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Predictors of learner performance in mathematics and science according to a large-scale study in Mpumalanga

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Eight hundred and ninety-nine (431 male, 467 female and one missing value) Grade 8 and 9 (n = 184 and 713, respectively, with two missing values) learners from secondary schools in Mpumalanga completed a science and mathematics questionnaire. Student's t tests showed that male and female, as well as language groups' scores, differed significantly. Stepwise non-linear regression shows that a combination of factors contributes significantly to learner, science and mathematics performance (R^2 = 25%, 20%, and 11%, respectively).

Introduction

Since the consequences of the former apartheid education system in South Africa are still "catastrophic" (Kahn, 2004:149) and seriously hamper the career prospects of (especially) black learners, education and training are being transformed and reorganised.

These changes have been prompted by a number of factors. The Third International Mathematics and Science Study Repeat Survey (TIMMS-R) of the worldwide trends in respect of scholastic performance in mathematics and science confirmed that South African mathematics learners' performance was significantly poorer than the vast majority of other participating countries in tests that measured basic mathematical skills (Howie, 2001:18). South Africa even fared significantly worse than the other two African countries that had participated in the survey, namely, Morocco and Tunisia. South African learners struggled especially to deal with problems involving language. In general learners experienced many problems communicating their answers in the language of the test (English) and they revealed that they did not have the basic mathematical knowledge that is required.

The failure rate in mathematics at school remains unacceptably high (Maree, Pretorius & Eiselen, 2003; Steyn & Maree, 2003). In South Africa there is a vast gap between the quality of schooling provided for and the achievement of white and African students (Maree, Claassen & Prinsloo, 1997; Saunders, 1996). Since the Grade 12 national examination results still largely determine whether a learner will be accepted to sought-after fields of study at tertiary institutions (Sibaya & Sibaya, 1997), technological and scientific fields of study in particular are, by and large, out of reach for black learners.

Research indicates that many learners in South African schools do not sufficiently master the knowledge and skills underlying learning and problem solving. Learners often acquire deficient, superficial, and rote knowledge of basic concepts (Maree & De Boer, 2003; Maree & Steyn, 2001).

Several hypotheses have been proposed and investigated, including those of the following researchers: Arnott, Kubeka, Rice and Hall (1997), Howie (2001), Maree and Molepo (1999), and Reynolds and Wahlberg (1992). Poor socio-economic background of learners (poor incentive to study at home), lack of appropriate learner support materials, general poverty of school environment, general poor quality of teachers and teaching (including poor subject knowledge and poor motivation), language of instruction (often not the same as learners' mother tongue), and an inadequate study orientation.

Despite the fact that mathematics and science are vulnerable to poor instruction (Freudenthal, in Maree, 1995), in South Africa mathematics is commonly presented at school and university level in a way that strongly encourages traits such as reticence, conformation to rules, and use of sophisticated language (Maree, 1999). Ramnarain (2003:33) argues that

> disadvantaged learners from seriously impoverished learning environments are lacking in the necessary informal mathematical knowledge prescribed by [the problem-centred approach to teaching and learning mathematics] to develop their own strategies for solving non-routine mathematical problems.

Over the last few decades, a plethora of national plans have originated in developing countries to promote educational provision for economic development (Louw, 2003). South Africa too, as a result of the new political dispensation of 1994, has followed a similar trend and the problem-centred approach in mathematics has received attention as an alternative to the more traditional approach in South Africa. The latter is associated with rote learning, learning without the necessary insight, a lack of creativity, a tendency to be too teacher-orientated and a lack of learner activity (De Corte, 2000).

The South African education system has been undergoing extensive restructuring since the advent of democracy. Coinciding with the formation of democracy in South Africa in 1994, an Outcomes-Based Education system was formulated. Introduced in 1998 and amended in 2001, this system asserts that all learners have the ability to succeed, and focuses on the acquisition of knowledge, skills, values, and attitudes, unlike the traditional practice that was based on content mastery only. According to this paradigm teachers are expected to introduce real-life mathematics into classrooms, and help learners acquire skills that will prepare them to become life-long learners and critical thinkers. According to McNeir (1993:1) "these outcomes are derived from a community vision of the skills and knowledge students need to be effective adults". In South Africa it was also envisaged that this new curriculum (colloquially referred to as Curriculum 2005, and abbreviated as C2005, modelled on principles which incorporate learner centredness, formative assessment, integration, and critical thinking that have gained much support and favour worldwide) should reflect the values and principles of the new democracy in South Africa.

However the introduction of an Outcomes-Based Education system at present does not appear to be yielding satisfactory results. Recent research has revealed that the vast majority of Grade 6 learners in the Western Cape in South Africa (normally one of the top achieving provinces in South Africa) have not even mastered the literacy and numeracy levels expected of Grade 4 learners (Kassiem, 2004). Of the approximately 35 000 Grade 6 learners tested in the Western Cape in 2003, only 15.6% passed the numeracy test. Moreover the results confirmed the huge discrepancy between the achievements of former model C schools (with predominantly white learners) and those of previously disadvantaged schools (with black learners) (Dugmore, in Kassiem, 2004). Teachers throughout the country, who were in no way responsible for or involved in developing the new curriculum, agree that learners in the Further Education and Training Phase (Grade 10) achieve increasingly worse results, with unacceptably high percentages of learners failing mathematics, and dropping the subject in mid-year (Perry, 2003).

In 2000 the Mpumalanga Department of Education began a three-way collaboration with the University of Pretoria and the Japanese International Co-operation Agency (including scholars from two Japanese universities) to optimize the achievements of learners in science and mathematics. In this article we reflect on the success ratio in learner performance in these two gateway subjects and report on the findings of this investigation into Grade 8 and 9 learner performances in mathematics and science (Aldous, Hattingh & Rogan, 2004).

Hypotheses were that

a) scores in science and mathematics tests would be correlated;
b) a combination of subscale scores in the tests would best predict the aggregate scores of first-year engineering students;
c) prediction models would be significant at the 0.05 level;
d) the difference between the mean scores of the two tests for different language groups would be significant; and
e) the difference between the mean scores of the two tests for different gender groups would be significant.

Method

Sample

A purposely selected sample of 899 (431 boys, 467 girls and one missing value) Grade 8 and 9 (n = 184, and 713, respectively, with two missing values) learners from secondary schools in Mpumalanga reflected the full range of socio-economic types of schools in this region. Curriculum Implementers, also known as subject advisors, were, among others, used to gather the data. Most of the schools in the sample were rural schools with only black learners in attendance.

Procedure

The survey was conducted in May 2002. All learners completed the survey within the space of three days. Learners were asked to complete a questionnaire, which probed for learner background, attitudinal data, teacher practices, as well as basic knowledge and understanding of natural science and mathematics. The data on knowledge and understanding of natural science and mathematics were scored as a test. This score was used as a dependent variable in a regression analysis with all the other variables that had probed for learner background, attitudinal data, and teacher practices as the predictors.

Ethical aspects

Permission was requested and obtained in writing from the Mpumalanga Department of Education as well as from the students to conduct the research and publish the findings. The assurance was given that no individual would be identified.

Limitations of the study

This research was limited to science and mathematics learners in a single province in the Republic of South Africa. The instrument was administered in English, the language of instruction in all the schools in the sample. However English was the mother tongue of only 0.64% of the learners.

Measuring instrument

The instrument consisted of five sections dealing with demographic data, learner background, learner attitude to science and mathematics, learners' perceptions of what was happening in the science and mathematics classroom, respectively, and a test (see Appendix A). The test required basic understanding of science and mathematics processes appropriate for the Grade 8 and Grade 9 level. It consisted of 15 multiple-choice questions, of which eight focused on skills required for natural science and seven on mathematical skills. All the questions in the questionnaire were aligned with the mathematics and science outcomes stipulated in C2005. The performance of the learners was measured by using three measures called the learner performance, the science performance, and the mathematics performance. The learner performance was calculated by adding all the questions that the learners had answered correctly in the test yielding a possible mark out of 15. The science performance was calculated by adding all the questions on science that the learners had answered correctly in the test yielding a possible mark out of 8. The mathematics performance was calculated by adding all the questions on mathematics that the learners had answered correctly in the test yielding a possible mark out of 7 (Table 1). Figure 1 shows the distribution of scores for learner performance for the entire sample of learners.

Results

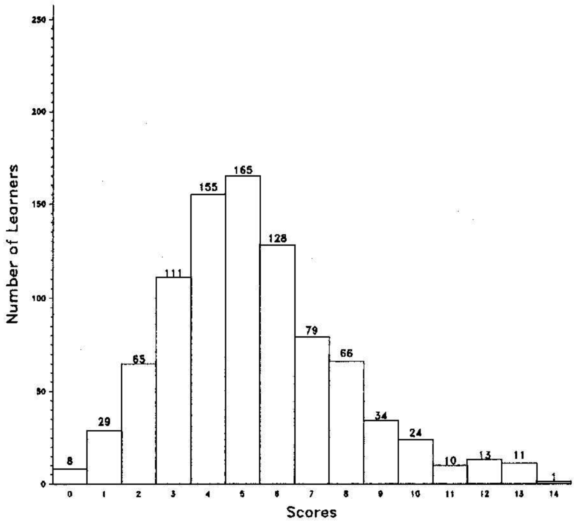


Figure 1 Histogram of learner performance scores (n = 899)

The Cronbach alpha reliability coefficient for the scores obtained from the administration of the mathematics and science questionnaire was calculated at 0.53. We readily admit that this internal consistency reliability score is low(ish), especially since, generally, researchers recommend an internal consistency score of 0.70 and higher (Thompson, 1994). The fact that

Table 1 Descriptive statistics: learner, science, and mathematics performance (n = 899)

Descriptive measure	Learner performance (Max: 15)	Science performance (Max: 8)	Mathematics performance (Max: 7)
Mean	5.29	2.77	2.51
Median	5.00	3.00	2.00
Mode	5.00	3.00	2.00
Standard deviation	2.53	1.56	1.56
Skewness	0.69	0.42	0.50
Kurtosis	0.60	–0.03	0.03
Minimum	0.00	0.00	0.00
Maximum	14.00	8.00	7.00
Interquartile range	3.00	2.00	3.00

most of the learners found the vast majority of the questions difficult no doubt contributed to this rather low score.

As far as the validity of the instrument is concerned, we would like to confirm that the questionnaire was perused by several senior science teachers with many years of experience, who all agreed that the contents of the questions reflected, to a highly satisfactory degree, the essential skills required for natural science and mathematics, that all the questions in the questionnaire were aligned with the mathematics and science outcomes stipulated in C2005, and that, in order to achieve in the questionnaire, a basic understanding of science and mathematics processes appropriate for the Grade 8 and Grade 9 level was required. This act confirmed the face and, indeed, content validity of the questionnaire.

The distributions of performance measures, in all cases, were positively skewed and non-normal (all three Shapiro-Wilk tests yielded p values < 0.05).

Regression models

We looked specifically at models that could be used to generalize to the majority of schools in the study region. Regression models were calculated to determine the variables and models that could be used to best predict the learner, science, and mathematics performance (dependent variable). The Stepwise Selection method of SAS (1990) was used to determine the relevant variables from a number of identified variables (V8 to V49, independent variables, which questioned demographic data, learner background, learner attitude to science and mathematics, learners' perceptions of what was happening in the science, and mathematics classroom, respectively) (Tables 2 and 3).

These models explained 25%, 20%, and 11% of the variation in the learner, science, and mathematics performance, respectively. The fact that all the learners performed poorly and scored very low marks (cluttered at the lower end of the scale) in their tests might have been the reason for the weak fit of the models and the resulting low R^2s. Table 4 shows the probes for the variables indicated in the models and their correlations with the performance measures.

Table 2 Anova results for models (n = 899)

Performance type	Source of variation	Degrees of freedom	Sum of Squares	Mean Squares	*F* value	*Pr* > *F*
Learner	Model	30	907.91	30.26	5.60	<0.0001
	Error	505	2728.03	5.40		
	Total	535	3635.94			
Science	Model	20	269.91	13.50	6.30	<0.0001
	Error	515	1103.96	2.14		
	Total	535	1373.86			
Mathematics	Model	16	149.33	9.33	4.17	<0.0001
	Error	519	1162.75	2.24		
	Total	535	1312.08			

Table 3 Regression models and R^2s (n = 899)

Performance type	Model	R^2
Learner	$= 5.89 - 2.57*V10 + 0.26*V11 - 0.65*V12 + 0.28*V15 - 0.57*V18 + 0.33*V21 - 1.42*V24 + 0.75*V28 + 0.13*V32 + 1.77*V33 - 1.20*V37 + 0.65*V38 - 1.57*V39 - 1.07*V43 + 0.32*V45 - 0.15*V46 + 0.72*V10^2 - 0.03*V11^2 + 0.11*V17^2 + 0.11*V22^2 + 0.28*V24^2 - 0.15*V28^2 - 0.25*V33^2 - 0.02*V34^2 + 0.24*V37^2 - 0.15*V38^2 + 0.36*V39^2 - 0.03*V41^2 + 0.26*V43^2 - 0.02*V49^2$	0.25
Science	$= 1.70 - 1.59*V10 + 0.14*V11 + 0.18*V19 + 0.14*V24 + 0.46*V28 - 0.42*V37 - 0.64*V39 + 0.74*V42 + 0.44*V10^2 - 0.01*V11^2 + 0.11*V15^2 - 0.09*V18^2 - 0.11*V28^2 + 0.02*V30^2 - 0.03*V34^2 + 0.02*V35^2 + 0.09*V37^2 - 0.02*V38^2 + 0.14*V39^2 - 0.10*V42^2$	0.20
Mathematics	$= 3.10 - 0.26*V20 + 0.23*V22 - 0.52*V25 + 0.09*V26 - 0.73*V43 + 0.13*V45 + 0.08*V48 - 0.14*V49 + 0.08*V10^2 - 0.01*V11^2 - 0.17*V12^2 + 0.06*V13^2 + 0.08*V17^2 - 0.10*V18^2 + 0.09*V25^2 + 0.17*V43^2$	0.11

Discussion

Comparison of learner performance by language

The Kruskal-Wallis test performed was based on the scores of the different language groups. Sample sizes were five (English), 42 (Afrikaans), 848 (African languages), and four (other languages), respectively. The Kruskal-Wallis test statistic equalled 65.74 ($p \leq 0.0000$), implying that significant differences existed between the performance of the different language groups. Further analyses by means of multiple comparisons showed significant differences between the Afrikaans learners and all the other language groups (Afrikaans learners always performing better than the other groups).

Table 4 Probes for variables in models with mean scores and correlations with learner- (LP), science- (SP), and mathematics-performance (MP) (n = 899)

Demographic data

Variable	Probe	Correlation with LP	Correlation with SP	Correlation with MP
$V10_{LS}$	What is your population group?	0.32	0.30	0.22
$V10^2_{LSM}$		0.33	0.30	0.22
$V11_{LS}$	What is your home language?	–0.21	–0.18	–0.15
$V11^2_{LSM}$		–0.18	–0.16	–0.13

Learner background information
Read each of the following statements and indicate whether each is "True" about you or "False" about you. (T=1, F=2)

Variable	Probe	Mean	Correlation with LP	Correlation with SP	Correlation with MP
$V12_{L}$	I come from a home that has electricity.	1.10	–0.10	–0.07	–0.09
$V12^2_{M}$		1.31	–0.10	–0.07	–0.09
V13	I come from a home that has water from a tap.	1.30	–0.07	–0.04	–0.07
$V13^2_{M}$		1.88	–0.07	–0.04	–0.07
$V15_{L}$	Family duties and obligations keep me from	1.64	0.12	0.12	0.08
$V15^2_{S}$	studying at home.	2.92	0.12	0.12	0.08
V17	I have to travel more than 5 km to attend school.	1.65	0.05	–0.01	0.09
$V17^2_{LM}$		2.95	0.05	–0.01	0.09
$V18_{L}$	My parents (or guardians) encourage me to	1.09	–0.05	–0.07	–0.02
$V18^2_{SM}$	study.	1.27	–0.05	–0.07	–0.02
$V19_{S}$	I have books and magazines at home that I can read.	1.20	–0.05	–0.03	–0.05
$V20_{M}$	I attend school almost every day.	1.07	–0.05	–0.02	–0.07
$V21_{L}$	Family duties and obligations regularly keep me out of school.	1.89	0.07	0.06	0.06
$V22_{M}$	I always have breakfast before coming to	1.22	0.01	0.01	0.02
$V22^2_{L}$	school.	1.67	0.01	0.01	0.02

Table 4 (continued)

Learner attitudes to science and mathematics
Read each statement below carefully and then decide how strongly you agree or disagree with each statement.
1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree.

Variable	Probe	Mean	Correlation with		
			LP	SP	MP
$V24_{LS}$	I feel the study of science in school is	3.56	0.12	0.14	0.06
$V24^2_{L}$	important.	13.15	0.13	0.14	0.07
$V25_{M}$	Mathematics is boring.	1.58	–0.03	0.01	–0.05
$V25^2_{M}$		3.32	–0.03	–0.01	–0.05
$V26_{M}$	With hard work, anyone can pass mathematics.	3.38	0.08	0.07	0.06
$V28_{LS}$	I would like to study more science.	3.40	0.06	0.03	0.06
$V28^2_{LS}$		12.25	0.05	0.01	0.06
V30	Science is a valuable subject.	3.37	0.12	0.12	0.07
$V30^2_{S}$		11.95	0.11	0.12	0.06
$V32_{L}$	I enjoy maths.	3.41	0.07	0.06	0.05
$V33_{L}$	I can use the science I learn in my daily life.	3.34	0.07	0.06	0.06
$V33^2_{L}$		11.63	0.06	0.04	0.05
V34	I cannot understand the science we do at	1.89	–0.06	–0.06	–0.04
$V34^2_{LS}$	school.	4.47	–0.07	–0.06	–0.05

Learner perceptions of what is happening in the science classroom
Read each statement below carefully and then decide how often your science teacher does what is mentioned.
1 = not at all, 2 = rarely, 3 = sometimes, 4 = often.

Variable	Probe	Mean	Correlation with		
			LP	SP	MP
V35	Teacher allows us to ask questions in class.	3.50	0.15	0.13	0.12
$V35^2_{S}$		13.05	0.16	0.14	0.12
$V37_{LS}$	Teacher demonstrates experiments to us.	3.04	0.10	0.12	0.04
$V37^2_{LS}$		10.15	0.10	0.12	0.04
$V38_{L}$	Teacher allows some learners to help with the	2.98	0.09	0.10	0.05
$V38^2_{LS}$	demonstrations.	9.84	0.07	0.08	0.04
$V39_{LS}$	Teacher gives us notes on the board to copy into	3.25	0.19	0.18	0.13
$V39^2_{LS}$	our books.	11.53	0.21	0.18	0.15
$V42_{S}$	Teacher encourages us to study on our own.	3.41	0.11	0.19	–0.01
$V42^2_{S}$		12.42	0.11	0.18	–0.01

Table 4 (continued)

Learner perceptions of what is happening in the mathematics classroom
Read each statement below carefully and then decide how often your science teacher does what is mentioned.
1 = not at all, 2 = rarely, 3 = sometimes, 4 = often.

Variable	Probe	Mean	Correlation with		
			LP	SP	MP
$V43_{LM}$	Teacher allows us to ask questions in class.	3.61	0.18	0.17	0.13
$V43^2_{M}$		13.67	0.18	0.17	0.13
$V45_{LM}$	Teacher shows us how to do mathematics problems on the blackboard.	3.56	0.19	0.18	0.13
$V46_{L}$	Teacher gives us notes on the board to copy into our notebooks.	3.02	0.11	0.09	0.09
$V48_{M}$	Teacher shows us examples of mathematics in everyday life.	3.43	0.01	–0.01	0.02
$V49_{M}$	Teacher encourages us to study on our own.	3.45	0.09	0.14	0.01

L = variables included in the learner performance model
S = variables included in the science performance model
M = variables included in the mathematics performance model

Correlation between science and mathematics performance

A Pearson correlation based on the scores of the African language group to determine if a linear relationship existed between science and mathematics performance (n = 848) yielded $r = 0.26$ ($p < 0.001$), indicating a weak positive linear relationship and a slope significantly different from zero. This result needs to be interpreted with caution since $R^2 = 0.0676$ (only 6.76% of the variation in the science performance is explained by the mathematics performance and vice versa). The fact that most of the learners performed poorly and scored low marks in both the science and the mathematics tests appeared to be the reason for the weak relationship and the resulting low R^2s.

Comparison of learner performance by gender

The Kruskal-Wallis test was performed based on the scores of the African language group to determine if a difference existed in the learner performance between the male and female learners (n = 444 and 403, respectively, with one missing value). The Kruskal-Wallis test statistic was calculated at 0.03 ($p = 0.86$), implying no significant difference between the performance of the male and female learners.

Conclusion

Positively skewed learner performances around the low median showed that learners did not perform well in the science and mathematics test in general. Mean scores for the whole test as well as for the mathematics and science subsections were well below 50%. This concerns all involved in education. The importance of scientific literacy in a responsible citizenry has been considered vital in a world being carried forward in leaps and bounds into a future where science continually impacts on human existence. Clearly the learners tested in this study are at a disadvantage, especially since they have not yet acquired the basic scientific or mathematical literacy considered essential for learners of their age. It is essential to redress the shortfalls in their recent science and mathematics education.

Three regression models included different variables beyond those that can be explained by deliberate exclusion due to selection of independent variables appropriate for mathematics and science separately. For example, having running water at home (V13) was included in the mathematics model but not in the science model. It is interesting to note that having breakfast contributed positively towards Mathematics performance but did not contribute to Science performance. Having electricity at home (V12) seemed to have an impact amongst the factors selected in the learner and mathematics models. It would be the more affluent homes that would have electricity suggesting that learners from homes with electricity would have fewer negatively impacting socio-economic circumstances weighing them down. On a more practical level having electricity at home can extend the working day into the night more effectively than candlelight or gas lamp. Having electricity at home affords learners the opportunity to spend more time doing homework and doing additional reading. Furthermore these households are more likely to have radio and television, which may support their education as sources of information. The relationship between the learners' home language and the language in which the paper was presented (English, which is the main language of instruction) was among the lowest impacting factors included in the model. The model suggests that home language is not an important factor in learner performance. However, Howie (2003:238) suggests that "it should be noted that language is a confounding variable and as it is also closely related to socio-economic status and schools with predominantly better resources". It should be continually borne in mind that the performance of the learners in our study was particularly poor. Seeking a relationship between any factor and poor performance and trying to draw inferences from this relationship may yield confusing results.

As far as the discrepancy, between the results of the Afrikaans-speaking group in particular and the other groups (excluding the English group; n = 5), is concerned, it needs to be stressed that owing to inadequate opportunities and resources for teaching and learning in traditionally disadvantaged schools, black learners (particularly in rural parts of South Africa) find themselves in an educational situation that rarely promotes optimal actualisation of their personal potential and satisfactory acquiring of new knowledge and skills. One possible outcome of this situation is inadequate achievement in science and mathematics as evidenced by this study. Our findings stressed the fact that science and mathematics teaching can never be divorced from the socio-economic context in which it is taught.

A positive relationship is expected between performance in science and performance in mathematics (Wang & Santos, 2003). Were this true in all cases one could expect that if there was an investment in mathematics education, a corresponding improvement would be observed in science performance. To test this hypothesis in this study, a correlation was sought between the science performance and mathematics performance scores. This relationship did exist in the case of this sample, but to a very small degree. This implies that a very large investment in one subject will result in some improvement in performance of the other subject. Variables in the model with the greatest positive impact on learner performance were V33, V28, V38, V21, and

V45, in this order. Variables in the model with the greatest negative impact on learner performance were V10, V39, V24, V37, and V43. V45 represented a conservative teaching method, i.e. chalk and talk method. This is interesting because it is assumed that the old-fashioned teaching strategies should be displaced by the new curriculum teaching strategies in many cases. This begs the question whether we are throwing the baby out with the bathwater. Higher order teaching practices such as allowing learners to ask questions and linking science to everyday life are also important, but in the learner performance model V43 impacted negatively indicating that learners were not encouraged to ask questions freely. The negative impact of V39 on learner performance suggests that learners are unhappy with copying notes from the blackboard. Although the correlations shown in Table 4 for each item are low, the highest correlations are for variables that support this trend.

Clearly there is no easy solution to our problem of low learner performance in this study. Fullen (1991) however cautions that education innovation of the kind implemented in this study (the introduction of C2005) takes between at least five and seven years' time to take root. Nonetheless the results in this study require educational planners to go back to the basics and redefine the intended achievement aims in mathematics and science. These intentions need to be uncluttered by political rhetoric, research fads, fashions, and ideologies. As is the case in other countries, South Africa urgently needs a mathematically and scientifically literate citizenry to ensure its survival and thriving in the knowledge and problem-solving era.

References

Aldous CM, Hattingh A & Rogan J 2004. Predictors of learner performance in a large-scale study in Mpumalanga. In: A Buffler & R Laugksch (eds). *Proceedings of the 12th annual conference of the Southern African Association for Research in Mathematics, Science and Technology*. Cape Town, SA.

Arnott A, Kubeka Z, Rice M & Hall G 1997. *Mathematics and Science teachers: demand, utilisation, supply, and training in South Africa*. Craighall: Edusource.

De Corte E 2000. New perspectives for research and practice in mathematics education. *Pythagoras*, 52:33-46.

Fullen M 1991. *The new meaning of educational change*. New York: Teachers College Press.

Howie S 2001. *Mathematics and science performance in Grade 8 in South Africa. 1998/1999*. Pretoria, SA: Human Sciences Research Council.

Howie S 2003. Conditions of schooling in South Africa and the effects on mathematics achievement. *Studies in Educational Evaluation*, 29:227-241.

Kahn M 2004. For whom the school bell tolls: Disparities in performance in senior certificate mathematics and science. *Perspectives in Education*, 22:149-156.

Kassiem A 2004. Grade 6 pupils can't read or write — poll. *Pretoria News*, 26 May.

Louw CJ 2003. The impact of tutorials on the mathematics achievement of students in first year mathematics. Unpublished master's dissertation, University of Pretoria, Pretoria, SA.

Maree JG & De Boer A 2003. Assessment of thinking style preferences and language proficiency for South African students whose native languages differ. *Psychological Reports*, 93:449-457.

Maree JG 1995. Comment on the new approach to the teaching and learning of mathematics in the RSA: how justified is the criticism? *South African Journal of Education*, 15:66-71.

Maree JG 1999. Difference in orientation towards the study of mathematics of South African high school learners: developing a study orientation questionnaire in mathematics. *Psychological Reports*, 84:467-476.

Maree JG & Molepo JM 1999. The role of mathematics in developing rural and tribal communities in South Africa. *South African Journal of Education*, 19:374-381.

Maree JG & Steyn TM 2001. Diverse thinking-style preferences in a university course in mathematics. *Psychological Reports*, 89:583-588.
Maree JG & Steyn TM 2003. *Study Orientation Questionnaire in Mathematics (Tertiary)*. Pretoria, SA: University of Pretoria.
Maree JG, Claassen NCW & Prinsloo WJ 1997. *Manual for the Study Orientation Questionnaire in Mathematics*. Pretoria: Human Sciences Research Council.
Maree JG, Pretorius A & Eiselen RE 2003. Predicting success among first-year engineering students at the Rand Afrikaans University. *Psychological Reports*, 93:399-409.
McNeir G 1993. Outcomes-based education. Available at http://eric.uoregon. edu/publications/ digests/digest085.html.
Perry H 2003. Female performance in the senior certificate examination: excellence hiding behind the averages. *Edusource Data News*, 39:14-25.
Ramnarain U 2003. A strategies-based problem solving approach in the development of mathematical thinking. *Pythagoras*, 57:32-35.
Reynolds AJ & Wahlberg HJ 1992. A structural model of high school mathematics outcomes. *Journal of Educational Research*, 85:150-158.
SAS Institute 1990. *SAS/STAT User's Guide. Version 6 (Glm Through Varcomp Procedures)*. Raleigh, USA: SAS Institute.
Saunders W 1996. One lost generation after another. *Frontiers of Freedom*, 4th quarter, 18-19.
Sibaya PT & Sibaya D 1997. Students' performance on a teacher-made mathematics test: the interaction effects of sex, class and stream with age as a covariate. *South African Journal of Psychology*, 27:9-15.
Thompson B 1994. Guidelines for authors. *Educational and Psychological Measurement*, 54:837-847.
Wang J & Santos S 2003. A comparative study of relationship between mathematics and science achievement at the 8th Grade. Paper presented at the *Annual Meeting of the American Educational Research Association*. Chicago, IL, April 21-25.

Appendix A

MSSI Implementation Research Project
Learner Questionnaire – May 2002

PLEASE RESPOND TO ALL QUESTIONS BY DRAWING A NEAT CIRCLE AROUND AN APPROPRIATE NUMBER IN A SHADED BLOCK OR BY WRITING YOUR ANSWER INTO THE SHADED SPACE PROVIDED

A	Questionnaire number	V1		1
B	Questionnaire type	V2	2	5
C	Repeat number	V3		6
D	District	V4		7
E	School	V5		9
F	M-Code	V6		11
G	S-Code	V7		18

SECTION A: BACKGROUND INFORMATION

1. What is your gender?

Male	**1**	
Female	**2**	

V8 ☐ 25

2. What grade are you in?

Grade 8	**1**	
Grade 9	**2**	

V9 ☐ 26

3. To which one of the following population groups do you belong?

Black	**1**
Coloured	**2**
Indian	**3**
White	**4**
Other (specify)	

V10 ☐ 27

4. What is your home language?

V11			28

5. Read each of the following statements and indicate whether each is "True" about you or "False" about you.
Please use the following codes:

1 = True 2 = False

"Home" in the questions below refers to where you stay while attending school.

		T	F			
a	I come from a home that has electricity	**1**	**2**	V12		30
b	I come from a home that has water from a tap	**1**	**2**	V13		31
c	I find it very difficult to study at home	**1**	**2**	V14		32
d	Family duties and obligations regularly keep me from studying at home	**1**	**2**	V15		33
e	I live in a safe neighbourhood	**1**	**2**	V16		34
f	I have to travel more than 5 km to attend school	**1**	**2**	V17		35
g	My parents (or guardians) encourage me to study	**1**	**2**	V18		36
h	I have books and magazines at home that I can read	**1**	**2**	V19		37
i	I attend school almost every day	**1**	**2**	V20		38
j	Family duties and obligations regularly keep me out of school	**1**	**2**	V21		39
k	I always have breakfast before coming to school	**1**	**2**	V22		40

SECTION B: LEARNER OPINIONS ABOUT SCHOOL MATHEMATICS AND SCIENCE

There are no right or wrong answers for the items that follow. Please give your honest opinion.

6. Read each statement below carefully and then decide how strongly you agree or disagree with each statement.

Please use the following codes:

1 = **S**trongly **D**isagree
2 = **D**isagree
3 = **A**gree
4 = **S**trongly **A**gree

		SD	D	A	SA			
a	I like to study maths at school	**1**	**2**	**3**	**4**	V23		41
b	I feel the study of science at school is important	**1**	**2**	**3**	**4**	V24		42
c	Maths is boring.	**1**	**2**	**3**	**4**	V25		43
d	With hard work, anyone can pass maths	**1**	**2**	**3**	**4**	V26		44
e	I do not enjoy science	**1**	**2**	**3**	**4**	V27		45
f	I would like to study more science	**1**	**2**	**3**	**4**	V28		46
g	Science is boring.	**1**	**2**	**3**	**4**	V29		47
h	Science is a valuable subject.	**1**	**2**	**3**	**4**	V30		48
i	I feel the study of maths in school is important	**1**	**2**	**3**	**4**	V31		49
j	I enjoy maths.	**1**	**2**	**3**	**4**	V32		50
k	I can use the science I learn in my daily life.	**1**	**2**	**3**	**4**	V33		51
l	I cannot understand the science we do at school	**1**	**2**	**3**	**4**	V34		52

7. Read each statement below carefully and then decide how often your science teacher does what is mentioned.

Please use the following codes:
1 = **N**ot at all
2 = **R**arely (only a couple times each term)
3 = **S**ometimes (usually at least once a month)
4 = **O**ften (usually every week)

		N	R	S	O			
a	Allows us to ask questions in class.	**1**	**2**	**3**	**4**	V35		53
b	Allows us to discuss our work in a group.	**1**	**2**	**3**	**4**	V36		54
c	Demonstrates experiments to us.	**1**	**2**	**3**	**4**	V37		55
d	Allows some learners to help with the demonstrations.	**1**	**2**	**3**	**4**	V38		56
e	Gives us notes on the board to copy into our books.	**1**	**2**	**3**	**4**	V39		57
f	Allows us to do experiments in small groups.	**1**	**2**	**3**	**4**	V40		58
g	Shows us examples of science in everyday life.	**1**	**2**	**3**	**4**	V41		59
h	Encourages us to study on our own.	**1**	**2**	**3**	**4**	V42		60

8. Read each statement below carefully and then decide how often your maths teacher does what is mentioned.

Please use the following codes:
1 = **N**ot at all
2 = **R**arely (only a couple times each term)
3 = **S**ometimes (usually at least once a month)
4 = **O**ften (usually every week)

		N	R	S	O			
a	Allows us to ask questions in class.	**1**	**2**	**3**	**4**	V43		61
b	Allows us to discuss our work in a group.	**1**	**2**	**3**	**4**	V44		62
c	Shows us how to do maths problems on the blackboard.	**1**	**2**	**3**	**4**	V45		63
e	Gives us notes on the board to copy into our books.	**1**	**2**	**3**	**4**	V46		64
f	Gives us new problems to solve in small groups.	**1**	**2**	**3**	**4**	V47		65
g	Shows us examples of maths in everyday life.	**1**	**2**	**3**	**4**	V48		66
h	Encourages us to study on our own.	**1**	**2**	**3**	**4**	V49		67

SECTION C: QUESTIONS ABOUT SCIENCE AND MATHEMATICS

Think about the following questions and select the answer you think is correct by circling the corresponding number in a shaded block.

9. Which event is explained by the sequence of energy changes indicated in the box below?

Chemical energy → Heat energy → Mechanical energy (with wasted heat)

	Possible answers	
a	A torch that is on	**1**
b	A candle that is burning	**2**
c	Petrol combusting in the engine of a car	**3**
d	Electric current running a refrigerator	**4**

V50 [ ] 68

10. A baby chick grows inside an egg for 21 days before it hatches. Where does the baby chick get its food from before it hatches?

	Possible answers	
a	The baby chick makes its own food	**1**
b	The mother hen feeds the baby chick	**2**
c	The food is stored in the egg.	**3**
d	The baby chick does not need any food.	**4**

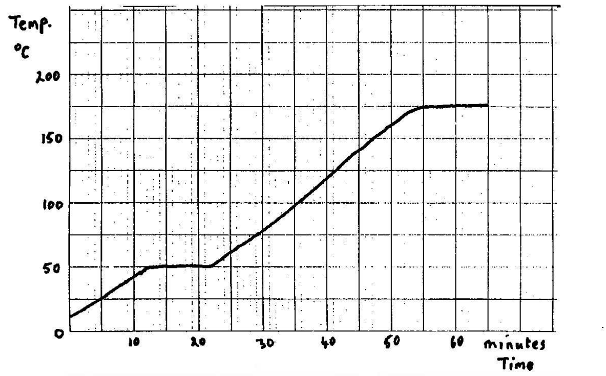
V51 [ ] 69

11 Tiles and carpets are always the same temperature as the room. Why then, do tiles feel colder to your bare feet than a carpet?

	Possible answers	
a	The carpet stores more heat than the tile.	**1**
b	The tile has a lower temperature than the carpet.	**2**
c	The tile and the carpet are both at the same temperature	**3**
d	The tile conducts heat energy away from your feet faster than the carpet.	**4**

V52 [ ] 70

12. A solid substance is heated until it changes to a liquid and then to a gas. Its temperature in °C is taken every minute. The results are shown in the graph.



12.1 What is the melting point of the substance?

	Possible answers	
a	10 °C	**1**
b	40 °C	**2**
c	50 °C	**3**
d	180 °C	**4**

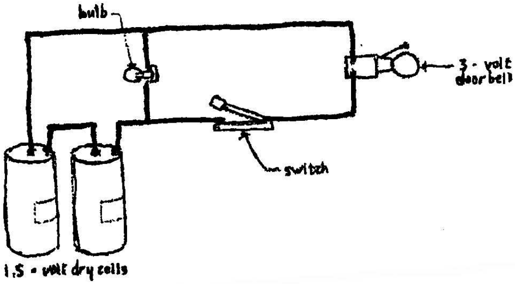
V53 ☐ 71

12.2 Using the graph above, how many minutes did it take for the substance to melt?

	Possible answers	
a	5 minutes	**1**
b	10 minutes	**2**
c	25 minutes	**3**
d	45 minutes	**4**

V54 ☐ 72

13. In the diagram below the dry cells are new and are in good working order.



What occurs when the switch is OPEN as shown in the diagram?

	Possible answers	
a	The bulb is lighted, but the bell does not ring.	**1**
b	Neither the bulb nor the bell operates.	**2**
c	The bulb is lighted and the bell rings.	**3**
d	The bell rings, but the bulb is not lighted.	**4**
e	No current flows from the dry cells.	**5**

V55 ☐ 73

14. Nomsa added ice cubes, one at a time, to a beaker of water. After each ice cube melted, she measured the temperature of the water and recorded the information in the following table.

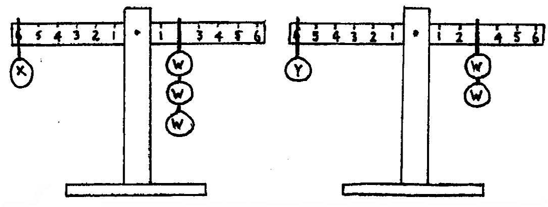
Number of ice cubes	0	1	2	3	....	?
Water temperature, °C	60	55	50	45	....	30

Predict the total number of ice cubes that will probably be needed to lower the water temperature to 30 °C.

	Possible answers	
a	4.	**1**
b	5.	**2**
c	6.	**3**
d	7.	**4**

V56 ☐ 74

15. Look carefully at the diagram below in which two objects, X and Y, are balanced with equal weights (W).



Which one of the following statements is correct?

	Possible answers	
a	Object X is heavier than object Y.	**1**
b	Object Y is heavier than object X.	**2**
c	Both objects Z and Y weigh the same.	**3**
d	Object Y is lighter than object X.	**4**

V57 75

16. You know that all insects have six legs. You find a small animal with six legs. What can you say about it.

	Possible answers	
a	It is definitely NOT an insect.	**1**
b	It is definitely an insect.	**2**
c	It could be an insect.	**3**
d	It is a spider.	**4**

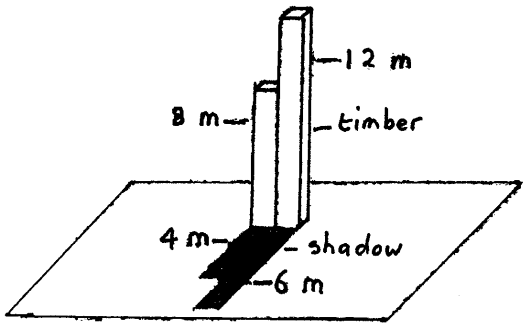
V58 76

17. Your friend says that "magnets attract metal". You give him some objects and a good magnet. He does a test and finds that the magnets attract steel scissors and iron nails.
How does this fact relate to his statement?

	Possible answers	
a	It supports the statement.	**1**
b	It contradicts the statement.	**2**
c	It gives no information about the statement.	**3**
d	It means the statement is true for all metals.	**4**

V59 77

18. Two pieces of timber are standing side by side as shown in the diagram below. One is 12 m tall and the other is 8 m tall. Their shadows are measured at the same time and are 6 m and 4 m long.



Later in the day the shadows have changed. The shadow of the LONGER piece of timber is now 9 m long.

How long is the shadow of the shorter piece of timber at this time?

	Possible answers	
a	5 m.	**1**
b	6 m.	**2**
c	7 m.	**3**
d	8 m.	**4**

V60 ☐ 78

19. Consider the information in the following table about the amount of oxygen produced in a pond.

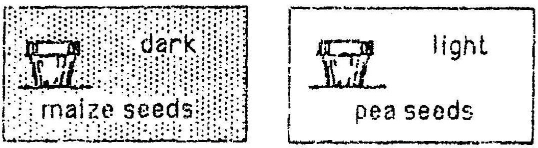
Location	Oxygen produced
Top metre	4 grams/cubic metre
Second metre	3 grams/cubic metre
Third metre	1 grams/cubic metre
Bottom metre	0 grams/cubic metre

Which statement is consistent with the data in the table.

	Possible answers	
a	More oxygen production occurs near the surface because there is more light there.	1
b	More oxygen production occurs near the bottom because there are more plants.	2
c	The greater the water pressure, the more oxygen production occurs.	3
d	The rate of oxygen production is not related to depth.	4

V61 79

20. Sipho wanted to find out whether seeds grow better in the dark or the light. He put a pot of soil with 6 maize seeds in a dark room and a pot of soil containing 6 pea seeds on the window sill.



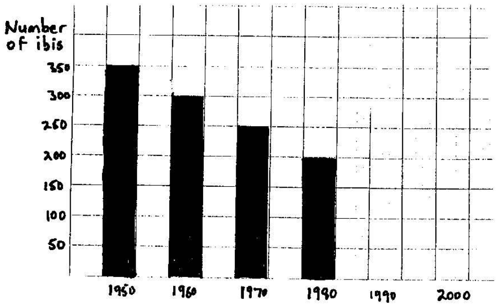
He added the same amount of water to both pots. Sipho said that his pea seeds grew better than the maize seeds, so he decided that seeds grow best in light.

To make this conclusion he should have ....

	Possible answers	
a	watered both pots more.	1
b	watered the maize seed more.	2
c	put the same kind of the seeds in both pots	3
d	grown the seeds in wet cotton wool instead of soil.	4

V62 80

21. The following graph shows the number of Ibis (a kind of bird) that returned to a dam in the spring after having spent winter elsewhere.



Predict the number of Ibis that will return in the year 2000 if the numbers keep dropping at the same rate.

	Possible answers	
a	50.	**1**
b	100.	**2**
c	150.	**3**
d	200.	**4**

V63 ☐ 81

22. Use the information in the table below to answer the question which follows.

	HEART BEATS/MINUTE	
DRUG	BEFORE DRUG	AFTER DRUG
Nicotine	120	135
Alcohol	118	99
Caffeine	119	135
Aspirin	117	129

Which one of the following drugs results in the GREATEST CHANGE in heart rate ?

	Possible answers	
a	Alcohol	**1**
b	Caffeine	**2**
c	Nicotine	**3**
d	Aspirin	**4**

V64 ☐ 82

Thank you for your co-operation.

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