RELATIONSHIP BETWEEN SCHOOL CLIMATE AND SOUTH AFRICAN GRADE 9 LEARNER ACHIEVEMENT IN MATHEMATICS AND SCIENCE

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Abstract

School climate has become a staple of organisational-educational research and is considered here in relation to learner academic achievement. In South Africa, poor learner achievement in mathematics and science has occupied the centre stage with the release of the Trends in International Mathematics and Science Studies (TIMSS) 2019 results. At Grade 9 level, 39 countries participated, and South Africa was very last and second from the last in science and mathematics achievement, respectively. We used a quantitative design with a positivist philosophical stance. Maslow's hierarchy of needs was used as theoretical framework, as learners attending a school with a negative climate cannot devote their full attention to learning. We analysed cross-sectional TIMSS 2019 South African data by considering two models: one with the dependent variable being mathematics achievement and the other with it being science achievement. For both models, gender and socio-economic status were included as control variables, the sense of belonging scale was included as a predictor at learner-level, and nine predictors relating to school climate were considered at school-level. The multi-level analysis using HLM software showed that learners with a high sense of belonging, schools with sufficient instructional materials, and technologically competent staff are significant predictors of both mathematics and science achievement. We recommend that South African schools with insufficient instructional materials be prioritised for receiving the necessary material and that all South African teachers be trained in the use of technologies, as these are significant predictors of learner achievement. This will, in turn, enhance learners' sense of belonging, which is also a significant predictor. Another recommendation is that stakeholders invest in school climate surveys and other interventions supporting a healthy school environment, as many researchers, including this study, have shown that a healthy school climate is a significant predictor of learner achievement. Additional research is encouraged to establish the nature of the impact that a healthy school climate has on learner achievement through longitudinal studies where causation can be proven.

Keywords: *School climate, learner achievement, TIMSS 2019, hierarchical linear models.*

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1. Introduction

In South Africa, poor learner achievement in mathematics and science (M&S) has occupied the centre stage with the release of the TIMSS 2019 results where TIMSS refers to the "Trends in International Mathematics and Science Studies" (Reddy et al., 2021, p. 1). TIMSS studies are conducted on Grade 4 and Grade 8 levels. South African learners tried participating on the Grade 4 and Grade 8 level, but due to low performance changed the participants to Grade 5 and Grade 9 level (Reddy et al., 2015). The focus of this study is on Grade 9 level. TIMSS 2019 can be divided into low (under 400), intermediate (under 475), high (under 550), and advanced (under 625) benchmarks (Mullis, Martin, Foy, Kelly & Fishbein, 2020) with learners achieving above 400 points being classified as "having acquired basic mathematical and science knowledge" (Reddy et al., 2021, p. 4) and only 41% and 36% of South African Grade 9 learners achieving this for mathematics and science, respectively. School climate has become a staple of organisational-educational research and is considered here in relation to learner academic achievement. Many researchers have found school climate to be a predictor of learner achievement (Belton, 2021; Berkowitz, 2021; Jackson et al., 2021; Richard, 2021; Zysberg & Schwabsky, 2021). Belton (2021) conducted a study in Virginia, USA, using Grade 5 data from 97 schools, and found a strong correlation between school climate and learner achievement. In another American study using data from 6,670 fifth-graders, Richard (2021) found that a positive school climate had a significant relationship with English Language Arts achievement. Another American study (Jackson et al., 2021), who used bootstrapping mediation analyses on 1,106 eleventh-grade learners, found that school climate partially explained the relationship between math identity and learner performance. Berkowitz (2021) used a multi-level model on data from 53,801 Israeli fifth- and eighth-graders, and also found school

climate to be a significant predictor of learner achievement. Zysberg and Schwabsky (2021), using data from 1,641 learners from 21 middle and high schools in Israel, built a model showing that self-efficacy mediates the association between school climate and learner achievement. Within the South African context, Arends, Winnaar and Namome (2021), using TIMSS 2015 data, showed that school climate and access to and use of school resources has a significant association with learner achievement. In another South African study, Winnaar (2021) used TIMSS 2019 data and found school climate to be significantly associated with learner achievement. Maslow's hierarchy of needs (Maslow, 1943) was used as theoretical framework, as learners attending a school with a negative climate cannot devote their full attention to learning, which, in turn, negatively impacts on learner achievement.

2. Methodology

2.1. Methods

We used a quantitative design with a positivist philosophical stance and a deductive approach. A secondary data analysis was run using South African Grade 9 TIMSS 2019 data. Secondary data analysis refers to a research design that mostly uses existing data, mostly quantitative data, to reapply and reanalyse such data to test hypotheses or to validate models (Mouton, 2001).

2.2. Participants and instruments

A total of 519 schools participated in TIMSS 2019, with 20,829 learners and 519 school principals completing the TIMSS questionnaires. Table 1 shows the TIMSS 2019 variables considered in this study. Multi-level models were built using HLM software (Raudenbush & Bryk, 2002). Re-coding has to be done since, for the multi-level model, it's ideal to either use continuous or dichotomized variables in the analysis. The majority of the variables are categorical (with more than two response options), which makes interpretation of the categorical variables difficult in relation to achievement since we do not know what the reference categories are, and HLM will most likely read these variables as continuous variables. Accordingly, all variables have been re-coded to be binary. For binary variables, it is typical to use no centring at Level-1 (learner-level) and grand-centring at Level-2 (school-level), and this is what we have done (Raudenbush & Bryk, 2002). Missing values were replaced using multiple imputation, which Van Ginkel, Linting, Rippe and Van der Voort (2020) have shown is the best way to deal with missing values regardless of the type of missing value it is.

Table 1. Details on the variables used in the multi-level model and information on re-coding.

Variable	Description	Response options	Re-coding done
	Level-1: Learner questionnaire answered by learners		
BSBGHER	"Home educational resources" (Martin et al., 2020, p. 16.168)	1 – 8.4 = "Few" 8.4 – 12.2 = "Some" > 12.2 = "Many"	1 – 12.2 = 0 = "Few or some" > 12.2 = 1 "Many" New variable name: BSBGHER ➔ L1V1
BSBG01	"Gender" (TIMSS, 2018b, p. 3)	1 = "Girl" 2 = "Boy"	0 = "Boy" 1 = "Girl" New variable name: BSBG01 ➔ L1V2
BSBGSSB	"Sense of school belonging" (Martin et al., 2020, p. 16.198)	1 – 7.8 = "Little" 7.8 – 10.7 = "Some" > 10.7 = "High"	1 – 10.7 = 0 = "Little or some" > 10.7 = 1 = "High" New variable name: BSBGSSB ➔ L1V3
	Level 2: School questionnaire answered by principals		
"How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?"[i]			
BCBG13AA	"Instructional materials (e.g., textbooks)"	1 = "Not at all" 2 = "A little" 3 = "Some" 4 = "A lot"	0 = "Some or a lot" 1 = "Not at all or a little" New variable names: BCBG13AA ➔ L2V1 BCBG13AB ➔ L2V2 BCBG13AC ➔ L2V3 BCBG13AD ➔ L2V4 BCBG13AE ➔ L2V5 BCBG13AF ➔ L2V6 BCBG13AG ➔ L2V7 BCBG13AH ➔ L2V8 BCBG13AI ➔ L2V9
BCBG13AB	"Supplies (e.g., papers, pencils, materials)"		
BCBG13AC	"School buildings and grounds"		
BCBG13AD	"Heating/cooling and lighting systems"		
BCBG13AE	"Instructional space (e.g., classrooms)"		
BCBG13AF	"Technologically competent staff"		
BCBG13AG	"Audio-visual resources for delivery of instruction (e.g., interactive white boards, digital projectors)"		
BCBG13AH	"Computer technology for teaching and learning (e.g., computers or tablets for student use)"		
BCBG13AI	"Resources for students with disabilities"		

[i]All direct quotes of the school questionnaires are from TIMSS (2018a, p. 2)

2.3. Ethical considerations

No permission was needed to analyse the TIMSS 2019 data, as the data is available for public use on the IEA's website where IEA stands for "International Association for the Evaluation of Educational Achievement" (Fishbein et al., 2021, p. II). The TIMSS 2019 data also has no identifiers so that schools and participants cannot be identified.

3. Results and discussion

Three multi-level analyses were conducted. Firstly, the null models without variables were created with the purpose of indicating the variance in achievement amongst schools (see Table 2).

Table 2. The null models.

		var component	*df*	χ^2	*p*	*var* explained
Mathematics	Intercept	3,036.75	518	20676.96	<0.001*	49.8%
	Level-1, r	3,065.79				50.2%
Science	Intercept	5,840.41	518	22580.62	<0.001*	52.5%
	Level-1, r	5,275.08				47.5%

Note: *Statistically significant $p < 0.05$, *var* = "variance", *df* = "degrees of freedom"

The parsimonious model was created by introducing all independent variables into the null model and then removing all insignificant variables one at a time with only significant variables retained. Table 3 shows the results of the parsimonious model (also referred to as the final model).

Table 3. The parsimonious models.

		var component	*df*	χ^2	*p*	*var* explained
Mathematics	Intercept	2,715.11	516	18,990.24	<0.001*	47.1%
	Level-1, r	3,044.37				52.9%
Science	Intercept	5,240.22	516	20,749.54	<0.001*	50.0%
	Level-1, r	5,243.00				50.0%

The average reliability estimate was 0.975 and 0.978 for the mathematics and science final models, respectively, indicating that sample averages reflected the true school means. By comparing the variance components of the final models to those of the null models, the percentage reduction in the variance at learner-level was 0.7% and at school-level was 10.6% for the mathematics model and 0.6% (learner-level) and 10.3% (school-level) for the science model. Table 4 shows the effect sizes (***β*'s**) of the significant predictors of the parsimonious models. The first value in each cell is for the mathematics model and the second for the science model.

Table 4. Significant predictors of the parsimonious models.

	β	***s.e.***	*t*	*p*
Intercept	378.61	2.84	133.11	<0.001*
	352.41	6.83	51.59	<0.001*
Level-1/learner-level (Learner predictors)				
L1V1: "Home educational resources"	18.29	3.52	5.19	<0.001*
(Martin et al., 2020, p. 16.168)	23.52	5.36	4.39	<0.001*
0 = *"Few or some"*				
1 = *"Many"*				
L1V2: "Are you a girl or boy"	0.12	1.02	0.12	0.904
(TIMSS, 2018b, p. 3)	3.64	1.62	2.25	0.027*
0 = "Boy"				
1 = "Girl"				
L1V3: "Sense of school belonging"	8.06	1.29	6.27	<0.001*
(Martin et al., 2020, p. 16.198)	8.94	1.67	5.36	<0.001*
0 = "*Little or some*"				
1 = "*High*"				
Level-2/school-level (School predictors)				
L2V1: "Instructional materials (e.g., textbooks)"	20.42	5.26	3.88	<0.001*
(TIMSS, 2018a, p. 2)	26.89	13.38	2.01	0.045*
0 = "*Some or a lot*"				
1 = "*Not at all or a little*"				
L2V6: "Technologically competent staff"	22.14	4.98	4.44	<0.001*
(TIMSS, 2018a, p. 2)	30.17	12.68	2.38	0.018*
0 = "*Some or a lot*"				
1 = "*Not at all or a little*"				

*Note.*Statistically significant $p < 0.05$, *s.e.* = "standard error", *t* = "Approximate *t*-ratio"

For both models, gender and socio-economic status were included only as control variables and not discussed in detail here. At learner-level, learners who reported a high sense of school belonging performed significantly higher (on average by 8.06 and 8.94 points for mathematics and science, respectively) than those that reported little of some sense of school belonging. This finding is not surprising, as Winnaar's (2021) South African study also used the TIMSS sense of school belonging scale and had a similar finding. At school-level, there were two significant predictors. Learners from schools where the principals indicated that the school's capacity to provide instruction is "not at all or a little" affected by a shortage or inadequacy of instructional materials performed significantly better (on average by 20.42 and 26.89 points for mathematics and science, respectively) than learners in schools where principals reported that it is affected "some or a lot". This is not a surprising finding, as Winnaar and Namome's (2021) South African study also showed that access to and use of school resources has a significant association with learner achievement. Learners from schools where the principals indicated that the school's capacity to provide instruction is "not at all or a little" affected by a shortage or inadequacy of technologically competent staff performed significantly better (on average by 22.14 and 30.17 points for mathematics and science, respectively) than learners in schools where principals reported that it is affected "some or a lot".

4. Conclusion

The multi-level analysis using HLM software showed that learners with a high sense of belonging, schools with sufficient instructional materials, and technologically competent staff are significant predictors of both M&S achievement. We recommend that South African schools with insufficient instructional materials be prioritised for receiving the necessary material and that all South African teachers be trained in the use of technologies, as these are significant predictors of learner achievement. This will, in turn, enhance learners' sense of belonging, which is also a significant predictor. Another recommendation is that stakeholders invest in school climate surveys and other interventions supporting a healthy school environment, as many researchers, including this study, have shown that a healthy school climate is a significant predictor of learner achievement. Additional research is encouraged to establish the nature of the impact that a healthy school climate has on learner achievement through longitudinal studies where causation can be proven.

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