

# Relationships Between Mathematics and Literacy: Exploring Some Underlying Factors

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This paper focuses on Grade 7 learners in two township schools where the relationships between performance on language and reading tests in the home language and English were investigated in relation to examination performance in mathematics. In both schools reading ability rather than language proficiency in English emerged as a strong predictor of mathematics achievement. The schools serve as a case study for exploring some of the socio-economic, teacher and classroom factors underlying differential school performance in mathematics. Because the new curriculum presupposes a highly literate environment, it is suggested that mathematics learning will be negatively affected if learners lack adequate reading skills. The findings suggest that quality schooling is a strong determinant of both reading and mathematical achievement. The new mathematics curriculum has the potential to make a difference only if schools improve learners' literacy development.

South Africa's poor performance in large national and international studies such as the Trends in International Mathematics and Science Study (TIMSS) and the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) is well known (see for example, Department of Education (DoE), 2005; Mothibeli, 2005; Reddy, 2006). Two factors impacting critically on mathematical performance are the language of learning and teaching (LoLT) of mathematics, and teacher qualification. For the majority of learners in South Africa, the LoLT for mathematics is not the home language. Although many primary schools have a home language as the LoLT in the first three years of schooling, the crossover to English as medium of instruction is typically made in Grade 4. There is also a pressing need for qualified teachers in the earlier phases of education. Yet in the TIMSS study, "internationally, most teachers had at least a four-year degree qualification ... (in) comparison ... the South African mathematics and science teachers are among the least qualified" (Reddy, 2006, p. xv).

Many of these large-scale numeracy studies also report similar poor performances in literacy. For example, the results of the national systemic evaluation showed Grade 6 learners obtaining a national mean of 38% for literacy in the LoLT

(DoE, 2005). In the latest Progress in Reading Literacy Study (PIRLS) South African Grade 4 learners came last of 40 countries in the literacy assessment (PIRLS, 2006).

In spite of poor trends in both mathematics and literacy, none of the above studies explores the relationship between numeracy and literacy in any detail. It is important to explore more closely the relationship between mathematics and literacy in a multilingual country such as South Africa since learners' proficiency in the LoLT will undoubtedly affect their understanding of mathematics.

This study provides a small-scale but unique perspective on the mathematics-literacy relationship by using the *de facto* mathematics performance of Grade 7 learners in two primary schools in a South African township to see whether their mathematics performance shows any relationship to performance in independently administered literacy tests in the first language (L1) of the learners (in this case Northern Sotho) and in English, the LoLT. In addition, the study breaks up the notion of literacy into two separate constructs, *language proficiency* and *reading*. This distinction is important for language proficiency is a necessary but not sufficient condition for reading ability. Reading only develops through extensive

reading, and it is reading specifically that predicts success at school for it forms the foundation for subsequent school-based learning (e.g. Snow, Burns, & Griffin, 1998). However, the role that reading accomplishment plays in mathematics, specifically during the senior primary school years, is under-researched.

Two variables are constant in this study: all the learners come from the township and they all speak an African language at home. However, the two township schools they attend provide different conditions for mathematics and literacy development.

There are three research questions that inform this paper:

1. How do the *de facto* Grade 7 mathematics examination papers in the two schools reflect the five learning outcomes of the new mathematics curriculum?
2. Are there significant differences in Grade 7 mathematics performance, language proficiency and reading ability between the two schools?
3. Are there significant relationships between Grade 7 mathematics performance, language proficiency and reading ability at the two schools?

Answers to these questions are considered in the context of similarities and/or differences between the two schools in terms of mathematics teacher qualification, classroom-based factors and school reading practices. Based on the findings we consider whether, by the end of primary school, Grade 7 learners have sufficient competence in mathematics, language and reading to cope with the demands of the new curriculum and whether there really is a relationship between mathematics and literacy.

In order to contextualise the study within the larger South African picture, we first identify some issues that relate to the teaching and learning of mathematics, before describing the methodology and discussing the results.

### **The importance of language and reading in mathematics learning**

mathematics learning is highly dependent on literacy. All of the five mathematics Learning Outcomes for the Senior Phase highlight those activities that depend significantly on language and reading. For example, Learning Outcome 1 (LO 1) states “The learner will be able to recognise,

*describe* and represent numbers and their relationships, and to count, estimate, calculate and check with competence and confidence in *solving problems*” [italics added] (DoE, 2002, p. 61). This outcome includes activities aimed to develop learners’ understanding of how numbers relate to one another. This implies that learners are confident with expressions such as ‘less than’, ‘twice as much as’, and so on. Even students at tertiary level find these concepts difficult (e.g. Bohlmann, 2006). The dependence on context also implies a dependence on verbal skills.

Much has been written on the discourse of mathematics and its dependence on verbal skills in the LoLT. It is thus not surprising that proficiency in English should feature prominently when the LoLT is English. Mathematics discourse generally contains items that have linguistic, cognitive and contextual dimensions (Gibbs & Orton, 1994). The linguistic dimension involves both the receptive level (e.g. reading) and the productive level (e.g. writing, discussing). The cognitive dimension reflects the level of complexity of the concepts and cognitive skills such as logical reasoning, critical analysis and interpretation of abstract concepts. The contextual dimension<sup>1</sup> reflects the level of contextual support provided. Difficulty with any one of these aspects has serious implications for studying mathematics.

The conceptual complexity and problem-solving nature of mathematics make extensive demands on the reasoning, interpretive and strategic skills of learners, especially when these activities are done in a language that is not their primary language. Many studies have investigated the role of *language* in mathematics (e.g. Bartolini Bussi, 1998; Ellerton, Clarkson, & Clements, 2000), and they all show that poorly developed language skills (in the LoLT) undermine mathematical performance. In general the mathematics register is abstract, non-redundant (Prins, 1997) and conceptually dense. Mathematical symbols and graphics (e.g. charts, tables and graphs) increase the conceptual density. Mathematical discourse features more complex and compact relationships than ordinary discourse. Furthermore, mathematics discourse is characterised by precision, requiring close attention to detail. Mathematics texts are also

<sup>1</sup> In this case the context of the problem within the text is implied, not the external context of the learner.

hierarchical and cumulative, such that understanding each statement is necessary for understanding subsequent statements. Overlooking or misunderstanding a particular step has severe consequences for overall comprehension. The language problem remains a complex issue; it has become increasingly clear that

only if students reach a sufficient level of familiarity with the use of natural language in ... mathematical activities can they perform in a satisfactory way. (Boero, Douek, & Ferrari, 2002, p. 242)

However, nothing can be understood about specific mathematical concepts (e.g. the square root of a number) through natural language alone; only once students have understood the particular mathematical notion of a power are they able to comprehend roots. In other words mathematical concepts need to be acquired in the context of mathematics, irrespective of whether the acquisition occurs through reading and/or other uses of natural language (Sfard, Nesher, Streefland, Cobb, & Mason, 1998).

Without well-developed reading and language skills learners will not be able to “develop mathematical thinking skills such as generalising, explaining, describing, observing, inferring, specializing, creating, justifying, representing, refuting and predicting” (DoE, 2002, p. 63). Reasoning ability, for instance, is dependent on an understanding of logical relations in language, one of many reading skills underpinning the ability to construct meaning from written material.

In theory, the learning outcomes represent sound mathematical pedagogy. In practice, for the contexts to be used effectively they need to be *available* (with implications for resources in the school and home) and *accessible* (with implications for learners’ reading levels). Learners need to access information and understand the context and content before they can even begin to apply any of the mathematical skills they have learnt.

### Mathematics in the GET Band

During the General Education and Training (GET) band mathematics (essentially mathematical literacy, at this stage) can be described in terms of the *contexts* that require quantitative literacy practice, the mathematical *content* that is required when such activities are practiced, and the relevant reasoning and behaviour (Frith & Prince, 2006). We briefly consider these next.

*Contexts and content:* Steen (2001) reinforces the idea that quantitative literacy practice, unlike mathematics, is always embedded within a context. However, the practice in many mathematics classrooms in South Africa still focuses on ‘chalk-and-talk’ rather than engagement with content in relevant contexts. Usiskin (2001) warns against the use of contrived ‘real-life’ examples. Doing mathematics requires the use of authentic contexts which need to be understood as clearly as the mathematical content that is being applied. The challenge for the GET Band is to find contexts that are sufficiently available, accessible and relevant. Van Etten and Smit (2005) point out that when realistic contexts are used, learners are then faced with “text consisting of a greater use of words/language ... this poses a problem, since ... learners’ reading skills are often under-developed” (p. 58).

### Numeracy and literacy

Being mathematically literate presupposes an ability to express quantitative information coherently in verbal or visual form. Kemp (1995) argues that this includes the ability to communicate clearly and fluently and to think critically and logically, skills which also underpin the Revised National Curriculum Statement (RNCS) (DoE, 2002). In dealing with quantitative or mathematical ideas in context, learners should be able to interpret information presented verbally, graphically or in symbolic form, and be able to translate between these different representations. The interpretation of quantitative information and concepts is dependent on learners’ ability to comprehend and express their understanding coherently. Learners must also choose the appropriate form for the expression of a quantitative idea, and produce a text that expresses that idea (e.g. an algebraic expression, table or graph).

To meet these many criteria, learners need adequate preparation during the GET phase. National assessments suggest that this is not yet happening. To study mathematics effectively in Grades 8 and 9 and make a smooth transition to mathematics or mathematics literacy in Grade 10, learners need to build up adequate language and reading skills in the LoLT as well as a solid foundation in relevant mathematical concepts during their senior primary school years. This study attempts to shed some light on the mathematics-literacy interface during the final year of primary school in two different township schools.

## Methodology

### Broader context

The two primary schools in this study are situated in a predominantly Northern Sotho/Tswana speaking township west of Pretoria. There are 26 state primary schools and one private school in the township. In the majority of these schools, schooling takes place in an African language from Grades 1-3 (Northern Sotho, Tswana, Zulu, Xhosa, Tsonga, Venda or South Sotho). The switch to English as LoLT is made in Grade 4. Thereafter the specific African languages continue to be taught as first language subjects.

One of these primary schools (School B below) is involved in a long-term reading intervention programme, the aim of which is to make reading an integral part of daily school activities. The private school in the township serves as a comparison school.

### *School B (state school)*

School B has just over 600 learners and 16 teachers. The school serves a socio-economically disadvantaged community and is a quintile 1<sup>2</sup> school, i.e. a non-fee paying school, with a fixed budget provided by the Department of Education.

Northern Sotho (henceforth NS) is the LoLT from Grade R–Grade 3. English becomes the LoLT from Grade 4, while NS becomes a subject of instruction from Grades 4–7. About half the teachers at the school have NS as their home language. In theory, this school provides additive bilingualism<sup>3</sup>, the most favourable of the various bilingual models, with initial literacy in the L1 for three years and with continued L1 support after English becomes the LoLT in the fourth year. Although the majority of the learners have NS as their home language, about 20% of Grade 7 learners each year have different home languages (e.g. Tswana, Tsonga, Ndebele, Venda, etc.).

The reading intervention project began at the school in 2005. The project's aim is to create a culture of reading in order to improve literacy skills

<sup>2</sup> Schools are classified into 5 quintiles according to socio-economic indicators. Schools in the first quintile are high poverty schools.

<sup>3</sup> In additive bilingualism, the home language of the learners is used for initial schooling, and continues to be taught as a subject even when the change to another language as LoLT is made at a later stage.

and thereby also academic performance. The multi-level approach adopted emphasises resource and capacity development. A collection of age-appropriate books has been built up in English and NS in the school library, which is now fully functional and computerised. The intervention also focuses on developing instructional capacity of the teachers and supportive capacity of the parents. Teachers are encouraged to create print-rich environments in their classrooms, small classroom libraries are being established, teachers attend reading workshops, and all the learners at the school are constantly encouraged to read, in both the home language and in English. (Due to space constraints, interested readers are referred to Pretorius & Mampuru (2007) for further project details.)

The mathematics teacher at the school has a 2-year Senior Primary Teacher's Diploma and an Advanced Certificate in Mathematics Education. She has 11 years teaching experience of Mathematics and Physical Science, Life Orientation and NS. The Grade 7 learners have 8×35 minute mathematics periods a week, i.e. 4 hours 40 minutes of mathematics instruction per week.

In order to monitor project progress, the project team assesses all the Grade 7 learners at the school each year for language proficiency and reading ability in both NS and English. The language and reading data presented here come from the first two project years ( $n = 107$  in 2005;  $n = 56$  in 2006). Mathematics is not assessed by the project; to obtain mathematics data, the final Grade 7 mathematics examination papers and results were obtained for 2005 and 2006. The mathematics data thus reflect the *de facto* performance of the learners as assessed by the mathematics teacher. After the first year of the project, it was decided to assess Grade 7 learners for language and literacy from another township school in order to extend the longitudinal data base.

### *School M (private school)*

School M is a small private primary school established in the township in 1991. Even though it serves the same community as the other schools in the township, many children at this school come from higher socio-economic homes, with many parents being white-collar professionals. However, out of a total of 300 learners at the school, 80 from poor homes receive full scholarships.

The classrooms are well resourced and the teachers well qualified and experienced. Classes are small

(about 25-32). Reading and storybooks are an integral part of each classroom in the lower grades, and teachers have high reading expectations of learners.

The Grade 7 mathematics teacher has a BEd (Special Needs) degree. She has taught mathematics for 15 years and additional mathematics for 7 years. The Grade 7 learners have 6×45 minute mathematics periods a week, i.e. 4 hours 30 minutes of mathematics instruction per week.

The school has a 'straight for English' language policy. The learners are not linguistically homogeneous but speak different African languages at home. No African languages are taught as subjects. Unlike many other private schools or ex-Model C schools, no learners at this school have English as L1. The school provides subtractive bilingualism, a bilingual programme often criticised for not providing support for the home languages of the learners. Because literacy testing by the project team only began at this school in 2006, only data from 2006 are presented here.

### **Language and reading assessments**

To properly explore the mathematics-literacy relationship, the notion of literacy was broken down into a distinction between language proficiency and reading ability.

#### ***Language test***

NS and English language proficiency was operationally defined as proficiency obtained in a dictation test. Because there are no standardised language tests in all official languages in South Africa for different age groups, it was felt that a dictation test would tap into language proficiency in both languages without requiring the learners to actually read a text. Dictation correlates "at ... high levels with a vast array of other language tests" (Oller, 1979, p. 58). Dictation tasks and standardised language tests thus tap into similar knowledge sources but the former do so via the auditory rather than the written medium. Because most language tests are written tests, they have to be read and thus they also tap into reading comprehension, resulting in covariance between language proficiency and reading comprehension. Because a dictation test taps into language knowledge via auditory comprehension, it avoids this covariance trap.

To ensure that the level of difficulty of the dictation test was age appropriate, the dictation passages were taken from approved textbooks

currently available for Grade 7 NS and English classes. For marking the dictation, spelling and punctuation were taken into account. NS words that were written conjunctively instead of disjunctively were accepted as correct, provided they were spelled correctly.

#### ***Reading test***

To make valid comparisons across languages the same reading tests were given in English and NS. On the assumption that the learners would find the NS reading test more readily comprehensible and would use their NS comprehension to facilitate understanding of the English texts, the latter were administered first, with the NS tests administered four weeks later. The time lag between testing was deemed long enough to minimise memory effects.

To avoid the bias that a single type of comprehension task can engender, reading proficiency was operationally defined as proficiency obtained in a reading comprehension test where a combination of test items was used, using texts taken from existing Grade 7 language textbooks. The types of questions included cloze items, identifying referents for anaphoric items, a combination of multiple choice inferential and vocabulary questions, and questions involving graphic information (finding places on a map, reading a graph, etc.).

To ensure that the learners understood what was required, all the question formats were explained to the learners before they started the reading test and examples were given on the chalkboard, in the language of the comprehension test.

#### ***Mathematics examination***

The mathematics results from the final Grade 7 examinations were obtained from the mathematics teachers at both schools and the results examined in relation to language proficiency and reading ability. The mathematics examinations were set and marked by the mathematics teachers at the schools. The questions were analysed according to the stated RNCS learning outcomes and assessment standards for Grade 7. Both papers showed an attempt to cover the required learning outcomes. Taking subsections into account, the paper at School B contained 18 questions, for which 40 marks were given. No time was specified. The paper at School M contained 71 questions, for a total of 120 marks, for which two hours were allocated. The formats for the examination papers at each school have remained similar for the past three or so years so can be

regarded as fairly typical of mathematics assessment at the schools. See Appendix 1 (School B) and Appendix 2 (School M) for sample questions.

The assessment standards specified for each learning outcome provide the criteria to determine achievement of learning outcomes. For LO 1 11 sets of criteria are given (broken down into a total of 26 items). For LO 2 the seven sets of criteria are further divided into a total of 16 items; for LO 3 there are 12 items; for LO 4 and LO 5 there are 15 and 19 items, representing nine and 10 sets, respectively.

**Assessment procedures**

The English language and reading tests were administered first in School B, followed 3-4 weeks later by the NS tests. Since no African languages are taught as a subject in School M, the NS tests were not administered to the Grade 7s at this school. All tests were written during two periods allocated during school hours and administered by the project researchers. The mathematics examination, set by the relevant teachers, was written in November.

**Results**

Data for the different language tests and the mathematics examination were captured and analysed using SPSS. Using the Cronbach alpha model, the reliability scores for the English tests were 0,77 and 0,74 respectively, while the alpha scores for the NS tests were 0,73 and 0,75 respectively. These results are regarded as satisfactory.

The first research question that was addressed was: *How did the Grade 7 mathematics examination paper in the two schools reflect the five learning outcomes of the new mathematics curriculum?* A breakdown of the examination questions in the two schools according to the five Learning Outcomes is shown in Table 1, followed by a description of the items in each Learning Outcome.

**Table 1: Learning outcomes and assessment standards**

	No. of items assessed					Total n=86
	LO 1 n=26	LO 2 n=16	LO 3 n=15	LO 4 n=19	LO 5 n=10	
School B 2005	7	0	0	2	0	9
School B 2006	2	3	1	1	1	8
School M 2006	7	3	4	5	5	24

Note: n is the total no. of items in the assessment standard

**Description of items, School B:**

- LO1: multiple operations using integers (only + and - ), associative law (involving only + and -)
- LO2: recognition of arithmetic sequence; description of sequence (using algebraic language); solution (using algebraic language and skill) of equations to find  $n^{th}$  term, and to find  $n$
- LO3: calculation of third angle of a triangle
- LO4: classification of angles and angle relationships
- LO5: drawing pie graphs

**Description of items, School M:**

- LO1: multiple operations using integers (only +, -, ×); associative law (involving only + and -); operations with common fractions (+, -, × ); comparison of decimals; equivalence of fractions; calculations with decimals (+, ×); percentages
- LO2: recognition of pattern; solution (using algebraic language and skill) of equations; use of relationships between variables to determine input/output values
- LO3: use of geometric properties of parallel and other lines to calculate angles; isosceles triangle properties; construction of triangle and quadrilateral; classification of triangle and quadrilateral
- LO4: classification of angles and angle relationships; calculation of length, perimeter and area, and volume; distance time and speed problems
- LO5: interpretation of double bar graph, and pie graph; calculation of mean and mode; calculation of range; drawing of stem-and-leaf graph

Mathematics assessment at School M was more rigorous than at School B, a wider variety of concepts was tested and greater use was made of placing mathematical activities within a context. How did the learners at both schools fare, faced with these differential challenges?

The second research question was: *Are there significant differences in Grade 7 mathematics performance, language proficiency and reading ability between the two schools?* Table 2 reflects the descriptive statistics.

Three patterns emerge from the results. Firstly, the Grade 7 learners in the private school (School M) far outperformed the learners in the township school (School B) in mathematics, despite the more challenging mathematics examination. The learners at School M also far outperformed their School B peers in English language and English reading comprehension. They also read faster. Independent t-tests showed these differences to be highly significant:

Mathematics:  $t = -4,462$ ;  $df\ 75$   $p < 0,0005$   
 English Language:  $t = -5,239$ ;  $df\ 77$   $p < 0,0005$   
 English reading:  $t = -8,056$ ;  $df\ 72$   $p < 0,0005$

**Table2: Grade 7 mean performance in language proficiency, reading ability and mathematics**

	School B 2005 n = 102	School B 2006 n = 56	School M 2006 n = 25
Mean age (range of years)	13,1 (11-16)	13,6 (11-16)	13,4 (12-14)
Mathematics * (SD)	54,3 (18,03)	49,2 (16,7)	67,6 (18,01)
Minimum	14	18	31
Maximum	92	89	95
Percentiles 25	42	34	54
50	54	48	74
75	66	58	84
NS language * (SD)	68,6 (12,6)	67,9 (25,6)	–
Minimum	1	0	
Maximum	95	98	
NS Reading * (SD)	37,2 (17,3)	38,5 (19,6)	–
Minimum	3	6	
Maximum	84	82	
English language * (SD)	62,7 (24,6)	56,1 (33,5)	92,4 (13,1)
Minimum	0	2	45
Maximum	97	100	100
English reading * (SD)	42,4 (18,7)	45,4 (19,9)	80,4 (11,9)
Minimum	4	9	52
Maximum	88	85	95
Reading speed**			
NS	93	106	–
English	106	131	169

\* Scores reflect percentages

\*\* Scores reflect number of words read per minute

Secondly, the reading performance of the Grade 7 learners in School B was better in English than in NS in both years. The modest increase in reading ability in School B in both NS and English, but especially the latter, suggested that the reading intervention programme was having an effect on reading (this becomes more evident in Table 5, which shows the breakdown of reading ability according to mathematics achievement). Thirdly, in School B there was a difference of almost 30% between language proficiency scores and reading scores in NS. Scoring well in their home language did not mean that the learners could read well in their home language. While the 2005 data in School B showed a similar but smaller gap between English language proficiency and English reading, this gap narrowed in 2006.

Given the differential challenges in mathematical assessment and performance at the two schools, does a relationship still obtain between mathematics and literacy? The third research

question addresses this matter: *Are there significant relationships between Grade 7 mathematics performance, language proficiency and reading ability at the two schools?* Pearson Product Moment correlations were performed, using data to correlate the results from the NS and English language and reading tests with the mathematics examination results. See Table 3.

**Table 3: Correlations between mathematics, language and reading comprehension in NS and English**

	NS Language	NS Reading	English Language	English Reading
<b>School B 2005</b>				
Mathematics Exam	0,50**	0,652**	0,677**	0,702**
NS Reading	0,544**	–		0,792**
English Reading		0,792**	0,696**	–
<b>School B 2006</b>				
Mathematics Exam	0,364*	0,401**	0,279	0,430**
NS Reading	0,693**	–		0,843**
English Reading		0,843**	0,784**	–
<b>School M 2006</b>				
Mathematics Exam			0,361	0,804**
English Reading		–	0,691**	–

\* Correlation is significant at the 0,05 level (2-tailed)

\*\* Correlation is significant at the 0,01 level (2-tailed)

While all the correlations are significant (except for the relationship between mathematics and English language in School B in 2006), not all are equally robust. In both years, for both NS and English, *reading ability* rather than language proficiency consistently correlated more strongly with mathematics. Furthermore, in both years, reading ability in English correlated more significantly with the mathematics examination score than reading ability in NS.

Secondly, we note the consistently strong correlations between reading ability in NS and in English: weak readers in NS were also weak readers in English and vice versa. Reading ability in one language correlated more strongly with reading ability in the other language than it did with language proficiency in the same language. Thirdly, there was a trend of a slightly lower correlation between NS language and NS reading than there was between English language and English reading. Learners could score high in NS language but not high in NS reading (see also Table 5).

Stepwise multiple regression analyses for each year were used to see which language and reading variables best predicted mathematical performance. Significant models emerged for both years, as can be seen in Table 4.

**Table 4: Multiple regression predicting mathematics\***

<b>School B 2005</b> F = 63,776; df = 2 91; $p < 0,0005$ Adj. R square = 0,574		
<b>Predictor variables</b>	<i>Beta</i>	<i>Sig.</i>
English reading	0,483	0,000
English language	0,345	0,000
NS language and NS reading were not significant predictors in this model		
<b>School B 2006</b> F = 37,308; df = 1 43; $p < 0,0005$ Adj. R square = 0,452		
<b>Predictor variables</b>	<i>Beta</i>	<i>Sig.</i>
English reading	0,682	0,000
NS language, NS reading and English language were not significant predictors in this model		
<b>School M 2006</b> F = 41,903; df = 1 23; $p < 0,0005$ Adj. R square = 0,630		
<b>Predictor variables</b>	<i>Beta</i>	<i>Sig.</i>
English reading	0,804	0,000
English language was not a significant predictor in this model		

\* The dependent variable is mathematics.  
The predictor variables are NS language, NS reading, English language and English reading.

In all the analyses, English reading consistently emerged as a robust predictor of performance in mathematics; NS language and reading were not significant predictors.

To further explore the relationship between language proficiency, reading and mathematics, the learners' performance on the language and reading tests were matched against their mathematics performance. The mean mathematics examination score placed learners into one of four achievement categories used by the Department of Education (e.g. DoE, 2003), namely *Not Achieved* (0%-35%), *Partly Achieved* (36%-49%), *Achieved* (50%-69%) and *Outstanding* (70%-100%). Language and reading performance can be seen within these four academic categories, as reflected in Table 5.

Three main trends emerge. Firstly, in both schools increased language and reading ability corresponded with category of mathematics performance. The higher the mathematics category, the higher the reading score. For example, the *Not Achieved* learners had much lower reading scores than the *Partially Achieved* learners, who in turn had lower reading scores than

**Table 5: Comparison of L1 and L2 language and reading proficiency with achievement categories in mathematics**

Mathematics examination performance	NS and English language and reading	School B 2005 Mean %	School B 2006 Mean %	School M 2006 Mean %
0% – 39% <i>Not Achieved</i>	NS language	39,3	50,7	–
	NS reading	15,3	21,8	–
	English language	22,9	30,4	88,8
	English reading	18,7	32,4	65,8
40% – 49% <i>Partly Achieved</i>	NS language	67,7	65	–
	NS reading	23,9	33,7	–
	English language	52,2	52,0	95,8
	English reading	31,7	38,1	72,6
50% – 69% <i>Achieved</i>	NS language	71,7	77,0	–
	NS reading	39,7	48,3	–
	English language	66,2	73,2	85,1
	English reading	42,1	54,8	75,4
70% – 100% <i>Outstanding</i>	NS language	77,2	88,7	–
	NS reading	54,9	58,6	–
	English language	86,4	85,4	97,6
	English reading	67,8	70,0	88,7

those in the *Achieved* group; learners in the *Outstanding* mathematics group were all competent readers. In School B, the *Outstanding* learners read better than their peers in both English and NS, but especially in English.

Secondly, the notion of being a 'good' or 'weak' reader varied considerably and was relative to the school context. It is instructive to compare the mean reading scores of the learners who failed mathematics across the schools. The failed mathematics learners in School B could hardly read in either their L1 or the second language (L2) after seven years of primary schooling, while the failed mathematics learners in School M were, by comparison, 'literate' failures with a mean reading score of 65,8%. *Achieved* mathematics learners in School B had mean reading scores that were about 10% lower than the mean reading level of the *failed* mathematics learners in School M. On the other hand, although lower than their private school peers, the reading scores of the *Outstanding* learners in School B were remarkable, given their disadvantaged home and school circumstances.

Thirdly, we note again the large gaps between achievement in NS language and reading, as also the slightly smaller gaps in English language and English reading. Learners could score high in NS language yet they struggled to read in NS. In sum, the results showed very robust relationships between mathematics and reading ability, especially reading in English despite the two different schooling contexts.



## Discussion

The findings reported in this paper come from two primary schools within the same township. Although one cannot generalise from two schools only, the study can be used to inform education improvement and point to future research avenues. We focus on three main trends that emerged. Firstly, there were obvious differences between the quality and quantity of mathematics assessment by the teachers at the schools and learners' concomitant performance. Learners at the private school who faced the longer and more challenging examination outperformed their peers who had the shorter, less challenging mathematics examination. Secondly, there were striking discrepancies between not only mathematics but also language and reading performance between School B and School M, with learners in School B generally performing poorly and learners in School M performing very well. The third salient finding relates to the consistent finding that English *reading* rather than English *language proficiency* related to mathematics examination performance. Although reading in NS was not a predictor of mathematics performance, there was a consistently high correlation between NS reading and English reading. Learners who comprehended texts in one language also comprehended texts in the other, and vice versa. Reading levels in English also tended to be generally higher than reading levels in NS. This robust reading relationship has implications for language policy and mathematics pedagogy, as discussed below.

The study is not without methodological failings; even though independent tests were not used to assess mathematics performance at the schools, the use of *de facto* mathematics performance results from the teachers themselves provide an authentic 'snapshot' of what is happening in schools and do not invalidate the findings. Despite the disparities in teaching and assessment across the two schools, a robust relationship between mathematics and reading still emerged.

In this study two variables were constant: all the learners came from the same township and all had an African home language, so differences in performance must be sought elsewhere. In School B conditions are similar to other disadvantaged primary schools in townships around the country. The two schools differed along several dimensions such as socio-economic status, teacher and classroom resources and practice, and language policy. These issues will be briefly visited below.

## *Poverty, literacy and mathematics*

It could be argued that the differences in mathematics and reading performance between the two schools are simply attributable to the poverty factor. Indeed, there is plenty of evidence around the world that it is difficult to educate poor children (e.g. Bradley & Corwyn, 2002), because the factors associated with poverty create barriers to learning. Poor children attend poorly resourced and managed schools, with large classes and fewer well qualified teachers. In the 1999 TIMMS study Ramirez (2006) found that inequalities in school resources and teacher qualifications in Chile were closely tied to the socio-economic profiles of learners. Poor children also have few literacy resources at home and parents with lower literacy levels. These socio-economic status (SES) related home and school factors are not conducive to creating stimulating learning environments. Rather than regard poverty as a causal factor in mathematics performance it is more constructive to consider what variables might mitigate or exacerbate the effects of poverty on schooling.

The Human Development Index (HDI) for South Africa was 0,684 in TIMSS 2003 (Reddy, 2006). Although socio-economic circumstances impact upon learning opportunity, Indonesia (HDI=0,682) and Morocco (HDI=0,606) had lower HDIs and higher TIMMS positions (mathematics scores of 411 and 387, respectively, against South Africa's 264) (Reddy, 2006). Of the five lowest achieving countries in Africa (Tunisia, Egypt, Morocco, Botswana, Ghana and South Africa, in that order) South Africa has one of the highest gross national incomes per capita, but the lowest mean score in mathematical performance, suggesting that SES factors alone do not account for learner achievement (Reddy, 2006).

## *Teacher qualification and resource management:*

The mathematics teachers at the schools differed in qualifications and teaching experience. There were also differences in terms of organisation and display of mathematical material. At School M the teacher was well organised and had an arch lever file for each Grade 7 learner containing various mathematics activities and test results. These files were displayed prominently in the classroom and the classroom was print rich, with mathematics textbooks, dictionaries, exercise books, mathematical paraphernalia, posters, mind games and inspirational messages. The classroom was clearly a 'mathematics classroom'.

In contrast, the teacher in School B had the challenge of having to cope with much larger classes. There were no up-to-date or readily accessible records of learners' activities, and although the classroom was swept and tidy, the classroom cupboard was disorganised. The cupboard's broken lock may have contributed to the teacher's disinclination to use it as an organising space for mathematics resources. The walls and notice board at the back of the classroom were bare. It did not obviously appear to be a mathematics classroom.

Obviously the socio-economic status of schools determines in many respects the availability of resources within the school. However, individual teachers also differ with regard to their perceptions of what constitutes good practice in their subject and to what extent they can act on their classroom environment. Although School B remains a high poverty school, it has started developing a stronger reading focus. Several of the teachers now try to mitigate the effects of poverty by creating print-rich environments even with their limited resources, and they include more reading activities in classroom activity.

The need to create a visually rich and stimulating mathematical environment should be an integral part of mathematics teacher training, particularly in high poverty schools where learners are unlikely to be exposed to such stimuli in their homes.

*Service delivery and 'time on task'*: Based on regular classroom observations at School B over two years, some general trends have been identified. Although a culture of reading is clearly starting to emerge, several aspects of daily classroom life remain challenging. Lesson presentations often seem to be superficially planned and prepared. Although classwork and homework appear to be more frequently given since the inception of the project, they appear to be undemanding and inconsistently managed. Teachers are often absent or out of the classroom, and maximum use of time and 'opportunity to learn' are lost, with considerable cumulative loss of valuable time. In contrast, School M lessons start soon after the learners come in and homework is a regular feature of school life. Even though learners at both schools have about 4½ hours of mathematics instruction per week, the contrast between the mathematics papers at the two schools (in terms of covering the learning outcomes) bears testimony to differences in the scope, variety of exercises, level of cognitive challenge (cf. Appendix) and constructive use of classroom time.

Loss of 'time on task' was identified as a critical variable that distinguished successful from less successful schools in the Grade 6 systemic evaluation (DoE, 2005). In their study of teacher absence in Peru, Alcázar et al. (2006) also found that teachers were more often absent in poorer schools with poor infrastructures.

### ***Reading and mathematics***

The findings suggest that during the senior primary school phase, English reading is strongly supportive of mathematics achievement. This is not surprising, given that English is the LoLT. It is significant that English *reading* rather than the more general construct of English language proficiency seems to determine mathematics achievement. Those who passed the final Grade 7 mathematics examination scored higher than their peers on both NS and English reading tests.

During the Senior Primary Phase mathematics and reading are strongly related. It is a matter of concern that even after seven years of primary schooling, many learners enter high schools with exceedingly low reading levels in both their home language and in English, with concomitant low levels of mathematical proficiency. 'Catching up' in high school, when the pedagogic focus is on content subjects and not literacy development, is unlikely. Poverty per se does not determine poor reading levels; rather, it is the virtual absence of good practice on which effective reading development depends. If schools wish to improve their mathematics teaching, these findings suggest that they simultaneously give serious attention to improving reading levels. Although schools cannot change the socio-economic status of the communities from which their learners come, they can make committed efforts to creating print-rich environments in the classrooms and ensure that reading is properly taught so that learners can develop appropriate literacy levels to support their mathematical development.

### ***Mathematics pedagogy***

It is clearly imprudent to generalise on the basis of examination papers from two schools. It is however cause for concern that the mathematics papers at School B were problematic. With scant assessment of three of the five learning outcomes, learners are unprepared for the continuation of these learning outcomes in Grade 8.

Given that the practice of quantitative literacy is embedded in real-life contexts, access to resources in the home, community and schools will influence

the extent to which learners can find appropriate material for relevant mathematical tasks. Learners' background knowledge is also affected by their parents' levels of education. Research in the USA and Chile has shown a strong correlation between the level of the parents' education and the mathematical performance of their children (Ramirez, 2006; Tate & Rousseau, 2002).

### ***Language policy and mathematics***

The findings in this study revealed stark differential language and reading performances that were linked to mathematical performance in two different multilingual educational contexts. How does language policy fit into this picture? Being taught in the home language confers linguistic, cognitive and affective advantages. However, the learners at School M far outperformed their peers at School B even though they were studying exclusively through the medium of English. The results from these schools do not by any means imply that subtractive bilingualism 'works' or that additive bilingualism 'doesn't work' or that extended home language instruction won't work. Whatever the language policy at schools, it will only be as good as the quality of education that undergirds it.

Even if the LoLT were to change to the learners' mother tongue, the reading challenge remains – using a language in the classroom does not guarantee reading ability in that language or that reading will become a central classroom activity. Reading only develops on extensive exposure to written language. The availability of books, a basic requirement for reading development, is often absent in poor schools, especially in the African languages (of the 4000 books in School B's library, there are only 169 NS titles, most of which are storybooks for children under 10 years).

The low reading levels and slow reading rates in NS in the current study point to the fact that not enough reading is being done in NS. Contributing factors include classroom practices, availability of print resources in NS and the diglossic differences between spoken and written NS. NS spoken in the Pretoria area (Sesotho sa Pretoria) is different in many respects from standard NS (Sesotho sa Leboa). Learners do not have enough exposure to written NS to develop proficiency in using written forms of the language.

The findings from the private school indicate that when conditions in a school are conducive to learning, very high language, reading and

mathematics levels can be achieved, even when the LoLT is not the L1 of the learners. In the special edition on education equity and quality in developing countries in the *International Journal of Educational Research*, the main theme to emerge was "the centrality of school quality as a driver of ...educational effectiveness" (Lockheed & Cueto, 2006, p. 98).

### **Conclusion**

Although this as a small-scale study, the findings point to numerous factors contributing to mathematical effectiveness in school. Within the two schools, reading ability in the LoLT was a determinant of mathematical performance. Across the schools, the quality of schooling seemed to be the central determinant of both reading and mathematical development in the primary school years.

The new mathematics curriculum presupposes a highly literate environment. Without easy access to material rich in quantitative information learners will find it difficult to find appropriate contexts in which to apply the mathematical concepts and skills they are being taught. Learning will also be negatively affected if aspects of content knowledge are neglected and if general knowledge (assumed by the 'context') is missing. Without adequate reading skills learners will be unable to properly understand mathematical topics. Without adequate understanding of the topics taught learners will continue to follow rote methods of learning often used by teachers who lack confidence and knowledge. If teachers themselves are less than comfortable with the discourse of mathematics they will resort to procedural, language-free problems in their assessment tasks (as the examination questions from School B show), further undermining learners' opportunity to grapple with these issues. Without consideration of the literacy scaffolding learners require, it may well be that the new curriculum is, at present, beyond the reach of many learners, partly as a result of limited literacy.

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## Appendix 1 (School B)

GRADE 7

LEARNING AREA: MATHEMATICS

MARKS: 50

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1. Answer all the questions
2. Number your answers correctly
3. Write neatly

### QUESTION 1

Integers

1. find the answer
  - a.  $-3 + 2 =$
  - b.  $-8 - 6 =$
  - c.  $-4 + 4 =$
  - d.  $4 - 10 =$  (4)

2. calculate

- a.  $-(-3 + 6) + 8$  (3)

### QUESTION 2

Number patterns

Study the following sequence:

- 4, 7, 10, 13, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_
- a. Complete the sequence. (1)
  - b. What is the formula for the sequence (2)
  - c. Find the 20<sup>th</sup> term of the sequence (3)
  - d. Which term of the sequence is 40 (6)

### QUESTION 3

DATA HANDLING

People were asked if Mr Jacob Zuma should be the next President of RSA (Republic of South Africa) out of 100 people

50 says they "Don't know"

25 says "yes"

25 say "no"

Draw a pie chart and indicate the information on it.

Appendix 2 (School M)

INDEPENDENT PRIMARY SCHOOL

Learning Area: Mathematics	
Grade 7	Time: 2h
Examiner:	Total: 120
Moderator:	Level Obtained: 95% (7)

Name: \_\_\_\_\_

Learning Outcome 1: Numbers, Operations and Relationships:

1. Integers:

a)  $23 + 34 - 34 - 12 - 23 =$  -12 ✓

b)  $-2(-11) + 10 = 44 =$  44 ✓

c)  $8 + 8 - 8 + 5 - 3 - 5 =$  5 ✓

d)  $-14 - 26 + 28 - 5 + 14 =$  -3 ✓

e)  $66 - 12 - 18 + (12 \times 3) =$  72 ✓

f) Write an integer ( positive or negative ) to represent the following:

i) Up three flights of stairs +3 ✓

ii) A bank withdrawal of R200 -R200 ✓

iii) The temperature drops a further  $10^{\circ}\text{C}$  from  $-3^{\circ}$ . What is the temperature now?

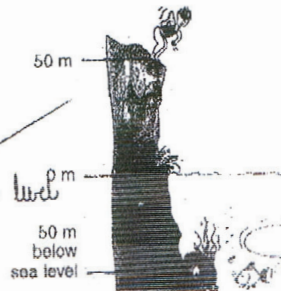
$-13^{\circ}\text{C}$  ✓

g) Look carefully at the picture. Sea level = 0 ✓

How high is the girl above sea level? 50 m

If the girl dives off the cliff and drops 100m.

Where will she be below sea level? -50 m below sea level



(10)  
10

Super  
Super  
Super  
Super!!