Art. # 1438, 14 pages, https://doi.org/10.15700/saje.v38n1a1438

The impact of language factors on learner achievement in Science

C.H. Prinsloo
Independent Researcher[i]
cashprinsloo@gmail.com
S.C. Rogers
Department of Psychology, University of the Witwatersrand, Johannesburg, South Africa
J.C. Harvey
Education and Skills Development Research Programme, Human Sciences Research Council, Durban, South Africa

South African learner achievement remains poor, despite large investment in schooling over the last two decades. Literature and research findings offer no single explanation or solution. In this article, the authors explored the relative contribution of specific language factors such as the role of home- and school-language equivalence, cultural and economic capital, and other school and classroom factors to Science achievement. The analysis identified specific language and/or contextual factors having the biggest influence on learner achievement. This was achieved through secondary analysis of South African Grade Nine (N = 12,000) data from the Trends in International Mathematics and Science Study (TIMSS) 2011. Multiple-regression modelling using contextual and achievement data suggested that home- and school-language equivalence and how frequently learners used the school language at home were strongly associated with the Science achievement results of Grade Nine learners in South Africa. Several other language factors that could be seen as cultural capital, beyond broader economic capital, some classroom-related contextual conditions and selected school-level factors, also showed strong influences. It is concluded that language, teacher training, and broader economic policy changes and their thorough implementation are required to address these concerns.

Keywords: cultural capital; economic capital; home language; language factors; language of assessment; language of learning; language of teaching; Science achievement; Trends in International Mathematics and Science Study (TIMSS)

Introduction

Many governments prioritise education transformation to escape resource limitations and poverty through an educated workforce achieving economic development. Within South Africa, implemented government initiatives include educational investment, no-fee schools, rural schooling, school infrastructure, and access to curriculum materials, which potentially have broader relevance (Archer, Scherman, Coe & Howie, 2010; Howie, Van Staden, Tshele, Dowse & Zimmerman, 2012). To assess intervention efficacy, large-scale assessments (LSAs) situate learners' academic achievements within environmental factors, especially in interaction with complex educational systems (Caro, Sandoval-Hernández & Lüdtke, 2014). Recent LSAs performed in South Africa have produced useful data to help understand the challenges and options within South Africa and other developing countries. They show that, despite increasing investment in education and some improvement, achievement remains poor among South African learners. In identifying possible contributing issues, language has been purported to be an influential factor, given the political history and multilingual context of South Africa. These concerns, and associated literacy challenges, are reflected in the poor reading achievement of South African learners in both the Annual National Assessments (ANA) and the Progress in International Reading Literacy Study (PIRLS) 2011. Selected language achievement results are cited next in support of the argument that low proficiency in language has been compromising learning across the curriculum.

ANA results (2014) indicated consistent increases in Home Language (HL) scores across Grades 1 to 6 (average between 55% and 65%). However, Grade Nine learner HL achievement increase was moderate at 48%, from 43% in the previous 2012 and 2013 assessments. Low achievement was present in First Additional Language (FAL), where all assessed grades achieved below 50 percent. Notably, Grade Nine learners' achievement (34%) showed no improvement. In Mathematics, in many ways at the basis of mastering Science (Chiu, 2007), Grade Nine learners achieved an average of 11%, with only 3% of learners achieving a mark of 50% or more (Department of Basic Education (DBE), 2014). The overall lower achievement of Grade Nine learners is likely to indicate that learners in later school years are increasingly compromised, and find it difficult to overcome foundational knowledge gaps.

In PIRLS 2011, an international reading comprehension assessment, South African Grade Five learners were assessed in either English or Afrikaans, and not in the nine African languages. Learners in 2011 showed non-significant improvement, compared to 2006 results, and again performed below the International Centre Point (500), achieving an average of 420 points (Howie et al., 2012; Mullis, Martin, Foy & Drucker, 2012). Grade Four learners from South Africa, Botswana, and Colombia also participated in prePIRLS assessments; an easier assessment designed to test developing fundamental reading skills. Assessed in all 11 languages, South African Grade Four learners performed below the International Centre Point in the prePIRLS (Howie et al., 2012; Mullis et al., 2012). The results indicated that South African learners would achieve an estimated 330 points had they taken the PIRLS assessment, below the Low International Benchmark (Mullis et al., 2012). This is similar to how the Grade Five learners performed in PIRLS 2011, despite Grade Four learners being assessed in all African languages, as well as in English and Afrikaans, indicating that language and literacy in South Africa is in need of intervention.

Howie, Venter and Van Staden (2008) attributed the low achievement and progression in reading literacy among South African primary school learners to language-related factors, particularly to the mismatch between current multilingualism policy and practical implementation. The underlying principle of the Language in Education Policy (LiEP) in 1997, later clarified in the Revised National Curriculum Statement (NCS) of 2002 and the Curriculum and Assessment Policy Statement (CAPS) of 2011, is to use the HL of the learner as the Language of Learning and Teaching (LoLT), while simultaneously having a FAL as a subject (DBE, 2010; Du Plessis, 2013). However, many schools use English as the LoLT, regardless. For schools using HL LoLT, a switch to English LoLT tends to occur after three years of instruction in the HL (Howie et al., 2012). Strong international evidence indicates that Grade Six to Eight may be a better transition point from HL LoLT to FAL, as the current convention is too soon for learners to have developed sufficient language skills (Heugh, 2009; Thomas & Collier, 2001; Wildsmith-Cromarty & Gordon, 2009). Many learners therefore struggle to develop their language and literacy skills.

Our argument so far supports sound first and additional language proficiency as key to the conceptual proficiencies required by learners to master all further academic achievement, in particular, the subject of Science. Analysis of the South African TIMSS 2011 results suggests that Science achievement is influenced to a greater extent by background influences than it is Mathematics achievement (Reddy, Prinsloo, Arends, Visser, Winnaar, Feza, Rogers, Janse van Rensburg, Juan, Mthethwa, Ngema & Maja, 2012; Reddy, Rogers, Visser, Winnaar, Janse Van Rensburg, Juan, Feza, Arends, Mthethwa & Prinsloo, 2013[ii]). This may occur because teachers and learners rely more on the instructional language when mastering knowledge and undertaking assessment in Science, whereas Mathematics (Setati, 2005, 2008) relies heavily on the ability to communicate with Mathematics-unique words, phrases, and abbreviations necessary for speaking, reading, and writing. Such highly-structured notation, code, or "language" is arguably less prominent in Science. Based on this argument and the early descriptive and correlational observations in the South African TIMSS report (Reddy et al., 2012; Reddy et al., 2013), Science is considered to be a more text- or language-dependent subject. The focus of the article is thus on the relationship between language proficiency and Science achievement due to the expected greater extent to which a lack of foundational skills would negatively impact learner achievement in a language-based subject.

Language factors in Science can be viewed from two perspectives. In the first, language is part of obtaining scientific literacy. Learners must be taught to read and write scientific texts, as well as to be knowledgeable about and able to understand scientific content (Fung & Yip, 2014; González-Howard & McNeill, 2016). This involves gaining access to the discipline community, in this case Science, as each has inherent knowledge that guides how texts are written, and thus how they must be read (Bharuthram & Clarence, 2015; Rollnick, 2000). The second perspective views language as the "symbolic representation of culture" within the science context (Fung & Yip, 2014:1221) whereby the common sociocultural practices dictate the accepted ways of talking, reading, writing, knowing, and doing (González-Howard & McNeill, 2016). Within South Africa, many textbooks are written from a Western viewpoint, which can shape the use of vocabulary, examples, and phrases that may not be common or easily understood by a learner, or teacher, from an African language background (Rollnick, 2000). However, English is noted to be indispensable for explanation of scientific concepts as well as international scientific communication (Fung & Yip, 2014; Rollnick, 2000). This links with the perception that in South Africa, reinforced by its language history, English proficiency is necessary to become successful (Probyn, 2009). It is likely that English will continue to be the dominant language in Science education, but this poses a formidable task for second-language learners who must master the Western discourse, the Science discourse, the Science content, and the English discourse while learning in English (Fung & Yip, 2014). In order to explore the poor achievement of South African learners, further investigation is required to ascertain the extent of the influence of the HL and the LoLT, and their possible mismatch, on Science achievement of South African learners.

This article thus aimed to explore the relative contribution of language factors (including the specific role of school-[iii] and home-language equivalence), cultural capital, economic capital, and other school and classroom factors on Science achievement, utilising South African TIMSS Grade Nine information. Direct research questions were:

- To what extent does home- and school-language equivalence influence learners' Science achievement?
- Does the influence of other language-based factors related to support, resources or limitations exceed

the effect of home- and school-language equivalence?
- Relative to the foregoing, what is the effect of other contextual factors (cultural capital, economic capital, and school and classroom factors)?

Theoretical Background

Although language factors are the focus, other factors of the South African context must be heeded. While Clegg and Afitska (2011) alert educators in Sub-Saharan African classrooms to the poor school achievement resulting from teaching and learning through a European language, they also emphasise the developing-country context where systems and resources are not well-developed, and may be further to blame for poor achievement. For this article, factors were categorised into either cultural or economic capital factors, in addition to some school and classroom observations. Analysis has been limited to these constructs due to their availability in the TIMSS data, and in alignment with Bourdieu (1983, as cited in Caro et al., 2014). The authors acknowledge that analyses of large-scale data and the intertwined nature of economic and cultural capital have been pursued in studies from other countries. However, the language focus of this article requires the isolation of variables of interest, those related to the influence of language rather than socio-economic status (SES), from conventional cultural and economic capital constructs or scales. Below, cultural and economic capital as well as selected classroom and school factors are discussed, in order to define these concepts and relate, as well as to separate them from the particular language factors of interest to the article.

Bourdieu (1983, as cited in Caro et al., 2014) believes that "the educational performance of students depends on the amount and composition of different forms of capital and on the extent to which these satisfy the symbolic requisites of the dominant culture legitimated by the education system" (Caro et al., 2014:436). Cultural capital within Bourdieu's theory looks at how the family environment and processes impact learner outcomes, but also satisfies the dominant culture symbolised in the present education system. Therefore, cultural capital includes goods of an educational nature and cultural objects, which include the number of books in the home, access to computers and the internet, and the highest level of qualification held by parents (Caro et al., 2014). These factors are considered to be the language contributors in this article. Bourdieu (1983, as cited in Caro et al., 2014) defines economic capital as those economic resources that can easily be transformed into money, including income and consumer goods, such as household income, SES and assets. The assumption is that economic capital and household resources create favourable conditions that support the cognitive development of learners and therefore educational achievement. Although parental education is accepted above as a form of cultural capital, it could be seen to contribute much to a family's economic capital. However, treating it as suggested better served the purpose of this paper. Low economic capital (poverty and low SES) is often offered as an important blanket explanation for low-achievement results. Timæus, Simelane and Letsoalo (2013), on the basis of national income data collected in South Africa in 2008, identified household poverty and low maternal qualification levels as being of particular importance in explaining learners' school attainment. The latter was operationalised through school enrolment, progress, and outcomes data (Timæus et al., 2013). Although this powerful effect is not denied, and these authors still included maternal qualification in their economic capital construct, the current article isolates the language-related economic capital sub-variables.

Frempong, Reddy and Kanjee (2011) explored the relationship between socio-economic conditions and school quality using multi-level statistical approaches and weighted data from a systemic survey of achievement among a large random stratified national sample of Grade Six learners in 2004. Results indicated that schools produce additional effects beyond learners' socio-economic background, i.e. the correlation between school-level SES and achievement scores was only prominent in schools where there were already high achievement levels (Frempong et al., 2011). In view of this, analyses factored in possible school and classroom factors while developing the regression models.

South African learner achievement has remained poor, despite various proposed explanations and solutions. Continuation of the present situation disallows many learners access to sound educational foundations and cognitive development. We argue that it is essential to determine the relative importance of factors related to the equivalence between home and school languages, specific language support variables isolated from broader cultural and economic capital factors, remaining cultural and economic capital (poverty and/or SES) factors, and school and classroom factors in South Africa. If we wanted to improve learner achievement, the order of priority among such factors has to be determined and known in order to help focus interventions and make decisions about how to improve policies and budgetary allocations.

Methodology

Secondary analysis was conducted on South African TIMSS 2011 country data, retaining the complex design features produced by the International Association for the Evaluation of Educational Achievement (IEA). Although other datasets may be available to underpin deeper analyses and comparisons, TIMSS data allow exploring relative language-in-education effects without adding confounding variables, and is therefore able to answer the research questions. The article contributes to the debate by focusing on language, cultural capital, and economic capital components deeply enmeshed in a complex and transforming education system. Further nuanced trend and comparative analyses will later be possible once the TIMSS 2015 data become available.

All three research questions were analysed using multiple regression modelling as statistical procedure. Other procedures or techniques mentioned, such as principal component analysis, recoding, creating indices, and merging sub-datasets, only served to prepare the data for modelling.

Data

The Data Processing Centre (DPC) of IEA released TIMSS 2011 data using its International Database (IDB) Analyser. This article focused on South African learner-level data, namely: Science achievement scores (standardised to a scale with a mid-point of 500 and a standard deviation of 100) and contextual information. The latter utilised two sources: IEA's socio-economic index, and additional items only administered in South Africa.

Sample

Education in South African public schools comprises four three-year phases. The first three phases comprise compulsory basic education termed General Education and Training (GET). Schooling can then be continued within the phase Further Education and Training (FET), either within schools from Grade 10 to Grade 12, or at technical, vocational or other training colleges. Learners begin their academic trajectory in the Foundation Phase (FP: Grades One to Three) following one compulsory reception year (Grade R). An integrated curriculum is followed and covers the home language, a first additional language, numeracy and life skills. Over the subsequent two phases, the Intermediate Phase (IP: Grades Four to Six) and the Senior Phase (SP: Grades Seven to Nine), where each covers 27.5 hours per week, and learners study different subjects as taught by specialised teachers. In the Senior Phase, these subjects include Home Language, First Additional Language, Mathematics, Natural Sciences, Technology, Social Sciences, Economic and Management Sciences, Life Orientation, and Creative Arts. Whereas Natural Sciences and Technology is a single subject taught over 3.5 hours per week in IP, it is separated into Natural Sciences (three hours per week) and Technology (two hours per week) in SP. Natural Science as a subject is divided into four strands, being Life and Living, Matter and Materials, Earth and Beyond, and Energy and Change, each with its relevant subtopics (DBE, 2011).

TIMSS was administered during August 2011 with 11,969 Grade Nine learners in 285 schools. Grade Nine learners, rather than the international Grade Eight focus, participated to avoid floor effects and ensure greater achievement-score variance. Instruments included Mathematics and Science achievement items, and related background questions.[iv] The sample was stratified by province (nine provinces), language of instruction (English, Afrikaans and dual medium) and school type (public schools, public schools in the Dinaledi Mathematics support programme, and independent schools).

Schools were randomly selected with probability equal to their proportion in the sample frame. A minimum of 30 schools was set for small categories (within school type and language of instruction) to ensure sufficient numbers. Intact classes were selected randomly during a second sampling stage.

Method

In the first stage of the conceptual strategy followed, four sets of factors at learner level were identified for use in the statistical modelling using regression analysis. They comprised: (a) equivalence between learners' home and school languages; (b) additional items that relate to learner's exposure to the school language; (c) factors listed as (remaining) cultural capital items; and (d) broader economic conditions related to living standards defined as economic capital. At a second stage, language-related school-level variables were added to the accepted learner-level model. Thirdly, language-related classroom-level variables were similarly modelled to the foregoing. A final adjustment was undertaken in the fourth stage.

Procedures

Variables selected for the article

Variables of interest were identified from available TIMSS data. Variables not in the appropriate format for modelling were recoded, or otherwise transformed, or combined in advance. A description of the variables selected all along for modelling and analysis appears in Appendix A.

The article theory and conceptualisation required unbundling of the conventional home-background factors related to SES, as indexed in IEA's BSBGHER variable, into individual items to isolate language, other cultural, and economic characteristics. Principal Component Analysis (PCA)[v] was used. Varimax rotation (with Kaizer normalisation), capping iterations at 25, and applying the critical Eigenvalue of 1 were used. Items were recoded to allow elimination of records with missing values, and to zero the basis point of items and scales. Certain material socio-economic household commodities (e.g. electricity; tapped water) were therefore distinguished from those related to language exposure (e.g. Internet access; dictionary). The latter items assume language-based interaction through listening, reading and/or writing. Additional variables unique to South Africa were home and school language equivalence, the number of books at home, the highest parent/caregiver qualification level, and the frequency with which learners spoke the school language at home.

In the process, new language-related cultural capital and economic capital item groups (constructs) were created on the basis of conceptual thinking. At the learner level, the input model contained the following components identified for language-related cultural capital: having more than 25 books, a computer, internet connection, a dictionary, and television in the home. Four characteristics were retained: the presence of a computer, internet connection, a dictionary, and television in the home (extraction loadings 0.47, 0.47, 0.39, and 0.33, respectively; 41.4% variance explained; 0.53 Cronbach's Alpha reliability coefficient). Although another solution producing two components explained 56% of the variance, it was difficult to interpret as more than 25 books and television in the home loaded on both components. Furthermore, the number of books at home loaded positively on one component and negatively on the other, and was therefore removed from the index.

Determining likely items for an index of learners' economic capital at home was pursued similarly. Input variables were the extent to which learners had a desk, their own room, a bicycle, electricity, running tap water, water-flushed toilets, a car, and a fridge at home. The latter five variables were confirmed as conditions best reflecting material wealth (extraction loadings 0.69, 0.68, 0.68, 0.49, and 0.70, respectively; 42.75% variance explained; 0.64 Cronbach's alpha reliability coefficient). As economic capital can purchase other forms of capital, such as social and cultural capital and greater language exposure, effects may be confounded. The modelling, however, intended to identify the relative contribution of different constructs.

At school level, school type was used as a control variable. A South African stratification variable, this served as a proxy for SES at school level as independent schools are better resourced than public schools. The IEA index reflecting the extent to which Science teaching resource material shortages (BCBSRS) influenced Science instruction, as rated by school principals, was also modelled.

Input variables at classroom level included Science teachers' ratings of the following as compromising to their classroom teaching: teaching materials and supplies availability; learners' lack of prerequisite knowledge/skills; and the use of selected teaching resources as the basis for teaching. Teaching resources included: textbooks; workbooks/worksheets; science equipment/ materials; computer software; and reference materials. Furthermore, the teacher-rated proportion of learners who found it difficult to follow school language (BTBG12 and BTBG13) was explored.

Statistical analysis approach

Only the statistics and tables from the first learner-level model, subsequent school- and classroom-level additions, and the final multiple regression model are reported. The details and sequence of individual variables inserted and removed and outcomes achieved are reported in the findings section to avoid repetition. The standard or generic formula used during the multiple regression analysis followed the following format:

$$y = b + bx_1 + bx_2 + bx_3 + \ldots + r$$

where:

y = Overall Science Achievement (dependent variable; estimated from five plausible values (PVs); BSSSCI01-05)
b = Intercept
x_1 = First analysis or independent variable (e.g., Home and School Language Equivalence)
x_2 = Second analysis or independent variable (e.g., Language-related Cultural Capital Index)
x_3 = Third analysis or independent variable (e.g., Economic Capital Index)
r = Error term

Analysis variables served as control variables for each other. The large learner sample allowed omitting cases with missing data through listwise deletion.

Results

First Level of Modeling – Learner Contextual Level

Three explorations were made towards defining a learner-level working model with which to start. They all comprised determining the relative predictive contribution of selected individual variables of interest, compared to intact indices. Each exploration explained 40% (*SE* = 0.02) of the Science score variance (R^2, adjusted) despite continued variable omission, confirming robustness and parsimony concerning the factors retained. The fourth refinement (Table 1) constituted the model best explaining learner-level outcomes, and served as entry model towards determining any additional impact of classroom- and school-level factors. It explained 40% (*SE* = 0.02) of the variance in Science scores. The two critical language variables (studying and being assessed in one's home language; regular use of school language at home) were still strongly supported (standard coefficients of 0.17 for both). Henceforth, during model iterations, individual factors were not retained unless contributions were statistically significant ($p = < 0.95$; t-value < 1.96).

Table 1 Final model explaining the relative contribution to Science achievement scores by learner-level background factors

	Regression coefficient			Standard coefficient		
Variable	Coefficient	*SE*	*t*-value	Coefficient	*SE*	*t*-value
Constant	210.42	6.22	33.81	-	-	-
School and home language equivalence	50.96	6.97	7.32	0.17	0.02	7.56
How often school language used home	43.01	5.23	8.22	0.17	0.02	8.18
Number of books at home	21.90	3.07	7.14	0.08	0.01	7.21
Highest education of either parent	23.36	3.73	6.25	0.10	0.02	6.59
Electricity at home	25.87	7.28	3.56	0.07	0.02	3.14
Running tap water at home	30.77	3.66	8.40	0.12	0.01	8.34
Water-flushed toilet at home	26.14	5.80	4.51	0.11	0.03	4.52
Motor car at home	12.93	4.00	3.23	0.06	0.02	3.25
Fridge at home	14.74	6.67	2.21	0.04	0.02	2.20
Internet connection at home	25.80	3.69	7.00	0.11	0.02	7.16
Dictionary at home	25.55	4.38	5.83	0.09	0.02	5.79

Second Level of Modelling – School Environment

Additional levels were added to the above learner-level model: school- and classroom-level. In the former, school type and the school principal rating of the impact of available Science resources (as per the IEA index) were included. The model explained 40% (*SE* = 0.02) of the variance in Science scores (Table 2). Independent school attendance predicted greater Science scores (72 points). However, the adequacy of Science resource materials was not significantly related. The contribution of all the learner-level factors remained largely as before, including the two critical language variables (see first exploration).

Table 2 Model explaining relative contribution to Science achievement scores by learner-level and school-level background factors

	Regression coefficient			Standard coefficient		
Variable	Coefficient	*SE*	*t*-value	Coefficient	*SE*	*t*-value
Constant	209.93	10.34	20.30	-	-	-
Home-level factors and conditions						
School and home language equivalence	50.99	7.39	6.90	0.17	0.02	7.08
How often school language used home	41.83	5.51	7.59	0.17	0.02	7.56
Number of books at home	18.80	3.08	6.10	0.07	0.01	6.14
Highest education of either parent	20.08	3.99	5.03	0.09	0.02	5.21
Electricity at home	26.25	7.34	3.57	0.07	0.02	3.16
Running tap water at home	30.58	3.78	8.10	0.12	0.01	8.13
Water-flushed toilet at home	25.48	5.92	4.31	0.11	0.03	4.31
Motor car at home	9.93	4.22	2.35	0.04	0.02	2.36
Fridge at home	15.59	6.72	2.32	0.05	0.02	2.30
Internet connection at home	22.84	3.45	6.62	0.10	0.01	6.71
Dictionary at home	25.35	4.39	5.77	0.09	0.02	5.75
School-level factors and conditions						
School type (Independent)	72.17	13.64	5.29	0.12	0.02	5.14
Resource shortages on instruction	1.64	8.83	0.19	0.00	0.02	0.19

Third Level of Modelling – Classroom Environment

At the classroom level, eight variables from the Science teacher background questionnaire were identified. The model explained 42% (*SE* = 0.02) of the variance in Science scores (Table 3). The contribution of attending an independent school (school-level variable) remained strong, although marginally decreased. Two teacher-level variables (adequacy of instructional Science materials and supplies; adequate foundational knowledge) predict slight increases in Science scores. The model otherwise remained largely as before. The latter two levels of modelling confirmed the robustness of the fourth learner-level model to the addition or elimination of variables.

Final Model

To eliminate further redundancies in the model, two adjustments were made. First, variables with non-significant effects were eliminated, explaining 42% (*SE* = 0.02) of the variance in Science scores (Table 4). A learner with a very low Science score (< 200 points) can achieve above the average (approaching 600 points) if she is able to harness the effect of four sets of underpinning factors, each linked to approximately a 100-point increment. These 100-point “sets” entail:

- studying in one’s home language (52.47) and speaking the school language at home (42.80);
- exposure to language-related cultural capital at home, i.e. internet (23.59), dictionary (24.45), more

than 25 books (18.65), and a parent/caregiver with formal schooling beyond Grade 12 (20.73);
- benefitting from economic wealth, i.e. living in a house with electricity (22.23), running water (30.94), water-flushed toilets (26.13), and a fridge (19.16); and,
- well-resourced school attendance, i.e. an independent school (64.00), adequate foundational knowledge (11.99), and intact instructional materials (20.04).

The second adjustment, not reported on, tested the effect of removing the remaining school-level variable (school type). A slight reduction occurred in the explained variance of Science scores (40%; *SE* = 0.02), along with small increases in the estimated contributions of individual remaining components.

Table 3 Model explaining relative contribution to Science achievement scores by learner-, school- and teacher-level background factors

	Regression coefficient			Standard coefficient		
Variable	Coefficient	*SE*	*t*-value	Coefficient	*SE*	*t*-value
Constant	196.66	11.58	16.99	-	-	-
Home-level factors and conditions						
School and home language equivalence	51.17	8.33	6.14	0.17	0.03	6.27
How often school language used home	41.43	5.78	7.17	0.16	0.02	7.17
Number of books at home	17.67	3.39	5.22	0.07	0.01	5.26
Highest education of either parent	19.02	3.81	4.99	0.08	0.02	5.14
Electricity at home	22.59	7.28	3.10	0.06	0.02	2.78
Running tap water at home	30.95	3.90	7.95	0.12	0.01	8.08
Water-flushed toilet at home	23.63	5.97	3.96	0.10	0.03	4.01
Motor car at home	8.57	4.48	1.91	0.04	0.02	1.91
Fridge at home	18.16	6.75	2.69	0.06	0.02	2.64
Internet connection at home	21.54	3.57	6.04	0.09	0.01	6.18
Dictionary at home	23.43	4.51	5.19	0.09	0.02	5.20
School-level factors and conditions						
School type (Independent)	62.65	12.13	5.17	0.10	0.02	5.04
Resource shortages on instruction	-1.26	9.87	-0.13	0.00	0.03	-0.13
Teacher- or classroom-level factors and conditions (helping/limiting instruction)						
Adequate instructional materials	19.41	4.59	4.23	0.08	0.02	4.23
Learner knowledge foundations	13.34	5.81	2.30	0.06	0.02	2.29
Textbooks: teaching basis	-6.45	6.35	-1.01	-0.03	0.03	-1.02
Workbooks/sheets: teaching basis	6.48	6.54	0.99	0.03	0.03	0.99
Equipment/material: teaching basis	9.84	7.15	1.37	0.04	0.03	1.33
Computer software: teaching basis	1.07	50.60	0.02	0.00	0.06	0.03
Reference material: teaching basis	-12.56	12.06	-1.04	-0.04	0.03	-1.04

Table 4 Final model explaining the relative contribution to Science achievement scores by learner-, school- and teacher-level background factors

	Regression coefficient			Standard coefficient		
Variable	Coefficient	*SE*	*t*-value	Coefficient	*SE*	*t*-value
Constant	193.70	6.81	28.45	-	-	-
Home-level factors and conditions						
School and home language equivalence	52.47	7.24	7.25	0.17	0.02	7.40
How often school language used home	42.80	5.67	7.55	0.17	0.02	7.55
Number of books at home	18.65	3.60	5.19	0.07	0.01	5.24
Highest education of either parent	20.73	3.59	5.78	0.09	0.01	6.05
Electricity at home	22.23	7.56	2.94	0.06	0.02	2.63
Running tap water at home	30.94	3.89	7.95	0.12	0.01	8.12
Water-flushed toilet at home	26.13	6.15	4.25	0.11	0.03	4.29
Fridge at home	19.16	6.47	2.96	0.06	0.02	2.91
Internet connection at home	23.59	3.78	6.24	0.10	0.02	6.40
Dictionary at home	24.45	4.61	5.31	0.09	0.02	5.32
School-level factors and conditions						
School type (Independent)	64.00	10.49	6.10	0.11	0.02	5.91
Teacher- or classroom-level factors and conditions (helping/limiting instruction)						
Adequate instructional materials	20.04	4.70	4.27	0.08	0.02	4.27
Learner knowledge foundations	11.99	6.56	1.83	0.05	0.03	1.82

Discussion

Despite sound transformation progress in South African education, both national and international LSAs indicate poor learner achievement. Important contributors are language proficiency and literacy. South Africa's complex political and educational history has obscured the school language issue further, particularly the influence of the alignment between the HL of the learner and the LoLT of the school. The unique blend of South African school language constraints likely masks comparable dynamics elsewhere in Africa and the world.

Science has been indicated as particularly susceptible to this influence. This article explored the relative effect of predictors related to specific structural LoLT conditions, other language-related cultural capital, and conventional economic capital on learners' Science achievement. Through modelling using the South African TIMSS 2011 dataset, the effect of language-related variables at learner, school, and classroom levels could be compared.

More than half the overall effect on Science scores was attributed to language and language-related cultural capital (see discussion of Table 4), even beyond learners' attendance of well-resourced schools and/or being from privileged homes. Home-language and school-language equivalence accounted for the greatest impact, followed by often speaking the LoLT at home. These factors accounted for a greater impact than home economic factors such as electricity, tapped water, and flushed toilets. Therefore, learners whose conceptual thinking, language proficiency and/or exposure to the school language at home are closely aligned to language demands posed by textbooks, other teaching materials, daily learning and teaching; and as a result, assessment will flourish academically. This would enable learners to internalise and apply the benefits of their formal learning to their broader lives.

Education language policies aim to foster simultaneous learner HL and additional language acquisition, resulting in bilingualism and biliteracy. However, practical policy implementation lacks efficacy and is hotly debated while learners continue achieving poorly. Briefly, the perceived greater economic benefit of English misleads African HL parents and schools into choices that do not benefit learners (Pretorius & Mampuru, 2007). Their decisions aim to foster early English acquisition but in actuality, compromise the foundation of academic achievement – HL literacy (Lafon, 2009, 2013; Webb, 1999, 2004). Most African HL learners, even in schools using an African LoLT early on, are required to switch to English instruction before developing sufficient proficiency in either the HL or the additional language. These learners therefore continue to struggle throughout their academic trajectory.

Systemic, even statutory, HL-LoLT misalignment would underpin the underdevelopment of sound language and literacy skills necessary for further academic studies. Cummins (2008) draws a distinction between Basic Interpersonal Communicative Skills (BICS) and Cognitive Academic Language Proficiency (CALP). For a given language, BICS is related to the daily conversation skills, whereas CALP refers to the skills needed in higher education academic studies. In order to develop CALP, the learner needs instruction in their HL for at least six to eight years (Cummins, 2008; Sebolai, 2016; Wildsmith-Cromarty, 2012). Learners who are instructed in an additional language, either from the first grade or from the fourth, fall further and further behind in CALP skills, compared to their HL-taught counterparts. As this type of literacy is fundamental to grasping concepts in other subjects, such as Science, this provides a plausible explanation for low achievement results.

The early entry into an English medium of instruction is also problematic, due to the teaching approach taken towards decoding and comprehension skills. During the Foundation Phase (FP; Grades 1–3), much attention is paid to teaching decoding skills. However, the manner of instruction is "often done in a superficial, haphazard and decontextualised way" (Pretorius & Currin, 2010; Zimmerman & Smit, 2014:1). Therefore, the learner may struggle with simple decoding even after entry into Intermediate Phase (IP; Grades Four to Seven). Teachers also assume that once decoding is mastered, comprehension automatically follows. Teachers thus do not focus on teaching reading comprehension, which requires specialised skills. This results in failure of the learner to smoothly transition between decoding to reading meaningfully, if at all (Pretorius & Currin, 2010; Zimmerman & Smit, 2014). Together, this indicates that the basics of decoding or comprehension in the HL may not be in place at the time, from Grade Four onwards, where the learner is expected to transfer these skills to English and read and learn in their additional language. This further reduces the ability of the learner to master CALP skills, subject content knowledge, and various other cognitive and metacognitive strategies (Zimmerman & Smit, 2014).

Many schools are inadequately funded, poorly resourced, and their teachers have insufficient training (Rollnick, 2000; Wildsmith-Cromarty, 2012). This compounds the above difficulties and also brings into focus the many curriculum changes over the previous two decades. Not only has this resulted in confusion regarding the contents of the curriculum and how best to teach it, but it also lowers the motivation of the teacher. We therefore argue that an already strained teaching and learning experience for learners is further hampered by non-optimal classroom and school conditions.

Given the observed positive influence of HL and LoLT equivalence on Science achievement scores, our results confirm that language proficiency in the medium of instruction is necessary for successful academic achievement. Although the additional beneficial influences of bilingualism and multilingualism on learner achievement are noted (Rollnick, 2000) and not elaborated upon further in this article, LoLT proficiency must be intact.

Recommendations

At the learner level, firstly, practical implementation of language policy in the classroom should extend teaching in HL to six to eight years, with English as an additional subject throughout. The authors recommend that literacy teaching in the FP, particularly comprehension skills, receive more focus so as to foster additive bilingualism. Necessary systemic changes are discussed below, but it is noted here that the bias against African languages can and should be altered at the learner level. Changing from a deficit mindset, where only English is set in a position of power and prestige, to one of valuing all languages, is not only in keeping with the constitution (Republic of South Africa, 1996), but will also improve learner wellbeing. It will also place the ability to speak an African language at the same level as English or Afrikaans, with regards to cultural capital. Thirdly, parents should be assisted with strengthening their economic capital in order to purchase educational opportunities outside those afforded by the public school system. Holistically, further implications and recommendations must also be made in relation to the larger systemic context, discussed next at school, teacher, and community levels.

At the school level, adjustments in learning and teaching practices could include greater attention to language resources and maintenance (Heugh, 2014), as well as longer exposure to sound HL instruction. Strong second-language exposure has to be effected for sound and strong parallel language development. In sum, optimal equivalence between home and school languages ought to be achieved for all learners, regardless of background. All above recommendations rely on efficient implementation of the LiEP, the resources to hire effective teachers, and the deployment of those teachers in all schools, as well as availability of library and text resources in all home languages in all schools. This further entails a closer look at the involvement and capacity of parents at schools, the training, capacity and quality of teachers, the resourcing allocated to education in the early grades, and available resources in all languages (e.g. readers). This should be in conjunction with the further development of teaching resources and methods related to the African languages; the most effective means of teaching English does not necessarily 'translate into' the most effective means of teaching other languages. Optimal learning can then be pursued through improved school and teaching quality, including school, curriculum, and materials management and provision.

At teacher level, the education ministry will be required to improve teacher training in language education, curriculum and assessment management and practices, learning materials provision, and language in education policy implementation. In addition, Clegg and Afitska (2011) recommend that teachers ought to be taught how to adjust their management of bilingualism in the context of the effective use of code switching and translanguaging in order to bridge the gap between HL and LoLT. Code-switching refers to using the HL within the classroom for key subject-content explanations, rather than the additional-language LoLT (Probyn, 2001, 2009; Rollnick, 2000), and translanguaging comprises the multiple ways in which all available language resources contributed by teachers and learners can be used in complex classroom encounters (Evans & Cleghorn, 2012; Wildsmith-Cromarty, 2012; Wildsmith-Cromarty & Gordon, 2009). An example of good classroom practice is tailoring assessment to learners' home and school language combinations, for instance, by using word glossaries or bi-linear texts (Heugh, Diedericks, Prinsloo, Herbst & Winnaar, 2007). Concretely, these recommendations imply that learners ought to be instructed and assessed in a language in which they are competent.

At community level, attention should be paid to: good lighting, electricity, work spaces, a hygienic and attractive environment; mobility and access to retrieving support materials from libraries or the internet; basic reference and reading materials at home; and parents or caregivers who are literate and who read, are informed, qualified up to school-exit level, and are able to speak the children's home and school languages well enough to provide support with their home and school work. There should also be efforts made to proliferate community centres and libraries, and adult literacy programmes in support of this.

Conclusion

In sum, provincial and district education officials, parents and other community leaders should study and understand the diverse language situations of learners and communities. This should be followed by deliberate arrangements by schools and options to learners that would allow alignment between the school- and home-language situations, as well as with the proficiency levels of families and learners. The article's findings are considered important not only because they are based on the data from a reputable international study, but also because it speaks to complex language situations such as those encountered in South African schools. No simple relationships exist between teaching and home languages, poverty, and related language conditions and their effects, but this article found important answers about their relative contributions. Further research is needed to address finer distinctions in relation to school-level SES, teacher proficiency and learner motivation to study Science.

Necessary compromises had to be made by unbundling well-conceptualised overall indices created by the IEA. Imprecisions that may have entered this way deserve further study, although they were accommodated in this study as best as theoretically and conceptually possible. Greater availability of teacher-level data on pedagogical and didactic knowledge and practice in the classroom would have enhanced the analyses. The findings may not be generalisable to homogenous or small school systems in countries with populations that are largely monolingual and/or highly proficient in the school language.

Acknowledgements

The South African Department of Basic Education for funding the study and providing access to schools. Dr Vijay Reddy, Principal Investigator and National Research Coordinator of TIMSS South Africa. The HSRC TIMSS team, especially those responsible for the data collection and processing.

Notes

i. Author was affiliated with the Human Sciences Research Council (HSRC) at the time of writing and submitting the article.
ii. An unpublished working document with technical analyses was created. Therefore, although full analyses were performed, only a summary version in the form of a SA highlights report was published.
iii. School language is consistently used to denote instructional language or LoLT (language of learning and teaching).
iv. The Research Ethics Committee of the HSRC provided ethics clearance for the study. All regular informed consent procedures were followed subsequently.
v. In the discussions and reporting that follow, the results from PCA are not reported in detail or in individual tables.
vi. Published under a Creative Commons Attribution Licence

References

Archer E, Scherman V, Coe R & Howie SJ 2010. Finding the best fit: The adaptation and translation of the performance indicators for primary schools for the South African context. *Perspectives in Education*, 28(1):77–88.

Bharuthram S & Clarence S 2015. Teaching academic reading as a disciplinary knowledge practice in higher education. *South African Journal of Higher Education*, 29(2):42–55.

Caro DH, Sandoval-Hernández A & Lüdtke O 2014. Cultural, social, and economic capital constructs in international assessments: An evaluation using exploratory structural equation modeling. *School Effectiveness and School Improvement*, 25(3):433–450. https://doi.org/10.1080/09243453.2013.812568

Clegg J & Afitska O 2011. Teaching and learning in two languages in African classrooms. *Comparative Education*, 47(1):61–77. https://doi.org/10.1080/03050068.2011.541677

Chiu MS 2007. Mathematics as mother/basis of science in affect: Analysis of TIMSS 2003 data. In JH Woo, HC Lew, KS Park & DY Seo (eds). *Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2). Seoul, Korea: PME.

Cummins J 2008. BICS and CALP: Empirical and theoretical status of the distinction. In B Street & NH Hornberger (eds). *Encyclopedia of Language and Education* (2nd ed., Vol. 2). New York, NY: Springer. https://doi.org/10.1007/978-0-387-30424-3_36

Department of Basic Education (DBE), Republic of South Africa 2010. *The status of the language of learning and teaching (LOLT) in South African public schools: A quantitative overview*. Pretoria: Author. Available at https://nicspaull.files.wordpress.com/2011/04/doe-2010-lolt_report.pdf. Accessed 11 September 2017.

DBE 2011. *National Curriculum Statement (NCS): Curriculum and Assessment Policy Statement Senior Phase Grades 7-9: Natural Sciences*. Pretoria: Author.

DBE, Republic of South Africa 2014. *Report on the Annual National Assessment of 2014: Grades 1 to 6 and 9*. Pretoria: Author. Available at http://www.saqa.org.za/docs/rep_annual/2014/REPORT%20ON%20THE%20ANA%20OF%202014.pdf. Accessed 10 September 2017.

Du Plessis E 2013. *Introduction to CAPS*. Available at https://www.education3sixty.co.za/wps/wcm/connect/multiplyedu/c1f2fa92-0f3b-4972-8d24-db27bc7cda44/Introductiont+to+CAPS.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=c1f2fa92-0f3b-4972-8d24-db27bc7cda44. Accessed 16 June 2016.

Evans R & Cleghorn A 2012. *Complex classroom encounters: A South African perspective*. Rotterdam, The Netherlands: Sense.

Foy P, Arora A & Stanco GM (eds.) 2013. *TIMSS 2011 user guide for the international database: Percent correct statistics for the released items. Science - eighth grade*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA). Available at https://timssandpirls.bc.edu/timss2011/international-database.html. Accessed 2 October 2017.

Frempong G, Reddy V & Kanjee A 2011. Exploring equity and quality education in South Africa using multilevel models. *Compare: A Journal of Comparative and International Education*, 41(6):819–835. https://doi.org/10.1080/03057925.2011.607488

Fung D & Yip V 2014. The effects of the medium of instruction in certificate-level physics on achievement and motivation to learn. *Journal of Research in Science Teaching*, 51(10):1219–1245. https://doi.org/10.1002/tea.21174

González-Howard M & McNeill KL 2016. Learning in a community of practice: Factors impacting English-learning students' engagement in scientific argumentation. *Journal of Research in Science Teaching*, 53(4):527–553. https://doi.org/10.1002/tea.21310

Heugh K 2009. Into the cauldron: An interplay of indigenous and globalised knowledge with strong and weak notions of literacy and language education in Ethiopia and South Africa. *Language*

Matters, 40(2):166–189. https://doi.org/10.1080/10228190903188559
Heugh K 2014. Language contact and languaging. In Z Bock & G Mheta (eds). *Language, society and communication: An introduction*. Pretoria, South Africa: Van Schaik.
Heugh K, Diedericks GAM, Prinsloo CH, Herbst DL & Winnaar L 2007. *Assessment of the language and mathematics skills of grade 8 learners in the Western Cape in 2006*. Pretoria, South Africa: Human Sciences Research Council (HSRC).
Howie S, Van Staden S, Tshele M, Dowse C & Zimmerman L 2012. *PIRLS 2011: South African children's reading literacy achievement*. Pretoria, South Africa: Centre for Evaluation and Assessment, University of Pretoria. Available at http://www.up.ac.za/media/shared/Legacy/sitefiles/file/publications/2013/pirls_2011_report_12_dec.pdf. Accessed 14 June 2016.
Howie S, Venter E & Van Staden S 2008. The effect of multilingual policies on performance and progression in reading literacy in South African primary schools. *Educational Research and Evaluation*, 14(6):551–560. https://doi.org/10.1080/13803610802576775
Lafon M 2009. T*he impact of language on educational access in South Africa* (Research Monograph no. 24). Brighton, UK: Sussex University Press. Available at http://srodev.sussex.ac.uk/2313/1/PTA24.pdf. Accessed 6 July 2016.
Lafon M 2013. The other side of the story. Colonial politics still shape attitudes to language use in school in Africa. Contrast between South Africa and Mozambique. In F Laroussi & F Liénard (eds). *Language policy education and multilingualism in Mayotte*. Limoges, France: Lambert-Lucas. Available at https://halshs.archives-ouvertes.fr/halshs-00905803/document. Accessed 13 September 2017.
Mullis IVS, Martin MO, Foy P & Drucker KT 2012. *PIRLS 2011 international results in reading*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College/Amsterdam, The Netherlands: International Association for the Evaluation of Educational Achievement (IEA). Available at https://timssandpirls.bc.edu/pirls2011/downloads/P11_IR_FullBook.pdf. Accessed 6 June 2016.
Pretorius EJ & Currin S 2010. Do the rich get richer and the poor poorer?: The effects of an intervention programme on reading in the home and school language in a high poverty multilingual context. *International Journal of Educational Development*, 30(1):67–76. https://doi.org/10.1016/j.ijedudev.2009.06.001
Pretorius EJ & Mampuru DM 2007. Playing football without a ball: Language, reading and academic performance in a high-poverty school. *Journal of Research in Reading*, 30(1):38–58. https://doi.org/10.1111/j.1467-9817.2006.00333.x
Probyn M 2001. Teachers voices: Teachers reflections on learning and teaching through the medium of English as an additional language in South Africa. *International Journal of Bilingual Education and Bilingualism*, 4(4):249–266. https://doi.org/10.1080/13670050108667731
Probyn M 2009. 'Smuggling the vernacular into the classroom': Conflicts and tensions in classroom codeswitching in township/rural schools in South Africa. *International Journal of Bilingual Education and Bilingualism*, 12(2):123–136. https://doi.org/10.1080/13670050802153137
Reddy V, Prinsloo C, Arends F, Visser M, Winnaar L, Feza N, Rogers S, Janse van Rensburg D, Juan A, Mthethwa M, Ngema M & Maja M 2012. *Highlights from TIMSS 2011: The South African perspective*. Pretoria, South Africa: Human Sciences Research Council (HSRC). Available at http://www.hsrc.ac.za/uploads/pageContent/2929/TIMSSHighlights2012Dec7final.pdf. Accessed 14 June 2016.
Reddy V, Rogers S, Visser M, Winnaar L, Janse Van Rensburg D, Juan A, Feza N, Arends F, Mthethwa M & Prinsloo C 2013. *Mathematics and Science achievement towards excellence and equity in South Africa* (SA TIMSS 2011 Unpublished Technical Report). Pretoria, South Africa: Human Sciences Research Council.
Republic of South Africa 1996. Constitution of the Republic of South Africa, Act No. 108 of 1996. *Government Gazette*, 378(17678). Cape Town: Government Printer. Available at https://www.gov.za/sites/www.gov.za/files/Act108of1996s.pdf. Accessed 14 June 2016.
Rollnick M 2000. Current issues and perspectives on second language learning of science. *Studies in Science Education*, 35(1):93–121. https://doi.org/10.1080/03057260008560156
Sebolai K 2016. Distinguishing between English proficiency and academic literacy in English. *Language Matters*, 47(1):45–60. https://doi.org/10.1080/10228195.2015.1124281
Setati M 2005. Teaching mathematics in a primary multilingual classroom. *Journal of Research in Mathematics Education*, 36(5):447–466.
Setati M 2008. Access to mathematics versus access to the language of power: The struggle in multilingual mathematics classrooms. *South African Journal of Education*, 28(1):103–116. Available at http://www.sajournalofeducation.co.za/index.php/saje/article/view/150/99. Accessed 25 August 2017.
Thomas WP & Collier VP 2001. *A National study of school effectiveness for language minority students' long-term academic achievement*. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.218.7013&rep=rep1&type=pdf. Accessed 6 June 2016.
Timæus IM, Simelane S & Letsoalo T 2013. Poverty, race, and children's progress at school in South Africa. *Journal of Development Studies*, 49(2):270–284. https://doi.org/10.1080/00220388.2012.693168
Webb V 1999. Multilingualism in democratic South Africa: The over-estimation of language policy. *International Journal of Educational Development*, 19(4–5):351–366. https://doi.org/10.1016/S0738-0593(99)00033-4
Webb V 2004. African languages as media of instruction in South Africa: Stating the case. *Language Problems and Language Planning*, 28(2):147–173. https://doi.org/10.1075/lplp.28.2.04web

Wildsmith-Cromarty R 2012. Reflections on a research initiative aimed at enhancing the role of African languages in education in South Africa. *Journal for Language Teaching*, 46(2):157–170.
Wildsmith-Cromarty R & Gordon M 2009. Policy versus practice: The role of the home language in learning mathematics and science in English-medium classrooms. *The Language Learning Journal*, 37(3):359–370. https://doi.org/10.1080/09571730903208520
Zimmerman L & Smit B 2014. Profiling classroom reading comprehension development practices from the PIRLS 2006 in South Africa. *South African Journal of Education*, 34(3): Art. #962, 9 pages. https://doi.org/10.15700/201409161101

Appendix A: Description of Variables and Constructs used During Modelling

Concept / construct	Variable	Source / Questionnaire	Level of measurement	Comments
Dependent variable				
Overall learner Science achievement	BSSSCI01 BSSSCI02 BSSSCI03 BSSSCI04 BSSSCI05	Learner testing *n* = 11,969	Ordinal (continuous) Min: 5.0-14.1 Max: 780.6-794.2 *M*: 352.0-355.7	Plausible Values 1–5 Midpoint of 500 Standard deviation of 100
Analysis / independent variables				
Possession at home of non-language / economic resources for learning selected from existing SES index (BSBGHER)	BSBG05H BSBG05I BSBG05N BSBG05O BSBG05R	Learner background *n* = 11,185–11,684	Ordinal Min: 0 Max: 1	Electricity (*M* = 0.9) Tapped water (*M* = 0.8) Water-flushed toilet (*M* = 0.6) [Car (*M* = 0.5)][a] Fridge (*M* = 0.9)
Language-related home resources for learning selected from existing SES index (BSBGHER)	BSBG05A BSBG05E BSBG05G BSBG05J	Learner background *n* = 11,466–11,625	Ordinal Min: 0 Max: 1	[Computer (*M* = 0.4)][a] Internet access (*M* = 0.4) Dictionary (*M* = 0.8) [Television (*M* = 0.9)][a]
Home and school language equivalence TL_HL_EQUIV	(BSBS23) (ITLANG)	Learner background *n* = 11,082	Nominal Min: 0 Max: 1	Derived from learners' home and school languages (*M* = 0.2)
Number of books at home (up to and over 25)	(BSBG04) BSBG04R	Learner background *n* = 11,706	Ordinal Min: 0 Max: 1	Recoded from 0–10, 11–25, 26–100, 101–200, over 200). (*M* = 0.3)
Highest qualification level of either parent/caregiver BSZG06ABRMIS (split at up to and over Gr 12)	(BSZG06A) (BSZG06B)	Learner background *n* = 8,777	Ordinal Min: 0 Max: 1	Recoded; use of merge-function to identify either parent's maximum) (*M* = 0.4)
Frequency with which learners spoke school language at home	(BSBG03) TestLang HomeR BSBG03R	Learner background *n* = 11,822	Ordinal Min: 0 Max: 1	Reverse coding. Original: 1 = always, 2 = almost always, 3 = sometimes, 4 = never Derived: 0 = never and sometimes, 1 = almost always and always (*M* = 0.3)
Extent to which instruction is rated as affected by teaching resource shortages	BCBSRS (BCDGSRS)	School questionnaire	Interval Min: 0 Max: 1	Index created by IEA (*M* = 0.9)
Extent to which schools send learning/teaching support materials home[a]	BC3G10CF (-R)ecode	School questionnaire	Interval Min: 0 Max: 1	Recoded: 1 = Once, 2–3 times and more than 3 times a year; 0 = never
Adequacy of teaching materials in classrooms being problematic	BTBG08E	Science teacher questionnaire *n* = 11,106	Ordinal Min: 0; Max: 1 (*M* = 0.7)	Recoded: 1 = serious problem; 0 = not, minor and moderate problem

Concept / construct	Variable	Source / Questionnaire	Level of measurement	Comments
Lacking prerequisite learner knowledge/skills limits teaching	BTBG15A	Science teacher questionnaire *n* = 11,139	Ordinal Min: 0; Max: 1 (*M* = 0.7)	Recoded: 0 = Not at all and some; 1 = A lot
Textbooks, workbooks / worksheets, Science equipment, computer software, reference materials as basis of instruction	BTBM20A BTBM20B BTBM20C BTBM20D BTBM20E	Science teacher questionnaire *n* = 11,045–11,197	Ordinal Min: 0; Max: 1 (*M* = 0.7) (*M* = 0.4) (*M* = 0.2) (*M* = 0.0) (*M* = 0.1)	Recoded: 0 = Not used and as supplement; 1 = As basis[a]
Portion of class rated to find spoken teaching language difficult	BTBG12 & 13 into EngDiffPortion	Science teacher questionnaire	Nominal 0.0–0.50 = 0 0.51–1.0 = 1	Proportion calculation: number of learners indicated divided by class size.
Confidence of teacher in teaching Science[a]	BTDSCTS	Science teacher questionnaire	Interval Min: 0 Max: 1	Index created by IEA[b]
Problems with working conditions reported by Science teacher[a]	BTDGTWC	Science teacher questionnaire	Interval Min: 0 Max: 1	Index created by IEA[b]
Control variables				
School type (SCHCAT1RMIS)	SCHCAT1RMIS	School questionnaire *n* = 11,969	Nominal Public: 0 Independent: 1	Recoded. Control variable.
Gender[a]	BSBG01	Student	Categorical (for interpretation of coefficient)	Original: 1 = girl, 2 = boy Derived: 1 = girl, 0 = boy

Note. Source: Reddy et al. (2012). For complete descriptive statistics, see the Science item percent correct statistics by Foy, Arora and Stanco (2013).
[a]Removed before / at the time the final model was run. [b]Not modelled. No effects in country report analysis, as with learners writing practice through homework (Reddy et al., 2013).