficulty, and capacity to differentiate among candidates.

However, participants expressed concern about continuous assessment, and negative comments on this aspect of the system have increased since our interviews and workshops were held. The principle is widely supported, but its implementation is regarded as problematic. CA's contribution of 25 per cent to learners' final grades is significant, and can make all the difference between passing and failing, and between one symbol and the next. Yet both educators and experts reported that educators were not being properly trained in how to administer CA, that administrative and quality control was inadequate, and that the degree to which it was taken seriously varied between provinces. Therefore, CA requires urgent attention.

School studies

The final and perhaps most significant component of CDE's qualitative research was its study of selected schools whose performances in maths and physical science were either excellent or improving. These case studies had the great value of confirming the findings of previous research of this kind, thus telling us unequivocally that success in maths and physical science in South African schools at the beginning of the 21st century hinges on a few basic and widely recognised factors, namely the quality of the principal; the competence of the educators; the effectiveness and efficiency of school management and administration; the extent of discipline in all aspects of school life; competition within the school and among schools; and the use of traditional methods in the classroom.

The next key finding from the case studies is that educators are, and continue to be, at the centre of all efforts to improve learners' performance, including 'learner-centred' methods. Successful educators emphasise clear explanations, the repetition of problems, homework done and marked, feedback on performance, and specific preparation for examinations once the syllabus has been covered. A good relationship among the school, parents, and the surrounding community also contributes to school and learner performance.

BOX 8.4: WHAT GOOD SCHOOLS DO

Flowing from our case studies, it is clear that good schools:

- Establish policies and procedures.
- Stick to these, thus creating standards of success.
- Maintain high levels of discipline.
- Create and refer frequently to a tradition of success.
- Maintain cleanliness and orderliness without becoming obsessive.
- Secure the safety of educators, other staff and learners.
- Involve parents and the local community.
- Seek private funding for specific initiatives.
- Enter competitions and celebrate wins.
- Invite successful former learners to the school to motivate the present learners.
- Offer assistance to other schools in the area.

CDE 2004

In summary, these 13 studies of carefully selected schools in five provinces show precisely what the elements are that contribute to high-quality education in the two subjects in question at the most important level of interaction – namely, between educators and learners in the classroom. Once again, massive – often miraculous – 'virtue' was found. Excellent teaching methods are being used in some very inauspicious settings. However, this virtue is not as widespread and consistent as it could be. A low percentage of South African schools continue to supply a high percentage of successful candidates. We also encountered illuminating faults, both of omission (ie not doing well-known things) and commission (ie doing things that were known to be incorrect). On balance, though, we can now state with confidence what the virtues are to be elaborated or created, what faults exist, and what can be done to remedy the latter.

The qualitative research has yielded a high level of agreement among our workshop participants and interviewees on the huge scale and intricate nature of the problem. This might seem like a largely negative outcome; however, they also agreed widely on what could be done to remedy the situation, which is a major ‘virtue’.

BOX 8.5: WHAT GOOD EDUCATORS DO

- Create and adhere to a learning plan that is understood by the learners.
- Cover the syllabus.
- Adapt teaching methods to the needs and capabilities of learners.
- Put in intensive effort at time when learners can give uninterrupted attention eg over some weekends or during vacations.
- Complete the SC syllabus by mid-year of Grade 12.
- Revise syllabus and set and mark practice examination questions.
- Find out each learner’s results, analyse the pattern and plan to improve.
- Update content knowledge regularly.
- Actively maintain personal professional development.

CDE 2004

But this unanimity of views also represents an opportunity. It signals that there is a group of committed professionals in this field who largely share the same views and outlook, and who could be a valuable resource for any well-planned reform strategy. They also understand that the problems cannot all be overcome at the same time, or by means of a single policy initiative. Indeed, it is one of their main criticisms that past policies have been overambitious and inflexible. In addition, ample information exists about the views of different groupings within the body of concerned professionals. This can be the basis of a sophisticated campaign to gain their support.

The principals, educators, learners, and parents CDE interviewed were knowledgeable about the factors for success, and the initiatives necessary for excellent maths and physical science performance. Our research has nevertheless shown that certain education theorists, policy-makers, and departmental officials are failing to ‘find virtue’ in this body of knowledge and experience, and continue to propose radical changes in approach, content and method. They don’t seem to realise that the current system can be greatly improved if more attention is paid to the basics.

BOX 8.6: VIRTUES IDENTIFIED BY THE RESEARCH

The following 'virtues' could serve as a point of departure for successful reform:

- Countrywide concern by key role players: 'We are not blind to the challenge.'
- A willingness by the public and private sectors to commit resources.
- Concerned private and NGO sectors, with a history of involvement in education.
- A recognition of and publicity for excellent achievements under difficult local circumstances.
- A commitment by all provinces to positive interventions.
- A high level of agreement within the education community about what the factors are that enhance quality.
- An excellent database of SC results, correlated with other relevant variables.
- An acceptance by those managing the Dinaledi programme of the need for focused strategies, and a flexible approach.

CDE 2004

INTERNATIONAL RESEARCH

A great deal of valuable research has been done internationally about education in general and the maths and physical science subsystem in particular, and successful reform initiatives have been introduced in many countries. These have been exhaustively documented and evaluated. It remains for us to apply these findings intelligently to the South African system.

A major feature of the international discourse on education is the widespread acceptance of the notion of 'systemic change', or 'systemic reform'. Much has been written about this concept, some of it academic in nature, and difficult to apply in practice. Other writers appear to confuse 'systemic' with 'radical', and assume that systemic change involves the rapid and fundamental change of an entire system. This is misleading, as systemic change is essentially a conservative approach, in the sense that it seeks to conserve what is good in a given system and build on it, rather than overturning everything at once and starting afresh.

In our view, the key elements of systemic change in education are:

- Acceptance that we are dealing with a system: ie, the coherent organisation of a number of components in dynamic relation with each other, each contributing a distinctive element to the working of the system, and with the system as a whole using specific inputs to achieve specific outputs within a certain time frame.
- Understanding that the system in question (education) relates to other social systems, providing an input to some (eg higher education or employment) and receiving inputs from others (eg finance from government).

- Anyone proposing systemic change must show the ability to understand the system holistically; ie to see it operating as a whole, from inputs to outputs, and to understand its various components, how they fit together, and the interests, motivations, and capacities of the people involved.
- Acceptance of the need to approach carefully any large educational system that has grown up organically over time under various historic pressures, and involves the hopes and fears of many people. There is great potential danger in tampering with social systems, because relationships between the parts may be damaged in unexpected ways. Thus the ethos of systemic change should be one of caution and incremental action, not unbridled enthusiasm based on untried theories and ideas.
- When the need to change a whole system is combined with caution, systemic change can be better understood. While based on a holistic understanding, it should be implemented by means of well-considered, incremental initiatives, each of which will seek beneficial results and limit possible negative consequences. Each intervention needs to be closely monitored to ensure that it is generating the positive outcomes envisaged, and remedial steps need to be taken if it has an unintended negative impact.
- We need to observe how the interventions interact with the broader dynamics of the system, and ensure that their impacts are cumulative. This can be achieved in two ways. First, a specific change may spontaneously set off other positive changes. Second, a specific change can provide a new input which is essential for further change. Systemic change puts a high premium on monitoring and evaluation, followed by corrective action.
- We need to accept, as the international literature repeatedly states, that systemic change takes time – but never as much time as doing the wrong thing, then having to go back to undo it and do the right thing all over again. Progress may seems slow, but it usually is progress, not retrogression.
- The sequencing of incremental initiatives must be decided on strategic as well as educational grounds. The best place to start may not be the most obvious educational deficiency. If any problem in society appears to be insoluble (for the moment, at least) starting with it will immediately halt any reform. In this case, it is better to start with smaller, solvable problems.
- The literature is unanimous that systemic change is the only approach likely to succeed in a large, operating, educational system with deep-seated problems. Small systems might, in principle, be changed all at once, while systems that are no longer functioning can be reconstructed from scratch. But when an attempt is made to change a system such as the one in question, it is essential to balance change with the need to maintain the best possible quality in routine operations. Only a portion of available resources can be committed to reform; most have to remain committed to the routine operations. This is another powerful reason for incremental change.

BOX 8.7: TWO SOUTH AFRICAN ISSUES

Two issues arising from South Africa's past have contributed to an inability to fully grasp the issues involved in improving school-based maths ad science education.

The first is a logical issue that besets countries with a history of discrimination in education. It is the difficulty of creating a framework in terms of which a system can at the same time be equitable to all and support the creation of excellence for a small proportion of its members. In terms of maths and science education, we have to devise a system that offers equal opportunities and resources to all learners while also allocating additional resources to developing some learners to a higher level of excellence. Given our history of discrimination, many argue that all available resources should first be used to ensure that every learner has the best possible chance to study these subjects in the most appropriate way. Once equity has been achieved, we can think about providing more resources to those capable of achieving excellence. Equity for all should come before excellence for some.

There are a number of problems with this view. First, denying gifted individuals the resources to develop their gifts is itself an inequitable act. If our resources genuinely do not extend to servicing both groups, then a sensible division is the only ethical route. Second, elevating equity over excellence as a matter of principle cannot be implemented. By definition, people with higher levels of knowledge and skill are needed to educate others. The entire education system operates on the assumption that there are people with more knowledge and skills than the learners in any subject. The more numerous and proficient (ie 'excellent') the educators, the more rapidly equity can be achieved for the learner population at large.

Third, nations have to develop competitive advantages to supplement their natural comparative advantages. In the modern world, most areas of competitive advantage are based on maths and science. Once again, only excellence will do; national economic growth and survival depends on excellence.

The second issue is that of 'transformation'. CDE believes that, in education, this term is being applied in a way that is actually hindering the improvement of the system, including maths and science.

Increasingly, 'transformation' is being used to support moves towards greater state control of education and greater uniformity of opportunity. In an understandable drive to achieve equity of provision, too little attention has been paid to values and practices that contribute to diversity and the overall quality of education. This is because these appear to favour certain groups over others. We have already referred to the way in which funding formulas are restricting the output of maths and science matriculants by disproportionately underfunding former Model C schools. However, this is based on a misunderstanding of the way in which the learner intake of these schools has changed.

The reason for such (surely) unintended negative outcomes is partly a lack of data (see chapter 4), but partly also a failure to realise that the most important transformation of modern educational systems has been away from centralisation and uniformity and towards local diverse opportunities. The American education system has always been strong in this regard, with federal, state, private and non-profit institutions being developed. And even the previously centralised public system in the United Kingdom is increasingly looking for the advantages of a diversity of opportunities.

A decentralised system needs more sophisticated administration; for example, quality control of a variety of qualifications supersedes direct control of a single national qualification. But the gains are often spectacular. School governing bodies, principals, educators, and learners make a bigger effort to contribute to institutions in whose future they have a direct say than to 'government schools'.

A recognition of diversity can encourage flexibility as well as excellence. The way in which Parktown Girls' High School maintains excellent performances in maths and science by learners from 81 suburbs and income groups, from very poor to very rich, shows what can be done if diversity is recognised as the driving force of transformation.

CDE 2004

THINK HOLISTICALLY, ACT INCREMENTALLY

Our understanding of systemic change means that we need to plan holistically to act at appropriate local levels, and in respect of local component parts of the system. There are obvious criteria for selecting sites at which to act: manageability of the change; realistic goals to be achieved by the change; visible and demonstrable outcomes; parts that are functioning quite well but could rapidly be improved to become excellent; parts that are failing so visibly that they are undercutting any positive outcomes; and many others.

The criteria for action must be different in different cases, because the system itself is heterogeneous. However, as we have seen before, we now have sufficiently detailed data about the system to allow us to intervene in different ways within a coherent broader framework.

KEY FACTORS

The international research also helps us to better understand the key ingredients of successful systemic change. All interventions require clarity about and planning in respect of:

- **Responsibility**: while systemic change must be flexible and multi-levelled, responsibility for formalising and launching interventions must rest with the highest level of authority in the system. In our case, this is the NDoE. However, it is important that other actors be involved, and some responsibilities delegated to them. For example, the provincial departments of education have a major responsibility for implementing policy and strategy. School districts are responsible for understanding different inputs required by different schools to achieve levels of quality. Schools themselves are responsible for implementation by educators in the classroom. All these accountabilities inevitably involve monitoring, and reporting results against targets.
- **Planning**: must above all be related to the capacity available to implement the plans. If the capacity does not exist, then plans must begin with its acquisition or development. Fullan's caution about the need to build the capacity needed to build capacity should be kept in mind. Contingency planning is preferable to blueprint planning. Professional development is the key to all planning in education.
- **Implementation**: must be the responsibility of the provincial departments of education, and delegated as appropriate to school, projects, partnerships, NGOs, and other

parties, via enforceable agreements. The NDoE should not be involved in implementation.

- **Incentives**: the education system is essentially a human system. For this reason, motivation – via incentives – is at the core of success. This is discussed in greater detail below.

INTERVENING AT DIFFERENT LEVELS

The literature makes it clear that systemic change does not work optimally by starting at the bottom of the system and working up; or by starting with improvements to the least effective components of the system. On the contrary, it is important to create positive outcomes as rapidly as possible, as these create a sense of progress, and motivate participants. Interventions need to be considered in the framework of the long-term goals of systemic reform, and should not be counterproductive from this perspective simply because they can be undertaken more quickly. But other interventions have to be considered in terms of quick gains, strengthening motivation, providing models that can be dispersed more widely, and other strategic objectives. A successful way of achieving focus is to group efforts relating to a particular problem into a 'programme', with specific participants inputs, activities, and goals that can develop quickly and provide results that can be generalised to the whole system. Potentially the Dinaledi Project (if restructured) could be a case in point, leading to the more wide-spread acceptance of specialist schools.

PEOPLE BEFORE STRUCTURES

The research also makes it clear that the priority area for initiating systemic change is not structures, but people. This is particularly true of education systems. The key factor in any systemic change is the supply and retention of competent and confident educators, closely followed by the supply of effective and efficient principals.

CDE's quantitative research shows that the South African school population has at least as many potentially successful maths and science learners as any other national system. Our immediate task is to ensure that more learners enrol for SC maths and science, and improve their performance, also at the HG.

However, it is quite another matter to ensure that enough school-leavers opt for a career as an educator in maths or physical science. Then there is the challenge of helping existing educators to improve their content knowledge and teaching skills. This is where our programme of systemic reform should begin. Using a variety of incentives, we must attract school-leavers to tertiary educational programmes that will lead to their employment as educators. We must user others to retain existing educators, and improve their knowledge and skills. And we must use others still to attract at least some of those skilled educators who have left back into the system. We can't achieve these goals by continuing to treat maths and science educators in the same way as other educators.

Every study CDE has had access to also shows that educators in developing countries tend to lack confidence, and become fearful and demotivated when confronted with large-scale changes over short periods of time. As a consequence, successful programmes avoid changing too many features at once. It would be quite inappropriate to change curricula, teaching methods, and examinations simultaneously, however strongly we might feel that these three components should dovetail. Dovetailing can be achieved over time, and a better curriculum with unchanged teaching methods and the same exam format in itself represents an advance. The low confidence levels of educators also lead to two other observations. Proposed changes must be thoroughly canvassed with educators, and effective training provided in respect of any changed procedures. Also, a major reason why educators lack confidence is low levels of content knowledge, and this issue must be addressed before teaching methods are changed.

PEOPLE RESPOND TO INCENTIVES

The most influential book on development theory published during the past decade contains the following statement concerning people's motivation to participate in developmental projects:

> People respond to incentives: all the rest is commentary.[1]

This is a fundamental truth for systemic change. Development depends on people, and people respond to incentives. Viewed from this perspective, an educational system is nothing more or less than a complex system of incentives that provides people with rewards for doing what they wish to do to the best of their ability. Of course, incentives are by no means limited to financial rewards; they could also include opportunities for personal and professional development, peer recognition, praise from superiors, respect from subordinates and many others. Systemic reform, then, should not start with the question: 'How can we make people do this?' It should start with the question: 'What incentives can we offer people to do this, and become motivated to do it better?'

CONCLUSIONS

In undertaking this study, CDE has drawn on its years of experience in analysing and assessing complex national policies and large programmes of delivery. We have been guided throughout by the realities of reform and the difficulties of implementation in a developing country recovering from the terrible legacy of apartheid. We have continually looked for what is working, trying to identify a sound foundation on which an improved system could be built. In the international literature, this is described as 'seeking virtue' in an existing system.

It is a very different approach from one that says, everything is wrong with a given system, and we must change it in its entirety. Experience over the past ten years in many sectors of South African society have emphasised the importance of identifying 'what works' in this country, and incrementally building on that base in order to improve delivery in a sustainable and more equitable manner.

Good work is being done, and initiatives are being successfully implemented. However, when all is said and done, we are left with the inescapable conclusion that the maths and science education system is still failing to deliver enough school-leavers equipped with HG maths and science to meet the country's needs.

It is clear to us that a new approach is required if our schools are going to deliver in this vital area. In chapter nine we outline 12 key insights that we feel are critical to designing and orienting this new approach, before we proceed to our recommendations in the final chapter.

ENDNOTES

[1] W Easterly, The elusive quest for growth: economists adventures and misadventures in the tropics, MIT Press, 2001.

Chapter 9

POINTS OF DEPARTURE FOR CDE'S RECOMMENDATIONS

Any report that aims to recommend long-term courses of action to public and private sector actors must be based on thorough research. There is too much at stake to base recommendations for costly, nation-wide action solely on ideology, theory, or opinion.

However, if it is to be effective at persuading such actors to implement its recommendations, such a report must also have a clear perspective on these issues. Research on its own seldom demonstrates the clear superiority of one course of action over others. Broader normative frameworks are also required to help determine goals and priorities, and to give social actors a context for making choices between possible courses of action identified by the research.

Finally, success in this field will require a national effort. This does not mean an effort solely by the national government or the NDoE; while they should obviously play a leading role, they need the support of all other stakeholders in education, and need to create, and benefit from, a wave of national public support. This topic is discussed at greater length in chapter 10.

CDE's insights

We have learnt a great deal from our research on maths and physical science education; it has confirmed much that was already known, but has also dispelled many incorrect assumptions. Drawing on this firm foundation, CDE has formulated 12 key propositions which serve as points of departure for our recommendations, spelled out in the final chapter. Not all are directly demonstrable or validated by research, but all are important to a more effective system. These are:

1. Maths and science are crucial to South Africa's success.

National development requires an increasing number of skilled personnel. Specifically, they require competencies based on mathematical and/or scientific knowledge.

Despite significant government efforts over the past 10 years, which are described and analysed in depth in our main report, significant results have not been achieved, and disillusion is setting in. This emerges clearly from our interviews with educators and education officials, as well as our school studies. These feelings contribute to a perception of national inability to stimulate development and meet promises, and will worsen should maths and science education be perceived as an area where delivery fails to match reasonable expectations.

We must and can persuade the nation as a whole to accept the significance of maths and science reform, and participate in it. A wide variety of groupings have legitimate and positive roles to play. We must go beyond a sense that maths and science education is simply 'the government's job', and mobilise resources on a nationwide basis.

2. Failure with respect to maths and science education is the most important obstacle to African advancement.

CDE's research has clearly demonstrated the extent of the national crisis in maths and science performance and participation since 1991. The effects of this national crisis are most evident in respect of African learners. To restate our findings: in 2002 only 4 637 African learners passed HG maths, representing only 13,14 per cent of all SC candidates, and only 23,42 per cent of all HG passes. And only 7 129 African learners passed HG science, representing only 14,06 per cent of the total number of SC passes, and 30,42 per cent of all HG passes.

This is holding back African advancement. It places a huge obstacle in the way of achieving almost all the government's ambitions to open up vast new areas of opportunity for black South Africans. The private sector's efforts to apply government policy and open its doors to Africans are held back if there are insufficient numbers of qualified candidates for increasingly skilled positions. Most of the jobs now being created require competence in at least mathematics – this includes work at nearly all skills levels, in the manufacturing, construction, retailing, service industry, engineering, and technology sectors. Successful businesses, enterprise creation, and management skills across the board require a competence in maths and languages. Access to higher education and the professions is in almost every case precluded without, at least, maths qualifications.

If we want to ensure African economic empowerment, increased employment equity, and growing numbers of Africans in more senior positions in the economy and society, we have to dramatically improve the number of school graduates in HG maths and science. This will also require more qualified candidates entering the education profession, and becoming dedicated and effective teachers in these subjects. There can be few higher priorities in South Africa today.

3. The present maths and science education system is failing many individuals and their communities, and is wasting national resources

Hundreds of thousands of young South Africans are enrolled in schools where they have little or no chance of passing HG maths and science. Simultaneously, there are thousands of young learners who, if given the right guidance, as well as competent teachers, would pass SC maths and science in the HG.

This is key to all our ambitions concerning community upliftment and local economic development not to mention individual or family advancement. An example from Gauteng illustrates this point: in 2003 the two Ekurhuleni townships of Tsakane and KwaThema, situated at the heart of the national economy, achieved 1 600 SC passes – but only 12 of these included HG maths.

4. We need to acknowledge the diversity and complexity of the system, and support targeted interventions over single policy approaches.

South Africa's schooling system is very large, and there are important variations in the conditions under which maths and science education are provided. One single, central, national policy and strategy for improving maths and science education would be inappropriate. Rather, within a broad framework, focused policies are required aimed at achieving specific outcomes in specific settings, utilising different strategies and methods of implementation tailored to individual schools and their particular levels of teaching skills and learner awareness.

A major obstacle to differentiated policies and implementation has always been inadequate information about the subcomponents of the system, whether these be geographical, managerial, functional, or learner-related. This project has started the process of overcoming this obstacle. We now have reliable information on performance in the SC examination over time, and in each of the provinces; the status of individual schools by name, location, and facilities; a profile of individual school performance year-on-year, and in comparison to all other schools; and individual learners, even the specifications of groups whose members could pass either or both subjects at HG but do not enrol for these subjects.

Therefore, it is now perfectly possible to act in different ways in respect of different parts of the system. But the reasoning and logic for this graduated and phased approach needs to be accepted by government, and communicated to all concerned, so that no misunderstandings develop about the government's medium- and long-term commitment to equal access to quality maths and physical science learning and teaching for all.

When such an approach is adopted, issues arise around the balance between 'transformation' and 'diversity', and 'equity' and 'excellence'. But that is exactly the point. This area of policy requires an ongoing debate among stakeholders within the general principle of differentiated policies, implemented intelligently in different ways in different parts of the system, according to local conditions. This will involve a wider spread of responsibility that will, in turn, release much greater initiative and responsiveness in the system.

5. We cannot change everything at once. Priorities are required.

Research cautions us to be realistic. Despite all the 'virtues' we have identified, we still haven't reached square one**.** The reality is that we do not have enough educators competent to teach maths and science, nor sufficient learners competent enough to study these subjects at the levels we require and in numbers that will make a difference to the economy and the education system. We certainly do not yet have the resources to introduce a bottom-up reform initiative, starting in the primary schools.

The implication of this is that, before we proceed, we must agree on the key priorities for immediate action. The system is too heavily constrained to attempt many things at once. In a situation of limited capacity in government, provinces, schools, the educator community, and the private sector, only a few priority areas can be addressed, but these must be the key priorities.

Our research indicates that we must intervene in grades 10 to 12, keeping as much of the present system intact as possible, and focus on increasing the number of good HG passes over a short period. Then we must try to draw as many of these graduates as possible back into education, and retain them by any means necessary, including incentives appropriate to their individual and professional needs. At the same time, the content knowledge and teaching skills of existing maths and science educators must be improved and upgraded. Vigorous attempts must be made to re-recruit well-qualified and skilled educators who have left the system. We must also accept the vital role played by language competence, and launch appropriate programmes to improve educators' skills in the languages of instruction and examination. We must be clear that, while this is only a first phase, it is a vital one without which further advances will not be possible.

Every resource available to us will be needed to achieve only these few priorities for action. We do not have the educator capacity to reform the system immediately, even in grades 10-12. We still have to build that capacity. Policies and strategies cannot assume that we have the capacity even to train our present corps of educators to deal with new curricula and teaching methods.

BOX 9.1: MATHS AND SCIENCE CHALLENGES IN BRIEF

- Increase the numbers of maths and science educators.
- Ensure that each educator has a sound knowledge of the curriculum.
- Improve the professional development of educators.
- Upgrade the language competencies of maths and science learners.
- Identify learners with an aptitude for maths and science early in the system.
- Give more time to maths and science in the school year.
- Benchmark performance, domestically and internationally.
- Apply policies and programmes in a flexible manner, relating them to individual schools.
- Launch programmes specifically aimed at improving pass rates in maths and science, including specialist schools, incentives for educators, and financial assistance to learners.
- Act on quality factors identified in the school-based research undertaken by CDE and others.
- Strengthen school management and administration.
- Strengthen school governing bodies and allow them to take substantive decisions in respect of maths and science.
- Temporarily suspend the maths and science programmes in extremely weak schools, and redeploy qualified educators and talented learners to stronger schools.

CDE 2004

6. Additional properly qualified and trained maths and science educators must be found.

There is no reliable national database on the qualifications of educators in South African schools. The best information available is based on self-reporting by educators concerning their qualifications. By this measure, only 14 per cent of schools reported in 2001 that their maths and science educators had the minimum qualifications prescribed by the NDoE (SC plus 3,5 years of higher education). The country faces a severe shortage of trained, qualified, and experienced educators if we wish to expand participation and improve the performance of learners at the levels required.

Experts indicate that the norms for higher grade maths and science teaching need to be sharper than we currently think about them. For maths the norm should be that all teachers who teach Maths HG (or Maths as opposed to Maths literacy in the proposed new system) should have a university degree with a mathematics major. For science, all teachers should have physics and chemistry as majors in their university degrees, or one major with the other at second year level. As temporary measures, one could use people with Maths 11 for maths, or people with two years in physics and chemistry for science. In general, three- or four-year college diplomas will not do for higher grade teaching in grades 10-12. Finding out who these teachers are in our system will take a special audit. Once we have this audit we will be in a position to measure the true extent of the enormous educator challenge that the country faces.

Serious consideration needs to be given to retaining our many excellent teachers (many of whom work under difficult circumstances); utilising their skills as effectively as possible, so that as many learners as possible can benefit from their expertise; attracting more of our small numbers of appropriately qualified SC graduates back to the teaching profession; ensuring the best possible system of upgrading the knowledge and skills of those who are already in place (CDE has identified international programmes that are directly relevant); and, if necessary once we know the results of a detailed audit of current educator qualifications, hiring qualified and experienced English-speaking educators from other countries (India, parts of eastern Europe, and other African countries offer real possibilities).

7. Anyone with aptitude and initiative should have access to maths and science education.

The maths and science education system must be purposefully broadened to encompass every learner with aptitude and the initiative to take up the learning challenge involved. However, not every learner has the capacity or interest to succeed at the highest levels, nor to go on to a degree and an education qualification. Therefore, the value of access across the system must be pursued at the same time as excellence is achieved in specific parts in the system. Mechanisms must be found to ensure that ‘no child with potential in maths and science is left behind’ because they live in a part of the country that has been historically neglected. This will require learners with potential to be identified at an early stage; and the country providing the organisation and resources needed to enrol them in schools competent to teach maths and science.

8. Incentives play a decisive role in development.

Development literature, evidence of what works internationally, and numerous projects and programmes increasingly show that incentives play a decisive role in human development, and thus in social development. It has become clear that development is often unsuccessful if it simply exhorts or encourages individuals, or even seeks to create specific opportunities. Meaningful incentives also need to be provided. These must be measurable advantages to individuals that, if taken up, will assist both the individual and society.

Incentives are already a major feature of the modern workplace: these arrangements are now so prevalent that an influential commentator, Professor William Easterly has stated: ‘People respond to incentives: all the rest is commentary.’

Our research shows that a sound theoretical basis exists for using incentives to improve the recruitment, development, and retention of maths and science educators. They need to be carefully implemented; however, if applied sensibly, incentives can play a positive role in overcoming constraints in the supply of and demand for maths and science educators. They can also encourage more students to study HG maths and science when they see the rewards available to them for working at these ‘difficult subjects’. Lastly, they can also be used to encourage schools to improve their maths and science performance.

9. State and markets – supply and demand in education.

In country after country in the developed and developing world, progressive modern states are facilitating the private sector increased scope and opportunities as the providers of more differentiated, specialised educational opportunities, often in response to rising demand from parents.

This is being accomplished in countries with both large and small populations, and without governments relinquishing their obligations for continuing to ensure that an efficient and effective public system of education exists. By creating the space for private providers in education, many public education authorities have successfully combined a degree of deregulation of the educational sector with expanded opportunities for private education providers to operate in tandem and/or parallel with public education. Increasingly, public monies follow the learner – whether that learner attends a registered public or independent school. As long as the regulatory system ensures public accountability for performance and some aspects of the curricula (a commitment to support the country’s democratic constitution, for example), such systems have positive outcomes on performance. A compelling example is the provision of publicly funded school vouchers for use by poor inner-city students, often drawn from minority communities, in the United States, and supported by a majority of African-American parents nation-wide. Another example from countries in the European Union and United States involves public schools operating under special agreements with state education authorities to provide specialised education – so-called ‘charter schools’.

Private education is also growing rapidly in most developing countries, and, as a recent International Finance Corporation report shows, it is no longer synonymous with ‘elite’ education. In fact, the opposite effect is evident, in that many poor learners previously trapped in underperforming, underresourced, poorly managed public systems now have access to reasonably priced, good-quality, and standardised educational opportunities provided by global or local education companies. South Africa is not excluded from these global processes. Our research shows that stimulating demand *within* the publicly provided system can also encourage greater flexibility and efficiency of provision; improve the motivation of principals, educators, and learners; and generally add value to the system.

The 21st-century state has an obligation to provide a public system of education and should do so as efficiently and effectively as possible. However, there is no value in insisting that public provision and overall accountability for a quality education in a given subject precludes working with private providers of education, or responding to demands from parents and learners for the more flexible use of public resources.

Real advantages accrue to countries that encourage a thousand (educational) 'points of light' to burn, while keeping a stern eye on quality control and standards. Flexibility of provision and responsiveness to need must balance the acceptance of responsibility by the public sector.

10. We need to demonstrate new attitudes towards educational reform.

The success of the initiatives CDE is proposing will depend on pragmatism, flexibility, prioritising the needs of one part of the system over others (at least temporarily), and providing special incentives for and status to certain educators and learners. The country needs to approach elements of educational reform in a more pragmatic and nuanced way. Such an approach in no way diminishes the long-term goals of equity and excellence, but does mean more flexibility in how we achieve these goals. Some areas of change must be prioritised over others. Excellence must be seen as the precursor of and not the successor to equity. Equity of provision in maths and science can only be achieved through excellent principals and educators. There may even be a need to discontinue expenditure on maths and science in long-standing unproductive areas, such as schools with long histories of pass rates below 20 per cent, so that we can focus all resources where the most positive results will be achieved most quickly.

Obviously, the approach CDE is proposing differs from any of those used thus far. We believe this is necessary and beneficial. Too many interventions have been attempted without lasting impact, and it is time to try something new. But we need to try it in a disciplined, conservative, and incremental way, in order to minimise possible negative side-effects, and maximise our chances of success.

11. The importance of a monitoring and research base for action.

Proposals to change even a badly functioning system have to be based on sound research of the that system and located in a solid understanding of what is being tried elsewhere.

We need to identify and monitor key indices of improvement. The system itself cannot be improved without frequent assessments of how it is performing, where its strengths lie, and which schools continue to disappoint despite the application of resources and support. We must, however, agree on what these key indices are: in our view, it is the increasing quantity of quality passes.

South Africa has erred by moving away from system assessments and probably has too few individual examinations as well. We need to sample our system more frequently, assess patterns of performance and participation in our schools, and begin to target our resources within a clear programme that supports participating schools and rewards individual schools on their respective merits.

12. The government must lead a national partnership that delivers results.

As in any large-scale system, government must provide a clear framework for action, with appropriate guidelines and targets for implementation at different levels.

However, this programme must be drawn up in consultation with all role players, and the government must ensure that its goals and outcomes are consistent with all its other actions and policies, and that individual school communities are empowered to respond positively to these initiatives. In the last instance the responsibility does lie with government to introduce and drive such a programme via an appropriate body, but it must find positive and productive ways of working with other role players.

CONCLUSION

'Fixing' South Africa's system of maths and science education is one of the country's most important national priorities. Energy, goodwill, and capacity to move ahead is evident across the public and private sectors. What is needed is an achievable set of activities that will demonstrate rapid progress, and improve confidence in our ability as a country to turn things around. Leadership is required that understands the constraints within which we need to move forward, and can pull together the energy and resources of all those willing and able to make a difference.

Chapter 10

CDE'S RECOMMENDATIONS

South Africa has to deal with a national crisis in respect of maths and science schooling. Current public and private sector efforts are insufficient to significantly change the system that is failing individuals, families, communities and the country. Almost all South Africa's ambitions to grow the economy, provide new job opportunities for black citizens, and ensure our success as a democracy are undermined by our collective failure in this area. We do not have the capacity to change everything we would like to immediately. A limited programme of action needs to be decided upon. Dramatic improvements in the number of quality passes are possible in the short term. Achieving these will require a new and common framework of understanding and investment by public and private leadership and other key players.

In this final section, we will define goals for a new approach to maths and science education in South Africa; outline our overall approach to reform; and put forward ten practical proposals.

GOALS

Over the next five years, South Africa should aim to:

- double the number of HG SC maths and science passes; and
- double the number of qualified and able teachers in the public school system.

APPROACH

CDE's recommendations are based on the following underlying guidelines that have emerged from our research:

- Any attempt to improve the maths and science education system must start with limited but achievable aims that will lay the foundation for an improving system over time.
- New initiatives must build on what is working in the system, ensure that performing schools continue to excel while changes are introduced, and ensure that their ability to deliver quality education is available to as many individuals as possible.
- During the next five years, every learner with aptitude and initiative, wherever he or she may live, must have the opportunity to study at a school that provides effective maths and science teaching;
- There is no 'single best national way' to improve maths and science education through centralised policies.
- Public and private sector leadership, energy, and initiative must pull together if we are to succeed.

PROPOSALS

We must introduce a comprehensive programme that provides for systemic change, involves public and private sector leadership and resources, achieves short-term results, and is implemented via an effective and accountable institution.

1. Mobilise the concerns of important stakeholders in maths and science education into a national programme.

There are many stakeholders in maths and science education, including national and provincial government, the private sector, foreign governments and donor bodies, international agencies, the independent schooling system, tertiary education, the scientific research community, educators, learners, and, last but not least, parents.

There is a worldwide recognition that this is a difficult field, and few countries are satisfied with their performance. Therefore, the challenge must be seen as a long-term one. Improving and reforming the system must be regarded as an ongoing process, not a single goal to be reached at a specific point in the future. We have to plan to produce a better system with a built-in capacity to improve further by monitoring and evaluating its own performance, and making additional incremental changes. In order to do this, we must assess progress much more often; and test learners more frequently. The outcome we all seek is better results, and a gradually improving system. In the process, we should aim at creating greater public confidence in the education system as a key pillar of a successful and increasingly prosperous democratic society.

Mobilising the energies and commitment of all the relevant role players will require an energetic programme. We need a systematic, country-wide initiative aimed at ensuring a common understanding of the nature of the challenge we face and mobilising commitment and involvement towards the common strategic set of interventions proposed here.

2. The key to successful reform is an increased supply of qualified maths and science educators.

Effective educators are vital to improving the system, but they are in short supply, thus constraining our reform efforts. Three programmes should be devised to deal with this situation:

- *Identify the qualified and able maths and science educators currently in the schooling system.* No one has reliable and comprehensive national information. This is urgently needed for the programmes we are suggesting, and also because our research indicates that there are a large number of educators qualified to teach maths and science but who are employed to teach other subjects.
- *Increase the supply of qualified maths and science educators, and retain existing competent educators by means of a well-conceptualised programme of incentives.* Maths and science educators are in short supply throughout the world Graduates with appropriate qualifications are at a special premium in South Africa. Nevertheless, the

issue of providing incentives to educators in certain subjects has long been resisted here. An incentives programme for maths and science educators should be launched immediately. It must be aimed at attracting new educators, as well as retaining the skilled educators we have. The best results will probably be achieved if the innovations are introduced as a distinctive 'programme' and not as part of the routine public administration of this sector. This will also give the programme a better chance of attracting financial support from other institutions, including private sector corporations, as it will give their funding a specific focus.

- *Institute a new approach to the professional development of maths and science educators; if necessary, adopt successful models from abroad.* The first emphasis in developing educators must be on content knowledge, followed by teaching skills. This is the basis of the most successful educator development programmes CDE has identified in the course of its research. Their success is also based on the principle of steady incremental improvement achieved within a comprehensive programme of support, marked by regular assessments, combined with appropriate incentives to participants. The motivational and communications dimensions of these programmes are also impressive. Educators who benefit from these programmes are expected to pass on some of their new-found knowledge and skills to colleagues who have not or could not attend. Should a high-profile international programme be adopted, other national government aid institutions, corporations, and private foundations might be persuaded to financially support its introduction in South Africa.

3. Build on the potential in the school system.

Given CDE's school performance index, we are now able to identify and classify the maths and science performance of every secondary school in the country. This enables us to formulate specific initiatives to improve their performance, and the access of talented learners to well-performing schools. Steps should be taken to:

- *Identify all high-performing schools* (ie schools with a pass rate of 80 per cent or more in large HG maths and science classes), *and investigate ways in which they could play an even bigger role*. Can they deal with larger classes; can they expand their maths and science departments; can they share their expertise with poorer performing schools in their neighbourhoods; can a city run a programme to encourage performing schools to 'adopt' the maths and science departments of non-performing schools in other parts of the city? Appropriate incentives must be provided for these schools to play such an expanded role.
- *Devise specific programmes to help those schools delivering pass rates in the 60-80 per cent band to improve their performance*. These could include programmes to improve general school management, and programmes to improve the skills of educators teaching maths, science, and the languages of instruction in those subjects. Again, incentives should be provided to motivate school administrators and educators to move to a higher performance bracket.

- *Establish an independent, objective measure of each and every school's annual performance in maths and science*. Incrementally 'raise the bar' for every participating school by setting realistic targets for increasing participation and performance. Link incentives to goals, so that schools are encouraged to progressively climb the ladder of success with respect to maths and science delivery.

4. 'No child left behind': provide mechanisms for learners and parents, wherever they live, to take advantage of new educational opportunities

South Africa's educational system has to deal with the legacy of apartheid. This means that many poorer, mainly African, households in urban as well as rural areas do not have access to good schools with functioning maths and science departments. This harsh reality cannot be fixed overnight, and CDE's proposals are designed to incrementally increase the country's supply of decent educational opportunities for everyone. This will take time. In the meantime, there are initiatives we can undertake to ensure that no one with initiative and aptitude need be denied opportunity.

We need to find ways of stimulating greater demand by parents and learners (and dedicated educators and principals) for quality maths and science education, by providing new avenues for accessing opportunity in maths and science.

A trial programme should be launched that works as follows:

- The introduction of a national aptitude test, available throughout the country on an annual basis. This should be for grade 9 learners and should be independently set, marked, and monitored.
- Any learner who does well in this test should be eligible for financial support to attend a school with a good delivery record in SC maths and science. This could be a neighbouring school, when all that would be needed would be a transport subsidy; or they might need to go to a boarding school, in which case more resources would be required.
- Money will follow learners – in other words, a learner would take his/her allotted public subsidy with him / her to the new school, which would, in turn, benefit educationally and financially.
- A pool of new funds will be needed for additional costs: running the aptitude tests around the country, providing boarding fees or transportation costs or both for promising learners.

This is a new proposal for the redistribution of financial resources towards poor parents, and will need to be thought through carefully, and implemented experimentally. But its long-term beneficial impact seems clear. Demand for better maths and science education will have a positive impact on the entire system, as schools lose or gain learners, and will provide incentives to schools to change and improve. There is international experience on which to draw. This would be an ideal area for attracting private sector support and involvement.

If we want results in the next five years we need to get much better matching between good learners, good educators and effective schools. This set of proposals – an aptitude test to identify learners with potential and then the mechanisms and resources to get those learners to effective schools who teach maths and science properly at HG level – will help the country to do this, and should be implemented as a matter of urgency.

5. All maths and science education initiatives should include appropriate language components

For ease of reference, CDE has used the phrase 'maths and science education' throughout this and the main report. However, as we have noted earlier, learners' proficiency in the language of instruction and examination plays a very significant role in their performance in maths and science. This has been confirmed by CDE's case studies, our interviews with practitioners, and our workshops with examiners. It is also stressed in the international research.

As a result, all maths and science educational activities should be closely linked with improved language education. Given the nature of global economic development, it will be most beneficial if the language involved is English, though learners with Afrikaans as a first language seem to experience little difficulty in proceeding to grade 12, and managing any necessary transition to English after that. How this issue is best approached and what steps ought to be taken should be a priority task of a National Task Force (see recommendation 10).

6. The Dinaledi programme should be reconceptualised, restructured, and expanded.

Dinaledi has broken new ground for maths and science in the public schooling system. However, in reviewing what has been achieved (and acknowledging the 'virtues'), we must also acknowledge where our performance has been disappointing, and take remedial steps, so that many more schools and learners can participate and benefit.

CDE recommends that the Dinaledi programme be reconceptualised, restructured, and expanded. It should be a permanent feature of the education system. It should also fall under the aegis of the proposed National Task Force (NTF) on Maths and Science Education (see recommendation 10 below).

7. Review all other educational policies for their effect on maths and science

As South Africa enters its second democratic decade, we are convinced that maths and science schooling is its top educational priority. If one accepts this proposition, then this has consequences for existing policies, approaches, and the allocation of resources.

Our research has indicated many areas in which general education policies and financing priorities are (unintentionally) having a negative impact on maths and science education.

This situation should receive the urgent attention of our proposed NTF (see later), in consultation with stakeholders. It should commission focused research, formulate specific proposals for change, and submit these as soon as possible to the minister of education.

8. The private sector and NGOs should review the support they have given to maths and science education, with a view to aligning with the proposed national thrust

Concerned private sector institutions should use this report as a basis for a discussion on how to focus their input more strategically. Without being prescriptive, but in the spirit of the systemic reform advocated here, the private sector should consider shifting its focus from small-scale research and programme implementation to some or all of the following:

- institutional support for a new public–private partnership to double the number of HG passes in five years. In other words, help to fund the proposed National Task Force (see later);
- support to individual schools that are performing well and/or improving, or to schools aspiring to join the specialised maths and science programme;
- support for an educator development programme based on credible international models;
- support for programmes to identify learners with maths and science potential by means of assessments in grade 9, ie, the aptitude test proposed earlier;
- financial support for learners with potential who need to travel to or board at well-performing maths and science schools;
- provision of financial and other incentives to the best performing educators and learners;
- financial support for maintaining and updating the CDE developed database on individual and school performance with respect to maths and science, as a tool for monitoring progress. The database and its development should be placed under the control of the NTF (see later).

The work already being done by many corporations in providing bursaries for higher education is acknowledged. Extension of these programmes to, or a tighter focus on potential maths and science educators could be considered.

9. International aid agencies and foreign national donors should forge links with the new national initiative, and develop synergies between themselves and other stakeholders.

Since 1994 financial contributions to South African education by international aid agencies and foreign national donors have far exceeded those of local businesses and other donors. The continued support of these foreign agencies will be essential for the success of any maths and science programme. We believe this is a good moment for international aid agencies and foreign national donors to commit additional resources and target their support behind the proposed national initiative and integrated programme of action being suggested here.

10. The cabinet should establish a National Task Force as the vehicle for focusing and directing a national partnership to dramatically change the future of maths and science schooling in South Africa.

In making this recommendation, we aim to focus the commitment to adopt a systemic nation-wide approach in a new institution devoted entirely to achieving the country's maths and science goals. Besides national and provincial government, there are a significant number of stakeholders with an interest in this task. At present, they are not formally involved in meeting this great challenge, except insofar as they are brought into government initiatives or pursue their own (necessarily much smaller) initiatives. They all do good work, but the whole effort is not greater (and may be smaller) than the sum of the parts. Their efforts could be harmonised and amplified by creating a broadly based institution with responsibility for the whole system of maths, science, and language education.

Specifically, CDE proposes the formation of a public–private partnership in the form of an NTF for the improvement of maths and science education in South Africa.

Goals

The NTF should be made responsible for achieving two specific goals:

- doubling the number of school-leavers with an HG pass in maths, physical science, or both within five years; and
- doubling the number of adequately qualified and trained educators in these subjects with the same period.

These are the indispensable first building blocks of an incremental approach to systemic reform.

Functions

The NTF should have specific functions that go well beyond 'advising the minister', and generally promoting the need for an effective maths and science education system, though both of these activities are necessary and desirable. It should also:

- Articulate and promote a strategy for achieving the goals referred to above, in a form acceptable to the largest possible number of bodies or institutions presently working in or providing funds for maths and science education. These should include independent schools; higher education institutions; researchers and professionals; donors; the South African private sector; NGOs active in education; maths, science, and language educator associations; and others that make themselves known. The aim is to achieve a greater alignment of effort than is presently the case, though without discouraging initiative and experimentation with alternative approaches.

- Act as the body receiving and approving applications by schools to be appointed as participating schools, and review the continued membership by each school after appropriate periods.
- Develop and administer a national assessment of learners' mathematics and science potential, and link successful candidates to the nearest competent maths and science school.
- Develop and administer a national incentive programme for learners, educators, and schools that will encourage them to participate positively in the national maths and science programme
- Maintain and update the school performance index created by CDE, and promote its use in setting targets, designing methods, setting priorities, and assessing outcomes. These potential uses are discussed in depth in the main report.
- Give substance to the urgent need to continuously monitor and evaluate the system. There are five dimensions to this:
  - Create and administer a credible assessment body that will give grade 9 learners a chance to volunteer for an assessment of their maths and science aptitude. This will enable parents, learners, and schools to make more informed decisions about choice of subjects for SC.
  - Commission ongoing and occasional monitoring and evaluation of aspects of the system in consultation with the NDoE, provincial departments, and other bodies.
  - Maintain a permanent monitoring and evaluation mechanisms for the system as a whole, to assess progress and advise on incremental adjustments.
  - Promote research into maths and science education trends, nationally and internationally, and bring findings relevant to the South African system to the attention of the minister of education and/or other parties.
  - Create and maintain a programme for communicating with interested audiences about the importance of maths and science education; the progress being made in improving it; the logic of the strategy being followed; and stories of specific successes. The programme should include an annual report to the cabinet, parliament, and the public on activities and progress.

Membership

The NTF is envisaged as an expert (not representative) body, with public and private participation. The co-chairs should be drawn from the South African cabinet and business sectors.

Staff

CDE proposes the appointment of an executive director and one assistant only. All other functions should be outsourced.

Funding

Initial funding should be sought from the public sector, the South African business sector, and international and foreign donors for a five-year period.

CONCLUDING REMARKS

South Africa is dealing with a national crisis in its maths and science schooling. The correct response to this worrying situation is to adopt a concerted new approach by both the public and private sectors. The key challenge is how to change a large and diverse system without disrupting those parts of the system that are working.

CDE's ten recommendations have far-reaching implications, especially as they would play themselves out over time. They are practical, do not require extensive further research, and can be implemented incrementally. We have set out to provide a broad framework for action which is not a rigid blueprint to be followed and implemented blindly. The proposed approach is a flexible one which takes account of existing public and private interests and involvement in maths and science education. It also takes into consideration the responsibilities and functions of different players from government at national and provincial levels to parents, learners, educators and schools. In most cases a start could be made at once.

Communication of this new approach, its benefits for all South Africans and its ambitions within current severe constraints is an important consideration as we move forward. The overall image of the new approach must be one of first building the higher level capacity in sufficient quantity and quality to develop the essential expanded capacity which will in turn allow a future transformation of the whole maths and science education system.

This report provides a moment of opportunity for government. Key organisations and interests in the private sector are willing and interested to help make a significant difference, hence their support for this privately funded initiative which has also received enthusiastic support beyond its original donors.

A bold response from government is required. If this happens, a dramatic increase in performance is achievable within a five-year period.

Appendix 1

THE PROJECT TEAM

1. Ann Bernstein, executive director, Centre for Development and Enterprise.
2. Dr Tim Clynick, senior consultant, Centre for Development and Enterprise.
3. Prof Diane Grayson, head, department of maths, science, and technology, UNISA.
4. Margie Keeton, executive director, Tshikululu Social Investments.
5. Dr Robin Lee, director, Robin H Lee & Associates.
6. Prof Gilbert Onwu, Head: department of maths, science, and technology, University of Pretoria.
7. Prof Sipho Seepe, academic head, Henley College of Management.
8. Prof Charles Simkins, Helen Suzman professor of political economy, School of Economics and Business Sciences, University of the Witwatersrand.
9. Dr Nick Taylor, executive director, Joint Education Trust.
10. Penny Vinjevold, chief director, education planning, department of education, Western Cape provincial government.

Appendix 2

BACKGROUND RESEARCH REPORTS

Brombacher, Aarnout (2004) Mathematics and physical science interventions in South Africa, 2001.

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- Blaauw, Denric
- Dube, Ruth
- Erskine, Mike
- Khumalo, Lucky
- Linkonyane, Nopi
- Maqutu, Tholang
- Mathews, Sharle
- Mkhize, Duduzile
- Mogari, David

- Onwu, Gilbert
- Philander, Johnny
- Sigabi, Makhosi
- Sirestarajah, Kulandaivelu

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13

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