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Exploring the association between teacher-related factors and Grade 9 mathematics achievement

Sarah Bansilal 

School of Education, University of KwaZulu-Natal, Durban, South Africa
bansilals@ukzn.ac.za

Thabo Lepphoto , Delia North  and Temesgen Zewotir 

School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Durban, South Africa

Teacher well-being is an important issue that needs to be considered within a teaching environment. However, little research exists about the relationship between teacher well-being and learner performance. In this study we used data from the 2015 Trends in International Mathematics and Science Study (TIMSS) to look at the interplay between teacher-related factors (including stress), and the mathematics achievement of Grade 9 learners from South Africa in the 2015 TIMSS. The results show that levels of teacher stress, teacher qualification, class size, as well as the type of area in which the school is situated are all significantly associated with learner achievement. The findings of this study reveal that learners who are taught by teachers who feel more stressed, have large classes to contend with, are in schools located in poorer areas, and who are less qualified, are significantly more disadvantaged with regard to their mathematics education than their counterparts who are taught by teachers who do not share these problems. These findings suggest that it is important to consider the role of positive working environments for teachers in trying to find ways to improve the mathematics learning outcomes.

Keywords: burnout; large classes; location of school; South Africa; teacher qualification; teacher stress; TIMSS 2015

Introduction

An important step in acknowledging the severe impact of stress in the workplace was the recognition in 2019 by the World Health Organization in its 11th Revision of *the International Classification of Diseases* that burnout is a syndrome, while providing much more detail about the symptoms (Beheshti, 2019). Stress or emotional exhaustion is one of three dimensions of burnout, while the other two are cynicism and feelings of inefficacy (Maslach, Schaufeli & Leiter, 2001). Workplace stress and, in particular, teacher stress has formed the focus of much research in recent years (Hakanen, Bakker & Schaufeli, 2006; Kyriacou, 2001; Maslach et al., 2001; Philipp & Schüpbach, 2010; Rudow, 1999). In this study we looked at teacher stress as one of the teacher factors with respect to the levels of mathematics achievement of Grade 9 learners in South Africa.

In South Africa there is much concern about the low achievement rates in mathematics. Analysis of the mathematics results in the national examinations for the last year of schooling (Grade 12) for 2015 to 2019 show that less than a quarter of the learners passed at the 50% level each year (Department of Basic Education [DBE], Republic of South Africa [RSA], 2019, 2020).

If these results are considered in terms of the number of learners who start school, it illustrates how dire the situation is. For example, the number of learners who passed with 50% or more in the Grade 12 mathematics examination in 2015 made up just 5% of the cohort who started school in 2004 (Bansilal, 2017). Access to careers in mathematics and science is hence limited to a large degree by these small numbers of mathematically proficient learners who progress through the South African education system. The country as an emerging economy urgently needs to ensure that more mathematically proficient learners are able to enter scientific careers which would improve the economic resources.

For this study, the learners' mathematics achievement was considered in terms of data from the TIMSS 2015 tests in South Africa. The TIMSS is an international large-scale comparative assessment that is conducted with Grade 4 and Grade 8 learners every 4 years. South Africa was one of three countries that had the special dispensation of having Grade 9 learners (rather than Grade 8 learners) participating in the TIMSS tests.

Since teachers are primarily responsible for mediating the content with their learners, they play an important role in helping their learners achieve positive outcomes (Barber & Mourshed, 2007; Taylor, 2011; Van der Berg, 2008). The McKinsey report (Barber & Mourshed, 2007) argues that the quality of an education system cannot be exceeded by the quality of the teachers in the system, while the *World Bank Development Report* (World Bank, 2018) emphasises that well-prepared, well-resourced and motivated teachers are a vital ingredient of learning. In trying to find ways to raise the very low outcomes in mathematics, it is important to consider teacher-related factors. The TIMSS 2015 mathematics test provided an opportunity for researchers to study whether learner achievement was associated with factors related to the learner, teacher, school or home background, as such data exist for all participants.

In this study we investigated whether the teacher-related factors were associated with levels of achievement attained by their Grade 9 mathematics learners in the TIMSS 2015 tests in South Africa.

We looked at personal factors of teacher age, gender, stress and qualification. The teacher stress variable measured the teachers' rating of how well they were coping with challenges related to teaching. When looking at teacher factors it is important to look at the situational factors contributing to the teaching environment. One situational factor that we considered was the size of the class that wrote the TIMSS test. An additional situational factor was the school location, which in South Africa is closely related to the socio-economic status of the school (Du Plessis, 2014; Maistry & Africa, 2020), which in turn is related to the effectiveness of the school (Van der Berg, 2008).

The research question relates to the South African teachers who participated in the TIMSS Grade 9 teacher survey: Are teacher-related factors (age, gender and qualification, teacher stress, class size and school location) associated with achievement in the TIMSS Grade 9 mathematics test?

It is hoped that the results can provide insight into the association between teacher factors and learner achievement in mathematics in general for the South African schooling system. In particular, we hope that the results can add more insight into teacher stress.

Background and Related Literature

The TIMSS is an international large-scale assessment for mathematics and science learners at various levels. Grade 8 learners from 36 countries participated in the 2015 TIMSS test, while in three countries, including South Africa, Grade 9 learners took that test. The TIMSS data are scaled to an international centre point (500), which means that a score of 500 reflects the midpoint for all TIMSS country average scores. Although the results in South Africa show signs of some improvement, the average score attained by Grade 9 mathematics learners in the country in 2015 was 372 – far from the midpoint of 500 (Reddy, Visser, Winnaar, Arends, Juan, Prinsloo & Isdale, 2016). These authors noted that there was an indication of an upward trend in performance in this TIMSS test for the country, since South African Grade 9 learners recorded the greatest increase in the learner average score between the years 2003 and 2015 among 25 countries for which data were analysed. However, Reddy et al. (2016) note that a great deal of work is required before substantial gains in performance can be claimed across school types, particularly with regard to the public, no-fee schools, where only 20% of the learners who attend achieved mathematics scores above the minimum level of competency.

Although many studies point to the importance of teachers having a sound knowledge of the mathematics content, there is little consensus

about the extent to which teacher qualifications contribute to improved learning (Goldhaber & Brewer, 2000). On the one hand, Darling-Hammond (2006) comments that learner achievement is not necessarily dependent on the educational level of the teacher while Hanushek and Rivkin (2006) note similarly that there was no significant difference in the outcomes of learners taught by teachers with a master's degree and those taught by teachers who did not have one. On the other hand, one study (Goldhaber & Brewer, 2000) found that students taught by teachers with a standard certification had greater gains in achievement in mathematics between Grade 10 and Grade 12 than students whose teachers did not have any certification for teaching mathematics. In this study we looked at three levels of qualifications, those with only a matric certificate, those with a certificate or diploma qualification and those with one or more degrees to determine whether the teacher qualification level was associated with achievement.

The extent to which a teacher is able to teach effectively may be influenced by the context of the teacher's working environment. Day and Gu (2007) show that school context was a key mediating influence on teachers' effectiveness. The authors argue that "schools are the primary site for teachers' professional learning" and that the environments they provide can enhance or diminish "teachers' sense of space and energy to learn, their sense of identity, efficacy and effectiveness, and whether they sustain or jeopardise their motivation and commitment to teach well in a range of circumstances" (Day & Gu, 2007:427).

Many South African studies have drawn attention to the role of the school environment in influencing teacher quality, and highlight that school effectiveness is a problem in many South African schools (Crouch & Mabogoane, 2001; Taylor, 2011; Van der Berg, 2007, 2008). The school where a teacher teaches forms the immediate working environment and is an important contributor to the professional satisfaction which they experience. Schools that are not managed well enough and do not prioritise participatory decision-making contribute to higher levels of teacher stress, as burnout is higher in people who have little participation in decision-making and those who have little autonomy in carrying out their work (Maslach et al., 2001).

Teachers' immediate working environments affect their well-being since emotional and other difficulties may arise if a teacher is not comfortable in the work setting (Maslach et al., 2001). These difficulties may result in teacher stress, which can be seen as the teacher experiencing unpleasant or negative emotions (e.g. frustration, anxiety, or depression) resulting from an aspect of their work (Kyriacou, 2001). A similar description of stress or

emotional exhaustion is put forward by Maslach et al. (2001) as feelings of being overstretched and stripped of one's resources. Furthermore, stress or emotional exhaustion is one of three dimensions of the burnout syndrome, where burnout is a "prolonged response to chronic emotional and interpersonal stressors on the job" (Maslach et al., 2001:397).

Maslach et al. (2001:397) emphasise that burnout is a complex construct and that research must consider the "individual stress experience within a larger organizational context of people's relation to their work." Hence it is important to look into the situational factors within the teaching environment. Philipp and Schüpbach (2010) show that the ability of teachers to manage emotional demands in class is associated with their levels of emotional exhaustion.

Teaching is associated with a high risk of burnout (Farber, 1991; Rudow, 1999). Schaufeli and Enzmann (1998) explored the burnout profiles of five different occupations and found that teaching was characterised by the highest levels of exhaustion or stress. It has also been shown that once teachers suffer from burnout, their job commitment (Hakanen et al., 2006) as well as their overall well-being and health (Milfont, Denny, Ameratunga, Robinson & Merry, 2008) may decrease considerably. Studies with teachers from different countries have shown that stress and burnout are associated with, among other factors, high workload, time pressure, lack of social support, and lack of autonomy and control (Maslach et al., 2001).

In South Africa, the places in which people live and work, and hence the geographic school locations, are still largely influenced by apartheid configurations (Du Plessis, 2014; Maistry & Africa, 2020). Du Plessis (2014) notes that the evolution of South African cities and towns was most profoundly influenced by policies enacted during the apartheid era, such as the Group Areas Act No. 41 of 1950. The apartheid period was characterised by forced removals based on ethnicity and the development of new, large-scale townships, which still dominate the structure of many South African cities (Du Plessis, 2014). Hence it is to be expected that the area where the school is located will be linked to the socio-economic status of the school. Suburban areas are where mostly middle-class people can afford to live, so the schools in these areas are mostly ex-Model C schools, which under apartheid were reserved for White learners. Urban schools are located in townships or cities which are much more densely populated than the suburbs, and typically do not have access to the level of resources that their suburban counterparts have. Schools in small villages are more isolated than urban schools, while schools in remote rural areas are the most

impoverished and are likely to be no-fee schools. Although the move to allow learners attending schools in these impoverished areas for free, such poor schools have to rely on the government for all their funding because they are not allowed to charge any fees (Maistry & Africa, 2020). In contrast, schools located in high income areas are able to set their own fees and are able to engage in successful fundraising so that they are not limited to government resources only, resulting in them being able to provide much more support for teaching and learning than no-fee schools (Maistry & Africa, 2020).

The number of learners in a class, or class size, can influence the overall learning environment positively or negatively. Although the education department aims to have a learner-to-teacher ratio of 40:1 in all South African secondary schools (Septon, 2017), most schools have larger classes. Teaching a class with a large number of learners makes the task of teaching a lot more onerous. Bansilal and Rosenberg (2011) conducted a study with 41 rural mathematical literacy teachers, who were asked to describe the problems of practice that they faced. The most cited problem was that of teaching large classes (Bansilal & Rosenberg, 2011). The teachers explained how teacher-learner interactions were severely compromised when class sizes were as large as 90, because the teachers were unable to even walk around the classroom to observe their learners' work. Regular assessment of learners' work was impossible in such large classes, with teachers having to come up with special strategies to motivate their learners to complete their work. One teacher who had 84 learners to teach in once class chose 10 students whose work would be marked on a particular day, without letting her class know beforehand whose work was going to be chosen for that day (Bansilal & Rosenberg, 2011).

Methodology

The data in this study were drawn from a corpus of data made available by the International Association for the Evaluation of Educational Achievement for the TIMSS 2015 at Grade 8 level. The test was written by Grade 8 learners except in South Africa and two other countries, where it was written by Grade 9 learners. From the 10,009 schools which offered Grade 9 in 2015, a sample of 300 schools was drawn, of which 292 agreed to participate in TIMSS 2015. A total of 12,514 learners and 334 mathematics teachers participated in the study. Mathematics achievement scores were calculated out of a possible 1,000 scale points, with a mean of 500 and a standard deviation of 100. The average score for the South African participants was 372, which was the second lowest of the participating countries (Mullis, Martin, Foy & Hooper, 2016). The sampling of the learner

participants was conducted using province, school type, public or independent, and language of learning and teaching as stratification variables. The results for reporting teacher responses to items are presented by reflecting on the percentage of learners that the teachers taught (Reddy et al., 2016).

In this study we considered the association between teacher factors and corresponding student achievement scores in mathematics. The personal or demographic teacher factors that were considered were age, gender, stress and qualification level. In addition, we looked at situational factors linked to the environment in which the teacher carried out the task of teaching. The situational factors of school location (area where the school is located) and class size were taken into consideration.

Details of Variables

Teacher-related factors

Our main teacher-level variables of interest were gender, age and qualification. The age group variable was coded 1 for under 29 years, 2 for 30 to 39 years, 3 for 40 to 49 years, 4 for 50 and older, and taken as ordinal. Gender was coded as 1 = Female; 2 = Male. The levels of teacher qualification were coded as 1 = completed Grade 12 or lower, 2 = post-matric certificate or diploma, 3 = first degree or higher.

Class size

Class sizes of 35 and below were coded as 1 and class sizes of 36 to 45 coded as 2, 46 to 55 as 3, and 56 and larger as 4, considered as ordinal. Note that the smallest class had five learners, while the largest had 95 learners.

School location

The variable for school location (BCBG05) is called “general or immediate area of school location”, and can be seen as a measure of how well-resourced a school is. The following five categories were used: urban, densely populated; suburban; medium size city or large town; small town or village; remote rural. We coded the school location as suburban = 1; densely populated urban = 2; medium size city or large town = 3;

small town or village = 4; and remote rural = 5. Note that the distribution of the learners is skewed towards the small town or village and remote rural areas, which together account for about 63% of the learners that took part in the study. We used the remote rural area as the reference category.

Teacher stress

The teacher stress variable was an index variable, calculated by combining the teacher responses to a set of eight questions related to their job demands. Each of the questions had a statement indicating a stressful situation (too many learners in the class, too much material to cover, too many teaching hours, need more time to prepare, need more time to assist learners, too much pressure from parents, too many changes in the curriculum, too much admin workload), where teachers were asked to respond with options aligning with agreeing a lot, through to disagreeing a lot for the question about that stress level. Each of the eight questions were scored on a scale from 0 to 3 corresponding with the respective options, where the higher the score the less stress was experienced by the teacher in the prompted situation mentioned in the question. The responses for each question were then aggregated so that scores ranged from 0 to 24, which was then transformed to a scale ranging from 1.3 to 18.7. The variable is referred to as the “challenges facing teachers index” and its derivation is described in more detail in the report by Martin, Mullis, Hooper, Yin, Foy and Palazzo (2016:15.143).

Note that a higher value for this index implies a low level of stress, while a lower value implies higher stress, so that we accordingly refer to the “Teacher stresslessness” score, which was then incorporated into the regression.

Results

We used multiple linear regression to study how learner achievement scores were influenced by teacher factors of teacher stress, school location, teacher qualification and gender. The dependant variable was the students’ achievement scores in the TIMSS 2015 study, while the independent variables were the teachers’ personal and situational factors.

Results of the Regression

Table 1 Students' achievement: multiple linear regression analysis results summary

	Estimate	SE	t	Standardised coefficient	Standardised coefficient (s.e)	Standardised coefficient (t-value)	95% CI	
							Lower	Upper
Constant	227.22	42.97	5.29	.	.	.	226.47	227.97
Age	-1.41	3.42	-0.41	-0.02	0.04	-0.41	-1.47	-1.35
Teacher stresslessness	9.95	2.07	4.80	0.21	0.04	4.82*	9.91	9.99
Class size	-6.22	2.32	-2.68	-0.12	0.04	-2.66*	-6.26	-6.18
Qualification	15.94	7.33	2.17	0.09	0.04	2.11*	15.81	16.07
School location (Ref. remote rural)								
Suburban	73.81	17.36	4.25	0.30	0.07	4.37*	73.51	74.11
Urban	49.96	10.17	4.91	0.20	0.05	4.41*	49.78	50.14
Large town	55.76	15.39	3.62	0.18	0.05	3.56*	55.49	56.03
Small town	23.85	10.14	2.35	0.12	0.05	2.38*	23.67	24.03
Gender (Ref. = Male)								
Female	8.37	7.31	1.15	0.05	0.04	1.15	8.24	8.50

Note. *Significant at 5% level of significance. Adjusted R^2 0.22 and F -statistic 392,21 with degrees of freedom 9 and 12505.

The goodness of the model fit presented in Table 1 was assessed using adjusted R^2 and residual diagnostics. The coefficient of determination, R^2 , is a measure of the proportion of variability in the response (achievement scores) that is explained by its linear relationship with the predictor variables. The adjusted R^2 0.22 and F -statistic 392,21 with degrees of freedom 9 and 12505 and p -values < 0.001 along with residual plots diagnostics showed the adequacy of the model for inference. Accordingly, the results presented in Table 1 show that the teachers' age and gender have no significant effect on students' achievement score. However, teachers' qualification level, factors of teacher stress, school location, and class size, were significantly associated with student achievement.

The regression output in Table 1 shows that all other factors being identical, learners who were taught by teachers who had a higher qualification level averaged 15.94 points higher than those learners taught by teachers who had the next lower. In other words, those who were taught by teachers who had a degree or a higher qualification achieved on average 31.88 points higher than those taught by teachers who had no qualification beyond Grade 12.

With regard to the effect of school location, the performance of suburban (fringe of urban area), urban (densely populated), large town and small town were compared with that of learners whose schools were in remote rural areas. Accordingly, given that all other factors were identical, suburban area learners' achievement score was 73.81 greater than that of remote rural area learners. Likewise, urban, large town and small town learners' achievement scores were respectively 49.96, 55.76, and 23.85, higher than that of remote rural area learners. We thus note that learners in the suburban schools had the highest mean result for mathematics in the TIMSS 2015 test, but the mean scores went down as we progressed to schools in densely populated urban regions, large towns, villages and remote rural locations. This pattern may be linked to the level of material resources and management capacity available at the school.

Similarly, as class size increased by 10, from a baseline class of 35 learners, the achievement score decreased by a factor of 6.22 on average.

The regression output further shows that a decrease in teacher stress results in a positive effect on learner achievement. Recall that the teacher stress variable in the regression was an index variable, calculated by combining the teacher responses to a set of eight questions related to stress. This means that less teacher stress was associated with higher achievement scores and was a significant factor in student achievement in the TIMSS 2015 study. That is, learners taught by teachers who were less stressed had an achievement advantage over those who were taught

by teachers from a similar background but who were more stressed. For every unit decrease in the teachers' stress level score, their learners' achievement scores increased by 9.95, provided all other factors remained identical. Recall that the teacher stress variable was an index computed by the International Association for the Evaluation of Educational Achievement ([IEA], Martin et al., 2016) whose scale ranged from 1.3 to 18.7.

Discussion and Concluding Comments

The results from the TIMSS can be used to provide information of broad trends in learner performance in mathematics so that barriers to improvements in performance could be identified earlier in the schooling system. South Africa, as an emerging economy, urgently needs to ensure that more mathematically proficient learners are able to participate in the economy, to increase its resources. The results in this study show that teacher factors were indeed associated with the mathematics achievement of their learners, thus providing information about specific areas which can be targeted to improve mathematics outcomes. The results of this study show that the situational teacher factors of class size and school location were significantly associated with differences in learner achievement. As noted by Johnson, Hodges and Monk (2000), when teachers worked in constrained circumstances they had little freedom to exercise their agency. Disabling environments such as large classes have the effect of limiting the repertoire of possible teacher actions. When teaching large classes the quality of teaching is affected, since effective teacher-learner interactions and regular assessment feedback are no longer possible (Bansilal & Rosenberg, 2011).

Despite the South African education departments' attempt to reduce class sizes (Septon, 2017) only 25% of the Grade 9 learners in this study were taught in classes with 35 or fewer learners. The results of the regression (cf. Table 1) in our study predict that on average, learners who are taught mathematics in classes with over 56 learners will have a decrease in achievement of greater than 41 points. In terms of the TIMSS calculations (Reddy et al., 2016), a change of 40 points is equivalent to 1 year of schooling. Hence it can be deduced that when class size is greater than 56 learners, those learners are likely to be at least 1 year of learning behind those taught by teachers in a similar situation with similar demographics but with class sizes of 35 or fewer. Noting that 25% of the Grade 9 learners who participated in the TIMSS study were in classes with more than 55 learners, this result is of serious concern for stakeholders as it is the teachers who struggle to carry out their tasks in such a disabling environment.

The results also show that learners who are taught by teachers with a degree or a higher

qualification achieve on average 31.88 points higher than those taught by teachers with no qualification beyond Grade 12. This finding adds to knowledge about teacher qualifications and effective teaching. It supports the finding by Goldhaber and Brewer (2000) that high school learners taught by teachers with a standard certification achieved statistically significantly higher test scores relative to teachers who were not certified in their subject. This finding also provides support for the South African education departments' interventions to institute large-scale programmes to enable teachers to upgrade their qualifications (Council of Higher Education, 2010).

The finding that the school location is significantly associated with student achievement points to the enduring effects of apartheid, because the location of schools is largely influenced by apartheid configurations (Du Plessis, 2014; Maistry & Africa, 2020). For example, the poorest schools are those found in the outlying rural areas, while those located in the suburbs are sought after by many middle-class parents. These findings hence suggest that it is the situational factors characterising schools which are key to differences in achievement. Schools in suburban areas are likely to be the more well-established and better functioning, such as Quintile 4 or 5 schools which have the freedom to determine their own fees and to engage in fundraising to maintain small class sizes and to retain good teachers (Maistry & Africa, 2020). In contrast, non-fee-paying schools are those most likely to be located in densely populated urban areas, small villages or remote rural areas, where there is an extreme shortage of resources and no funds to pay additional teacher salaries. The no-fee schools are constrained by only having the funding provided by the government and not allowed to charge any fees. They rely completely on the state for stationery, textbooks and utilities (Maistry & Africa, 2020), and do not have the means to implement and sustain innovative teaching and learning practices that they would want to introduce in their schools.

The results of this study bring new insight about the role of teacher stress in learner achievement in mathematics. Kyriacou (2001) comments that the teachers' perceptions of their circumstances and the degree of control they perceive to have over these are crucial in any study focusing on stress. This study elicited teachers' perception of their work overload and curriculum demands as well as parental pressure. The regression reveals that learners who were taught by teachers who were more stressed performed more poorly than those taught by their less stressed colleagues who taught in similar situations.

In this study the challenges that were explored as contributors to stress were identified to be

having extremely large classes, too much material to cover, too many teaching hours, too many administrative tasks, too much pressure from learners' parents, insufficient time for preparation and assisting individual learners, and not keeping up with curriculum changes. Teachers who are stressed by the challenges that they face in the classroom are more likely to struggle with carrying out their usual teaching tasks, which will then compromise the quality of student learning. For example, large classes inevitably result in even more challenges for the teacher, such as not being able to provide adequate feedback to their learners (Bansilal & Rosenberg, 2011). The curriculum itself places demands on teachers. Grade 9 mathematics teachers in KwaZulu-Natal reported that they found it very stressful to try to keep pace with the curriculum (Bansilal, 2017).

The findings in this study show that an increase in the level of stress is associated with a significant decrease in student achievement – a new result which contributes to the field of research on teacher stress and burnout. The results point to feelings of stress or emotional exhaustion among teachers, which refers to being overextended and depleted of one's resources. Research in the area of burnout generally agrees that feelings of emotional exhaustion occur first, and this is followed by feelings of cynicism, which refers to an indifferent or detached response to work in general (Hakanen et al., 2006; Maslach et al., 2001). Subsequently, or at the same time, a decline in feelings of competence and the impression that a person is not able to perform efficiently emerge. Reduced personal accomplishment is one of the key components of burnout (Maslach et al., 2001). Teachers who perceive themselves as having reduced personal accomplishment develop a growing sense of inadequacy to teach effectively, and this may result in a self-imposed verdict of failure (Maslach et al., 2001).

A significant finding by Zuze, Reddy, Visser, Winnaar and Govender (2017:52) is that none of the participant learners from the independent schools (in this study) were taught by teachers who experienced "many" challenges, suggesting that teachers who taught in the more privileged sector felt better supported and had a stronger sense of personal accomplishment than their counterparts from the less privileged schools. Hence it is recommended that further studies are conducted on teacher stress and possible ways in which the teaching environment can be transformed to help teachers feel more supported to improve their sense of personal accomplishment. This study points to the importance of teachers working in an organisational environment which is supportive and conducive to teaching and learning.

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Authors' Contributions

SB wrote the manuscript; TL did the statistical analysis as advised by TZ; DN wrote the descriptions and interpretations of statistical tests and methodology.

Notes

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