Overcrowded classrooms and its association with South African learners' mathematics achievement

Marien Alet Graham*
ORCID ID: 0000-0003-4071-9864

Department of Science, Mathematics and Technology Education, University of Pretoria, South Africa, *marien.graham@up.ac.za*

There is growing global concern concerning South African learners' mathematics achievement, with research identifying many factors contributing to poor mathematics achievement, with class size being one of them. When classrooms are overcrowded, this may lead to a stressful environment which can negatively impact the quality of teaching and learning that is possible. The purpose of this study was to gain a holistic understanding of the problem of overcrowded classrooms by using an explanatory sequential mixed-methods approach. We first investigate the association between large classes and mathematics achievement using the TIMSS 2019 data for Grade 9 mathematics. This is followed by the qualitative phase, which elicited educators' perceptions of the relationship between overcrowded classrooms and achievement. The quantitative results showed a significant negative correlation between the two, indicating that the larger the class size, the worse the achievement. It also showed that learners taught by teachers who strongly believed that there were too many learners in a class performed significantly worse than learners taught by teachers who did not feel this way. The qualitative results showed that participants believed overcrowded classes led to limited personalised individual interaction with learners, didactical neglect, and poor time management, which is associated with poorer mathematics performance. Recommendations include that the issue of overcrowded classes should be prioritised by all stakeholders at the different levels.

Keywords: mathematics achievement, class size, TIMSS 2019, thematic analysis

Introduction

When results of the Trends in International Mathematics and Science Studies (TIMSS) 2019 results were released, there was much concern about the poor achievement (Reddy et al., 2020). South Africa participated in TIMSS 2019 at Grade 5 and Grade 9 levels, respectively; the focus of this study is on the Senior Phase (SP), specifically the Grade 9 level, where the South African mathematics average score was 389 (below the TIMSS centerpoint of 500). Furthermore, only 41% of South African learners demonstrated that they had acquired basic mathematics knowledge (that is, the percentage above the TIMSS low benchmark of 400) (Reddy et al., 2020). Research has identified many factors contributing significantly to poor mathematics achievement, with class size being one of them (Kanyongo & Ayieko, 2017; Kanyongo et al., 2007; Olubunmi, 2019; Oni, 2020). In South Africa, overcrowded classrooms are a reality, with learner-educator ratios (LERs) reaching as high as 70:1 (Venketsamy, 2023). These ratios are much higher than the Organisation for Economic Co-operation and Development (OECD)'s international average of 15:1 for primary schools and 13:1 for secondary schools (OECD, 2020). It is likely that the problem of overcrowding in classrooms in South Africa will only get worse. The Centre for Development and Enterprise (2015) predicts South Africa will need 456,000 teachers by 2023 to have LERs of 31.2:1 and 26.3:1 for primary and secondary schools, respectively. South Africa is currently graduating 15,000 teachers per year, which is below the 25,000-mark needed to reach 456,000 teachers by 2023. Noting that between 18,000 to 22,000 teachers leave the profession annually, which is more than the teacher graduates each year, the shortage of teachers is likely to lead to worse overcrowding. The COVID-19 pandemic

worsened the impact as South Africa lost 2283 (0.57%) teachers between 27 March 2020 and 27 May 2021 due to COVID-19 (Shepherd & Mohohlwane, 2021). With the statistics suggesting that the problem of overcrowded classrooms in South Africa is likely to get worse, it is imperative that researchers provide more insight into the issue. The research question of the current study under investigation is: What is the association between teachers' and principals' views concerning classroom size and SP learners' mathematics achievement and what are their views regarding the challenges associated with overcrowded classrooms in South Africa? There is much research that has focused on how mathematics teaching and learning (T&L) could be made more effective (e.g., early intervention programmes) (Askew, 2020; Asmail et al., 2020; Biccard, 2020; Chikiwa & Graven, 2021; Fair & Stott, 2021; Juta & Van Wyk, 2020; Wilson Fadiji & Reddy, 2021) and we hope to contribute to this body of literature. In particular, we hope that the results can add more insight into South Africa's overcrowded schools and the challenges this presents.

Rationale of the Study

Increasing classroom sizes in South African schools is becoming a growing concern, and little research is available to address overcrowded classrooms and their association with mathematics achievement. This study aims to investigate the association between classroom size and SP learners' mathematics achievement using TIMSS 2019 data and to elicit teachers' and principals' views about how classroom size exacerbates the challenges of teaching in overcrowded classrooms in South Africa.

Literature Review

One of the earliest influential meta-studies on the impact of class size on achievement was conducted in 1979 by Glass and Smith, who analysed 300 studies involving approximately 900,000 learners in more than a dozen countries (Glass & Smith, 1979). The findings of their study, which covered approximately 70 years of research, were summarized by Glass and Smith (1979) with this statement: "There is little doubt that, other things equal, more is learned in smaller classes" (Glass & Smith, 1979, p. 15). Another well-known study investigating the influence of class size on learner achievement is the "Tennessee Student Teacher Achievement Ratio" (STAR) project, conducted in the United States of America, which provided evidence that all types of learners (low, medium, and high achievers) benefit from being in small classes (Barbara et al., 2000). More recently, a study in the United States of America using a large-scale longitudinal dataset showed that reducing class size is associated with significantly increased reading and mathematics achievement but not science achievement (Shen & Konstantopoulos, 2022). Prayitno (2023) conducted a review on the impact of class size reduction and mentioned that some advantages to reducing class sizes include teachers spending more time on instruction and less time on classroom management, more focussed individualised instruction, improved social interactions between learners and their peers and more opportunities for learners to engage in group discussions, work on collaborative projects and participate in class activities. Although some studies argue that class size is not a significant predictor of learner achievement (e.g., Khimm, 2012), it is indisputable that a teacher's pedagogical methods will change from a large-group lecture format to more personalised instruction as the class size gets smaller. In a study in Nigeria by Olubunmi (2019), conducted with 225 students in mathematics classrooms, it was found that there was a negative association between large class sizes and learners' mathematics performance.

Turning the focus to the South African context, overcrowded classrooms are a reality, with LERs as high as 70:1 being reported by teachers (Venketsamy, 2023). According to the Western Cape Department of Education (WC DoE-the Western Cape (WC) has the highest average LER in the country at 37:1, and in some schools, the principals don't take a full teaching load, which increases the LER to 40:1 ((WC DoE, 2020). The Organisation for Economic Co-operation and Development (OECD) indicates that the average LER in South African secondary schools is 27.6:1, however, LER figures for primary schools were not available (OECD, 2021). Although the current study focuses on secondary schools, it is important considering the overall picture of South African schools' overcrowdedness, and we turn to recent publications for information about realistic LERs in South African primary schools (Venketsamy, 2023; West & Meier, 2020). West and Meier (2020) conducted a qualitative study in the Foundation Phase (Grades R through 3) in Gauteng (GT), where 10 participants, who consisted of DoE officials, heads of departments, principals and teachers at schools with overcrowded classrooms, were interviewed, and one participant mentioned that she was in a classroom with more than 40 learners in a class and another went on to say that learners were almost sitting on top of each other. The participants felt that overcrowded classrooms led to didactical neglect, problems with discipline and teachers with negative attitudes. The fact that learners are almost sitting on top of each other is alarming when considering the United Nations Children's Fund (UNICEF)'s recommendation of a minimum of 3.8 square meters per child in early learning spaces (UNICEF, 2009). Venketsamy (2023) conducted a study with 150 primary school teachers in Durban, all of whom taught classes with an LER of at least 40:1, with some teachers reporting LERs as high as 70:1 were reported by the teachers. The author argued that overcrowding not only negatively affects the quality of T&L, but that most teachers do not know their learners. In another South African study with 150 Limpopo teachers, the participants reported that overcrowded classrooms made it difficult to stimulate learners' engagement, develop critical thinking skills and implement problem-solving activities with their learners (Matsepe et al., 2019).

Overcrowded classrooms can also have an indirect negative impact on T&L because of the stress that it may induce in teachers and in learners. Stress is a significant societal issue, e.g., workplace stress can lead to reduced productivity, absenteeism, and even mental health problems for employees (Hsu, 2019; Linden & Stuart, 2020). Studies in South Africa show that T&L in a stressful environment leads to many challenges and that teachers and learners experience overcrowded classrooms as stressful (Biyela, 2019; Muthusamy, 2015). Biyela (2019) found that there is often poor ventilation in the classrooms (as crowded spaces often mean that there is less open space for air to flow through), causing high temperatures, which increases the stress of people in the classroom. Bansilal et al. (2022), who analysed South African TIMSS 2015 data, found that learners taught by teachers who felt more stressed did significantly worse in mathematics than those where teachers were calm and unstressed.
Safety concerns also arise due to overcrowded classrooms, with studies conducted in South African schools showing that overcrowding leads to disciplinary problems such as fighting, bullying and harassment of smaller/weaker learners (Biyela, 2019; Marais, 2016; Obadire & Sinthumule, 2021). Overcrowding was also reported as a reason for different types of "unacceptable behaviour" in the classroom ranging from "minor to extreme incidents" (Obadire & Sinthumule, 2021, p. 4), causing both teachers and learners to feel unsafe. These studies refer to physical and psychological safety, but some studies have linked overcrowding with health safety, e.g., in Biyela (2019) a participant stated, "I have experienced learners getting sick of lung diseases and heat stress in overcrowded classrooms" (p. 9).

Theoretical Framework

This study was guided by the "Acute Stress Response", also known as the "Fight-or-Flight (FoF) response" (Cannon, 1915) and "Maslow's Hierarchy of Needs" (MHoN) theoretical framework (Maslow, 1943). The acute stress response theory focused on the body's immediate and automatic response to a perceived threat (Cannon, 1915). The theory and appropriate for this study as it describes a neurobiological reaction to stress, and many studies have shown that teaching and learning in overcrowded classrooms can be overwhelming and stressful (Biyela, 2019; Muthusamy, 2015; Olubunmi, 2019). When both teachers and learners are experiencing an FoF response (Cannon, 1915) in the classroom, it can create a tense and challenging environment as teachers may struggle to communicate information effectively, and learners may have difficulty retaining and processing information due to the impact of stress on their cognitive abilities. Studies conducted in South African schools show that overcrowding impacts on physical, psychological and health safety (Biyela, 2019; Marais, 2016; Obadire & Sinthumule, 2021). MhoN theoretical framework can also help us understand the stress-related and safety issues caused by overcrowding. According to this theory, lower needs must be satisfied before a higher need can be activated (Maslow, 1943); if teachers and learners are stressed and feel unsafe, they cannot devote their full attention to T&L activities. Feeling calm, unstressed, and safe in the classroom is a prerequisite for higher-order needs such as social needs (learners' sense of belonging and acceptance in the T&L environment), self-esteem needs (learners are given opportunities to advance their learning) and self-actualisation needs (learners and teachers performing to their maximum potential). These higher order needs can only be addressed once the safety needs are fulfilled, so that teachers can teach and learners can learn mathematics free from harm. Naturally, there are many other societal issues that as could negatively impact learner mathematics achievement. In their study, Panthi and Belbase (2017) explored various societal concerns associated with mathematics achievement. These concerns encompassed language barriers, ethnic disparities, social justice issues, and the significance of cultural and linguistic diversity. The main premise of their research was that if crowded classrooms have a detrimental effect on these key societal issues, they can ultimately lead to stress (triggering a fight-or-flight response) and hinder the fulfillment of lower-level needs related to Maslow's Hierarchy of Needs (MhoN). Consequently, it becomes essential to effectively manage stress and satisfy these lower-level needs in order to establish an environment conducive to high-quality T&L.

Method

An explanatory sequential mixed-method design was followed, and an abduction research process was followed, as this is typically used in mixed-methods research. For the explanatory sequential approach, we are interested in following up the quantitative (TIMSS 2019) data with qualitative data (interviews conducted in 2020 and 2021). In abductive inference, known premises are used to generate testable conclusions (Mitchell, 2018). Abductive reasoning addresses some of the weaknesses identified in deductive and inductive approaches by adopting a pragmatist perspective (Mitchell, 2018). In the current study, through abductive reasoning, we used the known premises from the quantitative data analysis to generate hypotheses or potential explanations for the observed associations. The qualitative interviews then served to test and refine these hypotheses, allowing for a more nuanced understanding of the factors contributing to the challenges faced by teachers in overcrowded classrooms. The secondary data analysis of quantitative data involved investigating how class size is associated with

mathematics achievement using TIMSS 2019 data. The data analysis of the qualitative data explored narrative accounts of principals' and SP teachers' perceptions of the association between class size and mathematics achievement. In-depth interviews (March to September 2020) were conducted with twelve SP mathematics teachers purposively sampled in two South African public schools to explore their formative assessment (FA) strategies used in the classroom. Following these interviews, later in-depth interviews, conducted in February and March 2021, were conducted with six principals and twelve SP mathematics teachers purposively sampled in six South African public schools to explore how safe South African schools are. For the earlier interviews, although the focus was on FA practices, all the teachers mentioned the difficulties that overcrowded classrooms caused in terms of FA, for example, not having time to properly complete FA activities during class because so much time goes into class management due to overcrowded classrooms. Studies have identified that some obstacles that hinder teachers from fostering a learner-centred classroom environment for formative assessment include large class sizes and the inability to provide immediate feedback (Bayat & Naicker, 2012). In the later interviews, while the primary emphasis was on school safety, the issue of overcrowded classrooms was also raised. This is because overcrowding can result in the installation of mobile classrooms, which, in turn, can compromise safety measures. In total, qualitative data analysis was conducted using the transcriptions from eight schools involving six principals and 24 teachers.

Participants

The quantitative phase is considered first. At Grade 8/9 level, 39 countries participated in TIMSS 2019. TIMSS 2019 made use of a two-stage stratified cluster sampling design (LaRoche et al., 2020) for Grade 8, which represented eight years of formal schooling, but South Africa chose ninth-graders because of curriculum matching concerns (Reddy et al., 2015). Firstly, schools were sampled according to their size, and secondly, one or more intact classes from the target grade of each participating school were selected (LaRoche et al., 2020). For South Africa, the realised sample was 519 schools, 543 mathematics and science teachers and 20,829 learners (Reddy et al., 2020). No permission was needed to analyse the TIMSS 2019 data, as the database is available for public use on their website (Fishbein et al., 2021). For the qualitative phase, purposive sampling was used to select participants based on their unique qualities, which are being principals and mathematics teachers in South African secondary schools. Permission to conduct the interviews was obtained from the necessary authorities, the principals and the teachers. As explained earlier, there were eight schools involving six principals and 24 teachers who participated in the qualitative phase. For anonymity, pseudonyms were used for principals (P1 to P6) and teachers (T1 to T24).

Data Collection and Instruments

The data collection for TIMSS 2019 in South Africa occurred in September 2018 (Cotter et al., 2020). In this study, certain questions from the TIMSS 2019 questionnaires and mathematics achievement scores were used. The TIMSS 2019 developers went through many rigorous steps in developing the TIMSS 2019 achievement instruments. The assessment frameworks cannot drastically change from cycle to cycle and undergo regular updates to incorporate new ideas and the latest information about curricula, standards, and instruction in mathematics and science education globally. The interested reader is referred to Cotter et al. (2020) for a detailed account of this process. The semi-structured interviews took place between March 2020 and March 2021 and were in-depth one-on-one interviews ranging between 30 to 45 minutes. During this period, South Africa was in various stages of lockdown due to COVID-19, and when participants felt safe to be interviewed in person, this was done. For the in-person interviews,

field notes were also taken. The interview was conducted online with participants who felt uncomfortable meeting in person. All interviews were recorded and transcribed.

Data Analysis and Quality Assurance

For the quantitative data, the International Association for the Evaluation of Educational Achievement (IEA) IDB Analyzer was used to analyse the TIMSS 2019 data and the reader is referred to Martin et al. (2020) for details on how TIMSS 2019 ensure validity and reliability; details are omitted here for conciseness. The IEA provides five plausible values that represent the mathematics achievement, and the IEA IDB Analyzer has a way of dealing with all five plausible values; this is why the IEA provided users with the IDB Analyzer software package. First, the correlation between the number of learners in a class (BTB10) and mathematics achievement was run, and if the p-value is less than 0.05, the correlation is statistically significant. Following this, t-tests were used to test for significant differences in the mean plausible values (mathematics scores) between the response options to the question to the level of agreement with the statement "There are too many learners in the class" (BTB09A). If the absolute value of the t-test statistic is greater than 1.96, the difference is statistically significant. These two items were chosen from the TIMSS dataset because they are most directly linked to the research question of the current study.

In the qualitative analysis, we employed the steps outlined in Braun and Clarke's (2006) thematic analysis framework. These steps encompassed familiarizing ourselves with the data, generating initial codes, and identifying recurring themes. Triangulation was used as a tool for consistency of analysis of the multiple data sources (field notes and interviews). Trustworthiness of the findings was ensured by member-checking; each participant received their transcript to check for accuracy. The final results were also sent to the participants to check for resonance with their experiences. Confirmability, which is concerned with the neutrality of the findings, was ensured by eliminating bias; this was done by making the participants feel accepted no matter what they answered (to avoid participant bias) and entering the process with an unbiased mind by ensuring pre-existing assumptions are kept at bay (to avoid researcher bias).

Results and Discussion

Quantitative Phase

The correlation between mathematics achievement and the number of learners in the class using the variable BTBG10) was calculated to be -0.247 and was statistically significant ($p<0.001$). This result indicates that as the number of learners in a class increase, their mathematics achievement gets lower. Conversely, as the number of learners in a class decrease, their mathematics achievement goes higher.

To examine significant differences in mean plausible values (mathematics scores) among groups based on their level of agreement with the statement "There are too many learners in the class" (variable BTB09A), a t-test was employed. The groups included "disagree a lot" (8.4%), "disagree a little" (9.3%), "agree a little" (28.4%), and "agree a lot" (53.9%). The findings of this analysis are presented in Table 1. It is worth noting that more than half of the learners were taught by teachers who "agreed a lot" that there were too many learners in the class.

Table 1. Statistical results for BTB09A (level of agreement with the statement "There are too many learners in the class")

Comparison group*	Mean plausible value reference group (Disagree a lot)	Mean plausible value comparison group	Mean plausible value difference	t-test statistic
Disagree a little	413.08	412.81	-0.27	-0.02
Agree a little	413.08	396.33	-16.75	-1.30
Agree a lot	413.08	378.50	-34.58	-3.15

*Each comparison group is compared to the reference group "disagree a lot"

From Table 1, it can be seen that the difference between the comparison group "Agree a lot" and the reference group "Disagree a lot" is statistically significant (|t|=3.15). This indicates that learners taught by teachers who agreed a lot with the statement that there are too many learners in the class obtained, on average, 34.58 points lower in comparison to learners taught by teachers who disagreed a lot with this statement. These results highlight that overcrowding in a classroom is a significant problem. Literature has consistently shown that overcrowding contributes to various challenges, including the creation of a stressed and unsafe environment that cannot stimulate learners' engagement, neglect of effective teching practices, discipline problems, demotivated teachers, and failure to improve learners' critical thinking skills and problem-solving abilities (Biyela, 2019; Marais, 2016; Obadire & Sinthumule, 2021).

Qualitative Phase

During the data analysis three themes emerged, which are now considered.

Theme 1: Limited personalised individual interaction with learners

All the teachers indicated that their classes were overcrowded, and some of these teachers highlighted that personalised individual interaction with learners was limited in overcrowded classrooms. This was the most prominent theme that emerged from principals' and teachers' responses. The teachers expressed that they can only create a personalised and meaningful learning experience when they are able to interact on a one-on-one basis with each learner, as opposed to addressing the whole group or a smaller group of learners.:

> Overcrowding, our classes are overcrowding. So, it is not easy to move around and see the learners who are not doing anything because if they are many in a class, it is difficult to control. (T2)

> Is the numbers we have in the class. We have a very large numbers; over 50 or 60 learners in one class and just one teacher. So that means it is very difficult, because there is no space to move around, especially when I am asking questions or when they are doing class activities, and I want to check what they are doing. It is not easy because of the numbers. (T4)

> When learners are overcrowded in your class, you can hardly help them individually. You help them as a group and some of them are very shy to tell you that they don't understand in that group. It's better when you attend to them individually. (T9)

> But in terms of in-class where they participate in, there's no interaction, there's no engagement in class, because some they are very shy to ask questions when there are

> many in class. But if they are few in class, maybe 20 or 30, you can be able to move from one table to another and assess whether are they on par in terms of what you are teaching at that particular time. (T20)

These extracts from the interviews, which describe how their interaction with their learners is limited in overcrowded classrooms, align with findings from other studies, that overcrowded classrooms lead to a lack of engagement and communication between learners and teachers (Prayitno, 2023).

Theme 2: Didactical neglect

This theme describes situations where teachers are unable to pay enough attention to the learner's individual educational needs, such as recognising their unique learning styles and abilities, as well as identifying and addressing individual problems that they may be experiencing. It also includes aspects such as teacher preparation, where teachers should possess the requisite knowledge and skills to effectively cater to the diverse learning needs of their learners. Note that while Theme 1 broadly centred around teachers not having limited individual one-on-one interactions with learners and being unable to physically move around in the classroom, the focus was not specifically on didactical neglect (Theme 2). Some teachers indicated that overcrowded classrooms led to didactical neglect, which has a negative impact on learner achievement as described in the extracts that follow:

> The challenges that I can say I am facing is overcrowding in classes. Because you find a class having 62 learners, you find a class having 48 learners and then sometimes, it becomes difficult for me to identify individual problem of this kids (T5)

> So, if a teacher has to be 1 to 30 [referring to LER], maybe it should be going to be 1 to 40 now. So, if the teacher is not well-prepared, the noise level, controlling of the learners, becomes your classroom management issues that becomes more compromised because, at this point in time, you can't reach each and every learner with the challenge that he or her is having. (T6)

> Sometimes this assessment, you will find out, maybe you want to assess, but because of the overcrowded classes then that one influenced your preparation. (T7)

A principal (P6) mentioned that the school doesn't have a functional library because the library is being used as a class due to its large size. The teacher working at the school where the library is being used as a classroom, T24, indicated that not having a library negatively impacts her learners because if there was a library, learners could sit and work there over break time; however, not having a library:

> Does contribute [to poor learner achievement] because some of the learners, they want to do their work during break time, they need your help during break time. Some they want to finish up. So, our classes are being locked during break time, most of the classes, so they can't actually finish their work. (T24)

The absence of a library can lead to didactic neglect because it deprives learners of an important resource for learning and personal development. These responses align with existing literature findings that highlight the connection between overcrowded classrooms, didactical neglect and poor learner achievement (Glass & Smith, 1979; Olubunmi, 2019).

Theme 3: Time management

The theme of time management refers to instances where there is limited time for proper engagement with the content and with learners. Effective time management plays a critical role in ensuring successful teaching and learning, and deficiency in this aspect can negatively impact both. If teachers fail to manage their time effectively, it can disrupt classroom routines and undermine the overall structure, leading to feelings of rush and stress among teachers. The extracts below explain how their overcrowding impacts on their time management:

> But with the overcrowded, it's a challenge. So, during the contact time, is never enough. (T2)

> As you know, now contact time is less because of this the current COVID-thing that we are going through. So, mostly the work we have to give it as homework. (T8)

These responses align with findings in the literature that teachers in smaller classes had more time to cover additional material, while those in overcrowded classrooms faced a scarcity of time (Prayitno, 2023).

Although the selected narrative quotes did not explicitly make mention of mathematics achievement, following each participant's description of the challenges they experienced due to overcrowding, the interviewer inquired about their views on the relationship between overcrowding and the T&L of mathematics. All participants acknowledge that such conditions have a detrimental impact on the T&L environment and expressed a belief in a negative association between overcrowding and learner mathematics achievement. The emergence of the three themes supports this notion that overcrowded classrooms not only result in poor teaching and learning outcomes but also amplify broader societal issues such as stress and safety concerns.

Conclusions and Recommendations

This study focused on a secondary analysis of the TIMSS 2019 data to explore the association between overcrowded classrooms and South African Grade 9 learner achievement in mathematics. Further data was collected through interviews to try to understand how overcrowded classrooms impacted on T&L. The quantitative results showed a negative correlation between class size and achievement, indicating that larger class sizes are associated with lower mathematics achievement. It also showed that learners taught by teachers who strongly believed that there were too many learners in a class performed significantly worse than learners taught by teachers who did not perceive their classes as overcrowded. The results from the qualitative data complemented these results by providing additional insight into the supporting factors contributing to this negative association. It showed that participants believed that overcrowded classes led to no personalised individual interaction with learners, didactical neglect and poor time management, which research has shown are factors significantly associated with poor learner performance.

This study has illustrated that overcrowded classrooms in South Africa pose significant challenges that have wide-ranging consequences. These challenges include the creation of a stressful environment triggering the "fight-or-flight" response and an unsafe environment due to unmet lower-order needs of MhoN. These circumstances hinder the stimulation of learners' engagement, contribute to didactical neglect, foster discipline problems, result in negative teacher attitudes, and fail to enhance critical thinking skills and problem-solving abilities. The

consequences of overcrowding extend beyond the confines of the classroom, exacerbating broader societal issues such as stress and safety concerns. It is evident that overcrowded classrooms not only compromise the quality of T&L outcomes but also have far-reaching implications for society as a whole. A recommendation is that the South African government intensify their efforts to eliminate overcrowding in classrooms. A further recommendation is that a similar study be performed using the TIMSS 2019 Grade 5 dataset and by conducting interviews with principals and teachers in South African primary schools. This recommendation stems from the literature review, which indicated that overcrowding is a prevalent issue across all levels of basic education in South Africa and it is possible that additional challenges related to overcrowding in early learning spaces may emerge

Limitations

We acknowledge that this study is based on nonexperimental data, and causal interpretations of relationships could not be drawn. Further research using experimental designs could potentially test whether improvements in school climate, specifically relating to overcrowded classrooms, through planned interventions actually result in improved achievement compared to control schools. We acknowledge that the qualitative data was collected during various lockdown restriction levels in a year that was not a typical school year due to COVID-19. We also acknowledge the fact that the quantitative data was collected in 2018 (pre-COVID era) and the qualitative data in 2020 and 2021 (during COVID).

Ethics approval and consent to participate

No permission was needed to analyse the TIMSS 2019 data, as the database is available for public use on the International Association for the Evaluation of Educational Achievement (IEA)'s website (Fishbein et al., 2021). For the interviews, ethical approval was granted by the GT Department of Education and the University of Pretoria [SM19/05/01 and EDU022/20].

References

Askew, M. (2020). Identifying effective mathematics teaching: Some questions for research. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(1), 1-9. https://doi.org/10.1080/18117295.2019.1710049

Asmail, R., Spangenberg, E. D., & Ramdhany, V. (2020). What Grade 8–10 learners from a mathematics-and-science-focus school value as important in the learning of mathematics. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(2), 241-252. https://doi.org/10.1080/18117295.2020.1818041

Bansilal, S., Lephoto, T., North, D., & Zewotir, T. (2022). Exploring the association between teacher-related factors and Grade 9 mathematics achievement. *South African Journal of Education, 42*(Suppl. 1), Article 2091, S1-S9. https://doi.org/10.15700/saje.v42ns1a2091

Barbara, N., Hedges, L. V., & Konstantopoulos, C. (2000). The effects of small classes on academic achievement: The results of the Tennessee class size experiment. *American Educational Research Journal*, *37*(1), 123-151.

Bayat, A., & Naicker, V. (2012). Towards a learner-centred approach: Interactive online peer assessment. *South African Journal of Higher Education*, *26*(5), 891-907. https://doi.org/10.20853/26-5-200

Biccard, P. (2020). Distance-education student teachers' views of teaching mathematics problem solving while on teaching practice. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(2), 205-215. https://doi.org/10.1080/18117295.2020.1812837

Biyela, B. N. (2019). *Leading teaching and learning in an overcrowded classroom: Experiences of four teachers in two secondary schools* [Masters' dissertation, University of KwaZulu-Natal]. University of KwaZulu-Natal ResearchSpace. https://ukzn-dspace.ukzn.ac.za/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.https://doi.org/10.1191/1478088706qp063oa

Cannon, W. B. (1915). *Bodily changes in pain, hunger, fear and rage: An account of recent researches into the function of emotional excitement.* D Appleton & Company. https://doi.org/10.1037/10013-000

Centre for Development and Enterprise. (2015). *Teachers in South Africa: Supply and demand 2013 – 2025*. CDE in depth. https://www.cde.org.za/wp-content/uploads/2018/07/Teacher-Supply-and-Demand-2013-2025-Full-Report-March2015-CDE.pdf

Chikiwa, S., & Graven, M. (2021). How pre-service teachers reflect on their own mathematics teaching practice compared with the practice of others. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(2), 211-224. https://doi.org/10.1080/18117295.2021.1968164

Cotter, K. E., Centurino, V. A. S., & Mullis, I. V. S. (2020). Developing the TIMSS 2019 mathematics and science achievement instruments. In M. O. Martin, M. von Davier & I. V. S. Mullis (Eds.), *Methods and procedures: TIMSS 2019 Technical Report* (pp. 6-41). TIMSS & PIRLS International Study Center.

Fair, D. L., & Stott, A. E. (2021). A longitudinal case study of mathematics and mathematical literacy achievement of boys at a high quintile school in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(2), 137-147. https://doi.org/10.1080/18117295.2021.1932331

Fishbein, B., Foy, P., & Yin, L. (2021). *TIMSS 2019 user guide for the international database.* TIMSS & PIRLS International Study Center. https://timssandpirls.bc.edu/timss2019/international-database/

Glass, G. V., & Smith, M. L. (1979). Meta-analysis of research on class size and achievement. *Educational Evaluation and Policy Analysis*, *1*(1), 2-16.

Graham, M. A., Mokgwathi, M. S., & De Villiers, J. R. R. (2021). Safety factors associated with mathematics achievement in South African schools. *EURASIA Journal of Mathematics, Science and Technology Education,* 17(12), em2052. https://doi.org/10.29333/ejmste/11416

Hsu, H. C. (2019). Age differences in work stress, exhaustion, well-being, and related factors from an ecological perspective. *International Journal of Environmental Research and Public Health*, *16*(1), Article 50, 1-15. https://doi.org/10.3390/ijerph16010050

Juta, A., & Van Wyk, C. (2020). Classroom management as a response to challenges in mathematics education: Experiences from a province in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(1), 21-30. https://doi.org/10.1080/18117295.2020.1731646

Kanyongo, G. Y., & Ayieko, R. (2017). Hierarchical linear modelling of sixth-grade students' socio-economic status and school factors on mathematics achievement: Case studies of Kenya and Zimbabwe. *African Journal of Research in Mathematics, Science and Technology Education*, *21*(2), 187-199. https://doi.org/10.1080/18117295.2017.1334368

Kanyongo, G. Y., Schreiber, J. B., & Brown, L. I. (2007). Factors affecting mathematics achievement among 6th graders in three sub-Saharan African countries: The use of

hierarchical linear models (HLM). *African Journal of Research in Mathematics, Science and Technology Education*, *11*(1), 37-46. http://dx.doi.org/10.1080/10288457.2007.10740610
Khimm, S. (2012, January 28). *Study: Class size doesn't matter*. The Washington Post. Study: Class size doesn't matter – The Washington Post
LaRoche, S., Joncas, M., & Foy, P. (2020). Sample design in TIMSS 2019. In M. O. Martin, M. von Davier & I. V. S. Mullis (Eds.), *Methods and procedures: TIMSS 2019 technical report* (pp. 51-83). TIMSS & PIRLS International Study Center.
Linden, B., & Stuart, H. (2020). Post-secondary stress and mental well-being: A scoping review of the academic literature. *Canadian Journal of Community Mental Health*, *39*(1), 1-32. https://doi.org/10.7870/cjcmh-2020-002
Marais, P. (2016). "We can't believe what we see": Overcrowded classrooms through the eyes of student teachers. *South African Journal of Education*, *36*(2), Art. #1201.
Martin, M. O., von Davier, M., & Mullis, I. V. S. (Eds.). (2020). *Methods and procedures: TIMSS 2019 technical report*. International Association for the Evaluation of Educational Achievement. https://timssandpirls.bc.edu/timss2019/methods/
Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370-396. https://psycnet.apa.org/doi/10.1037/h0054346
Matsepe, D., Maluleke, M., & Cross, M. (2019). Re-imagining teacher's experience with overcrowded classrooms in the public secondary schools in South Africa. *Journal of Gender, Information and Development in Africa*, *8*(Special Issue 2), 91-103.
Mitchell, A. (2018, July). A review of mixed methods, pragmatism, and abduction techniques. *The Electronic Journal of Business Research Methods, 16*(3), 103-116.
Muthusamy, N. (2015). *Teachers' experiences with overcrowded classrooms in a mainstream school* [Masters dissertation, University of KwaZulu-Natal]. University of KwaZulu-Natal ResearchSpace. https://ukzn-dspace.ukzn.ac.za/
Obadire, O. T., & Sinthumule, D. A. (2021). Learner discipline in the post-corporal punishment era: What an experience! *South African Journal of Education*, *41*(2), Article 1862, 1-8. https://doi.org/10.15700/saje.v41n2a1862
Olubunmi, O. L. (2019). Influence of class size and school environment on students' academic achievement in mathematics. *Journal of Emerging Trends in Educational Research and Policy Studies*, *10*(6), 343-349.
Oni, L. O. (2020). Influence of classroom environment on academic achievement in mathematics as perceived by junior secondary schools students in Oyo State. *Journal of Science, Technology, Mathematics and Education*, *16*(3), 159-168.
Organisation for Economic Co-operation and Development. (2020). What is the student-teacher ratio and how big are classes?, In *Education at a glance 2020: OECD Indicators* (pp. 370-383). OECD Publishing. https://doi.org/10.1787/315d95e6-en
Organisation for Economic Co-operation and Development. (2021). *Students per teaching staff*. OECD Publishing. https://data.oecd.org/teachers/students-per-teaching-staff.htm
Panthi, R. K., & Belbase, S. (2017). Teaching and learning issues in mathematics in the context of Nepal. *European Journal of Educational and Social Sciences, 2*(1), 1-28. https://files.eric.ed.gov/fulltext/ED573754.pdf
Prayitno, M. A. (2023). Getting to know the term of class size reduction (CSR) and its positive impact in the world of education (historical review). *Competitive: Journal of Education*, *2*(2), 103-112. https://doi.org/10.58355/competitive.v2i2.22
Reddy, V., Winnaar, L., Juan, A., Arends, F., Harvey, J., Hannan, S., Namome, C., Sekhejane, P., & Zulu, N. (2020). *TIMSS 2019: Highlights of South African Grade 9 results in mathematics and science*. Department of Basic Education. http://www.hsrc.ac.za/uploads/pageContent/1044991/TIMSS%202019_Grade9_HSRC_FinalReport.pdf

Reddy, V., Zuze, T. L., Visser, M., Winnaar, L., Juan, A., Prinsloo, C., Arends, F., & Rogers, S. (2015). *Beyond benchmarks: What twenty years of TIMSS data tell us about South African education*. Human Sciences Research Council Press. https://www.hsrcpress.ac.za/books/beyond-benchmarks

Shen, T., & Konstantopoulos, S. (2022). Are class size and teacher characteristics associated with cognitive outcomes in early grades? *School Effectiveness and School Improvement*, *33*(3), 333-359. https://doi.org/10.1080/09243453.2021.2023585

Shepherd, D., & Mohohlwane, N. (2021). *The impact of COVID-19 in education – more than a year of disruption*. Department of Basic Education. https://cramsurvey.org/wp-content/uploads/2021/07/11.-Shepherd-D-_-Mohohlwane-N.-2021.-Changes-in-education-A-reflection-on-COVID-19-effects-over-a-year.pdf

United Nations Children's Fund. (2009). *Child friendly schools*. United Nations Children's Fund (UNISEF). https://www.unicef.org/sites/default/files/2020-03/Child-Friendly-Schools-Manual.pdf

Venketsamy, R. (2023). Exploring the teacher-learner ratio and its effect on invitational teaching and learning: A South African study. *Journal for the Education of Gifted Young Scientists*, *11*(1), 33-43. http://dx.doi.org/10.17478/jegys.1237615

West, J., & Meier, C. (2020). Overcrowded classrooms – The Achilles heel of South African education? *South African Journal of Childhood Education, 10*(1), Article a617. https://doi.org/10.4102/ sajce.v10i1.617

Western Cape Department of Education. (2020, May 12). *Teacher absenteeism & learner/teacher ratio at schools in the province*. PMG Parliamentary Monitoring Group. https://pmg.org.za/committee-meeting/30201/

Wilson Fadiji, A., & Reddy, V. (2021). School and individual predictors of mathematics achievement in South Africa: The mediating role of learner aspirations. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(1), 65-76. https://doi.org/10.1080/18117295.2021.1874687