TOWARDS UNDERSTANDING STUDENT ACADEMIC PERFORMANCE IN SOUTH AFRICA:

A PILOT STUDY OF GRADE 6 MATHEMATICS LESSONS IN GAUTENG PROVINCE

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List of Abbreviations

ACE	Advanced Certificate in Education
CK	Content Knowledge
DAS	Developmental Appraisal System
DoA	Department of Agriculture
DET	Department of Education and Training (pre-1994 Department responsible for African education in urban areas
DoE	Department of Education
GDE	Gauteng Department of Education
HOD	House of Delegates (Department responsible from 1983 – 1994 for Indian education)
HOR	House of Representatives (Department responsible from 1983 – 1994 for coloured education)
EMIS	Education Management Information System
HEMIS	Higher Education Information System
INSET	In-service Education and Training
IQMS	Integrated Quality Management System
NED	New Education Department (New school established post-1994)
NGO	Non-governmental Organisation
OTL	Opportunity to Learn
PCK	Pedagogical Content Knowledge
PTR	Pupil/Teacher Ratio
REQV	Relative Education Qualification Value
SACE	South African Council for Educators
SACMEQ	Southern & Eastern Africa Consortium for Monitoring Educational Quality
SADTU	South African Democratic Teachers' Union
SAQA	South African Qualifications Authority
SES	Socio-Economic Status
SGB	Student Governing Body
TED	Transvaal Education Department (Provincial department responsible for white education in the province that became Gauteng in 1994)
WSE	Whole School Evaluation

Note on Terminology

Racially based terms such as African, Indian, coloured and white are recognised as social constructs with a history. They are used to identify the extent to which inequalities along racial lines have been overcome or not and as used in the official documentation.

The terms "learner" and "educator" are used in official documentation to speak about pupils or students and teachers. The term "educator" generally includes all school-based personnel in the term. Here the term "teachers" is used to focus on those who teach in public schools. Similarly, the official term in use for pupils is "learners." We use "students" and "learners" interchangeably.

INTRODUCTION

Despite widespread acceptance of the notion that improving student performance may have a high economic and social payoff, policy analysts in all countries have surprisingly limited hard data on which to base educational strategies for raising achievement. In South Africa this question is all the more pressing. South African students score at low levels in mathematics and language tests even when compared with students in other African countries (van der Berg and Louw, 2006). Further, the South African government's own evaluations of ten years of democracy show little improvement in educational outcomes despite significant policy changes (DoE, 2006). While some reasons for this poor performance may be evident, and there is widespread agreement that the main challenge in South Africa is the quality of education, there is little empirical analysis that helps policy makers understand the low level of student performance in South African schools or how to improve it.

As a first step toward an empirical approach to unpacking the factors contributing to low levels of learning in South African schools, the Human Sciences Research Council in partnership with a consortium of South African universities and researchers at the School of Education at Stanford University engaged in a small scale empirical pilot study that focuses on the role that teacher skills and practice play in South African students' learning within the socioeconomic and administrative conditions in those schools (and South African society more broadly).

The pilot was conducted in a sample of forty primary schools (Grade 6) in Gauteng, a geographically small and highly urbanized province in the northern half of the country. The pilot focused on mathematics lessons. Students in the selected sixth Grade classrooms filled out a short questionnaire on their socio-economic situation and some observations about their school. They took a predominantly fifth Grade mathematics test administered in July, 2007, and then a subset of the sample took the same test a second time in October. Students could choose to do the questionnaire and the test either in English, Afrikaans, or one of several African languages. Almost all chose to use the language of instruction (English or Afrikaans). Their teachers and their principals also filled out short questionnaires. The teacher instrument included questions about mathematics teaching, specifically content and pedagogical content knowledge questions. Each teacher was also asked to do a mathematics lesson with his/her class, and this was videotaped. Researchers visiting the schools/classrooms provided additional notes about the general situation at the school. The data provided by these instruments form the basis of this report. Although the information is copious, the pilot nature of the research means that its main purpose is to test the instruments and to assess the viability of the models.

The first chapter contextualizes these schools and teachers. We profile public school teachers in South Africa and in Gauteng and examine the curriculum, teacher education, supervision and evaluation and socio-economic context of the education system in which they teach. In the second chapter, we present our conceptual framework and methodology for the empirical analysis. We also discuss how we gathered the data and some of the lessons we learned from that process. The third chapter shows the results we were able to glean from the pilot. In the fourth chapter, we discuss the results and what they teach us about designing future research on a larger and comparative scale.

CHAPTER 1

THE CONTEXT OF THE STUDY

Under what conditions do teachers in Gauteng teach? Who are they and what are the characteristics of teachers in South Africa as a whole? What is the nature of the curriculum, teacher education and system of supervision and evaluation that equips teachers to teach? Can information on these and other contextual issues shed any light on the results that emerge from the study?

1.1 Profiling Public School Teachers in South Africa

There are a variety of data sources on teachers in South Africa, all providing different types of information based on different definitions of teachers. They include Department of Education, PERSAL (Personnel and Salary), Statistics South Africa (StatsSA), South African Quality Authority (SAQA) and other databases. This section draws on two reports, by Erasmus and Mda (2008) and Arends (2008) respectively, that analysed especially Department of Education and Statistics South Africa databases to provide information on teacher characteristics.

Race – The racial profile of the profession reflects the demographic profile of the country, where Africans are in the majority.

Figure 1-1: Race distribution in the ordinary school sector, in 2005

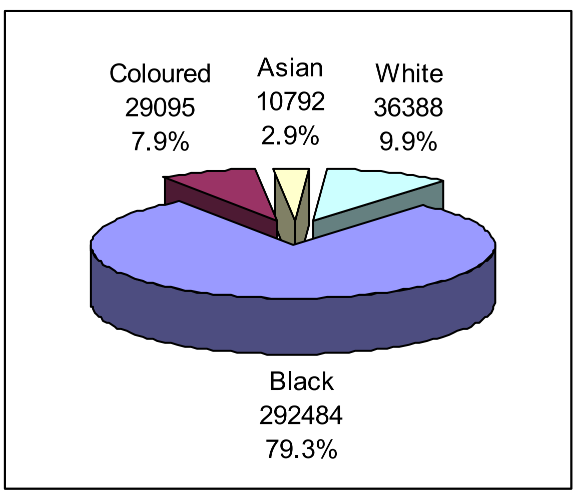


Figure 1-1 shows the number and proportion of teachers within public ordinary schools by race. In terms of race, approximately 79, 3 per cent of all teachers are black (=African), 7, 9 % per cent are coloured, 2, 9 per cent Indian and 9, 9 per cent white.

Source (Arends, 2008).

Gender – The 2005 gender distribution of teachers showed that women dominate the profession (Table 1-1). There were 256 782 female teachers in the ordinary school sector in 2005 (DoE, 2006:21). Female teachers accounted for "between 67 and 75 per cent" of teachers at primary school level by province in 2004 (DoE, 2005: 43). Gauteng province recorded the lowest percentage (27, 9 per cent) of male teachers.

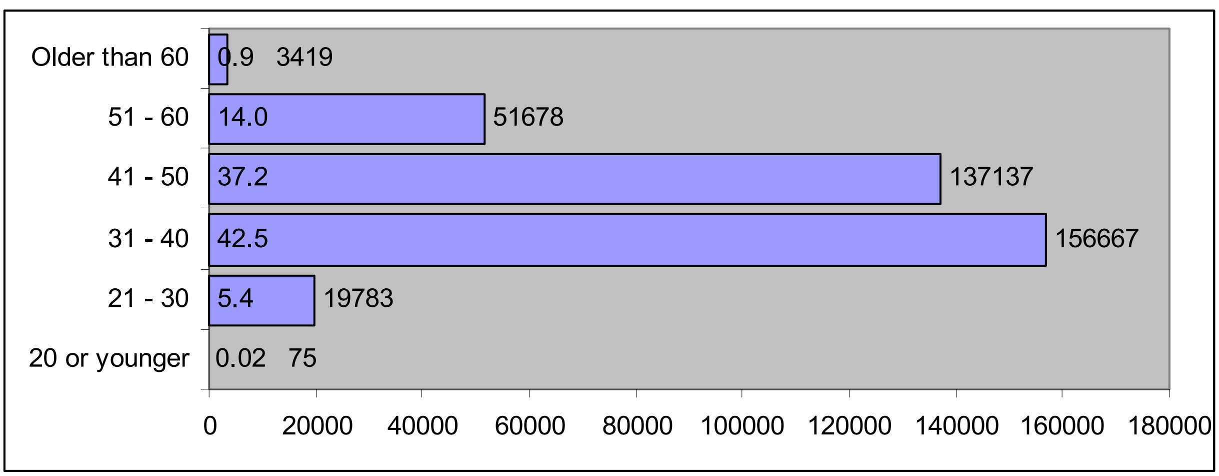
Table 1-1: Gender distribution in the ordinary school sector, by province in 2005

	Number of teachers				Distribution (%)		
Province	Female	Male	Total	Province	Female	Male	Total
Eastern Cape	47621	19609	67230	Eastern Cape	70.8	29.2	100.0
Free State	14844	8556	23400	Free State	63.4	36.6	100.0
Gauteng	43354	16767	60121	Gauteng	72.1	27.9	100.0
KwaZulu-Natal	56645	24334	80979	KwaZulu-Natal	70.0	30.0	100.0
Limpopo	31471	24689	56160	Limpopo	56.0	44.0	100.0
Mpumalanga	18001	9700	27701	Mpumalanga	65.0	35.0	100.0
North West	18635	8819	27454	North West	67.9	32.1	100.0
Northern Cape	4317	2324	6641	Northern Cape	65.0	35.0	100.0
Western Cape	21894	10553	32447	Western Cape	67.5	32.5	100.0
National (Total)	256782	125351	382133	National (Total)	67.2	32.8	100.0

Source: Erasmus and Mda (2008). Calculated from Table 7 in DoE (2006: 20-21)

Age - According to the DoE (2005:45), only a fifth of 375 000 or "twenty-one per cent of all South African teachers were under the age of 40" in 2004. A recalculation by Erasmus and Mda of the number and distribution of teachers by age group (published in Figure 3 by the DoE [2005:45]) shows that more than half (57,0 per cent) of the teachers were 41 years or younger in 2004. Arends (2008) finds that 42, 5 per cent of all teachers were 40 years or younger in 2005 (Figure 1-2 below). A further 37, 2 per cent fell within the 41 to 50 year age group and 14, 0 per cent within the 51 to 60 year old age group. This means that 51,2 per cent of teachers in the system in 2005 were above the age of 40.

Figure 1-2: Age distribution of teachers in 2005



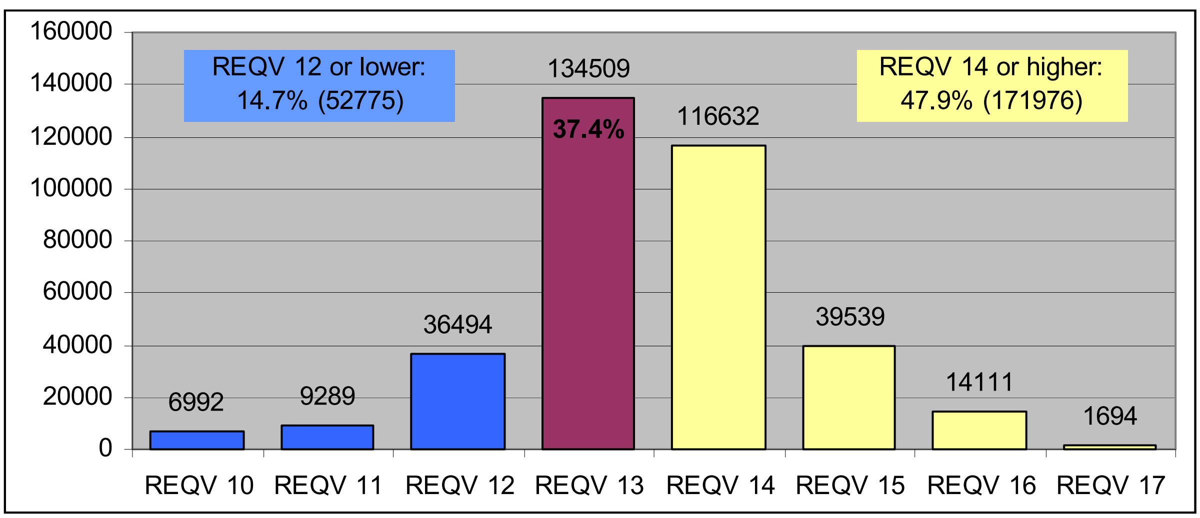
Source: Arends (2008).

According to Statistics SA (StatsSA), the mean age for all graduates in the field of Education and the mean age for practising teachers was 41 in 2005 (Stats SA, 2006). This is not significantly older than the mean age of 38 for all employed people in 2005 who had obtained a certificate/diploma or higher qualification. The Stats SA figures also show that the mean age for unemployed graduates in the field of Education was 35 in 2005.

Qualification levels of practising teachers - The Norms and Standards for Educators, published in 2000, regarded teachers who had obtained a three-year post-school qualification (REQV[1] 13 level) as adequately qualified (DoE, 2005:47). The 2007 National Policy Framework for Teacher Education has set the minimum entry level for all new teachers joining the teaching profession slightly higher, at REQV 14 level. The two recognised pathways are: 1) the four year professional Bachelor of Education degree and 2) a three year junior degree followed by a year-study of a post-graduate diploma (RSA 2007: 13-14). Less than half (47, 9 per cent or 171 976) of 359 260 teachers had an REQV 14 qualification in 2004 (Figure 1-3, below). A further 37, 4 per cent (or 134 509 teachers) had an REQV 13 level qualification. Only 14, 7 per cent (or 52 775 teachers) could be regarded as under-qualified because they had an REQV 12 or lower qualification.

Although 14, 7% seems like a small percentage, it means that in 2004 more than 50,000 teachers were still under-qualified. It is not clear at this stage how much of a dent the National Professional Diploma in Education (for upgrading under-qualified teachers) has made, as the Programme is still continuing.

Figure 1-3: Distribution of teachers by REQV level (October 2004)

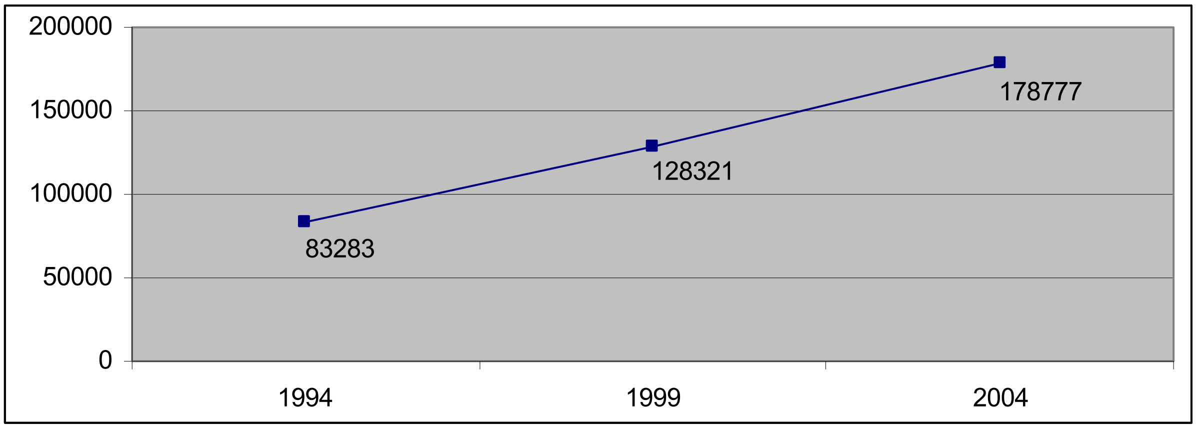


Source: DoE, 2005:48

[1] The Relative Education Qualification Value (REQV) is a relative value attached to an education qualification that is based primarily on the number of recognised prescribed full-time years of study. Matriculation value is REQV 10. All honours, masters and doctoral degrees have a REQV level of 15 and above. Higher diplomas and bachelors degrees have a REQV level of 14. All diplomas are at REQV level 13. Teachers are considered to be unqualified or underqualified if they have a qualification resulting in level 10, 11 or 12, that is, less than three years after matric.

Enrolments in the field of Education at universities suggest that South African teachers are eager to better their qualifications. For example, of the 107 000 students enrolled in 2001, only 20 321 were enrolled as full-time students, the rest registered as part-time students (DoE, 2005: 14). Figure 1-4 below shows that the total number of graduates who achieved an REQV 14 or higher qualification in the field of Education more than doubled from 1994 to 2004 (SAQA, 2007). REQV 14 equivalent graduates increased from 83 283 in 1994 to 178 777 in 2004. This constitutes a total increase of 114, 7 per cent over a period of ten years.

Figure 1-4: Growth in the number of REQV 14 equivalent Education graduates (1994, 1999, and 2004)



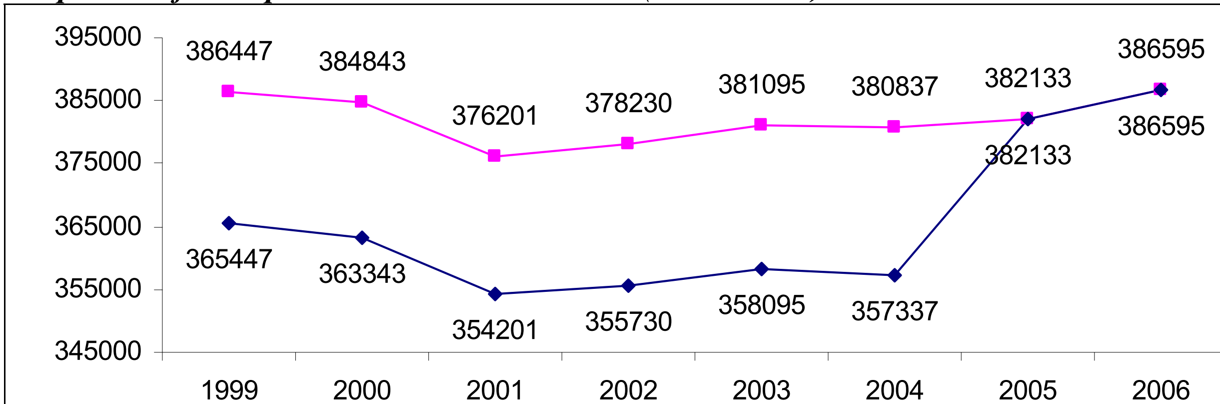
Source: Erasmus and Mda (2008). From South African Qualifications Authority (SAQA), 2007.

Erasmus and Mda (2008) point out that if the mean age for practising teachers was 41 and that only 5, 4 per cent (or 19 783) of all practising teachers were under the age of 30 in 2005 (Figure 1-2), it can be assumed that only the latter (5, 4% of teachers) had been prepared in their initial teacher education for Curriculum 2005 and its later revisions (see below). The implication is that the majority of teachers were not prepared for the new curriculum, and in many cases may not have had the skills needed to interpret and implement a new curriculum.

Teacher attrition: According to the DoE (2005:54), the teacher attrition rate is currently estimated at between 5 and 5.5 per cent nationally, which in absolute terms translates to between 17 000 and 20 000 teachers lost to the system each year. In Figure 1-5 below, Erasmus and Mda (2008) show that there was a decline in the number of teachers in the ordinary school system between 1999 and 2001 (a total of 11 246), but that the number of teachers increased by 3 894 over the next two years, with a slight dip (-758) between 2003 and 2004 (Figure 5). Over five years there was a total loss of 8 110 teachers. HIV AIDS plays a role in teacher attrition. A recent study found that, of 17, 088 teachers who gave a specimen for HIV testing, 12.7% were HIV positive (Shisana, et al, 2005: 53). Crouch (2003) has however pointed out that the attrition rate among South African teachers is "normal"; attrition is highest among younger teachers who first join the system, test it and leave for something preferable after a few years. Most teachers who remain are older. Available evidence suggests that there is currently a large pool of teachers to fill in for those who leave. How long they have been out of the system and how relevant their qualifications may still be is unclear.

The upsurge of employed teachers shown in Figure 1-5 between 2004 and 2005 can be ascribed, Erasmus and Mda suggest, to the fact that in the SNAP Survey reports[2] for 2005, schools included all School Governing Body-paid and not only government-funded teachers at public schools. As will be explained later, schools have the right to appoint additional teachers if they have the funds to do so. It is unclear how many of the 24 796 additional teachers in 2005 and of the added 4 462 in 2006 were School Governing Body-paid teachers (see below).

Figure 1-5: Number of teachers in the ordinary school system from 1999 – 2006: a comparison if SGB-paid teachers were included (1999 – 2004)



	1999	2000	2001	2002	2003	2004	2005	2006
Including SGB-paid	386447	384843	376201	378230	381095	380837	382133	386595
Teachers	365447	363343	354201	355730	358095	357337	382133	386595
SGB-paid (added)	21000	21500	22000	22500	23000	23500	SGB-paid included	
Attrition		-1604	-8642	2029	2865	-258	1296	4462
Ratio	32.0	30.8	31.2	31.5	31.6	32.0	32.0	31.8

Source: Erasmus and Mda (2008). Figures for 1999 – 2005 were calculated from Education in South Africa: A global picture published annually as "centerfold" in DoE's Education statistics in South Africa at a glance. 2006 figures were taken from 2006 School realities. "SGB-paid (added)" figures are based purely on assumption.

Analysis of DoE, SACE and StatsSA figures at an aggregated level seem to suggest that there is no shortage of teachers (Arends, 2008; Erasmus and Mda, 2008). DoE figures indicate that there were more than 380 000 practising teachers and a possible 12 000 surplus teachers in the ordinary school system in 2006. According to Stats SA (2006) figures, there were an estimated 524 159 employed graduates in the field of Education, and a further 23 021 unemployed graduates in the field of Education in 2005 in the country. By the end of March 2006, a total of 482 665 teachers were registered on the South African Council for Teachers' (SACE) database (SACE, 2007:5). The database of teachers includes those who are not currently teaching. But if it is considered that there

2 SNAP Surveys are conducted on the 10th day of each new school year.

were 386 595 teachers in the ordinary school system in 2006, then (in terms of supply) there were an additional 96 070 eligible teachers to practise their skills available to the country. Based on the figures supplied by these databases it can be concluded, as the DoE has done, that there is not currently a shortage in the absolute number of teachers. (DoE, 2005:35)

Although aggregated data point to the fact that there is no shortage of teachers, this belies the shortages of specific categories of teachers (see Arends, 2008). At local, school level there are few qualified Foundation Phase teachers, as well as teachers of Mathematics, Science and new curriculum subjects such as Technology and Economic and Management Sciences. Provincial departments consequently frequently employ unqualified teachers to teach these subjects.

1.2 Teachers in Gauteng

Gauteng province is the smallest but most populous of South Africa's 9 provinces, with only 1.4% of the land area, but a population of 9.6 million people (20.2% of the total population of 47.9 million). The languages most frequently spoken here are isiZulu (21%), Afrikaans (14%), Sesotho (13%) and English (12%). Gauteng is the largest contributor to South Africa's Gross Domestic Product and to its employment rate. The financial and business services, trade and manufacturing industries are the main contributors to economic development. Official unemployment rates are lowest for this province and highest among Africans. Unemployment is estimated at 7-9.1 % among white residents, 12.3-18.7% among Asians, 27-33.5% among coloureds and 33.5-38.5% among black residents (see DoA, 2005).

The level of education is substantially higher in Gauteng than the national average. Educational statistics for ages 20 and over show that 13% of this section of the population have tertiary education, 41% have at last Grade 12 and 8% have no education at all. Forty-five percent (45%) of the Province's working age population are employed; mainly in elementary occupations and the formal sector. Unemployment is high at close to 30%, and is prevalent particularly among young Africans and older women. In terms of communication technology, 56.1% of households have access to a telephone, including cell phones (DFEA, 2004).

According to the Gauteng Department of Education's Education Management Information Systems (EMIS) data for 2006, Gauteng province had a total of 64,197 teachers in public and private educational institutions. Of these 27,226 were primary school teachers. The majority were women in public schools: they numbered 18,359 compared with a small minority of 5,195 male teachers. Slightly more than half of the teaching force was African (53.7%), and the remainder were either white (38.3%), coloured (4%) or Indian (3.8%).

The largest proportion of teachers held as their highest qualification a professional diploma/certificate (62%), while 36% had an academic or professional degree and a small proportion of teachers, 2%, had a technical certificate/degree. More teachers in the senior primary Grades (7-9) have degrees but are still exceeded by teachers with professional diplomas. Although the pool of teachers who claim to have specialised with degrees in subjects such as Mathematics is quite small, these teachers are preferred particularly in the Senior primary phase (Grades 7 -9).

The average class size in primary schools in 2006 was 39:1. This varied by quintile, or the poverty ranking of the school. Counter-intuitively, poorer schools on lower quintiles had smaller class sizes than more affluent schools at higher levels.

Teacher qualification and subject specialisation: A study of 2003-5 EMIS data (Arends, 2008, forthcoming) compares the number of subjects/learning areas being taught and the number of teachers who have a formal qualification in subjects/learning areas. In 2004 more teachers in Gauteng were teaching in the learning areas regardless of teaching level (Foundation, Intermediate and Senior) and school type (primary, combined/intermediate and secondary) than were trained in these learning areas (see Table 1-2). The Mathematics learning areas had three times as many teachers teaching it than teachers with a qualification in this learning area. What this suggests is that teachers not trained to teach specific subjects such as Mathematics are in fact teaching them. The reasons for misallocation of teachers are not clear. The Gauteng provincial department of education attempts to coordinate supply and demand of teachers at local level through planning around the post-provisioning model.

Appointment to "Funded" and "School Governing Body" (SGB) posts: There are two kinds of posts available to teachers in schools. The vast majority are provincially-funded posts, referred to as "funded posts." Then there are "school governing posts," that are established and paid for by school governing bodies over and above the allocation of provincial posts to schools. Poorer schools are less able than more affluent schools to afford school governing body posts or teachers, who are paid for by fee-income. They are more dependent on the "vacancy" and "excess" lists created and managed by the provincial and district offices for their teachers.

The allocation of posts ("post provisioning") occurs on an annual basis. In terms of the Employment of Educators Act, and subject to collective agreements concluded in the Education Labour Relations Council, the national Minister determines the distribution model in consultation with provincial MECs, Department of Education and Treasury. Power to establish posts resides with Members of the Executive Councils (Ministers of Education of provincial departments). The post distribution model is based on the principle that available posts are distributed among schools, proportionally to their number of weighted learners. The concept of a "weighted learner" "is used to enable schools to complete on an equal footing for posts." (DoE, 2002a: 2) A number of other factors, including "maximum ideal class size," "period load of educators," "need to promote a learning area," "the size of the school," "the number of grades," "more than one language of instruction," "disabilities of learners," "access to the curriculum," "poverty," "level of funding" and ad hoc factors are taken into account.[3]

[3] Weighting norms for Grades 1-9 are based on the principle of a uniform curriculum. The following formula is used to determine the weighting of a learner: c divided by the ideal maximum class size, divided by the average prevailing period load, multiplied by the funding level. (w=c/m/l x f). The

School allocations are effected at the start of the academic year, in January of each year. Principals submit school data to provincial offices in the last quarter of the school year (i.e. during September and October). On this basis, provincial departments construct “vacancy lists”. Gauteng province circulates its “vacancy list” twice a year. If a school experiences an unexpected decrease in learner enrolment at the start of the school year, it would have an “excess” of teachers. On the other hand, an increased enrolment would create vacancies. In such cases, principals submit vacancies to the provincial office and names of “excess” teachers’ to district offices. Surplus teachers are re-deployed to schools with increased enrolments. The decision to redeploy teachers is a process conducted at school-level on the basis of specified criteria. If a school experiences a shortage, it approaches the district office and the district office allocates a teacher from the “excess” list. Each school is entitled to appoint one or two teachers on a temporary basis, but must be given special permission by the district office to recruit. Schools make recommendations to the district and teachers must adhere to the requirements. The district director has the leeway to appoint 10 teachers within the district without permission from the provincial head office.

In conclusion, then, Gauteng teachers are considered to be relatively well-qualified, but they are often not appointed to teach what they were trained to teach and an appointment process is in existence that enables richer schools to choose their teachers on the basis of advertisement and interview and poorer schools to select from a list of teachers considered by their school principals to be in “excess.” Like their counterparts in other provinces, it is likely that a substantial number were not prepared for the new curriculum in their initial training.

1.3 Curriculum policy

The apartheid curriculum was widely seen as playing a critical role in preparing black students with inferior levels of knowledge, understanding and skill in contrast with that of their white counterparts. Curriculum revision since 1994 has intended to reverse this by ensuring a curriculum that overcame the authoritarian past, and builds a high level of skills and knowledge while inculcating new social values related to social justice.

The adoption of a new South African curriculum framework for Grades 1-9 in 1997 formed part of the range of policies developed to reverse the legacy of apartheid and ensure equality of outcomes for black and white. This curriculum was simultaneously developed, implemented, reviewed and revised over a seven year period from 1997 to 2003. Curriculum 2005, as it was known, was implemented from 1997 to 2003. In 2003, the revised version, known as the Revised National Curriculum Statement (Grades R-9), began to be implemented. The curriculum for Grade 6 mathematics teachers in South Africa has accordingly undergone several and significant changes since 1994.

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value of c is set at 40 and refers to the highest ideal maximum class-size in relation to which others are expressed. For Grade 6 this is specified as follows: Maximum Class Size: 40; Period load %: 98; Funding level: 100%; Weight: 1,02. Grade R is weighted at 0, grades 1 – 4 at 1,166; Grades 5 -6 at 1,02, Grade 7 at 1,103 and Grades 8-9 at 1,229.

The new South African curriculum is based on the concept of outcomes-based-education. At the heart of South Africa's new outcomes-based curriculum policy is the notion that the expected outcomes will determine the content and process of teaching and learning. It also embraces a learner-centred approach to teaching. In South African curriculum documents, learner-centred pedagogy is described in terms of processes such as collaborative group work and independent hands-on activities linked to relevant everyday, real world problems. In its first iteration, Curriculum 2005, as it was known, placed a strong emphasis on integrating traditionally separate subjects into eight integrated learning areas. Rather than outlining specific subject content and skills to be covered, this 1997 version of the curriculum provided sixty six specific outcomes across the eight learning areas for the nine years of the three phases of General Education – Foundation Phase (Grades 1-3), Intermediate Phase (Grades 4-6) and Senior Phase (Grades 7-9). An assumption underpinning the new curriculum was that teachers had strong enough internalized conceptual schema to ensure that the necessary specialised core knowledge and skills were made available to learners over their learning careers.

In 2000, in response to mounting criticism of the new curriculum (see for example Taylor & Vinjevold, 1999; Jansen and Christie, 1999), the Minister of Education tasked a Review Committee with investigating the structure, design and implementation of the curriculum. The Report of the Committee (Chisholm *et al*., 2000) recommended stronger content specification for each grade level in the curriculum, especially for subjects such as mathematics, natural sciences and languages. Subsequent to the 2000 Review Report, the 1997 curriculum was re-defined through the Revised National Curriculum Statement (RNCS) (DoE, 2002b).

The Mathematics Learning Area (DoE, 2002b) now foregrounds the development of subject knowledge to a greater extent than before and expresses the skills, concepts and content learners are expected to achieve at each grade level. The idea is that learners are to be assessed against the national curriculum standards that indicate whether they have attained a learning outcome at an appropriate level for each grade. The curriculum is based on an assessment framework where learners are to be assessed on what they understand and know, and on their performance in tasks using new knowledge, skills and conceptual understanding. How well and to what level it is taught depends to a large extent on the teachers teaching the subject as well as the learning resources available to do it.

The Mathematics Learning Area statement marks a shift towards a more structured knowledge-based curriculum that focuses on attaining core skills and knowledge competences. In principle though, the outcomes-based and leaner-centred pedagogy advocated for in the implementation of the 1997 Curriculum 2005 remains in place for the implementation of the Revised National Curriculum Statement. The assumption is that making available a learner-centred pedagogy is the most effective approach to improving educational quality in classrooms and achieving greater equality in learning outcomes for socio-economically disadvantaged learners.

Evidence of the take-up of the new curriculum is mixed. Evaluations of educational interventions in South Africa show that, overall, teachers have taken up the outward forms of "progressive" methodologies (Schollar, 1999: 102). Qualitative, school-based research suggests that well-organized and well-resourced schools with good teachers generally adopt the methods more effectively than those teachers in under-resourced schools with a poorer subject content knowledge (Harley and Wedekind, 2004). Other studies, which have examined the link with performance, have argued that mathematics learning among low income children is strongly linked to teachers' professional expertise and the "opportunity to learn" that the curriculum provides through curriculum coverage and pacing. (Reeves, 2005; Hoadley, 2007). And whilst there is empirical evidence that implementation has been constrained by unequal conditions, the continuing high levels of underperformance of South African learners suggests that something more than take-up of the new curriculum is happening in the nation's classrooms that deserves further examination.

1.5 Teacher Education

Another major change that has affected teachers' lives since 1994 is related to the attempt to overcome the legacy of apartheid teacher education. In the second half of the twentieth century, teacher education was closely linked to the goal of separate and unequal development. The architects of apartheid explicitly located teacher education for Africans in rural and not urban areas to limit Africans' aspirations for higher education and constrain their participation in a common society. Under increasing pressure to expand educational opportunities in the 1980s, following the 1976 students' revolt, there was some expansion of teacher education colleges in urban areas. The role of teacher education colleges in shaping the nature of educational opportunities available to black children has accordingly been profound.

Teacher education, previously a provincial responsibility, became the responsibility of higher education in terms of the Constitution (Act 108 of 1996), and the Higher Education Act (Act 101 of 1997). Between 1994 and 1998, the number of colleges was cut from about 150 to 50 as a result of decisions taken by newly-created provincial departments of education. In 1998, the Minister of Education announced the incorporation of 27 colleges of education into higher education with effect from 1 January 2001. The 27 colleges incorporated were identified by the provincial departments of education from approximately 50 odd colleges that were still operational. The decision to merge the colleges into other institutions was made on the grounds of poor quality and cost-effectiveness. Some colleges had as few as 20 students. Many were disparagingly referred to as "glorified high schools" (*Mail and Guardian*, 18-24 April 2008: 2). The rationalisation and restructuring process was complete by 2005 (Kruss, 2008: 187), after which primary school teacher education moved into the tertiary education sector.

Mathematics teacher education for primary school teachers before 1994 was accordingly the domain of the teacher training colleges. On the eve of the democratic elections in 1994, the majority of pre-service teachers (70,731) were enrolled in 93 state-funded colleges of education. Three universities providing distance education enrolled 60,038 students and another eight colleges providing distance education enrolled another 44,117 students. Universities providing contact tuition enrolled only 28, 954, and these included higher degrees and INSET. INSET was also provided by 99 NGOs and 44 departmentally-funded institutions (Hofmeyr and Hall, 1996; Kruss, 2008).

Prospective teachers at the colleges graduated either with diplomas (3- or 4-year programmes) or degrees. This affected key issues such as the number of years of training necessary to qualify as a teacher and the levels of specialisation required in order to teach a subject. The colleges in Bantustans/homelands[4] and African urban areas as well as some of the colleges for trainees classified as coloured offered a more limited curriculum than those established for Indians and whites. The emphasis in the former was mainly on mastering high school content and classroom management skills. The latter enabled development of knowledge to a higher level and included conceptual and theoretical understanding. Some colleges, mainly the white and Indian colleges, had developed links with universities, whose staff either taught or moderated college exams. Colleges generally enjoyed low status and part of the intention of incorporation within higher education was to change this marginalised status.

Since 1994, the work of teacher trainers and educators has been conditioned by the restructuring of higher education, mergers and incorporation of teacher education colleges into higher education, and the national requirement for realignment of curricula in terms of outcomes, competences and the Norms and Standards for Educators (DoE, 2000; Kruss, 2008).[5] Although the process of curriculum restructuring has been uneven across institutions and there are differences between institutions, many continue to do what they did before while complying on paper with official requirements. Many institutions now structure their primary teacher training according to the phases of learning (Foundation, Intermediate and Senior Phases) established by the new school curriculum. Whereas the qualifications currently available for prospective teachers are not the same at all of the tertiary institutions, the majority of tertiary institutions now offer pre-service Intermediate Phase teacher training through a B.Ed. degree, a four year programme. Some institutions also offer a PGCE in Intermediate and Senior phase teaching. There are also in-service programmes at many universities, which over the years have had different names, but currently are called ACE (Advanced Certificate in Education) programmes. These qualifications enable teachers whose existing qualifications do not meet the minimum requirements for teacher training to upgrade their qualifications to the necessary level.

4 In the apartheid schema, self-governing territories included Transkei, Bophutatswana, Venda and Ciskei (TBVC). “Homelands” included Gazankulu, Lebowakgomo, KaNgwane, KwaZulu, KwaNdebele, Qwa Qwa, and Venda. Colleges in the so-called TBVC states and homelands were all in rural areas.

5 The Norms and Standards for Educators defined seven roles that a teacher should be able to perform: 1. Learning mediator, 2. Inerpreter and designer of learning programmes, 3. Leader, administrator and manager, 4. Scholar, researcher and lifelong learning, 5. Assessor, 6. A community, citizenship and pastoral role, 7. Learning areas/subject/discipline/phase specialist role. It prescribes the knowledge, skills and values that future teachers require in order to perform these seven roles.

The minimum teacher education qualification across the board has become a four year degree (or equivalent qualification). Many of the teachers observed for the purposes of this study would not initially have obtained a four year qualification, and would have had to upgrade their qualifications through one of the many programmes offered to teachers to do so. The quality and content of their initial and further training would have varied, depending on the institution at which it was obtained, since the curriculum for teacher training programmes was not centralised. Once teacher education fell into the tertiary sector, decisions about the curriculum was the responsibility of the faculties under which it was offered. These decisions would have been made by each institution within the context of the expectations set up for teachers by the new schools' curriculum and the Norms and Standards for Educators (Sayed, 2004). Beyond this, there is currently no uniformity in the content of programmes offered for pre-service and in-service training of teachers.

The extent to which the teaching programmes link their teaching to the maths curriculum (NCS) for schools varies. The mathematical content component differs enormously in the institutions offering Intermediate Phase teacher education. Some institutions teach only the mathematics which the teachers themselves would teach at the Intermediate Phase in a school. This means that for mathematics content, the work covered would only go as far as the current Grade 6, which does not deepen or extend teachers' own knowledge and understanding of mathematics sufficiently to equip them to teach learners at this level. There are other institutions that take the basic school leaving mathematics (the actual school mathematics curriculum, which up to 2007 would have been Standard 10 mathematics, and as of 2008 would be Grade 12 mathematics) to define the mathematics content. This extends the teachers' knowledge of mathematics, and to a certain extent deepens knowledge and understanding of Intermediate Phase mathematics. But how the content is mediated is critical since it could be taught in such a way that no links between concepts and the development of concepts are made.

There is also no uniformity in the degree of emphasis on knowledge, skills and pedagogy, as institutions design their own programmes. The majority of institutions offer input on knowledge, skills and pedagogy in a variety of ratios. This ranges from a curriculum based purely on mathematical content to one which focuses more on methodological and pedagogical content in relation to the teaching of mathematics. Such differences would have been the case before the merger of teacher training colleges with the universities, which is the time during which the majority of teachers observed for this study would have obtained their initial qualifications.

Evidence of the differences, and especially of the limited curriculum on offer at the majority of colleges pre-1994, is clearly visible in the observed lessons given by the teachers in this study. On the one hand, some (though not many) of the teachers teach using methods that indicate that they have been trained in the use of pedagogical methods that effectively teach the mathematical content to the learners in such a way that they should be able to understand and apply the mathematics. To do this they need to have a deep understanding of the mathematical concepts themselves, as well as the necessary pedagogical skills required for effective teaching. On the other hand, the majority of teachers teach in a way that indicates they have been trained to teach mathematics in a more circumscribed way. Videotaped lessons often revealed poor use of questioning, poor timing and poor choice of follow-up activities. The majority of teachers also appear to have a fair, though sometimes limited understanding of the mathematical content that they teach. Some actually say and write mathematically incorrect statements on the board. Some of these errors may be a result of careless use of language at a particular moment, but some are clearly based on incorrect knowledge or inadequate conceptual understanding on behalf of the teachers, probably linked to their prior training.[6]

The teachers observed for the purposes of this study trained at nearly 30 different institutions in South Africa. The institutions cut across all the racial groupings, and were located in urban and rural areas. The majority no longer exist. Those that remain have been incorporated into universities. The number of African graduates increased steadily after 1999, accounting for 82% of all education graduates in 2004. The share of white, coloured and Indian graduates declined correspondingly (Paterson and Arends, 2008). According to Paterson and Arends, the largest proportion (49%) completed undergraduate certificates while postgraduate certificate and honours degrees accounted for 30%, followed by undergraduate degree holders at 18%. Masters and PhD graduates accounted for 3% of all graduates.

The number of African students in the age-category of 25 and below in Initial Teacher Education Programmes is, however, low. Here enrolments have declined among African female students, and risen among white females. In the 26-30 year age group there was also a decline between 2000 and 2004; African females constituted 56.4% and African males 28.1% of that cohort in 2000, but declined to 50% and 24.9% respectively by 2004. The same declines are not evident among older students, as shown above. The reasons for the decline in enrolments by younger African female students are unclear. What the implications of this are for the production of mathematics teachers also needs further research. Those student-teachers who would have entered university-based teacher training programmes would have experienced staff and programmes in the throes of restructuring and realigning their curricula with new national requirements.

Available information suggests that the majority of teachers currently in the system were trained in institutions that were created in the apartheid period. History is, thus, to a significant extent, present in South African classrooms. Whether newly-restructured and re-aligned teacher education programmes for primary school mathematics teachers is now better and more cost-effective than before is as yet unclear.

[6] In the analyses of the videotapes, we found that most of the errors made by teachers were in the space and shape content area. We observed it in the lessons we videotaped more than we expected. This is an área that hás been neglected and poorly taught in the past. Thus, it makes sense that most of the errors committed by teachers were in this área of mathematics.

1.6 Teacher supervision and evaluation

A system of supervision and evaluation of teachers that developed during twentieth century South Africa broke down irreparably in the 1980s. It has not been replaced by anything acceptable to the teacher unions since then. The difficulties in establishing an effective system of supervision and evaluation date back to the 1980s.

Under apartheid, a differentiated system of inspection, control and appraisal existed in which inspection in black schools was characterised by bureaucratic control and in white schools by a light advisory function. White schools were better-resourced in all respects than black schools, and inspectors in former white schools were also better qualified, seeing their role mainly as trouble-shooting and assisting schools and teachers in their functions. Black schools, and in particular African schools, by contrast, suffered under a regime of inspection that was autocratic. At the centre of this regime was the summative "panel inspection" of schools and a form and process of individual teacher appraisal that teachers experienced as being used punitive and vindictive. Judgmental, summative forms of evaluation characterised inspection and appraisal in African schools.

The reaction to these negative forms of evaluation was overwhelming. Towards the end of the 1980s, in the context of widespread resistance against apartheid authorities in schools, inspectors and subject advisors were routinely and often violently cast out of African schools when they attempted to set foot there, and teachers refused any form of evaluation of their and their schools' work. In the process, the entire inspectorate and function of inspection in African schools became dysfunctional (see Chisholm, 1999; Jansen, 2004).

As the momentum towards democracy gained ground in the early 1990s with the unbanning of political parties and return of exiles, the newly-formed South African Democratic Teachers' Union in South Africa began an internal process of participatory research, discussion and mobilisation around new forms of teacher appraisal for a democratic South Africa to inform its negotiations with existing departmental structures around the issue. An approach to teacher appraisal emerged that rejected a bureaucratic, judgmental form of appraisal and emphasised development and support of teachers through a formative rather than summative evaluation process. The essential elements of the new proposed system of appraisal were self evaluation, peer review, consideration of contextual factors, and mediation, in the event of conflict, by an inspector. These were linked to both a development plan for the individual teacher and envisaged as being linked, in turn, to "more general school development planning." (Swartz, 1994, 1). The details of the latter were to emerge from restructured departments of education.

In the immediate aftermath of the elections, the bargaining and negotiating forum for all teachers, the Education Labour Relations Council, was created. Through it, new forms of evaluation emerged and were negotiated. Throughout the 1990s and early 2000s, government and unions were locked in battle over the best way to evaluate schools and teachers. Each step of the process was controversial and contested: who would control it, what the criteria of evaluation would be, whether there would be a rating scale, what it would contain, who would keep the records, who would do the evaluation and whether the departments would be able to enter classrooms to evaluate teacher performance or not. Many hours, weeks, months and years were spent hammering out the agreements.

After almost 14 years of negotiation between the new government and teacher unions, an agreement was finally reached in 2003 to implement the Integrated Quality Management System (IQMS). This was an agreement reached in the Education Labour Relations Council in 2003 (Resolution 8 of 2003). It integrated the union-supported Developmental Appraisal System (DAS) that came into being on 28 July 1998 (Resolution 4 of 1998), the departmentally-supported Performance Measurement System that was agreed to on 10 April 2003 (Resolution 1 of 2003) and Whole School Evaluation, introduced in 1999. The Integrated Quality Management System began to be introduced into schools in 2004. In this year, schools and teachers were scheduled to begin both processes of individual teacher appraisal and whole school evaluation.

Implementation was not effective. The IQMS was soon rejected by teacher unions and SADTU in particular. SADTU's main arguments for the rejection of IQMS were that there was no development or training of teachers and that the IQMS was undermined by the lack of support and commitment by the provincial departments of education. It also argued that "if teachers are not taken on board in these processes, it will not succeed" (SADTU, 2001). In addition, teachers complained of the amount of paperwork involved (Chisholm, Hoadley & Kivilu, 2005). The complexity of the envisaged process of evaluation militated against success.

As a result, the IQMS foundered. A new agreement on teacher appraisal was signed by the Department of Education and the unions on the 3rd April 2008, following highly contested negotiations. This is referred to as the Occupational Specific Dispensation (OSD). The OSD will reward teachers for "good" and "outstanding" performance. The OSD agreement introduces performance agreements for school-based managers (Principals and Deputy Principals) and office-based educators.

Since the collapse of the apartheid inspection system in the early 1990s, then, no effective system of teacher supervision and evaluation has emerged, particularly in African schools. Given the history of conflict around teacher evaluation, and the number of unresolved issues still under negotiation, it is unlikely that the new OSD system will result in improved teacher supervision in the short term.

1.7 Socio-economic context of the schools

School Resourcing

Schools are funded on the basis of a framework that provides for the use of both public and private resources. Between 1995 and 2003 there was a substantial dip in educational expenditure, but since 2003 there has been an upward trend. The state attempts to overcome inequalities between schools through its poverty-ranking of schools according to quintile. The five quintiles according to which schools are funded are based on a formula that takes school location into account. Fees have enabled schools in more affluent neighbourhoods to supplement state funding and maintain quality but reinforce inequality through appointing additional teachers. Since 2007, provision has been made for fee-free schools. The Gauteng Department of Education extended no-fee status to schools in quintiles 1-3 from April 2008. No-fee status means that children at the school no longer have to pay school fees and that the school would receive R775 (approximately $100) per learner.

Our sample schools are spread across five district municipalities of Gauteng province, namely the City of Johannesburg, City of Tshwane, Ekurhuleni, West Rand and Sedibeng. These district municipalities cut across formerly segregated, rich and poor neighbourhoods and schools. Table 1-3 indicates that the City of Johannesburg was most populous, followed by Ekurhuleni (East Rand), City of Tshwane (including Pretoria), Sedibeng (including former Vereeniging and Vanderbijl Park), West Rand and Metsweding. School fees vary in our sampled schools from 15 Rand per year to 4400 Rand per year in public schools and from 400 Rand to 8500 Rand in independent schools.

Table 1-2. Population of Gauteng by district municipality

Municipality	**Number**	**%**
Metsweding	126 436	1.4
West Rand	683 025	7.9
Sedibeng	794 605	9.0
Ekurhuleni	2 480 277	28.1
City of Johannesburg	3 225 812	36.5
City of Tshwane	1 527 023	17.3
Gauteng	**8 837 178**	**100**

Source: Statistics South Africa, 2001.

City of Johannesburg District

The City of Johannesburg, the financial hub of South Africa, comprises inner-city, suburban and township areas. Soweto forms part of the City of Johannesburg. In 2005 the City of Johannesburg municipality was estimated to have a poverty rate of 20.0% (DoA, 2005). It is the economic power house of South Africa, and contributes 44.5% to the GDP of Gauteng province. Fourteen of the sample schools are located within the City of Johannesburg district. They include three former white, two Indian, two coloured, and three African schools, as well as one new school established after 1994, and two private schools. Only one of these, a former white school, was in a high-income neighbourhood, whereas the others were all in working class, inner-city and poor township areas. All the former white, Indian and coloured schools, with the exception of this one, were predominantly African or substantially desegregated.

Ekurhuleni District

Ekurhuleni District encompasses the former East Rand, which includes a number of mining towns and their surrounding townships. Over the last two decades, there have been substantial job losses on the mines in this District resulting in growing impoverishment in towns and townships. The unemployment rate (in the expanded definition) was estimated to be 42.9% in 2005, the highest in the province (see DoA, 2005). Compared with the City of Johannesburg, which had an estimated poverty rate of 20%, the poverty rate among residents of Ekurhuleni stood at 33.4%. Ekurhuleni contributes about 22.5% of Gauteng's GDP compared with 44.5% contributed by City of Johannesburg (see City of Tshwane, 2006). Six of the sample schools are found in Ekurhuleni district municipality. Two had been white, two coloured and one African whereas one had been established after 1994. Among the white schools was an Afrikaans-speaking school that was one of the two schools in the entire sample that was still largely white. The enrolments in the other schools were all dominantly African. One of these was located in the middle of a poverty-stricken informal settlement.

City of Tshwane District

Tshwane includes Pretoria, the capital of South Africa, and its surrounding suburbs and townships. The number of residents here has increased almost as rapidly as in the City of Johannesburg, from 1 982 235 residents in 2001 to 2 345 908 in 2007(see StatsSA, 2007). Of all the districts in Gauteng, the city of Tshwane had the lowest poverty rate in 2005 (DoA, 2005). While the city contributes only about 20.5% to the GDP of Gauteng province, about 73% of its residents are employed and 27% are unemployed (*ibid*). Employment is mainly in government-related and some industrial work. Tshwane is a fairly literate district municipality. In 2001, 20.8% had tertiary education, 49.8% had secondary education while 21.7% had primary education (see City of Tshwane, 2006). This district municipality had the smallest number of our sample schools. They include a private Muslim school, a former white, Indian and an African school.

Sedibeng District

This is a heavily industrial area with metal, steel, chemicals and engineering industries. Job losses on the mines and in industry have also had an effect on this district. The poverty rate in Sedibeng was second highest in the province in 2005, at 39.2% (see DoA, 2005). Although Sedibeng has small pockets of affluence, the district is characterised by high levels of unemployment, illiteracy, low skills, and ill-health (see Sedibeng District Municipality, 2004). Eight of our sample schools are located within the Sedibeng district. Of these, one had been a white school, another Indian and a third coloured. They are all desegregated. The majority are African schools. One of them is a private school.

West Rand District

The West Rand includes both mining and small-holder communities including Carletonville, Westonaria and Krugersdorp. Census 2001 shows that there were 533 675 residents in the West Rand, which increased slowly to 539 038 as shown by Community Survey 2007 (see StatsSA, 2007). The West Rand was estimated to have a poverty rate of 20.6% (DoA, 2005). Eight of the sample schools in the project were in the West Rand district. Three of these were former white schools in relatively affluent surroundings with enrolments that are now predominantly black. The same applied to the former Indian school in the sample. The coloured and African schools were all in poor areas.

Schools and classrooms in Gauteng have become considerably more diverse than they were fourteen years ago, and not only in terms of race. Gauteng is a focal point of internal and cross-border migration. Migrated children are a significant albeit small part of the Gauteng school population, although numbers of those who have migrated to Gauteng from inside South Africa are much larger than those from outside. Thousands of children are recorded as having entered Gauteng schools from rural provinces such as Limpopo, KwaZulu-Natal, Eastern Cape and Mpumulanga in 2006.[7] Only about 5,959 were recorded as coming from outside the borders of South Africa, compared with 15,058 from Limpopo. Both official statistics and university-based research centres agree that numbers of foreign migrants or refugees are in fact extremely small, around two percent of the total population (StatsSA, 2003: 20-27; Landau, 2005: 3). Given the problems with estimating the numbers of migrants, and especially given the problems facing undocumented and unauthorised migrants, these figures are probably an undercount and also exclude those who have not been able to gain access to school because of being illegal, fees being too high or their inability to speak the dominant languages.

Teachers in Gauteng are teaching in schools that are demanding and diverse, and in a society that expects them to produce more and better students of Mathematics so that the society can prosper through their wider contribution. But available evidence suggests that although the number of unqualified teachers in the system may be declining, shortages of Mathematics teachers are not being met adequately by existing post-provisioning systems for the allocation of teachers to schools. The demand not only for increased numbers but also improved quality has been further complicated by necessary changes to the curriculum and systems of teacher education and supervision and evaluation brought about with the ending of apartheid. Substantial numbers of teachers were not prepared in their schooling and initial teacher education for a curriculum that expects more of them than apartheid-era curricula did. Although teacher education institutions have on the whole adapted rapidly to new requirements, institutional restructuring and official curricular requirements have influenced the capacity to meet the demand in the short-term, negatively in some instances and positively in others. In this context, the absence of a system for the effective and supportive supervision and evaluation of teachers has resulted in innovation in some areas and deteriorating teaching and learning in others. This is important, for, as has been pointed out elsewhere (Carnoy, 2007: 23), "most researchers are now concluding that student performance at a given level of schooling will not improve unless a more demanding curriculum is taught to students by teachers with reasonably high levels of subject matter knowledge well trained to teach that curriculum and believing that every student is capable of learning it (and) a supervision system (is) in place that helps teachers reach high levels of competence in their practice…".

[7] Information provided by Gauteng Department of Education: 15,058 from Limpopo, 12,245 from KZN, 11,842 from Eastern Cape and 8,528 from Mpumulanga.

CHAPTER 2

CONCEPTUAL FRAMEWORK AND METHODOLOGY

The purpose of the pilot study is to estimate whether and which classroom factors contribute to student mathematics learning gains in southern African schools. Our particular emphasis is on teacher pedagogical knowledge, classroom pedagogy, and opportunity to learn (including language issues) in a sample of Grade 6 classrooms in one South African province. Ultimately, the pilot is intended to provide insights into developing a larger comparative study that would exploit possibly large differences in teacher preparation and educational expectations (curriculum and pacing differences) across classrooms within countries and across countries for schools catering to various social class groups of students.

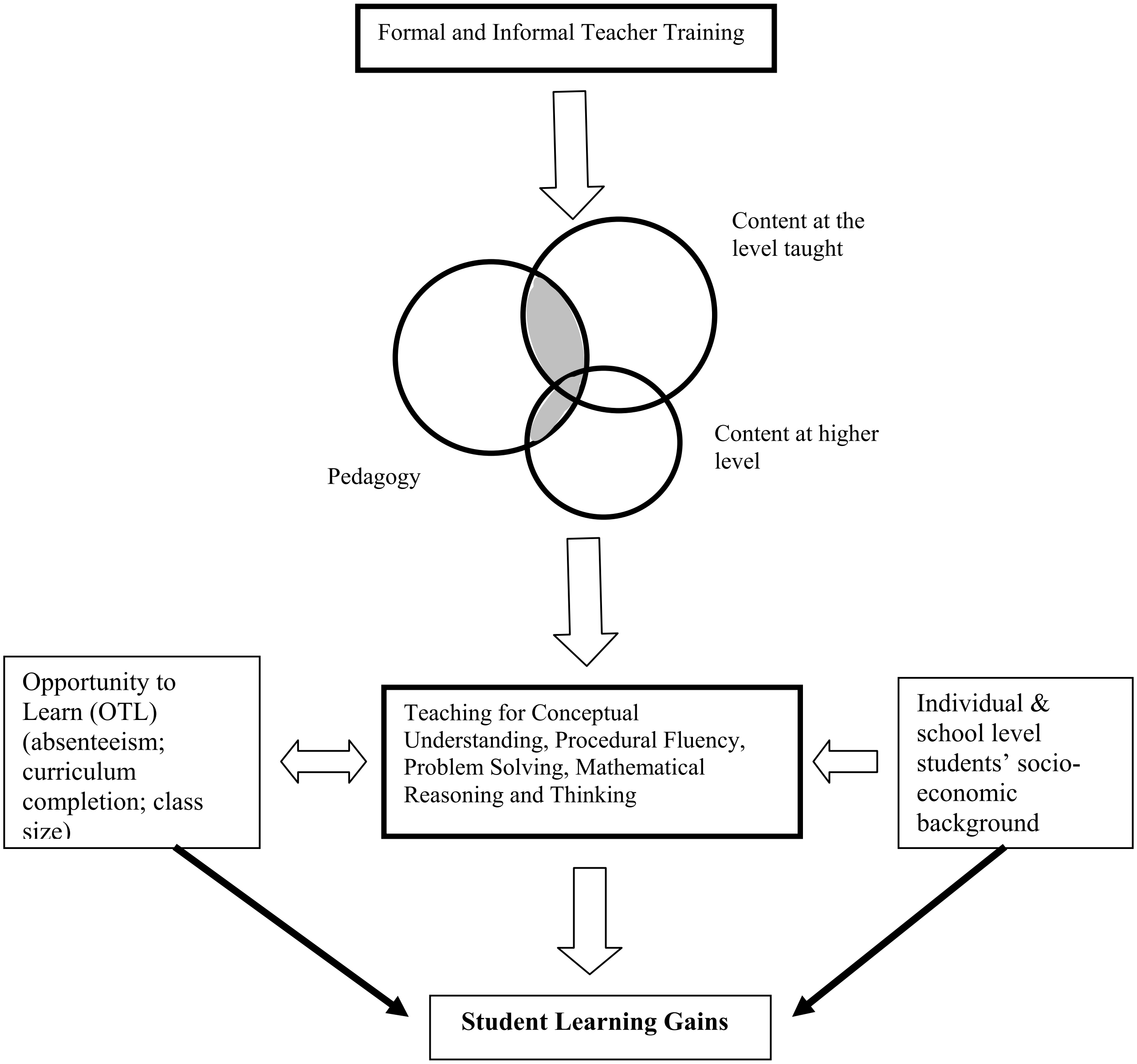
Our methodology is designed to explore possible variations in teaching factors across classrooms, schools, and countries to help understand their relation to the variation in student learning gains, if any. We hypothesise that teachers' content and pedagogical content knowledge is related to the depth of their teaching in classrooms. The study gets at this relationship by measuring teacher content and pedagogical content knowledge and using videotapes to assess the depth of these same teachers' classroom teaching. We also surveyed school principals and used observations in schools to understand whether differences in school conditions (reported violence and teacher absence) provide insights into the level and variation of teaching factors in different schools. Overall, the methodology takes us beyond the scope of other studies (which gather data on teachers and teaching through questionnaires) to gain a better understanding of the influences of teaching quality and other factors on differences in student performance.

One of the main distinctions between this study and others, such as SACMEQ and a current survey in South Africa's Western Cape province, is our focus on observing classroom lessons and linking learning gains of students with not only their own characteristics, but their teachers' measured capacity and teaching performances.

2.1. General Conceptual Framework

At the center of our analysis is how teacher knowledge may influence the depth of teaching and, in turn, student learning. Figure 2-1 provides a simple conceptual overview of different forms of teacher knowledge. This framework builds on previous work in Latin America (Carnoy et al, 2007a; Marshall and Sorto, 2008). The focus here is on mathematics, although Figure 2-1 is general enough to be applicable to all subjects.

Figure 2-1. Conceptual Framework



The three main components of the model are (a) the capacity/process of teaching; (b) opportunity to learn, which may influence student learning gains directly and indirectly, through its interaction with the quality of teaching, and (c) the students' socioeconomic background, which may influence student learning gains directly and indirectly, through its potential impact on teaching.

The left hand circle represents pedagogical knowledge. Teachers accumulate pedagogical skills in pre-service and in-service pedagogical training courses, through "experiential learning" that comes from trial and error in their own classroom, and through "mentor effects" that result from watching other teachers or working closely with other school personnel (teachers, directors, etc).

On the right hand side is the content knowledge circle divided into lower and higher elements. Lower refers to the level that is being taught (i.e. Grade 6), while higher is for more advanced grades or levels beyond the grade the teacher is responsible for. This is consistent with how higher level knowledge is defined in mathematics education circles in the United States, where "one level up" is a common reference for more advanced knowledge.[8] Teachers obtain math knowledge primarily in formal pre-service training mathematics classes. There are some additional opportunities for learning mathematics content, such as on-going formal study where the teacher is exposed to higher levels of mathematics.

At the intersection of pedagogical and content knowledge lies a specialised form of knowledge prized especially by education researchers. This domain is commonly referred to as pedagogical content knowledge (PCK) (Shulman, 1986), and its evolution in mathematics reflects a growing emphasis on practice-based metrics for analyzing teaching effectiveness in the classroom. PCK knowledge turns up in myriad ways in the classroom. It refers to the application of mathematical knowledge for teaching others, especially young children. Examples include the powerful explanations that teachers use to develop deep understanding of concepts that are part of the curriculum, the ways in which they draw linkages with other elements of mathematics, and the questions they pose to students. These kinds of skills, it is argued, can only be accumulated through practice or very specialised training activities, although they are still highly related to teachers' knowledge of subject content (Hill, Rowan, & Ball, 2005; Ball, Hill & Bass, 2005).[9]

In total there are four distinct knowledge areas depicted in Figure 2-1: lower and higher content knowledge, pedagogical knowledge, and pedagogical content knowledge. Which is most important? By definition the PCK element is made up of critical strands of knowledge that most directly influence the teacher's ability to develop curriculum. This form of knowledge is also likely to have the tightest link with the features of effective teaching, listed in the lower half of Figure 2-1. But this does not mean that PCK is the only teacher knowledge area that matters, or that the other knowledge elements affect teaching quality solely through their impact on PCK. A simple example is the teacher's ability to control the class, which is an element of general pedagogical skills rather than specific PCK.

The role of higher-level knowledge is especially difficult to assess, and is the source of some disagreement in the field. Among academic mathematicians especially

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8 In their 2001 report (*The Mathematical Education of Teachers*) the Conference Board of the Mathematical Science, American Mathematical Society, and Mathematical Association of America recommends "a thorough mastery of the mathematics in several grades beyond that which they expect to teach, as well as of the mathematics in earlier grades".

9 For example, Ball, Hill & Bass (2005) argue that a "mathematically literate" person would struggle to answer questions they created that measure specialised knowledge.

there is a strong belief that even primary school teachers should be comfortable with higher level (meaning university) mathematics content. This assumes to some extent that pedagogical skills are derived from studying higher-level math—a position that is strongly contested by many mathematics education researchers. But the emphasis on content knowledge also recognizes the importance in mathematics of making linkages with advanced levels, and the potential consequences when teachers make mistakes that result from deficient content knowledge. As these kinds of errors accumulate the overall integrity of mathematics instruction is affected, which can in turn cause student frustration and the perception that mathematics is "too hard" or "poorly taught."

2.2 Data Collection

Under the pilot grant from the Spencer Foundation, we placed emphasis on this distinctive aspect of the study. We tested those instruments and estimation techniques that related to measuring teacher knowledge and student performance. We also tested our videotaping method of classroom observations and the rubrics to measure time use and teaching quality from those videotapes. We drew a stratified sample of 40 schools in Gauteng Province. We administered learner questionnaires and an initial Grade 5 mathematics test (developed by JET Education Services) to more than 2,600 Grade 6 learners in those schools, investigated teacher background and content and pedagogical content knowledge in questionnaires that we administered to about 50 sixth grade teachers. We videotaped about 40 of those teachers teaching a mathematics lesson. We also administered a principal questionnaire and completed an observation sheet about the general physical and organizational conditions in each school.

Four instruments were prepared: a learner questionnaire and test, a teacher questionnaire, a principal questionnaire and a video analysis instrument (see Appendix 1). The learner questionnaire included biographical, language, family education and socio-economic status and school violence questions. The test was designed by JET Education Services based on the curriculum used in South African schools. The teacher questionnaire had two components: a general component and mathematical knowledge component. The general section included biographical, socio-economic status, education and training, home language, curriculum coverage, supervision, school violence, and absenteeism questions. The knowledge component required teachers to diagnose common errors made by children in primary mathematics. In this pilot study, we only surveyed teachers' mathematics knowledge at the grade level taught, but in future studies, we intend to provide a second questionnaire that examines higher levels of teacher knowledge. The principal questionnaire included questions linked to those asked of teachers about language, curriculum coverage, school violence, absenteeism and supervision.

The initial learner test was developed based on mathematics tests already being prepared by JET Education Services for more generalized testing in South African fifth grades at the end of the academic year. We felt that weighting the test toward fifth grade knowledge was appropriate since we planned to administer the test in the middle of the Grade 6 academic year. The test contained some fourth grade level questions, most fifth grade level questions and some sixth grade level questions, all based on the national curriculum. The test was applied only in July, somewhat delayed because of a teacher strike and human subjects ethical requirements (a form needed to be signed by each participating child's parent before the test could be administered and districts, school governing bodies, principals and teachers needed to be informed and their consent gained). The teacher and principal questionnaires and the videotaping were completed in the period between the beginning of September and early October. The process was aided by the sharing of experiences from videotaping and administering similar teacher questionnaires in other countries (Carnoy et al., 2007) during a short training period at the beginning of September. This process engaged participants from the four cooperating universities and the HSRC.

The plan was to administer the same test in all the sample schools in October, very near the end of the year. Although this was only three months after the initial learner test, and hence would not be very useful in measuring gains, we wanted to administer it to check if individual learners tended to make gains rather than losses even in such a short period. Unfortunately, schools were engaged in final examinations earlier than we had anticipated. Only fourteen schools and about 700 learners participated in this second test, but the number was sufficient for checking whether the learner gains tended to be positive.

Coding and cleaning the test and questionnaire data was completed in South Africa by end January 2008. The videotapes were analysed by a group of researchers both in South Africa and the U.S. Similarly, the analysis of learner and teacher questionnaire results was conducted by researchers in both countries.

In general, the pilot was successful in collecting the data it set out to collect, and was able to do so in a reasonably short period of time. The pilot provided a number of lessons regarding the data collection itself.

- Departmental records used to locate schools for the study were not completely accurate. In some cases, schools on the list had ceased to exist or their addresses had changed or were inaccurate. Many schools also did not have telephone lines. The only available telephones were the principal's cell phone. These were also not always on the departmental list provided. In some instances, local maps do not exist and the best way to find schools is from taxi drivers. The physical location of schools needed to be checked by physically driving to each one before the start of the study. This was also important in introducing the study to the schools after letters of introduction had been sent and received to check that they had actually been received. Many schools had not received letters sent because of poor postal services.

- Learner tests were administered in July by matriculants and in early November by undergraduate students from the University of the Witwatersrand after they had been trained. For the teacher, principal and classroom information, experienced researchers visited schools in teams of two: one took responsibility for administering the teacher and principal questionnaires and the other for videotaping the classroom lessons. Teachers' sensitivity to being filmed meant that their lessons were well-prepared for the classroom visits. Only greater familiarity will ensure that "normal" classes are filmed. This, in turn, will require a smaller sample.

- An analysis of the learner test instrument revealed that several questions lacked validity, in that the phrasing of the questions enabled those students who did not know the answer to guess the correct answer because the "distractors" (options given them to answer) were obviously wrong. In two items, no student selected the (d) which means the real options were narrowed down to 3 and so the option of guessing was even higher. In essence, on these two items we tested good guesswork rather than ability. The implication is to make the "distractors" stronger. One piece of further validity analysis will be to compare the detailed learner test results from this pilot with other mathematics tests applied to South African sixth graders (for example, the SACMEQ test).

- Similarly, there was one content knowledge question on the teacher knowledge questionnaire that had these types of validity problems (everyone gave the same correct answer to the question).

- Teachers answered most of the information questions on the teacher questionnaire, but the questions on the amount and nature of education and training teachers had received and the subjects in which they had majored, if they had done so, seemed to be badly framed. Nevertheless, the question on where the teacher had received his/her teacher training/university education was particularly useful.

- The instrument used to analyse the videos was helpful, but can be improved. The question about the kind of work included could be rephrased to separate out questions of homework from checking of class work – is homework checked, marked and given for the next day? Is class activity of all or only some learners checked? The question about textbooks can be refined to include worksheets, which are commonly used. Similarly, a distinction needs to be made between the presence and use of textbooks. Are they personal property of students or kept by the teacher and distributed or only used by the teacher? Some thought can also be given to analysing the social messages conveyed by charts, maps and other items on walls.

- None of the questionnaires had a question about class size. A question is needed on the video analysis sheet about class size. We derived class size by counting the number of people in the class we observed in the videotape.

- An attempt was made to videotape a student's notebook in each class as a way of measuring "opportunity to learn." Since the classroom videotaping took place almost at the end of the year, it was thought that this would provide sufficient information for a person knowledgeable in the curriculum to assess how much was covered during the year. However, after viewing the videotapes, the consensus is that this method will not work. Observers will have to sit-in on a class three to four times during the year and record what has been written in learners' books at each of those points. Since Opportunity to Learn appears to be highly related to learner gain scores (Reeves, 2005), any study has to focus on measuring this variable carefully. We encountered videotaping problems only in one school, where, for religious reasons, the school prohibited videotaping. In the future, we need to be prepared with alternative classroom observation techniques when such issues occur.

- Videotaping provided examples of textbooks that teachers use. Three of those observed to be in common use were analysed for this project (Johnson, 2008). They included: *Classroom Mathematics Grade 6 Learner's Book* – (Heinemann) *Oxford Successful Mathematics Grade 6 Learner's Book* – (Oxford University Press) *My Clever Mathematics through Issues Grade 6 Learner's Book* (Clever Books). The study concluded that although content is presented systematically, there is an assumption of background knowledge that either teachers or students who use them may not necessarily have. In the future it will be necessary not only to identify the textbooks used, but also whether and how they are used. Textbook analysis could also include a comparative assessment of level of clarity and difficulty.

- Learners were offered the possibility of taking the learner questionnaire/test in the language they spoke at home. About 95 percent of learners took the test either in English or Afrikaans, whichever was the language used in the school to teach mathematics. In retrospect, this is logical, since the mathematics lessons are taught in those two languages, depending on the school. We collected data on the learner's language spoken at home and were able to analyse whether it is correlated with test performance, once parents' education levels and other student characteristics are controlled for.

- The process of data gathering, coding and capturing yielded important insights into how the questionnaires could be improved overall. Not all of these items, some of them small but important, are mentioned here. The instruments have now all been improved but will need one more round of revision taking into account all the points made in the course of the project.

The process of collecting the data also provided important lessons for future research: With proper planning and training, it is possible to gather large amounts of useful data about students, teachers, and schools in a relatively short period of time, but timing of the data collection is crucial, and lead-time for the provincial governments and the schools is always longer than expected. Further, despite considerable communication with each school in the sample, several were not prepared for the researchers when they arrived. Principals were sometimes absent, and other principals had not discussed the study with their teachers. Such lack of communication between principal and teachers served as one piece of information about conditions in the school. But even where teachers had been informed, and the purpose discussed with them beforehand, considerable reassurance was needed that the research or its results would not be used against them.

CHAPTER 3

RESULTS

The surveys provide a wealth of data on students, teachers, and schools in one South African province. Because this is only a pilot study, whose purpose is to discover problems with the instruments and the data collection process, it is not possible to test all the hypotheses put forth in the larger proposal to the Spencer Foundation, namely whether greater teacher knowledge, better teaching, and greater opportunity to learn increases learner gains across student socioeconomic groups and whether some countries and schools are more effective in producing such gains. Nevertheless, the pilot data do provide insights into the schooling process in Gauteng Province, and, by implication, the educational process in South Africa. Although Gauteng is an urban province, and the quality of education is considered to be better in urban than in rural areas, many of the teachers had been trained in rural colleges.

In this report, we only present some key analyses, those that most inform future comparative research. The first section focuses on the problem of selection bias in the relation of teacher knowledge to learner performance. The second section reports on the way teachers allocate time in our sample of Gauteng classrooms. The third section reports on teaching quality in the sample and the relationship between teaching quality and teacher pedagogical content knowledge. The fourth section reports on a multilevel regression analysis of learner test performance as a function of learner characteristics, teacher capacity, and teaching quality.

3.1. Learner and Teacher Mathematics Knowledge

After administering a mathematics test to about 2,700 sixth graders in a sample of forty Gauteng schools in July 2007, researchers from participating universities and the HSRC administered three additional instruments in the same sample of schools in September 2007. These three instruments were (a) a teacher questionnaire, which included questions on the teacher's sixth grade level mathematics knowledge; (b) a principal questionnaire, and (c) videotaping a sixth grade mathematics lesson taught by one of the teachers who filled out a questionnaire. In October, we administered the same learner test to a subset of the students who took the test in July.

The results of the initial learner test suggest a rather low level of student mathematics learning in most of the schools we surveyed. The average on the test was a score of about 49 percent, with an individual standard deviation of more than 19 percent. There was less variation among the classroom average learner test scores (standard deviation of 13.4 percent)—several classrooms scored above 75 percent and 11 classrooms scored below 40 percent. Later in this paper, we show the results of average learner scores by former department and by several measures of school socioeconomic background.

The sub-sample of students who took the second learner test had scored about 10 points higher than the entire sample on the July test (59 percent) with a higher standard deviation (27 percent), so there is a serious question whether this second group of test takers was representative of the first group. Of the approximately 800 students who took the second test, we could match about 400 to the original test takers. The 400 showed an average gain of 7 points on the test.

Forty-nine teachers filled out questionnaires. Table 3.1 summarizes the sample of teachers who completed the questionnaires. We divide the sample by former department of the school and by one measure of socioeconomic level—the school average of our sample (those students who filled out the questionnaire and took the learner mathematics test) of sixth grade students' reported books in the home. Although the teacher sample is probably not completely representative of the province, it provides us with a good set of pilot data to be able to describe the level of teacher content and pedagogical content knowledge of sixth grade teachers and how that knowledge is distributed across different categories of schools.

Five of the schools are private (independent): two of these were former African (DET) schools, one former Asian (HOD), one former coloured (HOR), and one new school (NED). In our estimates of average teacher test scores, we separate out that category of schools from their former department categories. The vast majority of the teachers in our public school sample teach in former African (DET) or white schools (TED). The average student reported books in the home index is a good measure of students' family social capital, hence the average family social capital represented in each teacher's classroom. A value of 2 in the index represents 10 books, magazines, or newspapers in the home; 3 is 20 books, magazines, or newspapers; 4 is 50; 5 is 100, and 6 is more than 100. Most schools in the sample have students that have more than 20 reading articles in the home.

TABLE 3-1. TEACHER SAMPLE OVERVIEW

VARIABLE	NUMBER	VARIABLE	NUMBER
Total Teachers	49	*Total Teachers*	49
By Former Department:		*By Index of Books in the Home*	
DET	17	2-2.7	8
HOD	6	2.71-3.2	9
HOR	7	3.21-3.49	12
NED	6	3.5-4.49	13
TED	13	4.5-6	7

The distribution of our sample of schools may be skewed somewhat to the higher social class side (we probably inadvertently sampled too many former white (TED) schools). But it must be borne in mind that schools are increasingly racially integrated and that schools divided strictly along white, Indian, coloured and African lines are the exception rather than the norm. In our sample, there were no white teachers teaching in former DET schools, but they were teaching racially mixed classes, and teachers who previously were classified as Indian, coloured, and African were teaching across all categories of schools. By dividing the sample into categories, we try to offset some of this skewness by estimating teacher mathematics knowledge within type and social class level of schooling.

The teacher mathematics knowledge questionnaire is presented in Appendix A. Every teacher in our sample took this knowledge questionnaire, which focuses on basic operations, multiplication-division, fractions, geometry, and percentages. There were ten questions on the questionnaires, and some of the questions had multiple parts.[10] We graded the ten questions in two ways: (a) in Alternative A, each question was worth one point even if it had multiple parts—for example, question 9 had six parts asking about the same data, so a score on Q 9 could range from 0 to 1, with multiple values between; and (b) in Alternative B, questions with multiple parts were given more than 1 point, depending on the number of parts in the question. In the second grading method, questions 1-4 were given one point each; question 5 was given two points; question 6, two points, question 7 two points, question 8, one point, question 9 was given 3 points, and question 10, two points—for a total of 16 points. The results of the two grading systems had an $r = 0.96$, so we used the results of Alternative A for most of our comparisons.

The questions on the teacher questionnaire measured both content and pedagogical content knowledge. Content knowledge (CK) refers to knowledge of mathematics. Three of the questions on the test (Q 4, 5, and 9) measure content knowledge. One of the most original features of our data is the information on the teacher's specialised knowledge of mathematics instruction, also known as pedagogical content knowledge (PCK). What makes the PCK construct different compared with content or pedagogy is that every question is about a "big" idea or concept embedded in a teaching situation. The purpose of this is to measure if the teacher can apply the content knowledge to the job of teaching. Because this is rooted in deep understanding of the content, some think of it as simply conceptual understanding of the mathematics. Before this construct was considered in mathematics education research, it was believed that teachers simply learned mathematics and pedagogy separately before learning how to teach others by integrating these knowledge forms in the classroom. Seven of the questions on the questionnaire test (Q 1-3, 6, 7, 8, and 10) measure PCK.

The data analysis below is based primarily on descriptive statistics, with some statistical comparisons and correlation analysis. There is also a section that uses

[10] Teachers were assured that these questions were for research purposes only, and were asked to complete items when they had left them blank. However, in some cases they chose not to respond to items. These blank items are marked as incorrect. This is justified by some preliminary statistical analysis that shows that teachers tended to leave harder items blank, and these same teachers tended to score lower on the remaining items that they did answer. However, if teachers were simply skipping some questions then this strategy will bias the overall averages downwards. This is not a serious problem, however, since a small percentage (less than 5 percent) of the knowledge questions were left blank.

multivariate analysis to explain teacher knowledge levels as a function of various indicators of training, education, and relates teacher knowledge to student knowledge.

Teacher Content and Pedagogical Content Knowledge

Table 3.2 presents the results of our estimates of mathematical content knowledge and pedagogical content knowledge in our sample of sixth grade teachers in Gauteng. On average teachers scored about 60 percent on both parts of the test. This is not a high score for teachers testing on a Grade 5 test, although the standard deviation is about 15 to 19 points, suggesting that 15 percent of teachers in the sample score above 75-80 percent. The relatively low score is not very encouraging, but may reflect the fact that we administered these teacher questionnaires during the teachers' workday, so we cannot be certain they gave them full attention. The scores may be biased downward to some degree. Even so, we found very few cases of blank answers. Overall the score suggests that many South African teachers teaching sixth grade do not have high content and pedagogical content knowledge of mathematics.

Teachers teaching in the new schools (NED), the former African schools (DET), and the former coloured schools (HOR) score the lowest, and the Independent and former white schools score the highest. The variation among the types of schools is greater for PCK than it is for CK, although this may have to do with the number of questions on the test used to measure each type of knowledge.

When we divide the same by the books in the home index, we see a fairly strong correlation between the family social capital of sixth grade students in the school, and the mathematics content and pedagogical content knowledge of teachers teaching those students. Again, the differences in PCK among the school categories are greater than for CK. The difference between the lowest SES group of schools and the highest SES group of schools in the PCK of teachers teaching these sixth grades is about 1.5 standard deviations. Even though the sample is small, these differences are statistically significant.

The relatively low level of mathematics knowledge that teachers have in all but the highest student SES schools is somewhat troubling. It raises some doubts about the preparation of the teaching force. One way to further contextualize these results is to see actual examples of teacher mistakes. Box 3-1 provides an example of one of the PCK items taken from Grade 6 mathematics curriculum in the area of geometry. The example is useful because it shows how teacher response patterns for a specific item vary in this sample of teachers.

About one-half the teachers in our sample got this question correct about the correct way to estimate the perimeter. Almost all those who got it wrong mistakenly thought that Sally's answer was correct, even though she made two mistakes that made her perimeter estimate 4 cm. too large.

It is tempting to argue that higher levels of PCK for teachers are a factor in higher test scores for students, but as we shall argue repeatedly in this report, our data do not allow us to make this inference. Table 3-2 does suggest that teachers with higher levels of CK and especially PCK tend to teach in schools/classes in which students have higher math scores. It should be noted, as pointed out in the Context Section of this report, that Gauteng is a highly urban province, and the schools in this sample were quite urban. That means that the unequal distribution of teacher knowledge we observe in our sample could well be even more unequal in provinces where many students are in rural schools.

Teachers who have attended certain types of teacher training institutions appear to teach in schools with "better reputations." African teachers tend to teach in schools with mainly African students, Asian teachers with more Asian students, and white teachers with more white students or with African students from better-off families. Put another way, teachers appear to be more randomly distributed over schools than in the pre-apartheid racially-classified schools (former departments), but those with higher CK/PCK still teach students of higher socio-economic background. These facts suggest that the distribution of teachers among schools is not random. Thus, at best we can say that teacher mathematical CK and PCK are positively related to students' average test scores but are not necessarily the cause of such higher scores. We now turn to estimating the correlation between the two.

TABLE 3.2. TEACHER GRADE 6 MATHEMATICS CONTENT AND PEDAGOGICAL CONTENT KNOWLEDGE (PERCENT SCORE)

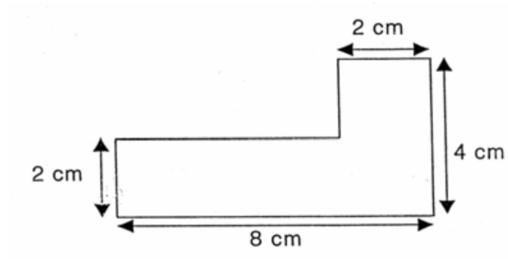
	Knowledge Test Score, by Scoring Alternatives A and B (percent score on test)					
Former Department	*Content Knowledge A*	*Pedagogical Content Knowledge A*	*Total Teacher Score A*	*Content Knowledge B*	*Pedagogical Content Knowledge B*	*Total Teacher Score B*
DET	59.6	47.5	51.1	52.2	48.4	49.9
HOD	66.7	60.2	62.2	60.0	58.3	59.0
HOR	56.5	49.0	51.3	47.2	45.3	46.0
NED	50.0	52.1	51.5	40.0	53.0	48.1
TED	66.7	75.1	72.6	60.3	72.1	67.6
INDEP	68.9	69.0	69.0	61.7	68.7	66.0
Total	61.8	59.0	59.8	54.3	57.9	56.5
Average	(14.9)	(19.4)	(16.0)	(18.2)	(19.4)	(16.2)
School Average Index of Books in the Home	*Content Knowledge A*	*Pedagogical Content Knowledge A*	*Total Teacher Score A*	*Content Knowledge B*	*Pedagogical Content Knowledge B*	*Total Teacher Score B*
2-2.7	55.6	44.8	48.0	46.9	46.5	46.6
2.71-3.2	58.0	54.2	55.4	49.1	51.5	50.6
3.21-3.49	60.2	56.2	57.4	52.8	56.9	55.4
3.5-4.49	63.7	63.4	63.5	57.1	60.3	59.1
4.5-6	73.0	77.9	76.4	66.7	76.2	72.6
Total	61.8	59.0	59.8	54.3	57.9	56.5
Average	(14.9)	(19.4)	(16.0)	(18.2)	(19.4)	(16.2)

Source: Gauteng Province survey of sixth grade mathematics classes, 2007. Alternative A refers to test score using 10 points for the test; Alternative B refers to 16 points for the test.

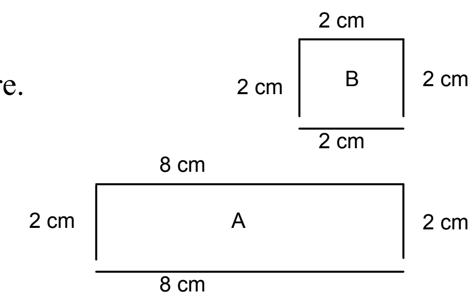
Box 3-1. Teacher Response to Grade 6 Geometry Item

Q 2. Mrs Sithole set her Grade 6 Class the following problem:

Calculate the perimeter of the figure.

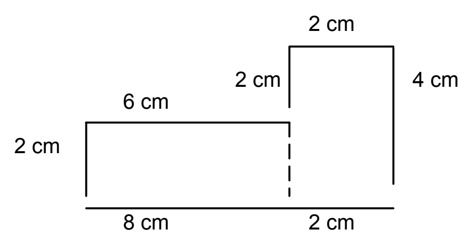


Sally answered the question this way:
I divided the figure into a rectangle and a square.
I then found the perimeter of each figure
and added them.



P = (2 + 8 + 2 + 8) cm + (2 + 2 + 2 + 2) cm
= 20 cm + 8 cm
= 28 cm

Bongi answered the question this way:
I drew a line to make two rectangles, but
did not separate them. I then calculated
the perimeter like this:



P = 2 + 6 + 2 + 2 + 4 + 2 + 8
= 26 cm

Which of the following is correct?

A. Sally is right.
B. Bongi is wrong because she did not use the middle line.
C. Bongi is wrong because she has put in an extra 2 cm.
D. The correct answer is 20 cm

Summary of Responses Given by Teachers:

Response	Number	Percent
A	18	36.7
B	3	6.1
C	***24***	***49.0***
D	1	2.0
No answer	3	6.1
Total	49	100.0

3.2 School Socioeconomic Level, Teacher Mathematics Knowledge, and Student Performance

One of the more interesting results of our pilot study is the relationship between the average socioeconomic level of students in the school, the total mathematical content knowledge (CK plus PCK) of teachers we surveyed in each school, and the average student mathematics test score in the school. It is not possible to impute any causal relations between these variables, although they are strongly correlated with each other, as we shall show.

We have four measures of school socioeconomic level in our survey: (1) the quintile of socioeconomic level of the district in which the school is located; (2) the fees charged by the school (public and private schools charge fees in South Africa); (3) the school average of the student's reported "highest level of education attained" of the primary parent or guardian (mother, father, grandparent, or other)—an index from 1 to 5; and (4) the school average of the student's reported "number of books, magazines, and newspapers in the home"—an index from 1 to 6.

The relationship between student test score, teacher pedagogical knowledge score and school socioeconomic level is fairly similar across these four measures of school SES, but there are important differences. Figures 3-1 to 3-4 display the relationships.

Figure 3-1. ***Gauteng Province: Grade 6 Student Test Score and Teacher Overall Knowledge Score as a Function of School District Socioeconomic Level, 2007.***

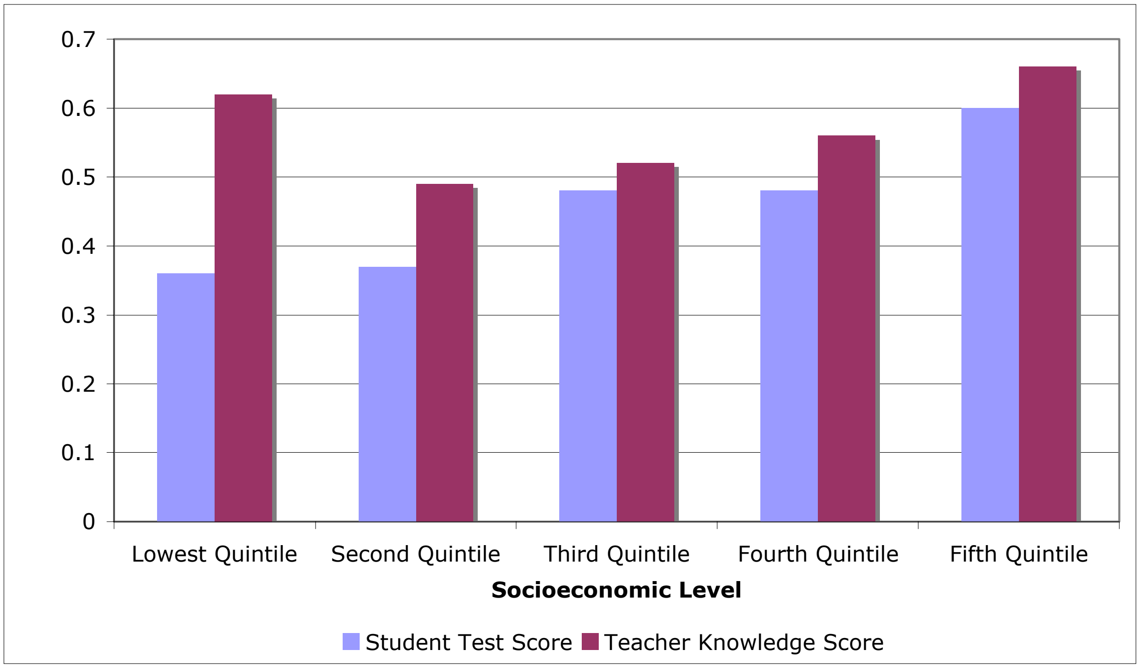


Figure 3-2. ***Gauteng Province: Grade 6 Student Mathematics Test Score and Teacher Overall Mathematics Knowledge Score as a Function of School Fees, 2007.***

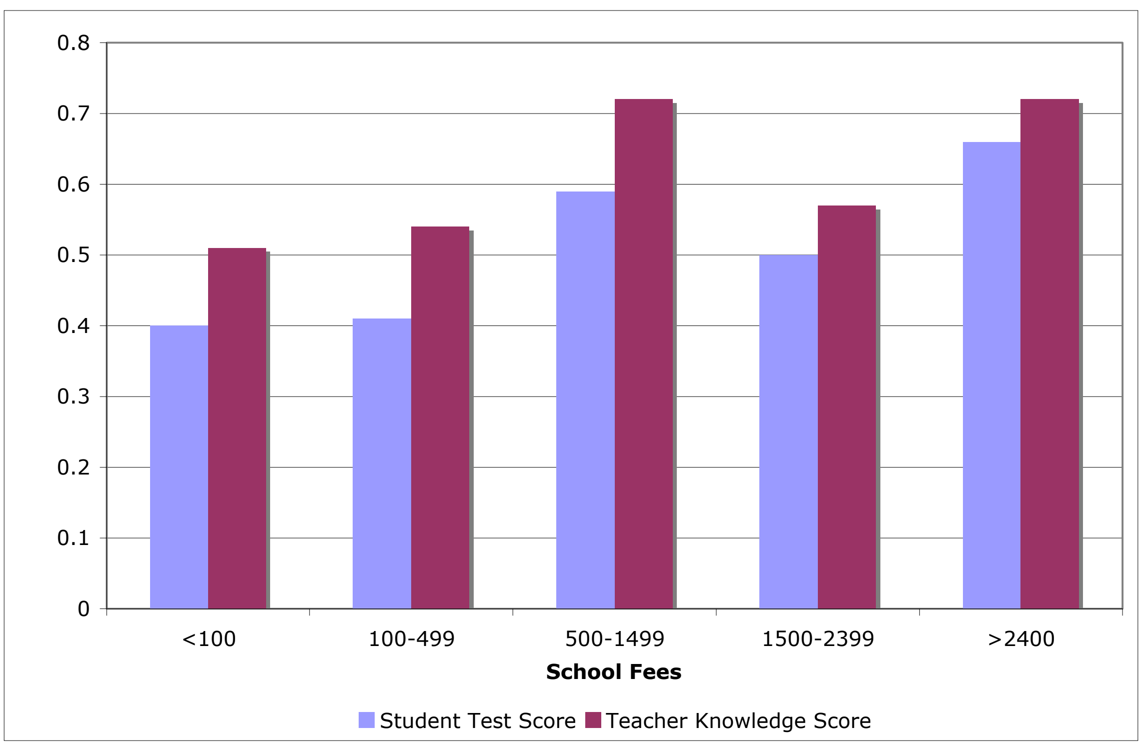
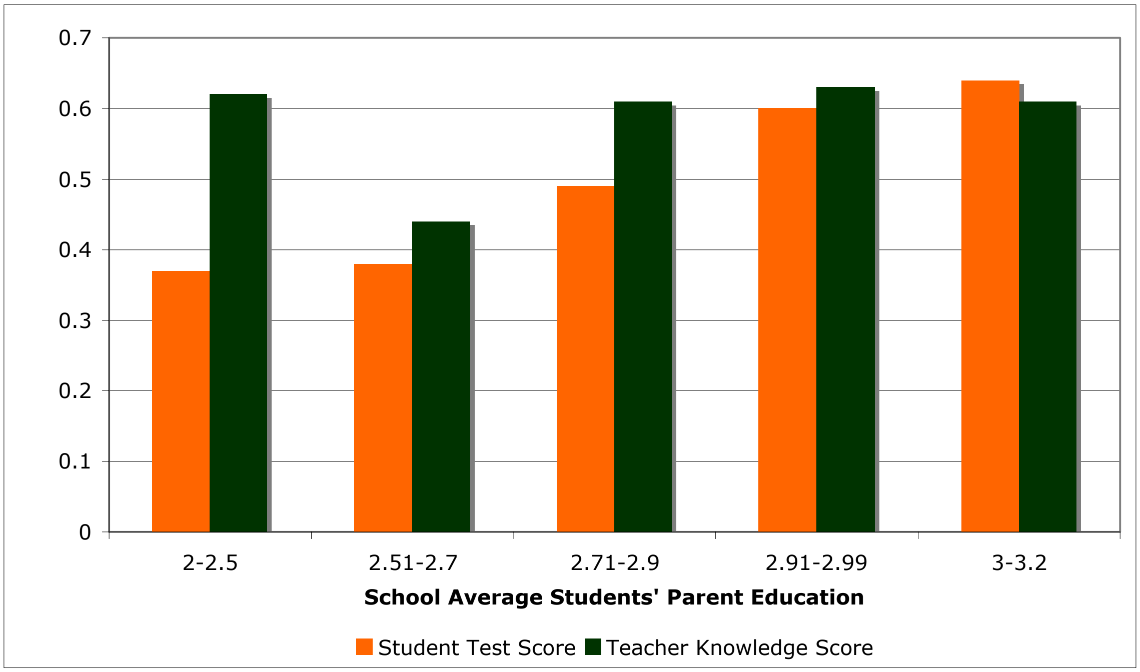
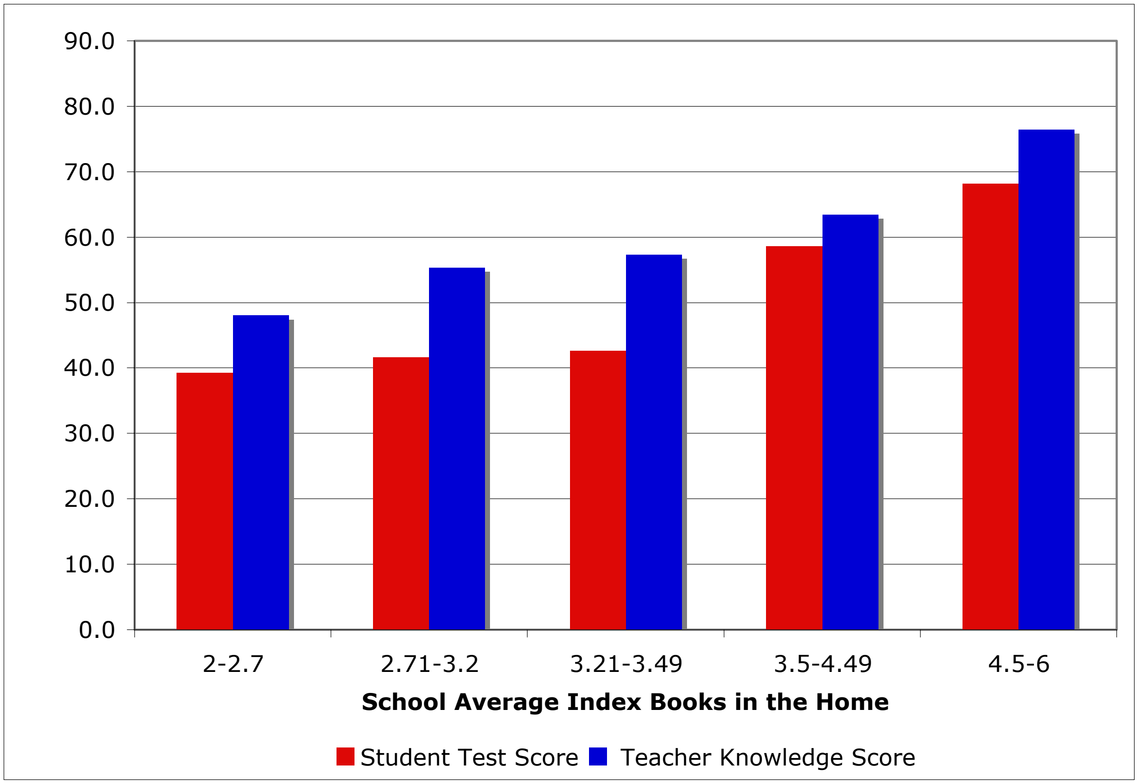


Figure 3-3. ***Gauteng Province: Grade 6 Student Mathematics Test Score and Teacher Total Mathematics Knowledge Score as a Function of Index of School Average Student's Reported Primary Parent's Education Level, 2007.***



Note: The index of parent education is primary schooling=1, some secondary schooling=2, completed secondary schooling=3, some college or technikon courses=4, and university completed=5

Figure 3-4. ***Gauteng Province: Grade 6 Student Mathematics Test Score and Teacher Overall Knowledge Score as a Function of School Average Index of Student's Reported Number of Books in the Home, 2007.***



Note: Index of number of books in the home is as follows: no books=1, about 10 books=2, about 20 books=3, about 50 books=4, about 100 books=5, more than 100 books=6.

- One relationship that emerges from these graphs is that in the bottom two categories of whatever SES index we use, student test score are lower, no matter what the level of teacher content plus pedagogical content knowledge.

- At the two highest levels in all the measures of SES, student test scores are much more closely related to teacher knowledge scores.

- In general, the Table 3-2 and these graphs suggest that an SES measure, such as books in the home, is a fairly good "predictor" of student mathematics test score performance and of the average pedagogical content knowledge of the teachers teaching in the schools.

- Even so, there is a clear correlation between teacher pedagogical mathematical content knowledge, student test scores, and socioeconomic background. This correlation is strongest when the SES measure used is students' reported books in the home, and weakest when the SES measure is school fees.

When we estimate student mathematics average test scores at the school level as a function of each of these measures of SES and teacher knowledge, we can "explain" with just these two variables between 0.48 (using district SES level) and 0.69 (using the index of parent education or books in the home) of the variation in student test scores. These are very high R^2's, but they should not be interpreted as implying causality between teacher knowledge and student performance. The results do suggest a strong relation between average school SES—particularly the school aggregated averages of individual student reported SES—and school average test scores.

The results also suggest that teacher capacity to teach mathematics (the CK and PCK score) is unequally distributed across schools catering to various social class groups of students. The fact that teacher knowledge is likely not distributed randomly means that we cannot infer that higher teacher mathematics knowledge is the source of higher student mathematics scores. Indeed, the opposite may be the case: all teachers may want to teach in schools with higher social class, more "able" students, but the higher mathematics knowledge teachers may have greater access to those schools. Thus, higher learner SES and learner mathematics ability may "cause" higher teacher mathematics ability to be in those classrooms. This is commonly known as the "endogeneity" or selection bias problem: it is difficult to identify the schooling source of student learning because students are not randomly assigned to schools with greater or fewer resources (mainly teacher capacity), and teachers are not randomly assigned to students with greater or fewer resources.

If we think of parent education as a proxy for the human capital resources available to students at home, and the number of books in the home as a proxy for family social capital (Carnoy, Gove and Marshall, 2007), the results suggest that teachers with greater pedagogical content knowledge are more likely to be teaching in schools where students have access to greater amounts of family human and social capital. We show below that teaching quality is significantly related to teacher PCK score, although the relationship is not very strong. Thus, it is likely that students with more human and social capital resources at home also have access to better teaching at school.

The results of the regressions of classroom average learner test scores as a function of various measures of school socio-economic context and average teacher mathematics knowledge are shown in Table 3-3.

Table 3-3. ***Gauteng Province: Estimates of the Relationship of Teacher Mathematics Knowledge and Various Measures of School SES to Classroom Average Learner Grade 6 Mathematics Performance, 2007.***

	Regression Estimates, Dependent Variable Student Mathematics Performance			
Independent Variables	*1*	*2*	*3*	*4*
Teacher CK Score (decimal)	20.02* (10.34)	22.79** (9.28)	29.30*** (7.93)	14.47* (8.06)
Teacher PCK Score A (decimal)	25.31*** (8.22)	20.71*** (7.56)	16.10** (6.34)	13.86** (6.49)
District SES (quintile number)	4.01*** (1.24)			
School Fees (Rand/month)		0.004*** (0.0008)		
School Average Parent Education (index 1-5)			33.47*** (4.76)	
School Average Books in Home (index 1-6)				10.85*** (1.56)
Intercept	7.73	18.74***	-70.18***	-5.28
N	49	49	49	49
Adj. R^2	0.48	0.58	0.69	0.69

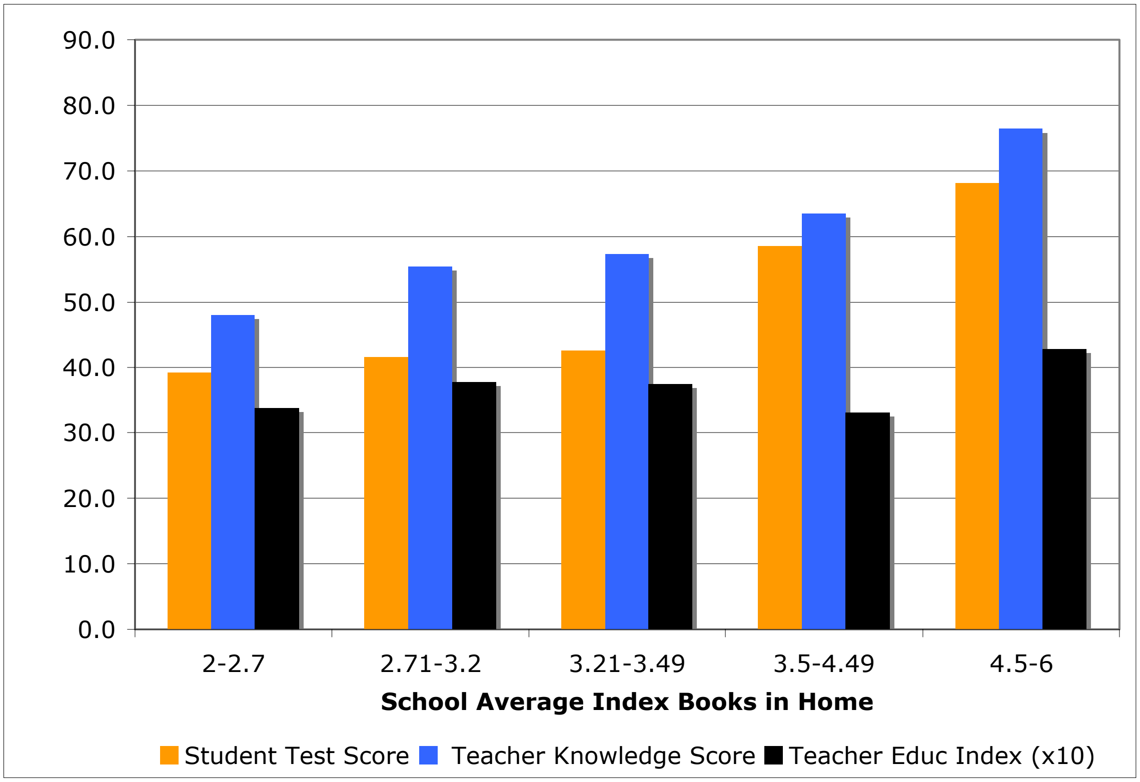
Note: ***: statistically significant at a 1 percent level; **: statistically significant at a 5 percent level; *: statistically significant at a 10 percent level.

We also note that typical measures used in many surveys—teachers' reported education and experience—are not significantly related to classroom average learner test scores (see Figure 3-5 for the teacher education variable). More telling, teacher pedagogical mathematics content and pedagogical knowledge are also not significantly related to reported teacher education level. This suggests either that the teacher education level is itself a poor measure of how much teachers know about the content they are teaching or that teacher education is usually misreported.

We anticipated this possibility in our teacher questionnaire (for example, we asked where the teachers took their teacher education and we asked whether they majored in mathematics). A number of teachers did not complete whether they majored in mathematics, but they did indicate that their primary teacher training courses did not provide for specialization and 'covered' most subjects they are expected to teach. They also did answer where they took their teacher training. Most teachers in the sample were trained before 1994, when teacher education colleges were divided into Bantustan (rural) teacher training colleges, urban African colleges, coloured colleges, Indian colleges, white colleges and universities. Since 1994, most of the colleges were closed and teachers trained in universities.

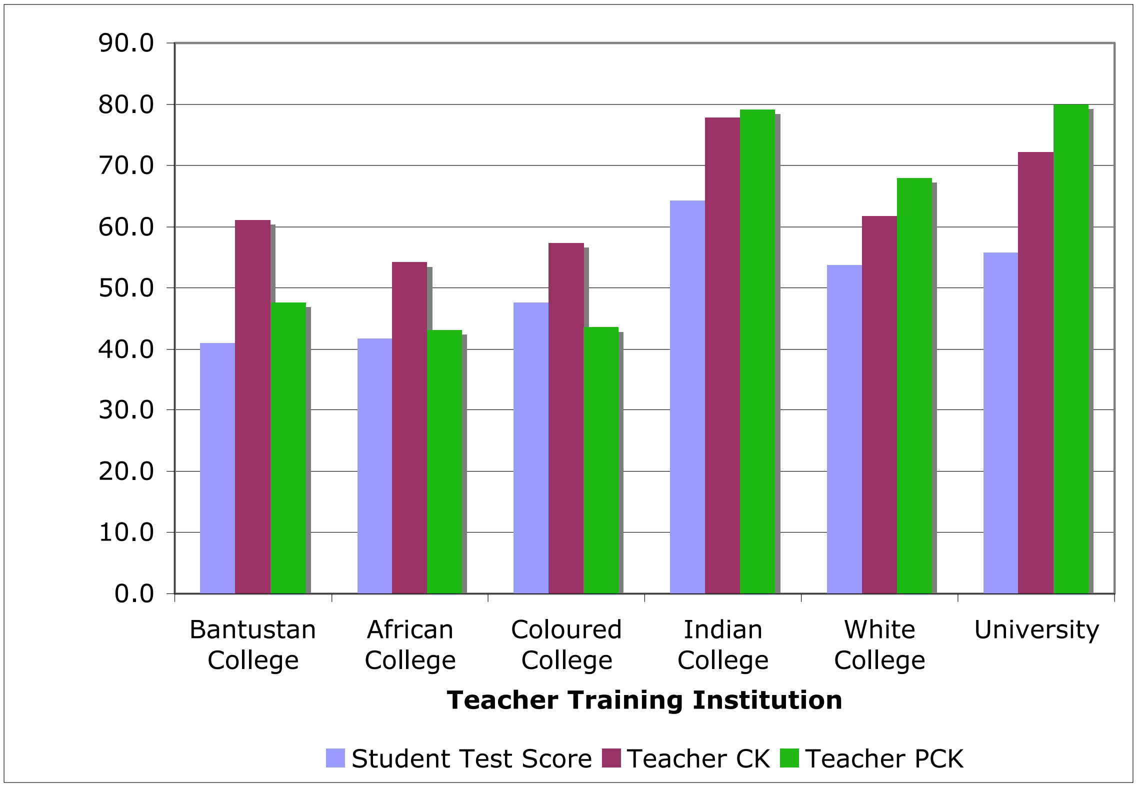
Figure 3-5 shows the relationship between where the teacher we filmed in each school was trained and the average mathematics content knowledge for the teachers trained in those institutions. The figure also shows the average student test score for the schools where the teachers with each type of training teach. The graph suggests that, except for those who attended universities and Indian colleges, content knowledge differences are not large. However, differences in pedagogical content knowledge for those who attended rural (Bantustan) and urban African colleges or Coloured colleges and those in Indian, white, or university institutions are large. This may be a function of the quality differences in the institutions or the previous math knowledge of the individuals who attended the various institutions.

Figure 3-5. ***Gauteng Province: Reported Teacher Education, Teacher Mathematics Knowledge Score, Student Mathematics Test Score by School Average Index of Students'*** **Books in the** ***Home, 2007***



Note: Teacher reported highest education level attained is an index from 1 to 6, with 1=primary schooling and 6=post-graduate education degree. In this graph, the index is multiplied by ten to compare it with student and teacher mathematics score.

Figure 3-6. ***Gauteng Province: Where Teachers Trained, Their Mathematics Content and Pedagogical Content Knowledge, and the Students' Average Grade 6 Mathematics Score in the Teacher's Class.***



Source: Gauteng Province School Survey, 2007.

In Table 3-4, we estimate the teacher's PCK score as a function of his or her pre-service training institution index[11](a possible proxy for the quality of training), gender, and age (a proxy for teaching experience). The results suggest a strong relation between the institution attended and the teacher's PCK score. Again, this should not be interpreted as a causal relation. Although we have no data on the teacher's socioeconomic background, where he or she attended teacher training college was a function of location (for Africans, Bantustan/homeland or urban South Africa) and, before 1994, race. Race, in turn, is highly correlated with the teacher's family's socioeconomic situation, hence the quality of schooling they received before attending pre-service training. Thus, we really do not know the impact of the teacher training institution per se on the teacher's PCK, but we can argue that there may exist a systematic combination of factors that resulted in lower PCK in some teachers than others, and this is probably in part related to the quality of pre-service training.

When we analyse the classroom teaching of these individual teachers below, we will try to draw further insights into this issue. As we will show, it appears that there is a

[11] We construct a rough index of teacher training institutions, as follows: Bantustan /homeland (rural) =1, African urban college = 2, Coloured urban college = 3, Indian urban college = 4, white urban college = 5, and university = 6.

weaker relation between the quality of classroom teaching and teacher PCK than between the quality of the classroom teaching and the institution attended. This suggests that the institution attended may have influenced the quality of classroom teaching in some direct fashion unrelated to the relation between quality of institution and PCK, which in turn could be a product of pre-teacher training effects.

Table 3-4. ***Gauteng Province: Teacher Mathematics Pedagogical Content Knowledge as a Function of Teacher Training Institution, Gender, and Age***

VARIABLE	ESTIMATED REGRESSION COEFFICIENT (STANDARD ERROR)
Male	-0.032 (0.055)
Age	-0.003 (0.003)
Teacher Training Institution Index	0.071 (0.015)***
Intercept	0.487 ***
No. Observations	38
Adj. R^2	0.36
Note: *** statistically significant at a 1 percent level	

3.3 Teaching Practice and Proficiency in Gauteng Province

In this section, using qualitative data taken from classroom observations, we first analyse the use of time in Gauteng sixth grade classroom, and second, we analyse the proficiency and *demonstrated* knowledge of the Grade 6 teachers we observed. We presented our conceptual framework above for capturing teacher quality. With the data incorporated in this section we can bring in pedagogy as well as alternative measures of content knowledge based on actual actions by the teacher in the classroom. The sample is a bit smaller because we administered the questionnaire to more teachers than we filmed, but these kinds of qualitative data provide an excellent addition to the teacher mathematical knowledge data. At the end of this section we also compare the different kinds of teacher quality measures taken from the different data sources.

In addition to applying questionnaires to teachers in each school the data collectors also used hand-held video cameras to film mathematics classes. This was done with the prior consent of the teacher, who was assured that the purpose of the video was purely investigative. The classes lasted roughly 30-45 minutes in mathematics. They were mainly review lessons of work that had been done before. The enumerators were trained in a very basic filming strategy designed to facilitate the different analyses. In most cases they stood in the back of the room and focused on the teacher and the chalkboard. With any taping procedure there are potential threats to validity and reliability. One concern is that teachers and students may alter their behavior because they have visitors. This is impossible to verify, at least based on only one class visit. However, the ability of these teachers to alter radically their instruction methods seems limited. The same is especially true for students who may be used to classroom norms established throughout the year. Nevertheless, we should probably allow for the possibility that these taped lessons reflect at least a more engaged and animated teacher (and student) than normal.

The more qualitative components of our analysis are based on a series of rubrics applied to the videotaped lessons. The most basic summary borrows heavily from the "time on task" framework pioneered in the 1960s by Carroll (1963) in order to address a simple question: how does each class spend its time? The five primary categories are seat work, recitation, group work, teacher-centered actions (lecturing, writing on chalkboard) and transitions and interruptions. For the first three categories we use a series of sub-categories to further specify the kind of segment that is taking place. The researcher watched the classroom video and classified the main category of activity taking place during in each 15 second period during the lesson. Each 15-second segment is marked with a click in the appropriate box. The total number of clicks is then added up, and each segment is measured as a percentage of total time. The time use data are augmented through several observational components, such as student engagement and the kinds of questions the teachers asks.

The lessons were then analysed separately by two mathematics education experts in order to consider four critical elements of teaching: *mathematical proficiency* of the lesson, *level of cognitive demand*, the *mathematical content* of the lesson, and the teacher's *mathematical knowledge* observed in the lesson.[12] *Mathematical proficiency* is based on the National Research Council's (United States) study of mathematics instruction, *Adding it Up* (2001). The term encompasses expertise, knowledge, and facility in mathematics. The five key strands of mathematical proficiency include:

- <u>conceptual understanding</u>—comprehension of mathematical concepts, operations and relations;
- <u>procedural fluency</u>—skill in carrying out procedures flexibly, accurately, efficiently, and appropriately;
- <u>strategic competence</u>—ability to formulate, represent, and solve mathematical problems;
- <u>adaptive reasoning</u>—capacity for logical thought, reflection, explanation and justification; and
- <u>productive disposition</u>—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy (Mathematics Learning Study Committee 2001, p. 117).

These strands are not taken as individual goals but rather as an interdependent and interwoven definition of proficiency. If any one of the five elements is missing, the learning process is not considered complete. Nevertheless, in the context of evaluating a (short) lesson it may be unrealistic to expect all five elements to be present—even in a very good class. This argues for some flexibility in how we assess the mathematical proficiency of the lesson. For the overall mathematical proficiency we consider whether each strand is present during the lesson.

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[12] The first three of these elements were included in Carnoy, Gove and Marshall (2007), and were created with help from Kim Stevenson.

For *level of cognitive demand* we derive a rubric from Stein et al.'s (2000) classification of higher and lower cognitive demand. These include:

- Memorization – recollection of facts, formulae, or definitions.
- Procedures without connections – performing algorithmic type of problems and have no connection to the underlying concept or meaning.
- Procedures with connections – use of procedures with the purpose of developing deeper levels of understanding concepts or ideas.
- Doing Mathematics – complex and non-algorithmic thinking, students explore and investigate the nature of the concepts and relationships.

The *mathematical content* is evaluated using the five Learning Outcomes from the National Curriculum Statement (NCS) Mathematics (Grades R-9).

- LO1: Numbers, Operations and Relationships – The learner is able to recognize, describe and represent numbers and their relationships, and count, estimates, calculates and checks with competence and confidence in solving problems
- LO2: Patterns, Functions, and Algebra – The learner will be able to recognize, describe and represent patterns and relationships, as well as to solve problems using algebraic language and skills
- LO3: Space and Shape – The learners will be able to describe and represent characteristics and relationships between 2-D shapes and 3-D objects in a variety of orientations and positions
- LO4: Measurement – The learner is able to use appropriate measuring units, instruments and formulae in a variety of contexts.
- LO5: Data Handling and Probability – The learner will be able to collect, summarize, display and critically analyse data in order to draw conclusions and make predictions, and to interpret and determine chance variation.

The last aspect measured in the video focuses more on the *teachers' knowledge*. We characterise the *observed* teachers' knowledge in a lesson in a similar way as in the written instrument that measures their PCK with questions. This includes:

- Content knowledge – this refers only to teachers' knowledge of the mathematics being taught, Grade 6 in our case.
- Pedagogical knowledge – this refers to knowledge of instructional techniques beyond lecture mode.
- Pedagogical content knowledge – this refers to the appropriate integration of the instructional techniques with the mathematical concept being taught and its effectiveness on student learning.

Together these four analytical elements make it possible to go beyond a simple reconstruction of each lesson and consider the deeper mathematical meaning of what is being taught. These elements also allow us to assess what the teachers know and how they apply this knowledge in the classroom, which in turn makes for some useful linkages between the lesson analysis and teacher questionnaires.

3.3.1 Results: Time Segment Summaries

Table 3-2 above, presented an overview of the videotape sample. We tested students and interviewed teachers in 40 randomly selected elementary school in Gauteng province, but in one we were not allowed to videotape because of religious considerations, and in another, an English lesson was videotaped instead of a mathematics lesson. Thus, the time segments and teaching content analyses are for 38 sixth grade mathematics lessons in 38 schools.

Class sizes in Gauteng are large, on average 37.1 students in our sample, varying from 11 to 67 (standard deviation equal to 10.1). The class sizes average larger in schools with lower SES students and somewhat larger in former African schools (DET). There is considerable variance in class size at all SES levels. The length of classes we observed were almost all from 30-40 minutes long.

In the bottom half of Table 3-5 we show the general summaries of the lessons by each of the main time segment categories. The totals are percentages, and sum to 100 percent for each category of school. The classes generally revolve around a considerable amount of teacher presentation (whole class, teacher-led), with the teacher asking the students in the class to reply individually or in chorus to questions as the teacher makes his or her presentation (we consider the answering part as recitation). This is usually followed by seatwork, in which the teacher circulates, checking students' work. Sometimes this is followed or preceded by students coming to the board and doing problems at the board (also classified as recitation); in other classes, it is followed by more individual and chorus recitation in response to questions from the teacher. When students were seated at tables or desks groups in clusters, we classified seat work as individual work in groups; when student seating was at individual desks facing the teacher, we categorized the seat work as individual seat work. In one way, this makes sense: if students are seated in clusters around a table, or more usually with their desks facing each other, they have opportunities for cooperation as they are doing their seat work. But in another sense, individual seat work should not be differentiated because of seating arrangements—it is still individual seat work, Thus, we estimated individual seat work in two ways: in alternative A, when students were seated in groups, we called individual seat work "individual group work;" in alternative B, we called all individual seat work, "individual seat work," no matter how students' desks were arranged.

In Alternative B, the percentage of the lesson classified as seatwork is obviously much greater. The main difference occurs in lower SES (as measured by student reported books in the home) schools and in former DET and HOR schools. These lower class and former department schools tend to arrange students' desks in groups more than in higher social class schools/TED schools.

In sum, a typical mathematics class in Gauteng's sixth grades is about one-third teacher-led whole class, in which the teacher is talking to the class, about 25 percent of class time the teacher's asking questions to the class which are answered by individual students or in chorus (on average, for the 38 classrooms we timed, 44 percent of the recitation time was individual recitation, 36 percent was chorus, 15 percent was solving at the blackboard, and 5 percent was groups reporting), and about one-third seat work.[13] Much of the recitation time (individual students and student chorus responding to the teacher) is mixed in with the teacher-led talking about the subject. In the highest SES schools, more time is spent on whole class teacher presentations and on seatwork, and less on recitation. In the lower SES classrooms, students are more likely to be seated with their desks grouped into 4-6 students facing each other, although when the students in such grouped situations are doing seatwork, it is almost entirely individual. That said, there are greater possibilities in a grouped situation of looking over at the other students' work, and students often do that. Actual work in groups uses only about 4 percent of class time.

We should also note that there is large variation from school to school in these numbers. In many of the categories, the standard deviation is as large or larger than the mean percent of time estimated for all schools. Thus, the average time use in the schools we observed may be characterised as typical, but there is large variation, at least in the lessons we observed. The data should also not be interpreted as representing the average of time use in a lesson in a given school. We only observed one lesson per teacher (although in one school we observed lessons with the same teacher on different days), and it is likely that a teacher uses time quite differently on different days. For example, in the case of the teacher we observed on different days, time use was very different.

TABLE 3-5A. GAUTENG PROVINCE: BASIC OVERVIEW OF GRADE 6 CLASSROOMS, ALTERNATIVE A, SEATING IN GROUPS TAKEN INTO ACCOUNT, BY PREVIOUS DEPARTMENT AND SCHOOL AVERAGE BOOKS IN THE HOME

	School's Previous Department					
Variable:	**DET**	**HOD**	**HOR**	**NED**	**TED**	**Total**
Number of classrooms	13	4	7	4	10	38
Number of students in classroom	38.9	31.2	37.6	39.2	35.9	37.1 (10.1)
Average length of video	33.8	35.3	38.9	34.3	31.3	34.3 (12.3)
Main Segments (% of time):						
Individual Seatwork	8	22	4	18	23	14.0 (20.5)
Recitation	31	20	17	23	31	26.3 (15.6)
Individual Seatwork in Group	23	9	25	11	11	17.6 (24.5)
Work in Groups	1	8	10	3	2	4.0 (9.6)
Whole Class Teacher-Led	34	35	39	38	29	34.1 (17.3)
Transition/Interruption	3	6	4	7	3	4.0 (4.1)

13 This is precisely the same percentage for seat work estimated in Guatemala.

Variable:	School Average Index of Student Reported Books in the Home Low	Low-Med	Medium	High-Med	High	Total
Number of classrooms	7	7	9	10	5	38
Number of students in classroom	41.0	43.9	34.9	34.7	31.0	37.1 (10.1)
Average length of video (minutes)	34.2	28.9	41.3	34.6	28.7	34.3 (12.3)
Main Segments (% of time):						
Individual Seatwork	5	11	11	15	35	14.0 (20.5)
Recitation	26	28	26	27	23	26.3 (15.6)
Individual Seatwork in Group	34	11	16	21	0	17.6 (24.5)
Work in Groups	0	9	6	3	1	4.0 (9.6)
Whole Class Teacher-Led	33	37	35	31	37	34.1 (17.3)
Transition/Interruption	2	4	6	3	4	4.0 (4.1)

Source: Videotapes of 39 classrooms in Gauteng Province, September/October, 2007. Note: Figures in parentheses represent the standard deviation of each variable.

Table 3-5B. Gauteng Province: Basic Overview of Grade 6 Classrooms, Alternative B, All Individual Seatwork Coded as Such Regardless of Seating Arrangement, by Previous Department and School Average Books in the Home

Variable:	School's Previous Department DET	HOD	HOR	NED	TED	Total
Number of classrooms	13	4	7	4	10	38
Number of students in classroom	38.9	31.2	37.6	39.2	35.9	37.1 (10.1)
Average length of video	33.8	35.3	40.9	34.3	31.3	34.3 (12.3)
Main Segments (% of time):						
Seatwork	26	28	26	29	35	29.4 (27.0)
Recitation	31	20	17	23	31	25.8 (16.0)
Individual Seatwork in Group	5	3	3	0	0	2.7 (7.8)
Work in Groups	1	8	10	3	2	4.0 (9.6)
Whole Class Teacher-Led	34	35	39	38	29	34.1 (17.3)
Transition/Interruption	3	6	4	7	3	4.0 (4.1)

Variable:	School Average Index of Student Reported Books in the Home Low	Low-Med	Medium	High-Med	High	Total
Number of classrooms	7	7	9	10	5	38
Number of students in classroom	41.0	43.9	34.9	34.7	31.0	37.1 (10.1)
Average length of video (minutes)	34.2	28.9	41.3	34.6	28.7	34.3 (12.3)
Main Segments (% of time):						
Seatwork	32	25	24	33	35	29.4 (27.0)
Recitation	26	28	26	27	23	25.8 (16.0)
Individual Seatwork in Group	7	0	3	3	0	2.7 (7.8)
Work in Groups	0	9	6	3	1	4.0 (9.6)
Whole Class Teacher-Led	33	37	35	31	37	34.1 (17.3)
Transition/Interruption	2	4	6	3	4	4.0 (4.1)

Source: Videotapes of 39 classrooms in Gauteng Province, September/October, 2007. Note: Figures in parentheses represent the standard deviation of each variable.

FIGURE 3-7A. ALTERNATIVE A, BY INDEX OF BOOKS IN THE HOME

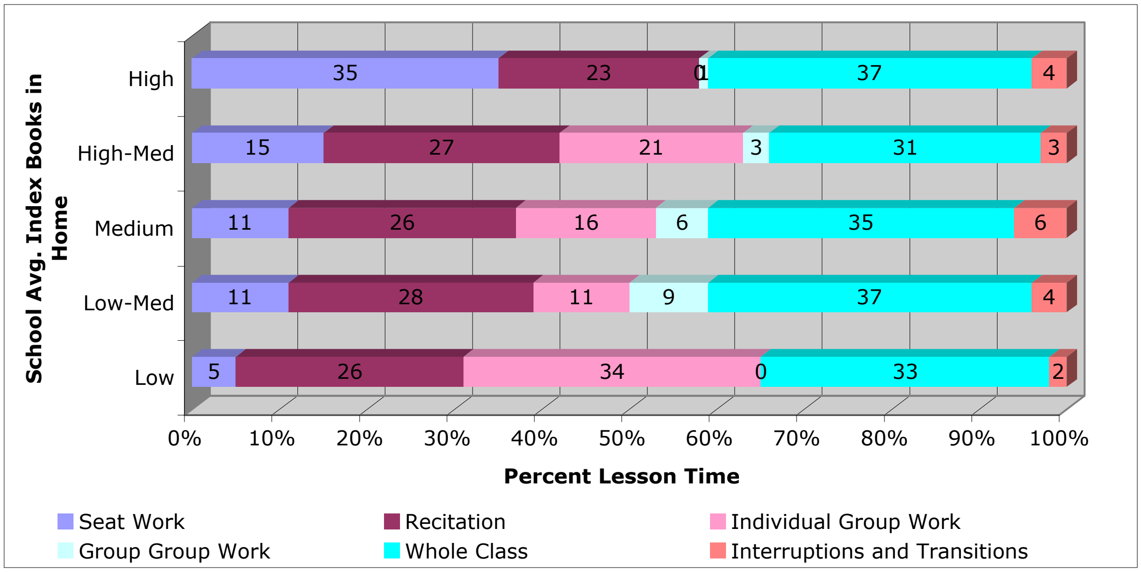
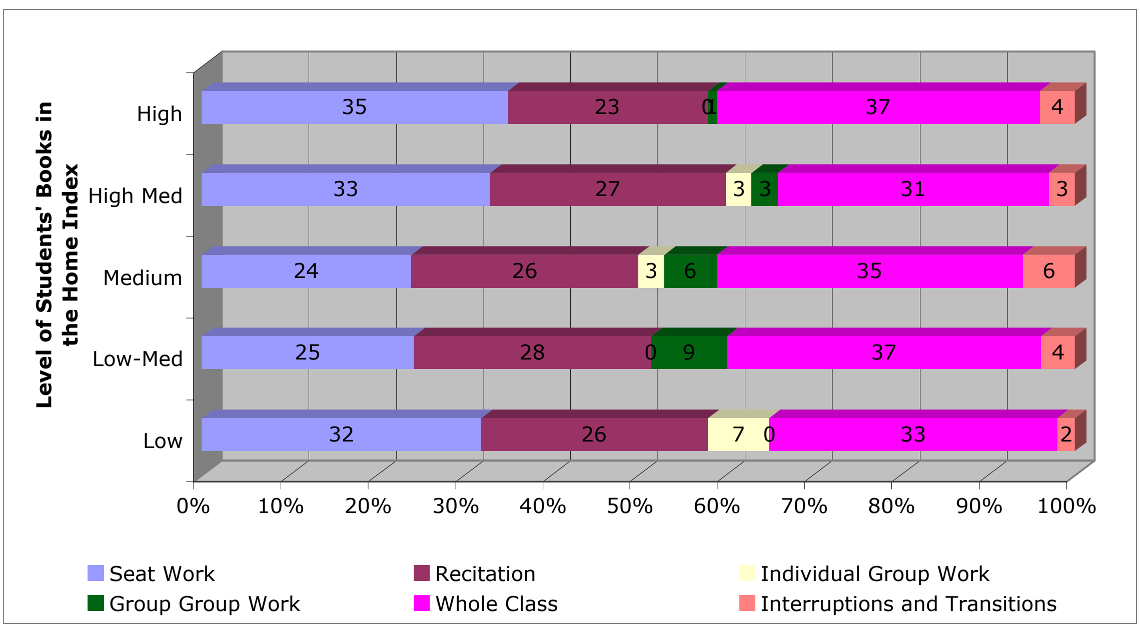


FIGURE 3-7B. ALTERNATIVE B, BY INDEX OF BOOKS IN THE HOME



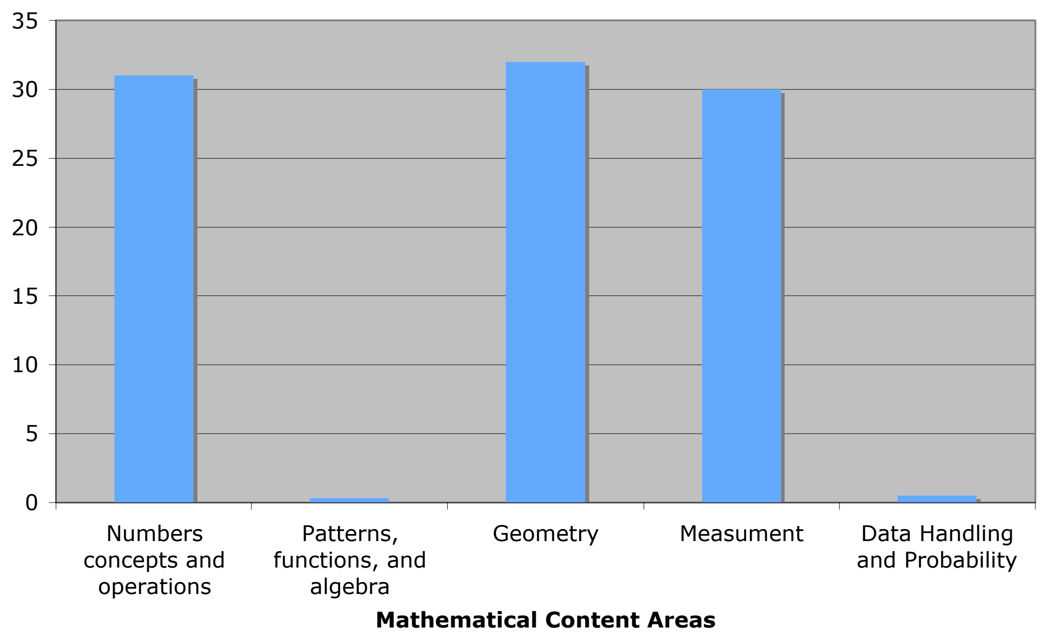
3.3.2 The Mathematical Content of the Lessons

The filmed lessons in South Africa (lessons were filmed in 39 of the 41 schools) come from the end of the school year. Because the lessons were not filmed over the entire school year there is little variation in the topics. This is an indication that though teachers are following the same curriculum, they are not doing so in the same sequence. If we had observed a larger variation of topics then it would have suggested that teachers were in the process of reviewing content for upcoming assessments.

The topics were grouped into five major categories or mathematical areas. These categories align with the mathematics covered in each of the Learning Outcomes from the NCS (Grades R - 9) Mathematics, as listed above, using the definitions of the Learning Outcomes as they are stated in the official curriculum document (February 2005).

Figure 3.8 shows the percent of the lessons that cover topics related to these five mathematical areas. The observed lessons were fairly evenly distributed among three major areas, Number concepts and operations, Geometry (Space and Shape), and Measurement. There was only one lesson that covered each of the other two content areas. This result seems to indicate that teachers were reviewing content at this time of the year, since we would expect a larger percent of lessons to be covering one particular area if teachers were following the national curriculum. It also indicates that teachers may be leaning toward the topics in the new curriculum that were present in the old curriculum, although it is interesting that geometry features so highly since it was generally neglected (though present) in the past. This suggests an increased interest in this part of the curriculum.

Figure 3.8. Gauteng Province: Percent of Lessons by Areas Covered



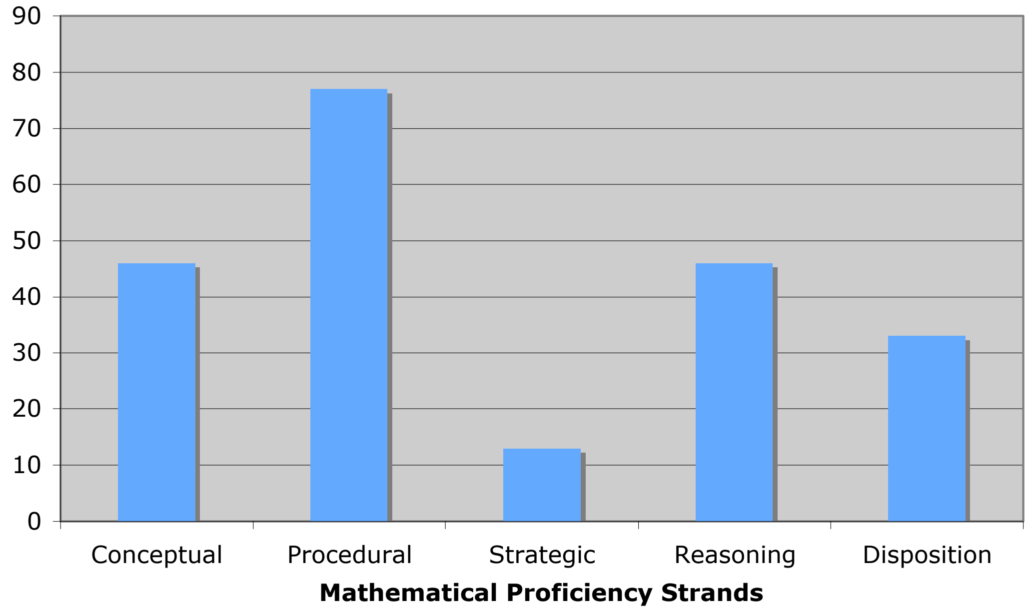
Another result that stands out is the low percentage of lessons covering the areas of Patterns and Data Handling. This could be due again to the time of filming. One can argue that teachers were getting ready to finish the school year and therefore teachers were reviewing topics that they considered more important. Another reason for this may be that Data Handling is an area that was introduced with the new curriculum, and teachers may not feel adequately prepared to teach this part of the curriculum. Patterns, functions and algebra are not new to the curriculum, though the emphasis on pattern work is new, which again may have resulted in feelings of inadequacy on behalf of the teachers. The variation shows that teachers make decisions that affect the opportunities students have to learn certain topics.

3.3.3 Mathematical Proficiency

The quality of the mathematics content being taught can also be assessed by observing the presence of five intertwined strands that form the mathematical proficiency variable: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (see above). It is a lot to expect all strands to be present in individual lessons, especially in short lessons. Instead we are more concerned about the extent to which all strands turn up in the overall summary of multiple lessons. In other words, are there specific elements of proficiency that are largely absent from these classrooms as a whole?

The overall pattern of the proficiency in mathematics in South Africa is somehow balanced. Even though the majority of the lessons have procedural aspects of mathematics, nearly half of them also include conceptual and reasoning aspects (See Figure 3.9). It was clear from the observations that some teachers value conceptual understanding before students move to the manipulation of symbols or computation. This is also consistent with the summaries of the kinds of questions used by teachers in the classroom. However, as we will see later, not all teachers did it in an efficient way. There were few instances where students had to show the ability to formulate, represent, and solve mathematical problems, also known as strategic competence. When this strand was observed the students were given mathematical problems applied to real word situations and asked to apply their knowledge of previous mathematics content learned to arrive to a solution. The students were either engaged in whole class or group discussions. In one lesson where the mathematics focused on the concept of fractions, students were solving problems, making conjectures, and sharing their reasoning in relation to questions involving dividing sausages and groups of apples into different fraction parts. The teacher demonstrated excellent questioning and guiding skills. In another lesson the learners were actively involved in making models of 3-D shapes from which they could then count the faces, edges and vertices in order to analyse and compare 3-D shapes. A third example, on the topic of time (Measurement), the teacher assigned questions to groups and gave time for them to work out their solutions before they had to present these solutions to the class. When learners presented, he pushed them to explain their answers and enabled them to understand where they had gone wrong. Learners had to re-think when necessary, and had to give clear explanations for their solutions.

Figure 3.9. Gauteng Province: Percent of Lessons by Mathematical Proficiency



For the lessons that lack the aspects of "Reasoning", rules, definitions, and procedures were often presented without providing an opportunity for students to wonder why they were true. When students were involved in working in a problem or asked to give an answer, they were not expected to explain their reasoning or provide a valid justification. Many educators call this type of teaching as "answer-centered". One such lesson was a session where the teacher went over a fairly traditional worksheet that learners had evidently done as homework. The sheet called for writing numbers in words, giving values of underlined digits in given 5 digit numbers, writing numbers represented on abacus diagrams and writing numerals for numbers given in words. The class chorused when called to do so, while individual learners wrote their solutions on the board, once the solutions had been confirmed by the teacher. There was no discussion and there were no questions that created opportunities for reasoning. An extreme example was a lesson where the learners spent the whole time copying down information from the board onto a chart. The teacher circulated answering questions very curtly, she seemed to just want them to get on with the copying. The words "copy" and "copied" very often formed part of her answers.

Finally, the last category refers to the level of the students to see mathematics as sensible, useful, and worthwhile ("Disposition"). This category was observed only during the lessons where students were either involved in the application or reasoning of mathematics. This occurred in about half the lessons. However, in those lessons students seemed to enjoy and value the logical thinking and problem solving activities.

3.3.3 Level of Cognitive Demand

Beyond the topic covered in the lesson, lessons involve the kind and level of thinking required of students on a particular topic or mathematical task, which enriches and relates to our previous measurement of mathematical proficiency. We refer to this aspect as the level of cognitive demand. Even though the level of cognitive demand is an aspect more related to the learner, it is the teacher that controls and directs the required level for his or her students. In a similar study using videotapes from a large group of TIMSS participants, the researchers found that teachers implement lessons at a lower level than what the lessons are intended (TIMSS 1999 Video Study). This was a characteristic especially of countries with lower student achievement overall.

Why analyse the lessons on this aspect? What do we gain by analyzing the level of thinking of students? There are several reasons for doing this analysis. First, the level of cognitive demand of the lesson, or the mathematical activities the students engage in, are closely associated with the deep understanding of concepts in mathematics. This is independent of whether students are put in groups or are given manipulatives. It also enables us to make inferences about the teacher's pedagogical knowledge, since he or she needs to be involved in the same kind and level of thinking.

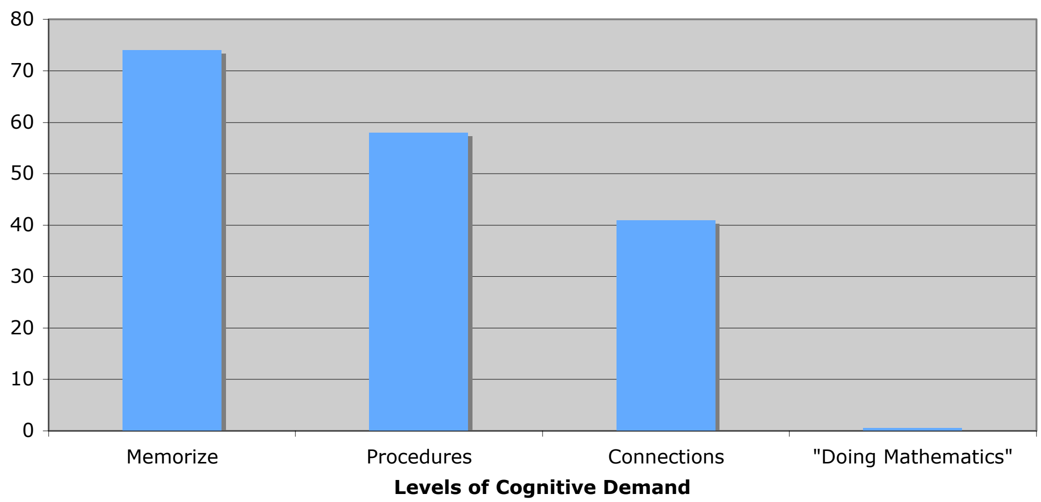
The actual measurement is not easy. Lessons often have multiple stages, and students and teachers are involved in several mathematical activities that vary in their complexity, often driven by the main goal of the lesson. Therefore, one lesson can be characterised on the whole as a low-level lesson or a mixture of low and high levels. To provide a more systematic way to characterise the lessons, we used Stein et al.'s categories (see reference above). These include memorization, procedures without connections, procedures with connections, and doing mathematics. The memorization and procedures without connections are related to the aspect of mathematical proficiency of procedural fluency. Tasks that engage students on procedures with connections often call for conceptual understanding and reasoning, and tasks that engage students on "doing mathematics" are tasks that have the presence of all aspects of the mathematical proficiency strand.

Results are shown in Figure 3.10. A large percentage of the lessons (77%) required students to simply recall rules and definitions, or perform algorithms with no relation to the underlying concepts. Opposite patterns are observed for the higher-level cognitive demands. A smaller percentage of lessons require students to understand the meaning of operations or underlying concepts behind the procedures, and a very small percent require students to investigate or explore relationship between mathematical ideas. The distribution of lessons for the first three levels is to some degree uniform.

We have an important observation about the level of cognitive demand for lessons we saw in South Africa. The observed level was the one *implemented* by the teacher and not necessarily the level *intended*. For example, the videotaped lessons show that about 90% of the teachers had intended to deliver a higher level lesson, guided by textbooks, pre-prepared activities, and concrete models. However, only about 30% successfully implemented it. The South African lesson designs tend to include demanding questions, but the actual formulation and sequence of questions does not always make it possible to probe the students' conceptual understanding. These findings are consistent with results from the TIMSS 1999 Video Study and with findings by Stein et al. Mathematical tasks or problems with high level cognitive demands "are most difficult to implement well, frequently being transformed into less-demanding tasks during instruction" (2000, p. 4).

Another important observation was the lack of coherence in a large percentage of lessons. Teachers tend not to have a clear goal of the lesson. Some of the lessons started with a short mini-lesson on some topic and ended with an "activity" related to the topic, but unrelated to the mini-lesson. Often the teacher does a mini-lesson and then does not follow up with other activities. That is a big problem – lessons do not have sufficient substance to allow learners opportunities to consolidate what has been learned. The other pattern observed was the lack of whole class discussion on the activities or worksheets. The "discussion" is often just a chorus of agreement to given answers – or the completion of comments-prompted answers, that really give no indication of whether or not the learner actually was able to give the answer him/herself.

Figure 3.10. Gauteng Province: Percent of Lessons by Cognitive Demand



3.3.4 The Teacher's Observed Knowledge

In the previous part of this report we provided extensive measures of teacher knowledge based on their answers to items on a questionnaire In this part of the analysis we turn to observations to classify teacher knowledge. This is a novel approach with few antecedents, and implementing it faces a number of challenges. It clearly requires mathematics education experts to classify the teacher's knowledge based on his/her actions and choices in the classroom.

For content knowledge there are a number of possible "clues" for assessing what the teacher knows. It is fairly straightforward to focus on the examples they solve in class or the corrections they make of student mistakes, etc. Careless mistakes when teaching operations or procedures, or more serious misconceptions about underlying concepts, are each indicators of content knowledge deficiencies. This same standard can also be applied to higher level content knowledge, although we expect this element to be less applicable in the average lesson.

There are also the "general" pedagogical skills we referred to earlier, although we have not compiled a complete list of these actions. Once again a trained expert in the subject with extensive experience observing teachers is needed to classify the teacher's *pedagogical knowledge*. Elements include how well the teacher has all of the students engaged, his/her use of proper classroom management techniques, and the quality of instructional materials.

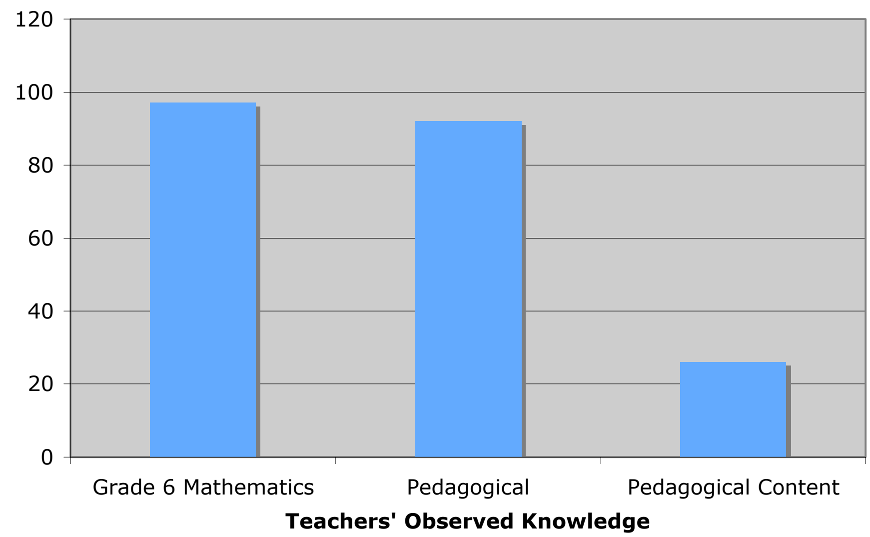
The third and final domain of knowledge is formed by the integration of the two previous knowledge areas. This *pedagogical content knowledge* is not necessarily separate knowledge, but it is demonstrated in the class by how well a teacher uses the mathematical and pedagogical knowledge to help students learn.

Of course, what is observed in one lesson does not measure the entire body of knowledge a teacher has in mathematics, or any of the other kinds of knowledge. But the purpose of looking at the teacher's knowledge for these lessons is not to characterise the entire knowledge of a teacher; for this we would need a case study where we observe a teacher for a long period of time. The purpose is to measure how well the teacher uses these specific knowledge forms in a particular lesson.

Figure 3.11 shows the percentage of teachers that demonstrated knowledge in each of the kinds of knowledge described above. One important note is that the kind of knowledge demonstrated was connected with the goal and level of cognitive demand of the lesson.

For the mathematical knowledge category, teachers were coded to demonstrate knowledge of the mathematics by the correctness in their written and spoken mathematical statements. Almost all teachers did not say or write anything incorrect. In terms of pedagogical knowledge, there was evidence of the knowledge of pedagogical techniques. In particular, the use of concrete models to illustrate concepts and the more frequent use of hands-on activities such as cutting, coloring, pasting. This measure is linked with the intended level of cognitive demand of the lesson analysed above. The final element is the degree of effectiveness of the use of these techniques and how well they were connected with the mathematical concept being taught is measured by the last category. Note the small percent of teachers (26%) in this category.

Figure 3.11. Gauteng Province: Percent of Teachers by Observed Knowledge



Some teachers in this category showed a well-planned lesson with a rich task presented to students and a good "flow" of the lesson. Others were effective because of the powerful explanations and skillful level of communication on the part of the teacher to bring the complex mathematical ideas to the level of the student. The better teachers use questioning to elicit answers given independently by learners, from which an observer can say that the learner has understood what he/she is talking about.

3.4 The Relation between Overall Teaching Quality Rating and Teacher Content and Pedagogical Content Knowledge

In addition to the analyses above, the two mathematics experts gave an overall rating of teaching quality (from 1 to 3) to each of the teacher lessons we videotaped. These ratings were a composite of the several analyses above.

The breakdown of the overall ratings is shown in Table 3.6. Teaching in the DET and NED schools is rated below that of other former department schools, and the ratings of teaching in the TED and Independent schools were higher. There do not appear to be teaching quality differences between schools with different levels of average student reported books in the home.

What is the relationship between this overall teaching quality rating and our measures of teacher mathematics content knowledge and pedagogical content knowledge? We would expect that teachers with higher mathematics knowledge would be "better" overall math teachers as rated by our two experts (who had not seen the CK and PCK scores for the teachers whose lessons they rated.

We found a significant relation between overall teaching score and mathematics PCK but not mathematics content knowledge. The proportion of the variance in teaching score explained by the variance in PCK is on about 10 percent, but if one extreme point (a school where the teacher had a perfect score on the PCK part of the questionnaire but had a low math teaching rating) is left out of the regression, the R^2 increases to 0.2. Table 3.7 shows the two estimates, and Figure 3-12 shows the relationship graphically of PCK to teaching score (1, 2, or 3) when the one "extreme" case is omitted.

Table 3.6. *Gauteng Province: Overall Teaching Quality Rating by Former School Department and School Average Index of Books in the Home*

Variable	Teaching Score
Former Department	
DET	1.36
HOD	2.25
HOR	2.00
NEW	1.67
TED	2.40
INDEP	2.50
School Index Books in Home	
2-2.7	2.00
2.71-3.2	2.00
3.21-3.49	1.78
3.5-4.49	2.22
4.5-6	1.80

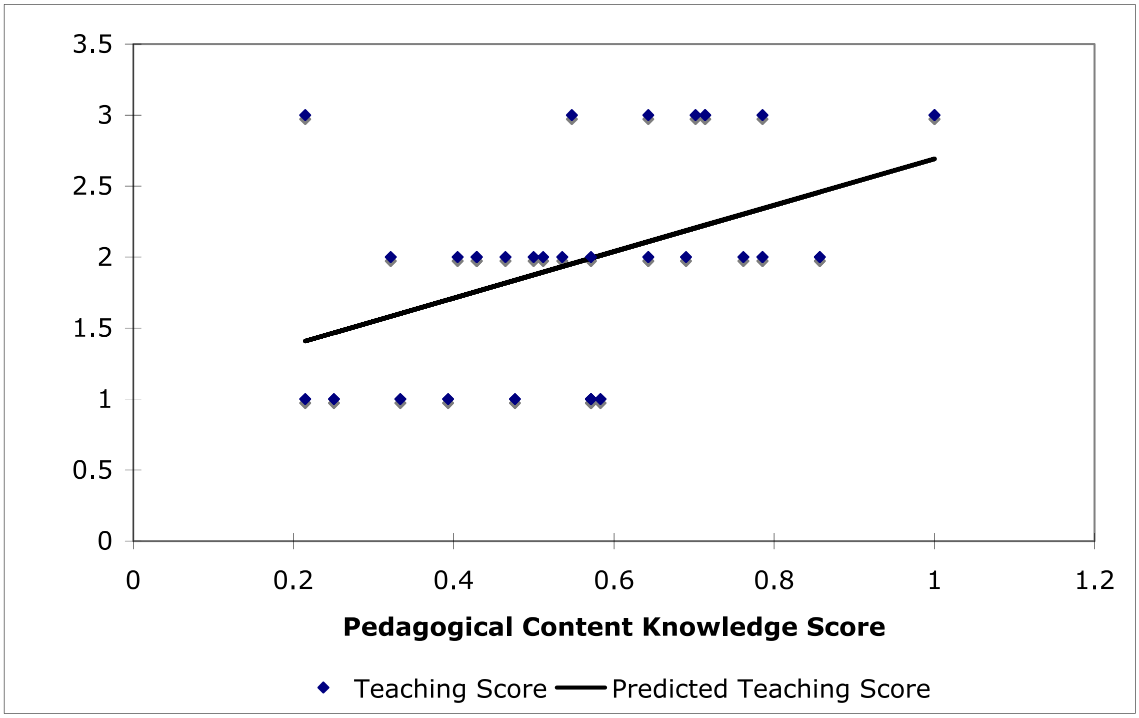
Table 3.7. *Gauteng Province: Estimate of Relation between Teacher Overall Teaching Score and Teacher PCK*

Variable	*All Schools*	*Extreme Value School Omitted*
Teacher PCK Score	1.204**	1.636***
	(0535)	(0.530)
Intercept	1.266***	1.057***
No. of Observations	38	37
Adjusted R^2	0.10	0.19

Note: Standard error in parentheses.

This is an important finding. It suggests that there is a connection between teachers' mathematical pedagogical content knowledge (teacher capacity) and teaching and the quality of the teaching in South African classrooms. We have already shown above that there is a correlation between teacher PCK and where the teacher was trained. This latter relationship is highly subject to the possibility that other factors associated with teacher training and PCK are the "true" explainers of PCK, not teacher training, but the fact that teacher training institution, PCK and teaching quality are all related suggests a possible relation between training and teaching quality.

Figure 3-12. ***Gauteng Province: Mathematical Pedagogical Content Knowledge and***



3.5 School Principal Results

The results of the principal questionnaire gave us some indicators of language of instruction, opportunity to learn, the impact of HIV/AIDS on the school environment, the degree of teacher supervision in the school, and the level of violence in the school. We intend to do a thorough analysis of these data in conjunction with teacher and student characteristics, as well as student outcomes. In this report, we present just a few important insights that the principal results reveal about schools catering to different SES groups of students. As in the analyses above, we use the school average of the index of books in the home as the school SES indicator.

Figures 3-13 and 3-14 present four indices of school context that could affect student performance. The first two of these (in Figure 3-13) refer to the principal's reported school violence. The student violence index is constructed in answer to the question of how often students threaten or hurt other students. The answers are often (15%)=1, sometimes (50%) = 2, rarely (32.5%) = 3 or never (2.5%) = 4. The teacher violence question is constructed in response to the question of how often teachers threaten or hurt students. Often (12.5%) = 1; sometimes (27.5%) = 2, and never (60%) = 3. Thus, the higher the index, the *less* the violence the principal reported in the school.

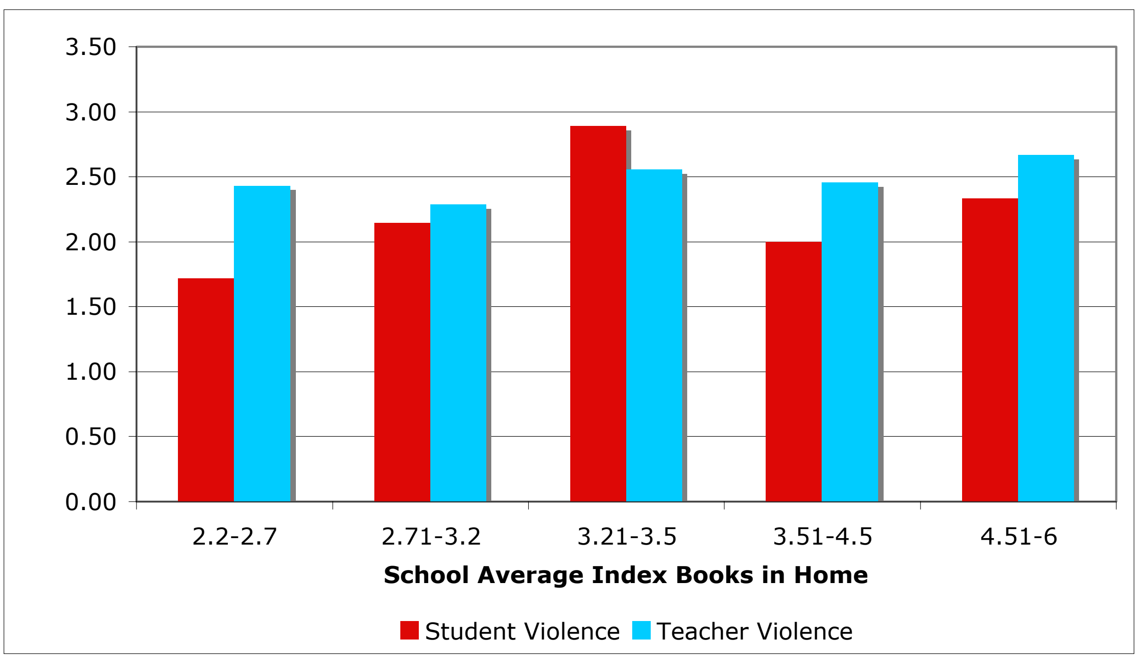
The second set of indices (in Figure 3-14) concerning school context are the principal's answer to the question of whether he or she thought that the sixth grade teachers in the school completed the required curriculum (1=yes, completely (57.5%);

2=yes, partially (35%); 3= no (5%); 4=I don't know (2.5%)—we graded 1=1 and the other three = 0), and the answer to the question of whether teacher absenteeism is a significant problem in the school (0=yes, for a few of the teachers (45%); 1=it is not a problem (55%).

Figure 3-13 suggests that student violence is greater than teacher violence and that student violence is somewhat more likely (somewhere between "often" and "sometimes") in the lowest SES schools, whereas middle SES schools are closer to "rarely." Teacher violence average between "sometimes" and "rarely' across the various SES school levels.

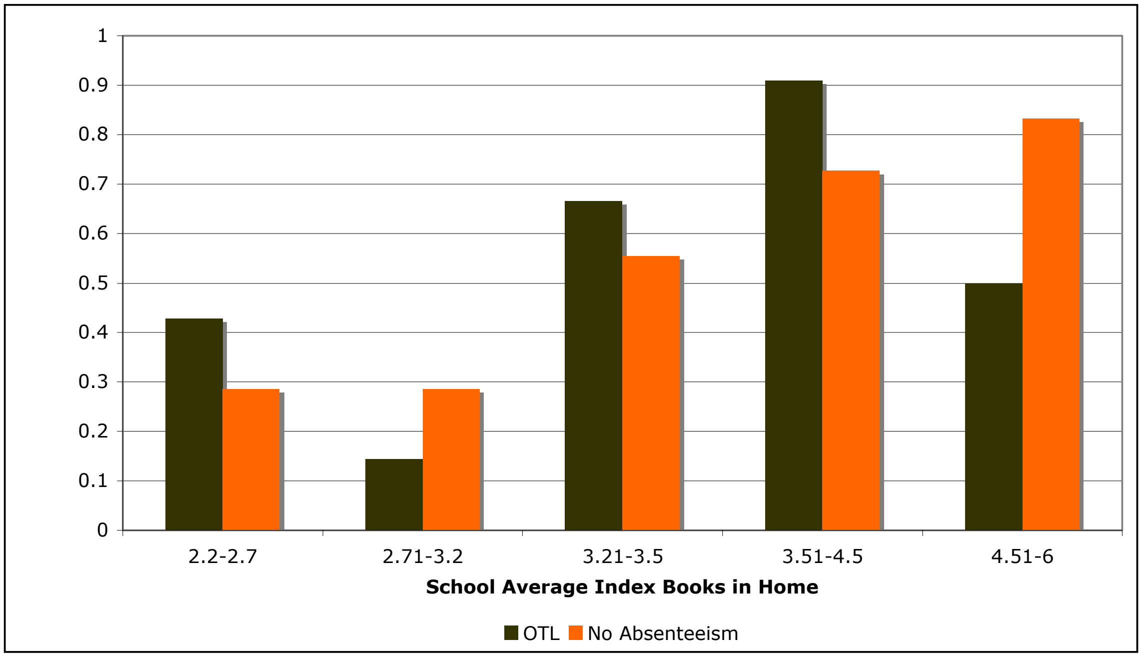
Figure 3-14 suggests that the proportion of teachers completing the required curriculum is much lower in the lowest two SES levels of schools, and they are much more likely to be absent sometimes than in higher SES schools. In the lowest two SES categories of schools, principals reported that only about 25-30 percent of schools completed the required curriculum. In the next to the highest SES level, this rises to 90 percent, although it drops in the highest level to 50 percent (we have no explanation for this drop except that the principal interpretation of "required curriculum" may have been a higher criterion than the interpretation in the schools in the four other SES categories. In more than 70 percent of the schools, teacher absenteeism was a significant problem for some of the teachers. This proportion drops to less than 25 percent in the higher SES schools.

Figure 3-13. ***Gauteng Province: Student and Teacher Violence, by School Socioeconomic Index***



Source: Gauteng School Survey, Principal Questionnaire

Figure 3-14. ***Gauteng Province: Proportion of Schools Completing Curriculum and with No teacher Absenteeism***



Source: Gauteng School Survey, Principal Questionnaire

3.5 Regression Estimates of Student Achievement Outcomes

Typical empirical research that relates teacher inputs and school context to student achievement outcomes measures students' socio-economic background and teacher characteristics such as education levels and years of teaching experience, as well as some school characteristics, and relates all these "inputs" to student achievement scores at a given point in time.

We have identified some serious problems with this approach, particularly that teacher characteristics are not randomly assigned to schools with different groups of students, and that students are not even randomly assigned to teacher characteristics within schools. Thus, the relationship between teacher's teaching capacity and student achievement levels is not causal (see Clotfelter, Ladd, and Vigdor, 2007 for an analysis that does approach causality).

We have also attempted to measure teachers' capacity more specifically than simply their level of educational attainment and years of teaching experience. Our surveys and videotapes have enabled us to estimate teachers' mathematics content knowledge and pedagogical content knowledge, where they were trained, and their teaching quality,

In Table 3-8 we present the means and standard deviations of the variables we use in the anaysis. The independent variables are divided into student's family human capital (primary parent's educational attainment) and family social capital (reported books in the home); the student's teacher's mathematical content and pedagogical content knowledge, and the student's teacher's mathematics teaching rating (by our two mathematics teaching experts); the student's class size; the average reported index of books in the home in the student's class; the student's report level of student violence to other students in the school; the student's reported level of teacher violence toward students; the student's reported level of teacher absenteeism; and the principal's report of whether teachers in the sixth grade completed the required curriculum or not.

For example, only 17 percent of students speak the language at home which is used to teach the mathematics classes in their school. Sixty percent of students have parents with completed high school education, or at least that is what the students report. About 30 percent of students in the sample have 10 books, magazines, or newspapers in their home, and about 22 percent have 100 or more of these at home. More than one-half the students report at least some student and teacher violence in the school, and more than 90 percent report at least some teacher absenteeism.

Table 3-9 shows one set of regressions that estimates Grade 6 students' mathematics *achievement level* in July 2007 as a function of teacher inputs and school characteristics, including school average student family social capital, reported violence among students and teachers, and two proxies for opportunity to learn (reported required curriculum completion and reported approximate incidence of teacher absenteeism), controlling for student socio-economic characteristics.

We also present a second set of regression estimates in Table 3-10 that relate a similar set of covariates to student *achievement gains* over a three-month period for a subset of students who took both the initial mathematics test in July 2007 and the second test in October 2007 (at the end of the academic year). As we discussed in the methodology section, the second learner test was applied at a time when many schools in our original sample refused to participate because of final examinations, so only about one-third of them are represented. Furthermore, only about one-half the students who took the first test took the second test even in the schools that participated in both tests. Thus, the student sample size in the student achievement gains estimates is only one fifth the size of the sixth Grade achievement level on the learner test applied in July.

The regression estimates of student achievement level have the disadvantage that teacher skills are not randomly distributed across schools and classrooms. The regression estimates of student achievement gains avoid part of this problem in that teacher skills are probably more randomly distributed on student gains. However, the data collection process may distort the quality of the sample of students and schools available for these estimates. The estimates should be viewed with these limitations in mind.

It is apparent from the estimates of student mathematics achievement level that student home language (whether the same as language of instruction), parent education, and books in the home—together a good measure of a student's cultural, human, and social capital—are highly related to a student's achievement level. This is also true of teacher mathematics knowledge, but as we have explained, students' higher mathematics performance may be attracting more knowledgeable teachers to their schools. Similarly, when students' family resources and the school's teacher resources are accounted for, larger class size is associated with higher student mathematics performance. As in the case of teacher knowledge, this may be describing a situation where students are attracted to better performing schools, making class sizes larger. We have observed this in other urban areas marked by school choice—the schools with a better reputation are characterised by "better" teachers and larger classes. This should not be interpreted as implying that larger class size results in higher test scores.

In the second set of regressions, we estimate the absolute and relative test score gains for a much reduced sample of students who took both tests. The average gain was about seven points, but the gain varied greatly. When the absolute and relative gains are compared, it is evident that students who scored lower on the first test had a larger gain on the second test. The initial test coefficient shows that the gain score is negatively and significantly related to initial score. The result is consistent with most other value added studies. In our case, we gave the same test to the students the second time around because of the short time that had elapsed since the first application, so the test was no more difficult.[14] The fact that students with lower scores on the initial test made larger gains influences the coefficients of student socio-economic variables. For example, in the first two regressions in Table 3-10, students whose parents are high school completers had a (not statistically significantly) lower gain, but this is the result of their scoring higher on the initial test.

Nevertheless, the negative, statistically significant coefficient for class size (number of students in the class) is robust across all the regressions, whether the dependent variable is absolute gain or relative gain. The regressions in Table 3-9 show that, on average, students in larger classes have higher initial scores, so class size might be picking up part of this effect even when we control for initial test score (the class size coefficient is smaller when we control for initial test score). However, it could also be argued that class size actually does have a negative effect on mathematics gains for those with similar initial test scores. We would need a larger sample of classes in order to test this hypothesis using, for example, propensity score analysis.

Those teachers with the highest teaching rating also seem to have a significant impact on mathematics gains. But again, we have to interpret this coefficient with care. Teaching rating is somewhat positively related to pedagogical content knowledge, and PCK is positively related to initial test score, so teaching rating should, in that sense, be negatively related to absolute gain. The fact that the several high rated teachers are associated with higher absolute and relative gains provides one of the more interesting and important results of this tentative analysis based on a reduced sample of students.

[14] In any subsequent research, we would allow at least six months between tests and would administer a test with more sixth grade items the second time around.

Table 3-8. Gauteng Province: Means and Standard Deviations of Dependent and Independent Variables in School Sample

Variable	**Number of Observations**	**Mean of Variable**	**Standard Deviation of Variable**
Mathematics Test Score Level, July	2192	48.2	19.6
Test Score Gain, July-October	423	7.2	16.3
Initial Test Score Level for Gain	442	59.0	27.7
Same Language at Home as Teaching Language	2169	0.17	0.37
Parent Education			
Parent Primary Schooling or Less	2144	0.07	0.25
Parent Some Secondary Schooling	2144	0.21	0.41
Parent Secondary Complete	2144	0.60	0.49
Parent College/ Tech/University	2144	0.12	0.33
Student's Books in Home			
0 books in the home	2174	0.05	0.22
10 Books in Home	2174	0.25	0.43
20 Books in Home	2174	0.25	0.43
50 Books in Home	2174	0.22	0.42
100 Books in Home	2174	0.10	0.30
>100 Books in Home	2174	0.11	0.32
Teacher Math Knowledge			
Content Knowledge	2192	0.50	0.18
Pedagogical Content Knowledge	2192	0.56	0.22
Teaching Quality			
Low Rating	2192	0.25	0.43
Medium Rating	2192	0.47	0.50
High Rating	2192	0.20	0.40
Missing Rating	2192	0.08	0.27
Class Size	2192	38.8	8.9
School Avg. Books in Home	2192	3.43	0.78
Curriculum Completed (OTL)	2159	0.59	0.49
Student Reported Student Violence			
Never	2174	0.49	0.50
Some	2174	0.46	0.50
Often	2174	0.05	0.22
Student Reported Teacher Violence			
Never	2175	0.45	0.50
Some	2175	0.48	0.50
Often	2175	0.073	0.26
Student Reported Teacher Absence			
None	2179	0.06	0.24
Some	2179	0.92	0.28
Often	2179	0.02	0.15

Table 3-9. Gauteng Province: Estimates of Student Grade 6 Achievement Level, July 2007

Variable	**Test Score Level I**	**Test Score Level II**	**Test Score Level III**
Same Language at Home as Teaching Language	12.02***	8.16***	7.35***
	(2.70)	(1.91)	(1.83)
Parent Education			
Parent Some Secondary Schooling	2.03	2.76	2.71*
	(1.36)	(1.45)	(1.29)
Parent Secondary Complete	18.33**	16.22***	15.94***
	(1.59)	(1.61)	(1.45)
Parent College/ Tech/University	3.38*	3.67*	3.23*
	(1.62)	(1.55)	(1.40)
Student's Books in Home			
10 Books in Home	1.32	-0.85	-1.40
	(1.77)	(1.46)	(1.38)
20 Books in Home	4.57*	0.97	-0.06
	(1.85)	(1.44)	(1.27)
50 Books in Home	10.26***	4.84***	3.27**
	(1.79)	(1.30)	(1.18)
100 Books in Home	11.95***	4.95***	4.59**
	(2.16)	(1.33)	(1.30)
>100 Books in Home	13.58***	6.21***	5.80***
	(2.46)	(1.54)	(1.45)
Teacher Math Knowledge			
Content		12.97**	12.39**
		(4.63))	(3.53)
Pedagogical Content		10.38*	11.64**
		(4.73)	(3.53)
Teaching Quality			
Medium Rating		-1.13	-3.42
		(2.13)	(1.70)
High Rating		-0.43	-2.73
		(2.24)	(1.94)
Missing Rating		-3.79	-7.07
		(4.37)	((4.27)
Class Size		0.11	0.25***
		(0.07)	(0.06)
School Avg. Books in Home		5.16**	2.60
		(1.46)	(2.51)
Curriculum Completed (OTL)			7.18***
			(1.55)
Student Reported Student Violence			
Some			-1.51
			(0.77)
Often			-4.04*
			(1.66)
Student Reported Teacher Violence			
Some			-1.75
			(1.04)
Often			-3.82
			(1.95)
Student Reported Teacher Absence			
Some			1.34
			(1.65)

Often			-3.40
			(1.97)
Intercept	28.27***	0.96	-3.78
Adjusted R^2	0.40	0.48	0.51
No. Observations	2110	2110	2039

Note: * p<0.05, ** p<0.01, *** p<0.001

Table 3-10. Gauteng Province: Estimates of Grade 6 Student Achievement Gain, Test Score Difference and Relative Test Score Difference, July-October 2007

Variable	Test Score Difference I	Test Score Difference II	Relative Test Score Difference 1	Relative Test Score Difference II
Learner Test Score #1			-0.41***	-0.44***
			(0.06)	(0.05)
Same Language at Home as Teaching	3.73	3.41	4.27	2.89
	(2.58)	(2.16)	(2.87)	(2.79)
Parent Education				
Parent Some Secondary Schooling	-0.19	0.66	0.23	1.16
	(3.13	(3.80)	(3.17)	(3.47)
Parent Secondary Complete	-4.36	-3.29	2.35	4.15
	(2.84)	(3.81)	(3.22)	(3.31)
Parent College/ Tech/University	-1.63	-1.19	0.76	1.49
	(2.98)	(2.49)	(2.99)	(2.54)
Student's Books in Home				
10 Books in Home	-4.05	-3.39	-1.25	-0.80
	(3.90)	(3.81)	(3.95)	(4.78)
20 Books in Home	-2.74	-2.77	0.94	0.20
	(3.30)	(2.83)	(3.23)	(3.54)
50 Books in Home	-1.91	-1.28	3.57	3.29
	(4.16)	(4.21)	(4.48)	(5.08)
100 Books in Home	-2.87	-2.19	2.12	2.32
	(4.11)	(3.93)	(3.96)	(4.11)
>100 Books in Home	-1.92	-1.60	4.18	4.68
	(5.12)	(4.43)	(4.54)	(4.67)
Teacher Math Knowledge				
Content	-36.49*	-39.77	-20.55	-26.70
	(15.58)	(14.55)	(13.29)	(12.89)
Pedagogical Content	1.57	-1.10	4.85	5.43
	(6.84)	(6.18)	(8.92)	(8.30)
Teaching Quality				
Medium Rating	0.03	0.89	-0.31	-1.56
	(2,87)	(3.25)	(3.24)	(3.68)
High Rating	5.68*	6.42*	6.36*	5.39*
	(2.58)	(2.55)	(2.50)	(2.21)
Missing Rating	n.a.	n.a.	n.a.	n.a.
Class Size	-0.68**	-0.83**	-0.48**	-0.54**
	(0.18)	(0.23)	(0.15)	((0.17)
School Avg. Books in Home	2.55	3.40	2.60	3.49
	(3.04)	(2.96)	(2.51)	(2.58)
Curriculum Completed (OTL)		-1.24		2.44
		(2.91)		(2.16)
Student Reported Student Violence				
Some		0.51		-0.45
		(1.80)		(1.11)
Often		3.19		-3.22
		(2.03)		(2.44)
Student Reported Teacher Violence				
Some		-0.06		-0.78
		(2.18)		(2.05)
Often		-3.97		-5.37
		(3.28)		(2.69)
Student Reported Teacher Absence				

Some		1.00		1.45
		(3.41)		(2.94)
Often		5.14		3.47
		(3.97)		(3.20)
Intercept	45.10***	49.23**	38.81**	40.75**
Adjusted R^2	0.11	0.10	0.24	0.24
No. Observations	404	367	404	367

Note: * p<0.05, ** p<0.01, *** p<0.001

CHAPTER 4

CONCLUSIONS

In 2006, there were more than 380,000 practising teachers in the South African public school system including teachers paid by government and school governing bodies. Of these, 27,226 were primary school teachers. The majority of primary school teachers in South Africa and in Gauteng are African, female, and below 41 years of age. The pool of qualified mathematics teachers in primary schools is small. Many qualified mathematics teachers are not teaching their subject, and there are large numbers teaching mathematics who are not qualified to do so. The reasons for this are obscure as a system exists to match supply with demand in the Post Provisioning Model and the administration of "excess" and "vacancy" lists.

Qualified primary school teachers are on the whole diploma-holders. In 2004, more than 50,000 teachers were considered under-qualified. Only 5,4% of teachers in 2005 had been prepared in their teacher training for the new Curriculum. The majority had been trained in teacher education colleges whose quality varied enormously. Those established in the former bantustans and homelands, now South Africa's rural areas, were notorious for their limited curricula and the link between this curriculum and the expectations of the roles of teachers under apartheid as docile and low-skilled. The system of college-based teacher education was brought to an end in 1999 on the grounds that it provided poor quality education and was not cost-effective. Teacher education for both primary and secondary teachers is now conducted at universities, but the quality of this has not yet been evaluated. The point remains that most teachers in the system were trained under a dispensation that did not equip them to teach the curriculum. There have been consistent complaints that the short-term training provided for teachers to enable them to teach the new curriculum has not been effective. There is also evidence of a decline in enrolments in initial teacher education programmes since 1999. Numbers are low especially for those in the under 25 age group. The decline here has been greatest for African women.

This new curriculum expects not only that teachers draw on professional knowledge to teach to a higher level than before, but that they also employ learner-centred teaching methods, a variety of forms of assessment and embrace values consistent with the new Constitution.

A system of supervision and evaluation acceptable to all teachers to assist them in meeting the new challenges has not been in existence for the entire 14 years since the advent of democratic government in South Africa. The process and content of successive forms of teacher and whole school appraisal have been contested for more than twenty years. The consequence has been a system in which absenteeism is reportedly high and teachers on average spend 3.2 hours of each school day teaching.

These changes have occurred in a broader climate of constrained resources for education, and a growing gap between rich and poor in South Africa. The schools in which our pilot study was conducted were located in both affluent and impoverished neighbourhoods in South Africa's most prosperous and highly urbanized province, Gauteng. The fees the schools charge partly reflect the resource differences available to these schools, since those schools charging medium and high fees can spend considerably more per student than low-fee public schools that depend on public resources. This is the case even with the commitment by the government to spend more on low-income public schools than on higher income schools (Motala, 2007). Our research suggests that there may be an impact of these unequal school resources in terms of the quality of education and student outcomes in South African schools.

The model we proposed in this study supplements the substantial body of qualitative and some quantitative research in South Africa on mathematics teaching and learning. Our model links teacher training to teachers' mathematical knowledge, which in turn influences the quality of teaching in the classroom. Controlling for differences among schools and classrooms in the opportunity to learn and the family resources students bring to school (family human capital, social capital and cultural capital), the quality of teaching should have a positive impact on student learning gains.

The data from the 40 schools we sampled in this most highly urbanized of South African provinces revealed a primary school system characterised by a low average level of learner and teacher mathematical knowledge and by considerable inequality in the distribution of mathematical knowledge among those who teach students of lower and higher socioeconomic background. Thus, students who are disadvantaged academically in terms of family resources (including regularly using the language of instruction employed by the school) are also likely to be instructed by teachers with less capacity to impart mathematical understanding to students in the classroom. Although many teachers we observed are good pedagogues in the way they handle the classes, use class time, and communicate with the students, the lack of an adequate pool of teacher mathematics content and pedagogical content knowledge seems to be a major factor in influencing how much mathematics the students we observed are likely to learn.

Even with our relatively small sample of schools and teachers, we are able to provide some evidence that where teachers took their pre-service training (most were trained before 1994 in teacher training colleges that have since been closed) may have an impact in how much mathematical pedagogical content knowledge they have, and that their mathematical pedagogical content knowledge is related positively to the quality of their mathematics teaching, as measured by evaluations of their videotaped lessons.

Although our estimates using the difference in student performance between a test we administered in July and the same test again in October are rather tentative because of the reduced sample of students who took both tests, the results are interesting nonetheless. They support one of our main hypotheses—namely that high quality mathematics teaching is positively related to mathematics gains. The estimates are consistent with many other studies that show higher scoring students making lower absolute gains than lower scoring students, but these same higher scoring students making higher relative gains. This last finding is particularly characteristic of highly socially stratified societies. The results also support the notion that larger class size reduces the absolute and relative gains in test scores.

Thus, our study tends to support empirically the claim (Shulman) that pedagogical content knowledge is important in improving student achievement, and that the mechanism by which this occurs is through the improved teaching of a subject by those who know more about the subject and how to teach it. A more tenuous result of the study is that PCK and therefore better teaching are related to the quality of pre-service teacher training teachers receive. Recent work by Bill Schmidt and a group of researchers in five other countries (Schmidt et al, 2008) has shown very large differences in the preparation of mathematics middle school teachers in the United States, Korea, Taiwan, Mexico, Germany, and Bulgaria. Mexican teachers receive much lower amounts of direct training in mathematics and a higher fraction of training in pedagogy. We suspect that were a similar study to be done in South Africa, it would show even lower amounts of mathematical content and PCK training of teachers than in Mexico.

Our results seem to complement those of an excellent earlier study done in the Western Cape province by Cheryl Reeves (2005) which argued that opportunity to learn is a vital measure of teaching quality in explaining student learning gains. Reeves had a better measure of opportunity to learn than we did (she reviewed student notebooks at three points during the school years in each of her sample of classrooms), but probably not as good a direct measure of classroom teaching. There are resulting differences in findings. One interpretation of the difference in results may be that the two variables are highly related, so that doing a better job of capturing the variation in one of these variables would make that variable more important in explaining the variation in student performance. We are convinced that Opportunity to Learn is indeed key to learning gains, but the question remains as to how independent Opportunity to Learn is from teaching quality.

We have urged caution in drawing causal inferences from our results. This was meant to be a pilot study, so the empirical results, while important, are meant to provide direction for further research. The pilot taught us a lot not only about improving our instruments, but as important, how to insure that our data collection achieves the research project's empirical goals. Timing and communication are very important in getting accurate data from schools.

The pilot involved both qualitative and quantitative researchers in an intensive, complex, multi-faceted relatively large-scale quantitative research project. It was a challenging and demanding project and as such has the capacity to stretch abilities and build capacity. The pilot showed that it is possible to combine different kinds of skills to conduct such a project, but that implementation in future at university level would probably require:

- A full-time researcher, research assistant (PhD student) and a core team of people with a range of skills;
- Inclusion in the core team of people with planning, organisational, instrument-development, survey, data management and analytical skills—these were the people who made it possible for us to carry out this study and do the analysis of the data;
- Involvement of a full-time PhD student in all aspects of the project;
- Involvement of postgraduate education students in fieldwork;
- Adequate time to check the existence of sampled schools;
- Sufficient time to provide for ethical clearance, departmental requirements, school holidays, tests, strikes and other ad hoc eventualities delaying activities;
- Need for careful introduction of the study to schools, and especially teachers, as well as reassurances about the purpose of the study;
- Some, but not major revision of the instruments—the pilot provided useful information for revising instruments, so it does argue for a small sample pilot as a precursor to future studies in other countries;
- Development of an approach to analysing content and use of textbooks in classrooms;
- Careful, supervised attention to data coding, capturing and cleaning;
- A reference group for feedback;
- Possibilities for more sustained interaction between the US and South Africa-based counterparts in the study, although thanks to e-mail, Skype, and the Comparative and International Education Society meeting in New York in March, the level of interaction was very high in this case;
- Adequate resources so that different parts of the research are not short-changed—even in this pilot, we could have done considerably more analysis with more resources.

That said, the amount of information derived from even such a small study and its implications for educational policy suggest that others should replicate it in other provinces and that we should move forward to implement it in at least one other country for comparative purposes. We are confident that our model could go far to explain why sixth grade students in other African countries seem to know so much more mathematics than students in South Africa. We would hypothesize from this study that the quality of teachers' training is probably a key variable in this explanation, and that we should find better teacher training reflected in higher teacher measured CK and PCK in those other countries. In further studies we would also focus more energy in measuring opportunity to learn. Opportunity to Learn is undoubtedly also an important factor in explaining student learning differences.

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