INDONESIAN JOURNAL OF SCIENCE AND MATHEMATICS EDUCATION
08 (1) (2025) 13-25
https://ejournal.radenintan.ac.id/index.php/IJSME/index
E-ISSN: 2615-8639
DOI: 10.24042/ijsme.v8i1.21855
March 2025

Internet access at home and varied usage as determinants of South African students' mathematics performance

Petronella Elize Saal[1*], Sylvia Hannan[2], Vandudzai Mbanda[3]
[1,2,3]Equitable Education and Economies, Human Sciences Research Council, Durban, South Africa

*Corresponding author: psaal@hsrc.ac.za

Article history:

Submitted: April 5, 2024
Accepted: February 3, 2025
Published: March 30, 2025

Keywords:

digital divide, home internet access, mathematics achievement, socioeconomic status, technology in education

ABSTRACT

Mathematics plays a crucial role in economic and technological advancement; however, disparities in internet access can affect students' academic performance. This study examines the relationship between home internet access, varied internet usage, and mathematics achievement among Grade 9 students in South Africa, using data from the 2019 Trends in International Mathematics and Science Study (TIMSS). Employing descriptive statistics and multi-level modeling, the findings reveal that less than half of the students had internet access at home, with significant disparities based on school socioeconomic status. Students with internet access who used it to find information, articles, or tutorials for mathematics performed better than those without access. However, students who relied on the internet to access textbooks, course materials, assignments, or teacher communication demonstrated lower performance than their peers. This study highlights the impact of the digital divide on education and suggests policy interventions to enhance equitable access to educational resources. The findings imply that addressing this gap through targeted digital infrastructure investments and ICT training for both students and teachers can improve mathematics achievement and promote educational equity.

Akses internet di rumah dan penggunaan yang bervariasi sebagai penentu prestasi matematika siswa di Afrika Selatan

Kata Kunci:

kesenjangan digital, akses internet di rumah, prestasi matematika, status sosial ekonomi, teknologi dalam pendidikan

ABSTRAK

Matematika memainkan peran penting dalam kemajuan ekonomi dan teknologi, namun kesenjangan dalam akses internet dapat mempengaruhi prestasi akademik siswa. Penelitian ini bertujuan untuk meneliti hubungan antara akses internet di rumah, variasi penggunaan internet, dan prestasi matematika di antara siswa Kelas 9 di Afrika Selatan, dengan menggunakan data dari Studi Tren Matematika dan Sains Internasional (TIMSS) 2019. Dengan menerapkan statistik deskriptif dan pemodelan multi-level, temuan penelitian ini mengungkap bahwa kurang dari setengah siswa memiliki akses internet di rumah, dengan kesenjangan yang signifikan berdasarkan status sosial ekonomi sekolah. Siswa yang memiliki akses internet dan menggunakannya untuk mencari informasi, artikel, atau tutorial matematika menunjukkan prestasi yang lebih baik dibandingkan dengan mereka yang tidak memiliki akses. Namun, siswa yang mengandalkan internet untuk mengakses buku teks, materi perkuliahan, tugas, atau komunikasi dengan guru menunjukkan prestasi yang lebih rendah dibandingkan dengan rekan-rekan mereka. Studi ini menyoroti dampak kesenjangan digital terhadap pendidikan dan menyarankan intervensi kebijakan *untuk meningkatkan akses yang lebih merata terhadap sumber daya pendidikan. Penelitian ini memiliki implikasi bahwa mengatasi kesenjangan ini melalui investasi infrastruktur digital yang terarah serta pelatihan TIK bagi siswa dan guru dapat meningkatkan prestasi matematika serta kesetaraan pendidikan.*

Contribution to the literature

This research contributes to:

- Specifically, it examines how internet access and use impacts student performance in mathematics by considering the socioeconomic status of schools, which has not been widely studied in previous studies.
- Highlight the digital divide that still exists between schools of different socioeconomic status.
- Identify how students use the internet in different ways.

1. INTRODUCTION

At the peak of the COVID-19 pandemic, more than 1,6 billion students globally and their teachers were expected to use the internet to continue teaching and learning as schools closed for varying lengths of time to minimize the spread of the virus. However, about 826 million students could not transition from traditional to online learning because, at that time, about 706 million (around 43% globally) had no internet access at home [1]. This necessary transition to online learning was even more challenging in South Africa, where only 7% of households that accommodated people aged between 5 and 24 had access to the internet at home [2]. This means that 93% of the population does not have internet access at home. The shift to online learning environments during the pandemic has sparked an interest among researchers investigating internet usage in educational settings. For instance, some researchers have explored the importance of internet usage [3], while others have focused on the effectiveness of the Internet on educational outcomes [4]–[6]. In the case of South Africa, researchers have included internet access as part of a set of predictors of student achievement but have not considered it as the sole predictor [7], [8].

Despite this growing body of research on using the Internet in educational contexts, there remains a significant gap in understanding how internet usage relates to student achievement in mathematics, especially when considering the socioeconomic status (SES) of schools. The socioeconomic composition of schools in South Africa is highly diverse, due to the wide disparities in access to resources across the country and the poor level of education provided to Black Africans by the Apartheid government [9]. Post-Apartheid, the school quintile system was implemented as an initiative designed to address educational inequalities [10]. The quintile system ranks schools into five categories, from Quintile 1 (the poorest) to Quintile 5 (the most affluent), based on the poverty level of the surrounding communities. Resources and/or funding are distributed accordingly, aiming to redistribute funds to benefit those in more economically disadvantaged areas [11].

Furthermore, Reddy *et al.* [12] explain that schools grouped in Quintiles 1 to 3 are referred to as no-fee schools, while those belonging to Quintiles 4 and 5 are fee-paying schools. Fee-paying schools are located mostly in areas with better access to resources and often have greater access to internet facilities, while no-fee schools are located in low-resourced areas and face significant challenges, including limited or no internet access [13]. This unequal access to the internet related to the SES of schools directly impacts students' access to quality educational resources, which could influence their academic achievement. Therefore, this study aims to explore how home internet access and internet usage relate to student performance in mathematics.

In addition to foundational skills, the modern workplace increasingly requires 21st-century skills, including non-routine problem-solving skills, communication skills, teamwork, learning and innovation skills, and information and communication technology (ICT) skills [14]–[16]. Developing skills in science, technology, engineering, and mathematics (STEM) to respond to the current and future demands of the labor market has been widely acknowledged [17].

Mathematics is widely recognized as a fundamental discipline contributing to economic prosperity, scientific advancement, and technological innovation. However, despite its importance, students in South Africa continue to struggle with mathematics performance, as evidenced by poor outcomes in national and international assessments, such as TIMSS 2019, where South Africa ranked among the lowest-performing countries [18]. Previous research has explored various factors influencing mathematics achievement, including socioeconomic status, school resources, and instructional quality [12].

A few researchers focused on the role of technology and internet access in enhancing mathematics education. Studies have highlighted that home internet access can provide students with additional learning resources, such as online tutorials, digital textbooks, and collaboration platforms, which may positively impact their academic performance [4]. However, the relationship between internet usage and mathematics achievement remains inconclusive. Some studies have found a positive correlation between using the Internet for academic purposes and improved performance [19], [20], while others have reported a negative or negligible effect [5], [21]. There have been limited studies concerned with the impact of internet usage on mathematics achievement in the South African context, particularly when considering the socioeconomic status of schools. Prior research has largely relied on earlier TIMSS datasets, which do not fully capture the evolving digital landscape and its educational implications [22]. Moreover, most existing studies have examined internet access as part of a broader set of predictors rather than an isolated factor influencing mathematics performance.

Therefore, this research was intended to investigate the extent of home internet access among South African Grade 9 students and examine its relationship with mathematics performance while controlling for the socioeconomic status of schools. By utilizing data from TIMSS 2019, this study aims to provide updated insights into how internet access and varied internet usage contribute to students' mathematics achievement, addressing the gaps in previous research. This study aims to determine the percentage of South African Grade 9 students with internet access at home and examine how different forms of internet usage for mathematics-related activities influence their performance. Furthermore, the study seeks to analyze whether the socioeconomic status of schools moderates the relationship between internet access and mathematics achievement.

2. METHOD

This study aimed to examine the availability of internet access at home for South African Grade 9 students, their use of the internet for mathematics, and the potential relationship between internet use and mathematics achievement. The researchers used a secondary quantitative research design to analyze the South African Grade 9 dataset from the 2019 TIMSS. This dataset includes survey data on the mathematical and scientific abilities of fourth- and eighth-grade students from over 60 countries and contextual questionnaire data enabling nations to assess their educational effectiveness globally [23]. However, countries may administer the assessment to students in a higher grade (Grade 5 or 9) to better align with the assessment's demands. For example, in South Africa, data was collected from Grade 9 students [24]. The researchers utilized data from the student and school background questionnaires and mathematics achievement scores collected from 20,829 Grade 9 South African students across 519 schools nationwide who participated in TIMSS 2019. The study was conducted after obtaining consent from both parents and students. A stratified two-stage cluster design was employed to select participants: in the first stage, a random sample of schools was drawn, and in the second stage, one or more intact classes were selected from each sampled school [25]. In South Africa, the sample was explicitly stratified by the nine provinces and school types (public and independent) and implicitly stratified by school performance level [12]. After receiving ethics approval, the research was conducted.

Student-level variables (Level 1) were obtained from the student background questionnaire, while school-level variables (Level 2) were sourced from the school questionnaire completed by each school's principal (see Table 1). The dependent variable was students' mathematics achievement scores, represented by five plausible values. The TIMSS administration collaborated with National Research Coordinators (NRCs) and mathematics experts to develop new assessment items. NRCs reviewed the items before and after field testing, while the TIMSS & PIRLS International Study Center prepared an international version of the achievement assessment. 325 new mathematics and science items were developed in 2019 and added to the existing TIMSS trend items. Participating countries then translated these items into their respective languages, ensuring high-quality, culturally appropriate, and internationally comparable assessments [26]. Each mathematics and science assessment item was compiled into 14 student achievement booklets as part of TIMSS' matrix sampling methodology. Each student completed one achievement booklet and a background questionnaire [12]. This rigorous process ensured the validity and reliability of the data collected for the study.

Table 1. Predictors Used in This Study

Variable Explanation	Variable Code	Response Choices	Re-coding
Student-level Predictors (Independent Variables)			
Internet access at home	BSBG05D	1. Yes	1. No
Using the Internet to access textbooks or other course materials	BSBG12A	2. No	2. Yes
Using the internet to access assignments posted online by the teacher	BSBG12B		
Using the Internet to collaborate with classmates	BSBG12C		
Using the Internet to communicate with the teacher	BSBG12D		
Using the internet to find information, articles, or tutorials to aid in understanding mathematics	BSBG12E		
Using the Internet to access learning games	BSBG12F		
School-level Predictors (Independent Variable)			
School Status	SchStatus	1. No Fee 2. Fee-paying	1. Fee-paying 2. No Fee
Dependent variable	Mathematics achievement (5 plausible values) BSSMATTO-01-05		

To address research question one, the International Association for the Evaluation of Educational Achievement (IEAs) International Database (IDB) Analyzer version 5.0.16 was used in conjunction with Statistical Package for the Social Sciences (SPSS) to run percentages and means to determine the extent to which South African Grade 9 students have home internet access and used the internet, and whether the use of the internet influenced their mathematics achievement. For the second research question, the researchers used HLM version 8 [27] to build multi-level models to examine whether a relationship exists between the mathematics achievement of students and their use of the internet. HLM was suitable for analyses since it considers the nested structure of schools and student differences and grouping within the schools [27]. Managing missing values to prevent biased estimates is important because HLM can only handle missing data at the student level [28]. Missing values were replaced using the expectation-maximization (EM) method in SPSS 28. Research revealed that the EM convergence process can be very slow when the missing data is large [29]. However, the researchers increased the number of iterations to 1000 to address this challenge. Besides, the EM method considers the conditions under which missing data occurred and provides better parameter estimates than either listwise or pairwise deletion [30]. Using the proper weighting processes is also critical because it considers the complicated sampling approach used in TIMSS and maintains the contribution of students and schools proportional to the population. Student-level weights were computed as Stuclwgt = WGTAC2*WGTFAC3*WGTADJ, and the calculation for Level-2 weight was Schoolwgt = WGTFAC1*WGTADJ1 (WGTFAC1 is the school weight factor; WGTADJ1 is the school weight adjustment; WGTFAC2 is the class weight factor, WGTADJ2 is the class weight adjustment, WGTFAC3 is the student weight factor, and WGTADJ3 is the student weight adjustment) [31].

3. RESULTS AND DISCUSSION

3.1 Home Internet Access Among Grade 9 South African Students

First, the researchers determined the percentage of Grade 9 South African students with access to an internet connection at home. Findings showed that less than half (41%) of these students had internet access at home. Results further showed that students without an internet connection at home were outperformed by their peers with an internet connection at home, who scored, on average, 44,63 points higher in mathematics (Table 2). The difference in achievement between students with and without an internet connection at home was significant, as shown in Table 2. Furthermore, the percentage of students without home internet access was even higher when considering the SES of the schools. The researchers found that almost 70% of students who attended no-fee schools lacked internet access at home. Students from no-fee schools without home internet access scored an average of 362.09, 12.18 points lower (statistically significant) than those without internet access. Compared home internet access between no-fee and fee-paying schools, the researchers found that around 40% of students from fee-paying schools lacked home internet access, 30% less than students from no-fee schools. Furthermore, students enrolled in fee-paying schools without home internet access scored 408.15 on average for mathematics, 55.51 points less (statistically significant) than their peers from fee-paying schools with an internet connection. Another interesting result is that students from fee-paying schools with home internet access scored 463.66 on average in mathematics, outperforming students enrolled in no-fee schools with internet access at home by 89.39 points. This finding indicated that the fee-paying status of a school is an important predictor of academic success, regardless of students' home resources.

Table 2. Internet-related Variables and Students' Average Mathematics Achievement Scores

Internet-related Variables	Response Option	Math Mean (s.e.)	Difference in Achievement (s.e.)	t-Value
Internet access at home	Yes	417.31 (2.58)	-44,63	-15.72
	No	372.68 (2.49)	(2.84)	
Internet access at home, considering the fee-paying status of the schools	Yes (No-fee)	374.24 (2.92)	-12.18 (2.78)	-4.38
	No (No-fee)	362.09 (2.80)		
	Yes (Fee-paying)	463.66 (3.40)	-55.51 (4.40)	-12.61
	No (Fee-paying)	408.15 (3.40)		
Using the Internet to access textbooks or other course materials	Yes	389.02 (2.36)	3.16	1.68
	No	392.18 (2.54)	(1.87)	
Using the internet to access assignments posted online by the teacher	Yes	387.51 (2.97)	4.99	1.94
	No	392.49 (2.21)	(2.57)	
Using the Internet to collaborate with classmates	Yes	393.58 (2.18)	-14.75	-5.51
	No	378.83 (3.36)	(2.67)	
Using the Internet to communicate with the teacher	Yes	379.50 (2.68)	20.42	9.10
	No	399.92 (2,26)	(2.24)	
Using the internet to find information, articles, or tutorials to aid in understanding mathematics	Yes	395.74 (2.32)	-19.68	-10.36
	No	376.06 (2.49)	(1.90)	
Using the Internet to access learning games	Yes	392.21 (2.46)	-4.31	-2.25
	No	387.90 (2.38)	(1.92)	

3.2 Students' Use of the Internet at Home

Next, we explored the students' uses of their home internet, as shown in Figure 1. The most common internet use reported by the students (79%) was collaborating with classmates. Findings showed that the students who used the internet for collaboration with their peers outperformed those who did not use it for collaboration purposes by an average of 14.75 points. The difference between the mathematics scores of these groups was statistically significant (see Table 2). Furthermore, almost three-quarters of students (72%) indicated that they used the Internet to find information to aid their understanding of mathematics. The students who used information found via the internet to improve their understanding of mathematics also obtained higher mathematics scores than their counterparts who did not use the Internet. The difference (19.68 points) in mathematics scores between those who used the internet to find information and those students who did not was also statistically significant (see Table 2). Students who used the internet to access learning games were also shown to have achieved higher scores than those who did not, with a statistically significant difference of 4.31 points on average between these groups. These results highlight the positive impact of utilizing the internet for collaborative learning, information gathering, and educational gaming on students' mathematics performance. This indicates that specific, purposeful internet usage at home can significantly contribute to improved academic outcomes in mathematics.

Results further showed that around three-quarters of students accessed textbooks via the internet, while the internet activities undertaken the least by the students were accessing assignments and communicating with their teacher. For these three aspects, those students who did not use the internet for these purposes scored higher than those who did undertake these activities. The difference in achievement concerning communicating with the teacher was statistically significant; however, for accessing textbooks (or other course materials) and assignments, the differences in achievement were not statistically significant. In summary, students who relied less on the internet for academic interactions generally performed better.

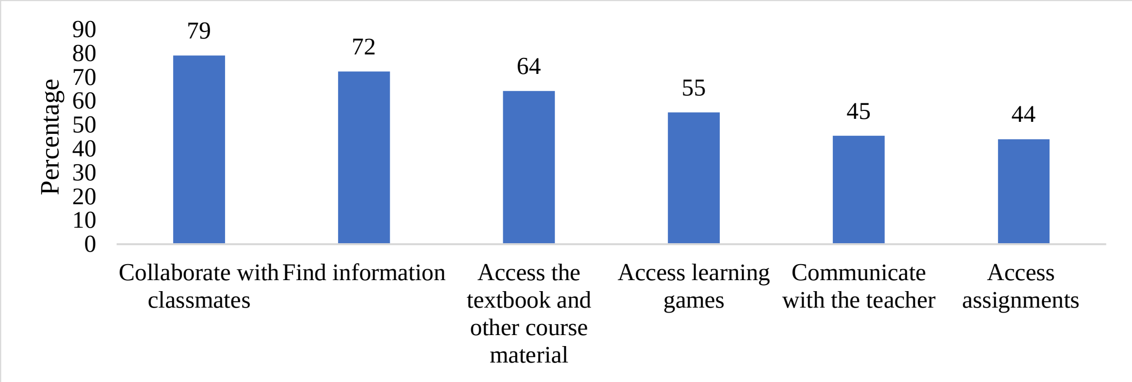

Figure 1. Students' Use of Home Internet for Different Tasks

3.3 Relationship between Internet Use in Mathematics and Student Performance

To investigate the relationship between internet use and students' mathematics achievement further, a null model without any explanatory variables was created using HLM 8.2. The purpose of the null model was to show the variance in mathematics achievement between the different school types in South Africa (see Table 2). The variance of the null model at Level 2 is 2952.08, which represents 2952.08/(2952.08 + 2996.09)*100 = 50% of the total variance. Moreover, the variance at Level 2 is significantly different from zero (p-value < 0.001), indicating that the data is suitable for conducting analysis using multi-level models, and predictors at Level 2 contribute to the variation in the outcome variable. The variance at Level-1 is 2996.09, which represents 2996.09/ (2952+ 2996.09) *100 = 50% of the total variance.

Table 3. Null Model

Level	Standard Deviation	Variance Component	Chi-Square	*p*-Value
Level-2	54.33	2952.08	19,120.32	<0.001 *
Level-1	54.73	2996.09		

Secondly, the full model containing Level-1 and Level-2 predictors was created. The SES or fee status of the school was included in the model as a control variable. Thereafter, the final model was created by removing all insignificant variables one at a time from the model until only significant predictors remained. The variance at Level 2 is 2635.44, which represents 2635.44/ (2635.44 + 2827.85) *100 = 48% of the total variance. Subsequently, the variance at Level-1 is 2827.85, representing 2827.85/ (2635.44 + 2827.85) = 52% of the total variance, as shown in Table 3. The fact that Level-1 variance is slightly higher (51%) than Level-2 variance (48%) suggests that individual-level factors (internet access and usage) play a slightly larger role in explaining the variation in the outcome (mathematics achievement) compared to school-level factors. Furthermore, the results show significance at Level 2 (p < 0.001). The sample averages accurately represented the actual school means, as evidenced by the average reliability estimate of 0.977.

Table 4. The Final Model

Level	Standard Deviation	Variance Component	Chi-Square	p-Value
Level-2	51.33	2635.44	19,462.60	<0.001 *
Level-1	53.17	2827.85		

Table 5 displays the final model's findings, together with the response options, coefficients, standard errors, t-values, and levels of significance. The correlation between internet-related factors at the student and school levels is then addressed.

Table 5. The Final Model with Significant Predictors

Variable Explanation	Response Choices	Coefficient (ß)	Standard Error (S.E)	t-Value (t)	Standard Deviation	p-Value (p)	Effect Size
Intercept		388.64	4.10	94.75	77.45	<0.001*	
Level-1 (Student-level)							
Internet Connection (at home)	1-No 2-Yes	10.74	2.02	-4.84	0.49	<0.001*	
Students use the internet to access textbooks or other course materials	1-No 2-Yes	-6.65	1.87	3.54	0.47	<0.001*	
Using the internet to access assignments posted online by the teacher	1-No 2-Yes	-7.99	1.33	5.99	0.49	<0.001*	
Using the Internet to communicate with the teacher	1-No 2-Yes	-15.43	1.84	8.37	0.44	<0.001*	
Using the internet to find information, articles, or tutorials to aid in understanding mathematics	1-No 2-Yes	6.51	1.64	-3.95	0.49	<0.001*	
Level-2 (School-level)							
School Status	1- Fee-paying Schools 2- No fee Schools	-56.85	11.74	4.84	0.24	<0.001*	

3.4 Student-Level Predictors

Findings from the final model showed that students with an internet connection at home outperformed their peers without an internet connection at home by 10.74 points on average in mathematics. Students who used the internet to find information, articles, or tutorials to aid their understanding of mathematics also achieved 6.51 points higher than their counterparts who did not use it for such purposes. Furthermore, students who used the internet to access textbooks or other course materials, to access assignments posted online by their teacher, and to communicate with the teacher were outperformed, on average, by 6.65, 7.99, and 15.43 points, respectively, in mathematics by their counterparts who did not use the internet for these purposes.

3.5 School-Level Predictors

The SES of the schools, in this case, the school fee status (fee-paying and no-fee schools), was included in the model as a control variable. The results showed that students who attended no-fee schools outperformed by 56.85 points on average for mathematics by those who were enrolled in fee-paying schools. This study sought to determine the extent of home internet access and varied internet usage among Grade 9 South African students. We further aimed to investigate the relationship between home internet access and different uses and students' mathematics achievement in TIMSS 2019 while controlling for schools' SES.

The first research question in this study was: What percentage of South African Grade 9 students had internet access at home, and for what purposes were they using the internet? According to Bronfenbrenner's ecological theory [32], the microsystem in this study, the student's home environment, is where the individual operates. The results of this study revealed a concerning reality aligning with the findings of Survey [2] and van Zyl *et al.* [13], finding that less than half of South African Grade 9 students had internet access at home. Consequently, almost 60% of South African students lacked internet access at home. What's more concerning is that when we considered the school's SES (fee status), almost 70% of students attending no-fee schools lacked an internet connection at home. This finding highlights a significant digital divide within the country. We also found that the fee status of a school could be regarded as a significant predictor of academic achievement, particularly in the context of home internet access. Results showed that students from fee-paying schools with home internet access outperformed students from no-fee schools who also had internet access at home. One possible reason for this result could be the different resources and support available to students based on their school fee status, which reflects the surrounding communities. Fee-paying schools typically have greater financial resources [12], which translates into better access to educational resources than no-fee schools. Students attending no-fee schools come from homes with less financial and social resources. Therefore, students attending fee-paying schools, even with similar home internet access to students from no-fee schools, may benefit from a more conducive learning environment and additional support systems that could enhance their mathematics performance.

This study's mesosystem [32] encompassed the interplay between internet access at home and varied internet usage. We found that most students employed the Internet for collaborative purposes and to seek information to aid their understanding of mathematics. Results also showed that these students obtained higher mathematics scores than their counterparts who did not use the internet for these purposes. The finding related to seeking information for enhanced mathematics understanding contrasts with the finding of Kruger [5], which showed that students' mathematics scores decreased when they sought mathematical concepts and information online.

The second research question addressed in this study was: What is the relationship between the use of the internet in mathematics and student performance in mathematics when the status of the school is considered? In our study, we conceptualized the exosystem, as defined by Bronfenbrenner [32], as encompassing the SES of the school, distinguishing between fee-paying and no-fee schools. This distinction is important as the fee status of schools can significantly impact the resources available to students, thus influencing their educational performance. Echoing the results of Reddy *et al*. [12], who found a 75-point achievement difference between students from fee-paying and no-fee schools, we found that students enrolled in fee-paying schools outperformed their peers registered in no-fee schools. In fact, the SES was the most significant predictor of the Grade 9 students' mathematics scores.

In line with the results of Shala and Grajcevci [4], our results revealed a statistically significant positive relationship between home internet access and students' mathematics achievement. This finding contrasts [33], who found no statistically significant relationship between internet access at home and student achievement using TIMSS 2015 data. One possible explanation for the contrasting findings between our study and that of Saal *et al*. could be attributed to our study controlling for the schools' SES.

Furthermore, we found statistically significant negative relationships between students' mathematics performance and using the internet to access textbooks and other course materials, to access assignments posted online by the teacher, and to communicate with the teacher. Possible explanations for these negative relationships could be that students may have encountered difficulties navigating the online textbook and course materials, which could have impeded their comprehension of mathematical concepts. Also, online communication with the teacher may not have been engaging or effective. Furthermore, online assignments may have lacked the interactive feedback and guidance provided during in-person instruction, which could have led to the misinterpretation of the requirements of the assignments by the students.

Supporting the findings of Falck *et al.* [19] and Zhang and Wang [20], who found positive relationships between looking up information and mathematics scores, we found that using the internet to find information, articles, or tutorials to aid students' understanding of mathematics was positively correlated with the Grade 9 students' mathematics achievement. A possible explanation for this result could be that students were exposed to various quality educational resources. That they did not usually have access to, that catered to their learning styles and needs. Future research could explore the use of the Internet and its relation to mathematics achievement in the stern Cape and Gauteng provinces of South Africa, where there is more extensive availability of ICT in classrooms since ICT availability and usage are very limited in the country. To ensure more equitable education in South Africa, policymakers must prioritize bridging the digital divide by increasing internet access, especially in disadvantaged communities. Additionally, the negative impact of some current online educational resources on student achievement indicates the importance of improving the quality and accessibility of these tools and promoting digital competencies among students and teachers through capacity development and training programs. Lastly, targeted support for no-fee schools, including investments in infrastructure and resources, is important to reduce educational disparities and improve educational outcomes for all students.

4. CONCLUSION

This study presented findings on internet access in South African homes as reported by Grade 9 students who participated in TIMSS 2019. We further showed statistically significant relationships between internet access and different uses based on the school's socioeconomic status. These findings highlight the significance of internet access in mathematics outcomes, with students having internet connectivity at home exhibiting notably higher mathematics performance. Moreover, active utilization of various online resources for educational purposes emerged as a consistent predictor of enhanced academic achievement. These findings highlight the imperative to 1) bridge the digital divide that exists in the country between fee-paying and no-fee schools, ensuring equitable resource allocation in educational institutions; 2) develop students' ICT competencies and encourage the use of educational online resources; and 3) prioritize teacher training in online teaching and learning.

Even though this study was a nationally representative sample of South Africa, it relied on self-reported data from background questionnaires completed by students and principals, which can be subject to response and social desirability biases. The TIMSS study also followed a cross-sectional design, which provided valuable insights. However, a limitation of cross-sectional studies is that they do not allow the establishment of causal relationships. While this study primarily relied on quantitative data, future research can benefit from incorporating qualitative methods to explore students' experiences, perceptions, and challenges in utilizing the internet for mathematics education. This research implies that addressing this gap through targeted digital infrastructure investments and ICT training for students and teachers can improve mathematics achievement and educational equity.

AUTHOR CONTRIBUTION STATEMENT

PES contributed to conceptualizing the study, designed the research framework, and led the data analysis process. She also contributed significantly to the interpretation of findings and the drafting of the manuscript. SH contributed to Providing methodological expertise, particularly in the application of multi-level modeling and statistical analysis. She played a key role in refining the research design and contributed to the writing and revision of the manuscript. VM contributed to conducting the literature review, assisted in data collection and organization, and contributed to the discussion and policy implications. She also played a crucial role in editing and formatting the final version of the manuscript.

REFERENCES

[1] C. O'Hagan, "Startling digital divides in distance learning emerge," *UNESCO*, 2020.

[2] S. S. G. H. Survey., "General household survey.," *J. Public Health Med.*, vol. 21, no. 4, pp. 482-490, 2022.

[3] S. H. H. Al-Taai, H. A. Kanber, and W. A. M. Al-Dulaimi, "The importance of using the internet of things in education.," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 1, pp. 19–39, 2023, doi: 10.3991/ijet.v18i01.35999.

[4] A. Shala and A. Grajcevci, "ICT and internet usage among kosovar students: The impact of trends on achievement in the PISA scales.," *J. Learn. Dev.*, vol. 10, no. 1, pp. 122–133, 2023, doi: 10.56059/jl4d.v10i1.775.

[5] G. M. Kruger, *The relationship between investment in ICT and mathematics achievement*. University of Pretoria (South Africa), 2018.

[6] C. O. Guzeller and A. Akin, "Relationship between ICT variables and mathematics achievement based on PISA 2006 database: International evidence.," *Turkish Online J. Educ. Technol.*, vol. 13, no. 1, pp. 184–192, 2014.

[7] C. Namome and M. Moodley, "ICT in mathematics education: An HLM analysis of achievement, access to and use of ICT by african middle school students," *SN Soc. Sci.*, vol. 1, no. 9, pp. 1-21, 2021, doi: 10.1007/s43545-021-00230-6.

[8] P. E. Saal, L. Van Ryneveld, and M. A. Graham, "The relationship between using information and communication technology in education and the mathematics achievement of students," *International Journal of Instruction*, vol. 12, no. 3 pp. 405-424, 2019, doi: 10.29333/ejmste/8939.

[9] M. McKeever, "Educational inequality in apartheid South Africa," *Am. Behav. Sci.*,

vol. 61, no. 1, pp. 114–131, 2017, doi: 10.1177/0002764216682988.
[10] D. Grant, "WCED: Media release. Background to the national quintile system." *Westerncape*, 2013. [Online]. Available: https://wcedonline.westerncape.gov.za/comms/press/2013/74_14oct.html. (Accessed Jun, 12, 2024)
[11] Department of Education, "National Norms and Standards For School Proposals for amendments," M.S thesis, Dept. Account. and Inform., Durban Univ. of Tech., Durban, South Africa, 2004.
[12] V. Reddy *et al.*, "The South African TIMSS 2019 Grade 9 results: Building achievement and bridging achievement gaps," Research Output Repository, 2022.
[13] A. Van Zyl, E. M. Webb, and J. E. Wolvaardt, "Striving for equity: Life orientation resources in South African high schools," *South African J. Educ.*, vol. 41, no. 1, 2021, doi: 10.15700/saje.v41n1a1830.
[14] Z. K. Szabo, P. Körtesi, J. Guncaga, D. Szabo, and R. Neag, "Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills," *Sustainability*, vol. 12, no. 23, pp. 1-28, 2020, doi: 10.3390/su122310113.
[15] L. D. English and J. Gainsburg, "Problem solving in a 21st-century mathematics curriculum," in *Handbook of international research in mathematics education*, Routledge, 2015, pp. 313–335.
[16] I. of E. S. (Project), *Education policy analysis*. Organisation for Economic Co-operation and Development, 2001.
[17] K. Maass, V. Geiger, M. R. Ariza, and M. Goos, "The role of mathematics in interdisciplinary STEM education," *Zdm*, vol. 51, no. 1, pp. 869–884, 2019, doi: 10.1007/s11858-019-01100-5.
[18] P. E. Saal, L. Van Ryneveld, and M. A. Graham, "Comparing the relationship between using educational technology in mathematics and student achievement in South Africa and Germany," *J. Res. Technol. Educ.*, vol. 54, no. 4, pp. 581–598, 2022, doi: 10.1080/15391523.2021.1904062.
[19] O. Falck, C. Mang, and L. Woessmann, "Virtually no effect? Different uses of classroom computers and their effect on student achievement," *Oxf. Bull. Econ. Stat.*, vol. 80, no. 1, pp. 1–38, 2018, doi: 10.1111/obes.12192.
[20] Y. Zhang and Q. Wang, "Content learning opportunities, computer-based instruction, and students' mathematics and science achievement," *Int. J. Math. Educ. Sci. Technol.*, vol. 51, no. 8, pp. 1164–1180, 2020, doi: 10.1080/0020739X.2020.1717659.
[21] D. Rozgonjuk, K. Täht, and K. Vassil, "Internet use at and outside of school in relation to low-and high-stakes mathematics test scores across 3 years," *Int. J. STEM Educ.*, vol. 8, pp. 1–14, 2021, doi: 10.1186/s40594-021-00287-y.
[22] P. E. Saal, M. A. Graham, and L. Van Ryneveld, "The relationship between integrating educational technology in mathematics education and the mathematics achievement of german students.," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 16, no. 12, 2020, doi: 10.29333/ejmste/8939.
[23] N. S. C. E. Results, *NSC Exam Results*. South Afica : NSC, 2023.
[24] S. LaRoche and P. Foy, "Sample implementation in TIMSS 2019," *Methods Proced. TIMSS 2019 Tech. Rep.*, 2020, ch. 9, pp. 9.1-9.261.
[25] S. LaRoche and P. Foy, "Sample implementation in TIMSS 2015," *Methods Proced. TIMSS*, 2015, ch. 5, pp.1-175.
[26] K. E. Cotter, V. A. S. Centurino, and I. V. S. Mullis, "Developing the TIMSS 2019

mathematics and science achievement instruments," *Methods Proced. TIMSS*, 2019, ch. 1, pp. 1.2-1.36.

[27] S. W. Raudenbush, "*Hierarchical linear models: Applications and data analysis methods*," Adv. Quant. Tech. Soc. Sci. Ser., 2002.

[28] Y. Suryono, "Teacher's achievement in curriculum 2013 training: A hierarchical linear model.," *Int. J. Instr.*, vol. 15, no. 1, pp. 891–910, 2022, doi: 10.29333/iji.2022.15151a.

[29] R. J. A. Little and D. B. Rubin, *Statistical analysis with missing data*, vol. 793. John Wiley & Sons, 2019.

[30] Y. Dong and C.-Y. J. Peng, "Principled missing data methods for researchers," *Springerplus*, vol. 2, no. 1, pp. 1–17, 2013 doi: 10.1186/2193-1801-2-222.

[31] L. Rutkowski, E. Gonzalez, M. Joncas, and M. Von Davier, "International large-scale assessment data: Issues in secondary analysis and reporting," *Educ. Res.*, vol. 39, no. 2, pp. 142–151, 2010, doi: 10.3102/0013189X10363170.

[32] U. Bronfenbrenner, "Toward an experimental ecology of human development.," *Am. Psychol.*, vol. 32, no. 7, p. 513, 1977, doi: 10.1037//0003-066X.32.7.513.

[33] A. Posso, "Internet usage and educational outcomes among 15-year old Australian students," *Int. J. Commun.*, vol. 10, no. 1, pp. 3851–3876, 2016.