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Comparing the Use of Educational Technology in Mathematics Education between South African and German Schools

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Abstract: This mixed-method study investigated how primary school mathematics teachers in South Africa and Germany utilise educational technology. The perceptions of the principals and teachers regarding the use of educational technology and the obstacles to its integration were contrasted. In addition, the Trends in International Mathematics and Science Study (TIMSS) 2019 data from these countries were used to evaluate the relationship between educational technology and learner accomplishment. The results showed that teachers from both nations employed educational technology as a presentation-, reinforcement-, supplement-, and problem-solving tool, and also used it to stimulate the learning environment, as shown through semi-structured interviews and classroom observations. In addition, obstacles such as a lack of tablets/computers, technical support, and a lack of relevant continuous professional development impeded the incorporation of educational technology in mathematics by these teachers. Additionally, multi-level models revealed that access to a computer and internet connectivity at home correlated positively with German learners' mathematics performances, while no statistically significant relationship was observed in South Africa. The results of this study have policy implications and are discussed at the end of this paper.

Keywords: educational technology; HLM; interview; mathematics education; mixed-method; multi-level model; TIMSS

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1. Introduction

Nearly all of the 57 countries that participated in the Trends in Mathematics and Science Study (TIMSS) 2019 highlighted the importance of using educational technology to enhance the effectiveness of teaching and learning [1]. In fact, several countries, including South Africa and Germany, made substantial investments in rolling out educational technology in schools. For instance, the South African government allocated approximately 15.3 billion rands towards instructional equipment that included educational technology [2]. In a similar vein, the German government allocated about 2.4 billion euros for the proposed Digital Pact program, aiming to equip schools in Germany with digital infrastructure [3]. Sadly, these investments do not automatically result in improved learner performance. Instead, educational technology only provides teachers with new teaching strategies, which might positively influence learner performances if integrated correctly [4]. Several studies documented the advantages of using educational technology in mathematics education. For instance, the British Educational Communication and Technology Agency (BECTA) stated that educational technology could develop learners' visual imagery and assist them in observing patterns and exploring data that can be beneficial for learning mathematics [5]. Nevertheless, regardless of the ways in which educational technology can benefit teaching and learning, many mathematics teachers still do not recognise its advantages [6]. The distribution of educational technology to schools does not automatically translate into a situation where teachers actually use it for instruction purposes or to improve the quality of education [7]. To this point, very few studies are interested in the use of educational technology in South African and German schools. Consequently, this study investigated the use of educational technology in two schools per country. These schools were purposefully sampled as they had educational technology available for mathematics education. This mixed-method study explored the different ways in which mathematics teachers use educational technology in German and South African primary school classrooms. Educational technology is not restricted to technology but is anything that enhances classroom learning in the utilisation of blended, face-to-face, or online learning. In this study, educational technology refers to (but is not limited to) all digital devices, such as computers, laptops, tablets, mobile phones, internet, audio-visual assets, and computer software. These teachers' and principals' perceptions regarding the use of educational technology and the barriers hindering educational technology integration were compared. Additionally, the association between using educational technology and learner achievement were investigated. The following research questions were investigated in this study:

- What are the similarities and differences in how teachers use educational technology in mathematics in South African and German elementary schools?
- What are the similarities and differences regarding the barriers influencing these teachers' integration of educational technology in mathematics?
- How do these teachers' perceptions concerning the use of educational technology in mathematics compare?
- How does the use of educational technology correlate with the mathematics achievement of learners when the socioeconomic status (SES) of the school and the teachers' and learners' gender are controlled for?

2. Literature Review

The use of technology rapidly increased in society over the past decade or so [8]. Consequently, many educational systems incorporated the use of educational technology in their curricula. Elementary and secondary education teachers were urged to integrate technology into education [9]. However, during the global pandemic (COVID-19), most schools rapidly shifted from face-to-face teaching to online teaching. This global change in education resulted in more researchers investigating educational technology's uses and influences on learner achievement [10]. However, in this literature review, the different ways in which teachers use educational technology and their perceptions regarding integrating educational technology are discussed.

2.1. Different Ways in Which Teachers Use Educational Technology

The adoption of educational technology by mathematics teachers largely depends on whether or not they use it voluntarily [11]. Many mathematics teachers are, however, pressured by curriculum requirements to integrate technology into their classroom instruction. Others are willing to change their teaching approach due to the known benefits of using educational technology in mathematics education. One of the most basic conditions is that the devices must be readily available in the classroom for teachers to use computers in mathematics lessons.

In Turkey, Birgin et al. [12] used a descriptive survey to investigate mathematics teachers' perceptions while using Information Communication Technologies (ICTs). Their study included 242 mathematics teachers from Grade 5 to Grade 12. They found that almost all teachers owned a computer and smartphone and had access to the internet. Almost 70% (69.8%) of these teachers received training on Computer Assisted Instruction (CAI), and therefore, one would assume that most would use computers in their instruction. However, Birgin et al. [12] found that only 14.0% of these teachers used computers very often, while 28.9% used computers often, 19.4% barely used them, and 7.4% never used computers in mathematics instruction. Their findings also showed that just over one-quarter (25.6%) of these teachers frequently used the smartboard, while 7.0% rarely used it during mathematics lessons. An interesting finding is that these teachers had ICT available and had some knowledge about which software was available (for example, Mathematica, Cabri II, Cabri 3D, Maple, and Geometer's Sketchpad), which means the training they received on CAI did not necessarily result in their use of educational technology in mathematics. Another interesting finding was that teachers mostly used ICT as a communication tool rather than an instructional tool [12].

In South Africa, Umugiraneza et al. [13] investigated the extent to which mathematics teachers from schools in the KwaZulu-Natal province used technology in the classroom. These authors distributed a questionnaire to a sample of 75 mathematics teachers. Only 44.0% of these teachers indicated that their schools have computer facilities, and 28.0% explained that some computers could be used for mathematics instruction. Their findings also suggest that these teachers are more comfortable using calculators than computers. An area of concern is that computers are not used for instructional purposes, but more for administration in schools with computer facilities [13].

Xiang [6] used a mixed-method approach to compare how mathematics teachers from England and China integrate technology into mathematics. In total, 348 mathematics teachers completed a questionnaire (229 from China and 119 from England). Additionally, 11 teachers were interviewed and observed (six from China and five from England). Findings showed that mathematics teachers from China mostly used computers, data projectors, Microsoft Office programmes (such as Word, Excel, and PowerPoint), followed by calculators, interactive whiteboards, and Geometer's Sketchpad, and most reported that they barely use mobile phones in mathematics teaching.

On the other hand, teachers from England reported mostly using calculators, computers, interactive whiteboards, GeoGebra, and Autograph, while they barely use smartphones and projectors in mathematics education. Chinese teachers mainly used Baidu (search engine) to browse websites focusing on specific subjects, download pictures and videos, and look for interactive programs focusing on specific content, while teachers from England mostly used Google for these purposes. Interestingly, Chinese teachers mostly used local communication platforms like WeChat to exchange teaching material. Findings from Xiang [6] also showed that Chinese teachers mostly use the technology mentioned above to explain mathematical knowledge, while the teachers from England use technology to demonstrate exercises and problem-solving steps. Teachers from both countries mostly used computers as presentation tools, particularly for explaining and justifying concepts (Chinese teachers) as well as for calculations and checking purposes (teachers from England).

2.2. Teacher Perceptions about the Integration of Educational Technology

Pajares [14] describes beliefs as personal guides that aid individuals in defining and understanding the world and themselves. Tezci [15] explains that teachers' perceptions of Computer-assisted Learning (CAL) can be cognitive, affective, and behavioural. For instance, a teacher's perception of educational technology as useful is referred to as a cognitive perception. Secondly, an example of an affective perception is when teachers like or dislike educational technology. Thirdly, teachers who had a positive experience with educational technology and recommended other teachers to integrate it into teaching are using a behavioural perception. However, educational technology researchers group beliefs mostly as teacher- and learner-centred [16]. The literature revealed that teacher perceptions and attitudes are important elements in determining whether teachers will use educational technology in their classroom and how they plan to implement it [16].

Various studies have been conducted to determine teachers' perceptions based on integrating educational technology [17–19]. Research has shown that it is mostly teachers with learner-centred (constructivist teaching styles) who are most likely to use educational technology in their teaching practices [20–22]. Farjon et al. [23] found that the attitudes and beliefs of pre-service teachers had the strongest influence on their actual use of educational technology, while access to educational technology was the weakest predictor. In fact, an earlier study by Moila [24] found that mathematics teachers from a rural school in South

Africa believed that the use of ICTs improves learner performances, motivates and encourages learners, and provides different teaching approaches which ensure that learners enjoy mathematics. Most recently, Bardakcı and Alkan [25] found that performance expectancy positively and significantly influenced Turkish pre-service teachers' behavioural intention to use the interactive whiteboard for teaching purposes. This finding is supported by Stols et al. [26], who found similar results using South African data. Researchers who used the Technology Acceptance Model (TAM) also found that "perceive usefulness" influences teachers' attitudes towards using educational technology, which in turn influences their intention to use it in teaching and learning [27,28].

3. Materials and Methods

This study followed a sequential exploratory mixed-method design. Mixed methods can be described as the "research approach in which quantitative and qualitative data or techniques are combined or mixed in a single study" [29] to understand the research problem more completely [30]. This study benefited from using mixed-method research because using more methods to collect data increased the study's credibility. However, conducting mixed-method research requires more analytical skills and is time-consuming [30]. To overcome these challenges, the study draws on the interdisciplinary skills of the researchers. During the sequential exploratory design, qualitative data collection was given priority to identify themes and address the first three research questions; thereafter, quantitative data was collected to address the last research question.

3.1. Participants

For the qualitative phase, multiple explanatory case studies were used to compare the differences and similarities between South Africa and Germany [31]. These countries were specifically selected to participate in this study because of their recent investments in educational technology. Furthermore, Germany is a first-world country, and a developing country such as South Africa can learn much from it. Purposeful sampling was employed to select two schools in each country with educational technology available in the mathematics classroom [32]. Thereafter, convenience sampling was applied to select schools that were geographically easily accessible [30]. We acknowledge the sample size is small, but this was due to the number of schools the South African researcher could arrange to visit during her time in Germany. Another reason for the small sample size is that very few mathematics teachers (at the time of the data collection process) had computers and/or tablets available during lessons in both countries. Another justification for the small sample size is that the project was small, and "6–10 participants are recommended for interviews" [33]. The principals of each school in both countries identified mathematics teachers with access to educational technology to use in mathematics. One principal, one deputy principal, and three Grade 5 mathematics teachers from South Africa, and one principal and three mathematics teachers from Germany participated in this study. It is worth mentioning that the German principal participated in this study in her capacity as the principal of the school and as a mathematics teacher. Consequently, 10 interviews were conducted.

For the quantitative phase, a secondary data analysis was conducted, drawing on data from principals, mathematics teachers, and learners who participated in TIMSS 2019. TIMSS 2019 used a two-stage stratified cluster sampling approach by firstly selecting schools based on their size and intact classes at the second stage [34]. The sampling frame of South Africa was stratified according to the province, school type, and SES of the school [35]. South Africa conducted the less difficult mathematics assessment (TIMSS-Numeracy) with their Grade 5 learners "to provide a better match with the demands of the assessments" [34]. In Germany, schools were stratified based on school type and SES [36]. Mathematics teachers and principals from 203 schools and 3437 Grade 4 learners from Germany participated in the study. On the other hand, mathematics teachers and principals from 297 schools and 11,891 learners from South Africa participated in the study [35].

3.2. Data Collection and Analysis

Semi-structured face-to-face interviews, which ranged between 30 and 50 min, were conducted with the mathematics teachers, principals, and deputy principals and were digitally recorded and transcribed. The background information about the participants in terms of nationality, geographical location, gender, teaching and/or managing experience, as well as the status of the school, are outlined in Table 1.

Table 1. Background information of the participants.

Participant	Country	Geographical Location	Gender	Teaching/Managing Experience	Status at School
SA_{P1}	South Africa	Gauteng province	Male	One year and five months	Mathematics teacher
SA_{P5}				Four years (managing)	Deputy Principal
SA_{P2}		Western Cape province	Female	Seven years	Mathematics teacher
SA_{P3}				Six years	
SA_{P4}			Male	Nine years (leadership), three months (acting principal)	Principal
DEU_{P1}	Germany	North Rhine-Westphalia	Female	Two years (managing) Twelve years (teaching)	Principal and mathematics teacher
DEU_{P2}				Eleven years	Mathematics teachers
DEU_{P3}			Male	Three years and six months	Mathematics teacher
DEU_{P4}				(DEU_{P4} was not interviewed, but rather, his classroom was observed)	Mathematics teacher

The South African schools were called $SA_{School\ 1}$ and $SA_{School\ 2}$. The schools in Germany were coded $DEU_{School\ 1}$ and $DEU_{School\ 2}$. For the South African schools, the male teacher from $SA_{School\ 1}$ was coded SA_{P1}, where P stands for "Participant", the female teachers from $SA_{School\ 2}$ were coded SA_{P2} and SA_{P3}, while the principals were coded $SA_{P4(SA\ School\ 1)}$ and $SA_{P5(SA\ School\ 2)}$. For the schools in Germany, the female teachers from $DEU_{School\ 1}$ were coded DEU_{P1} (she is also the principal of the school) and DEU_{P2}, while the male teachers were referred to as DEU_{P3} and DEU_{P4}. The latter participant from $DEU_{School\ 1}$ only agreed to classroom observation. Content analysis was employed, which included the coding and categorisation of data [37]. Additionally, three mathematics lessons (two in South Africa and one in Germany) were observed and recorded using an observation checklist.

For the quantitative phase, the school, mathematics teacher, and learner questionnaires—designed by various stakeholders—were used in this study. One of the measures taken to ensure validity was to "clearly defin[e] the target construct to be measured" [38]. TIMSS used a collaborative approach to develop 12 new assessment blocks for the 2019 administration while using 16 blocks from the previous cycle, TIMSS 2015 [39]. A matrix sampling approach was used for packaging the assessment pool into 14 achievement booklets, and a rotated-booklet design was used to assign one booklet to a learner [38]. Each learner received 45 min to complete a segment of the achievement items in the booklet [40]. Two-level multi-level models were built using Hierarchical Linear Modelling (HLM) software, as it considers the nested structure of the data [41]. The expectation-maximization (EM) procedure was applied to impute the missing data. Firstly, a null model with no predictors was conducted to explain the variance at each level. Next, a full model with all school and learner predictors was produced to determine the association between the use of educational technology and the learners' mathematics achievement. The full model is outlined as follows:

Level-1 Model

$$ASMMAT01_{ij} = \beta_{0j} + \beta_{1j} \times (ASBG01_{ij}) + \beta_{2j} \times (ASBG05A_{ij}) + \beta_{3j} \times (ASBG05D_{ij}) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01} \times (ATBG02_j) + \gamma_{02} \times (ATBM04CA_j) + \gamma_{03} \times (ATBM04CB_j) + \gamma_{04} \times (ATBM04CC_j)$$
$$+ \gamma_{05} \times (ATBM04CD_j) + \gamma_{06} \times (ATBM08_j) + \gamma_{07} \times (ACBG03A_j) + \gamma_{08} \times (ACBG13AF_j)$$
$$+ \gamma_{09} \times (ACBG13AH_j) + \gamma_{010} \times (ACBG13BB_j) + u_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$

where

- Score ij is the mathematics achievement score for learner i in school j,
- γ_{00} is the average mathematics score for all schools included in the sample,
- β_{1j} is the slope of gender for learner i in school j,
- β_{2j} is the slope of computer availability at home for learner i in school j,
- β_{3j} is the slope of internet availability at home for learner i in school j,
- γ_{01} is the slope of the teachers' gender,
- γ_{02} is the slope of the teachers' use of computers for activities to support learning for the whole class,
- γ_{03} is the slope of the teachers' use of computers for activities to support learning for low-performing learners,
- γ_{04} is the slope of the teachers' use of computers for activities to support learning for high-performing learners,
- γ_{05} is the slope of the teachers' use of computers for activities to support learning for learners with special needs,
- γ_{06} is the slope of the learners' use of computers or tablets to complete mathematics test,
- γ_{07} is the slope of the socioeconomic status of the school,
- γ_{08} is the slope of the schools' shortage or inadequacy of technologically competent staff,
- γ_{09} is the slope of the schools' shortage or inadequacy of computer technology for teaching and learning,
- γ_{10} is the slope of the schools' computer software/applications for mathematics instruction,
- u_{0j} is a unique error to the intercepts linked with school j, and
- r_{ij} is the residue for learner i in school j.

3.3. Quality Criteria

Transferability is the extent to which we can transfer the findings found in a specific context to another very similar context, and for the findings of the current study, we caution that researchers who wish to "transfer" the findings to a different context should be held responsible for making the judgment of how sensible the transfer is [42].

Credibility is concerned with the truth; more specifically, it is concerned with the congruence of the findings with reality [43]. The researcher returned the interview transcripts to the participants for member checking and comments. A native German transcriber also verified the German interview transcripts. To further enhance the credibility of the study, multiple sources (methodological triangulation), such as semi-structured interviews and non-participatory classroom observations, were employed.

Validity refers to the extent to which an instrument used in the data collection process measures what it is supposed to measure [44]. A Science and Mathematics Item Review Committee (SMIRC) (this team consists of seven mathematics and six science experts who guided TIMSS within the assessment development process), which was appointed by the IEA, scrutinised all instruments and ensured that they were of high quality (face validity) [38]. The SMIRC, together with policy analysts and mathematics experts, designed the items which were reviewed after the field test [40]. The comments of these experts were then used to finalise the instruments and ensure that the items used measured what they set out to measure [38].

Reliability refers to the consistency with which an instrument yields the desired results, meaning the instrument is consistent as well as repeatable [45]. The TIMSS instruments can be regarded as reliable since the assessment takes place every four years, which allows for comparisons over time [40]. Assessment reliability was ensured by designing a large pool of items which were included in the assessment booklets [39]. TIMSS 2019 used Cronbach's Alpha reliability coefficients to calculate the reliability of the assessment booklets and the items. The international median reliability was 0.97 for mathematics [39].

4. Results

4.1. Research Question 1: What Are the Similarities and Differences in How Teachers Use Educational Technology in Mathematics in South African and German Elementary Schools?

Findings show that mathematics teachers in South African and German schools used educational technology for various purposes, as shown in Figure 1. Teachers were asked how they use educational technology in mathematics instruction and many different responses were given. Therefore, differences in the use of educational tools ranged from "engagement tool" to "additional activities" (see Figure 1). For instance, South African teachers used educational technology as an online portfolio, while German teachers did not. The next section discusses the similarities in how these teachers used educational technology in mathematics.

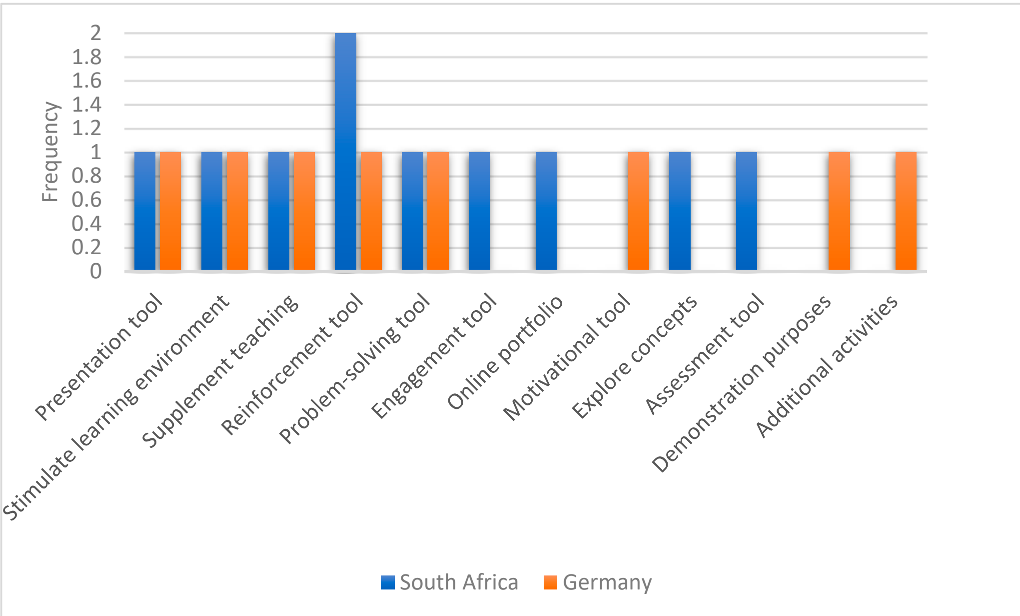

Figure 1. Similarities and differences in how South African and German teachers use educational technology in mathematics.

4.1.1. Similarities in How Teachers Use Educational Technology in Mathematics in South African and German Elementary Schools

At least one of the mathematics teachers from South Africa and Germany used educational technology in mathematics instruction as a presentation tool, to stimulate the learning environment, to supplement teaching, and as a reinforcement and problem-solving tool (see Figure 1). For instance, SA_{p1}, during classroom observations, used the smartboard as a presentation tool. He instructed individual learners to calculate the distance from Cape Town to Durban. The presence of the smartboard in the class created a stimulating learning environment, and almost all the learners were eager to perform calculations using the smartboard. SA_{p1} confidently adjusted the smartboard's settings to the learners' needs. SA_{p1} also used YouTube as a presentation and reinforcement tool. After that, he assisted learners in solving middle and higher-order problems with the support of the smartboard. SA_{p2} also used YouTube videos; however, she used the videos to supplement teaching because she felt that sometimes her learners might not understand her. She additionally used software called Quizzes to practise learners' skills in mathematics. Additionally, SA_{p3} explained that Green Shoots MCO, which is aligned with the Curriculum and Assessment Policy Statement of South Africa, was being used throughout the school to assist learners in solving low, middle, and higher-order problems. In Germany, for example, learners use certain programs to practise skills according to their ability (weak/strong learners). Furthermore, DEU_{p1} explained that she used computers as a presentation tool and to substitute her traditional teaching method. The next section discusses the differences found between the uses of educational technology in mathematics among these teachers.

4.1.2. Differences in How Teachers Use Educational Technology in Mathematics in South African and German Elementary Schools

Differences between the uses of educational technology were also found among the mathematics teachers of these countries, as shown in Figure 1. Mathematics teachers in South Africa used educational technology as an engagement tool, an online portfolio, to explore concepts, and as an assessment tool, while the teachers in Germany did not use it for these purposes. For example, SA_{p1} explained that he used videos to engage all learners. Furthermore, SA_{p2} explained that a YouTube video might perhaps provide a better explanation, which can improve the learners' understanding of a certain concept. During the classroom observation, SA_{p3} had her learners use the internet to explore concepts such as polygon shapes. Once these learners understood polygon shapes, they completed an assessment regarding polygon shapes on Green Shoots MCO. The latter was not just used for mathematics tasks but also used as an online portfolio. On the other hand, German mathematics teachers used educational technology for demonstration purposes, as a motivational tool, and to give learners additional activities, while South African mathematics teachers did not use it for these purposes. For instance, during observations, DEU_{p3} used Lego WeDo 2.0 programming software to demonstrate to the learners how a snail could be built. Only nine learners could use this software due to not having enough tablets. Furthermore, DEU_{p3} explained that he used computers as a motivational tool to provide additional activities to learners who completed their work for the day and used his phone to explain mathematics operations to the learners.

4.2. Research Question 2: What Are the Similarities and Differences Regarding the Barriers Influencing These Teachers' Integration of Educational Technology in Mathematics?

Findings from this study revealed various barriers hindering educational technology integration in South African and German primary schools (see Figure 2). It is worth mentioning that teachers were not asked to indicate barriers to integrating educational technology, but rather, the barriers formed a theme that emerged from the content analyses. More barriers to the use of educational technology in mathematics emerged from South African schools than from German schools. Consequently, a barrier such as "insufficient plugs", which is shown in Figure 2, indicates that it emerged from a South African school, but not from any of the German schools. The next section will discuss the similarities found regarding the barriers between the countries, followed by the differences.

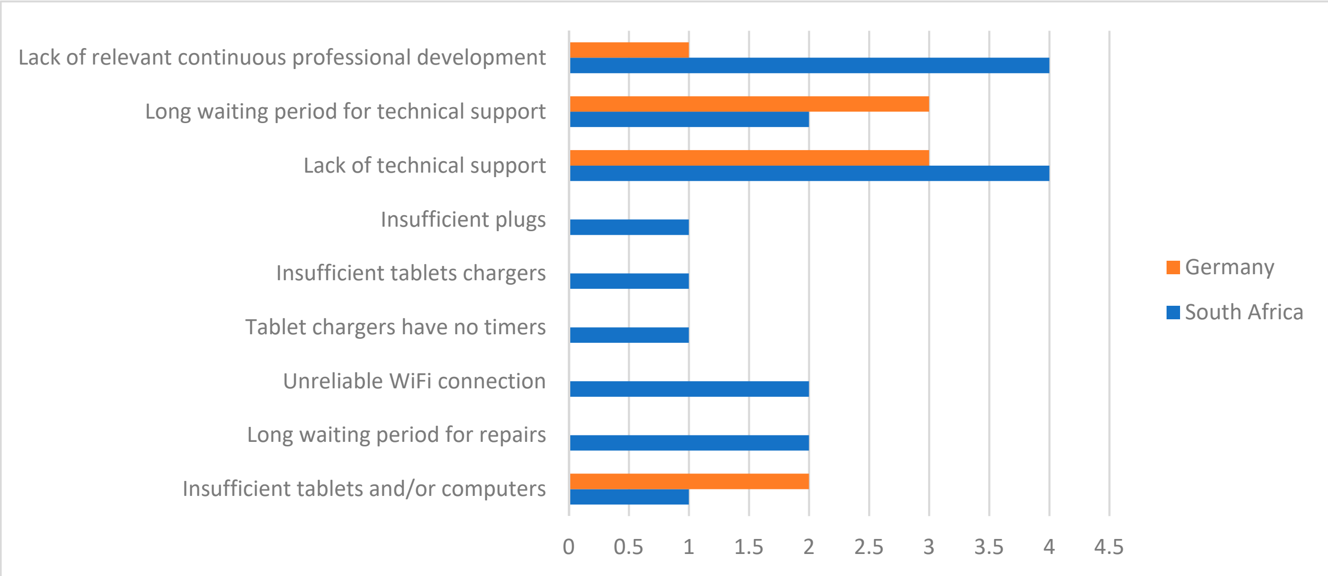

Figure 2. Barriers to the integration of educational technology in mathematics education in South African and German schools.

4.2.1. The Similarities Regarding the Barriers Influencing South African and German Teachers' Integration of Educational Technology in Mathematics

Both German and South African teachers and school principals indicated that they have insufficient tablets and/or computers. For instance, SA_{p1} could not use tablets in his class because only one grade had access to tablets (at the time the interview was conducted). SA_{p1} explained: "only the Grade 7 learners in the school can practise skills and procedures in mathematics using educational technology because they use tablets". In Germany, mathematics teachers highlighted the need for more educational technology at their schools. For instance, DEU_{p2} believed that it would be better to use educational technology in the classroom if every learner were equipped with a tablet and each classroom had at least one computer. However, DEU_{p1} explained that they do not have the finances to buy more technology because they "had a technical budget of 2000 to 3000 euro which was used for the WiFi". Additionally, DEU_{p2} explained that there is only one computer for teachers in the staffroom, and learners must share the computers in the computer room. DEU_{p3} explained that the school's educational technology is insufficient because he cannot always use the computer room, which is "kind of annoying" because the computer room is also used for other teaching projects. He stressed that "two computers in one classroom are not enough for 30 learners". He explained that a researcher from the university in the same town brought tablets for his learners to use during mathematics lessons, but "she is not coming anymore, so the learners do not use tablets anymore".

Another similar finding is that teachers from both countries highlighted the lack of technical support and long waiting periods for technical support. SA_{p1} explained: "So far we had problems with two interactive boards . . . they [Gauteng Department of Education] sent a technician, but he was clueless . . . he didn't know what he was doing, so at the end of the day, the problem was not solved". At $SA_{School\ 2}$, SA_{p2} and SA_{p3} explained that they had to wait a long time for laptops and tablets to return from repairs. SA_{p3} explained: "We are not experts in technology, and therefore when something happens, in my case, for example, the laptop crashed. I had to kind of cope without it for two months". In Germany, DEU_{p2} explained that they did not have any technicians at school and had to ask one of the teachers who was, according to the principal, technically competent to assist them when the technology failed. However, they had to wait until after school or during break time for him to attend to their needs because he could not leave his class unattended. Four participants also stressed that the teacher-technician and the learner-technician ratio were not favourable in the comments below:

- "We only have one person [IT intern], but he is responsible for admin only. I'm the one who responds to the (technical) problems whenever they arise" (SA_{p1}).
- "So, the IT support is not really efficient; at least there's someone ... it's a face. There is only one IT technician for 32 teachers, and three IT technicians for about 1000 learners. It would be really great to have more IT technicians to help support and to help run things" (SA_{p3}).
- "There is one technician in town for 50 schools, and if you phone him, he'll come in one or two weeks" (DEU_{p1}).
- "We have an external technician who comes if we have really big problems ... Sometimes he comes fast, sometimes we have to wait [and] other times we have to call him again because he forgets" (DEU_{p3}).

Correspondingly, four participants from South Africa and one from Germany explained that the lack of relevant and continuous professional development hindered their technology integration in mathematics instruction. For instance, SA_{p1} and DEU_{p3} explained that the workshops they attended had nothing to do with incorporating educational technology in mathematics and focused merely on mathematics content. SA_{p1} explained the desire for relevant continuous professional development in the next comment:

> "I need at least two workshops a month that are aligned with the Annual Teaching Plan [ATP] that can help me to cover the curriculum through the use of technology. I think the workshops will help me grow because right now, I'm using my own knowledge and experience. Let's say we are dealing with whole numbers; then the department [Education] must provide us with workshops [focusing on] how to best teach whole numbers in the classroom using certain software".

On the other hand, SA_{p3} explained that the professional development she attended at the Cape Teaching and Leadership Institute (CTLI) was relevant because she could apply the skills she learned in her classroom. However, she still urged for continuous professional development that would assist her in developing exercises using educational technology. SA_{p2} explained that she wanted to incorporate the programs she found online during her mathematics lessons. However, she could not use them due to her limited technical knowledge and skills. She (SA_{p2}) explained that there is no support, especially to advise teachers on which applications to use during mathematics, as shown in the next comment:

> "There's nobody that's coming to ask us, 'Listen, why do you not try this app?' We, as the teachers, must go and watch tutorials and stuff. There's nobody that's helping us. Some nights, I'm up the whole night just watching tutorials just to understand how a certain program works. We are busy; we must mark and do admin. We can't still go and watch tutorials all night ... all the time ... you know".

Furthermore, DEU_{p2} explained that she obtained basic skills at university and teacher training for using computers, but not specifically for their use in mathematics. Thus, she expresses the need for training on using the "whiteboard" [smartboard] in her mathematics classroom. She also explained that "it is not clear how to use a computer, or which software is suitable for teaching geometry".

4.2.2. The Differences Regarding the Barriers Influencing South African and German Teachers' Integration of Educational Technology in Mathematics

What was different is that more barriers to integrating educational technology in mathematics emerged in South Africa than in Germany. South African teachers reported additional barriers such as a lack of plugs, insufficient tablet chargers, lack of WiFi, and lack of tablet timers. Therefore, one cannot compare the differences because these barriers were absent in Germany but reported in South Africa. For instance, SA_{p3} described the WiFi connection as "terrible, completely dead, weak and moody". SA_{p3} could also not use her laptop during the classroom observation because it was returned after some repairs were completed the day before the interview, and all the programs she normally used for teaching were deleted. Consequently, she had to resort to chalk and a blackboard. She also mentioned that her learners had to share tablets because the tablets could not charge overnight and the cage where the tablets were charged could only take 30 tablets at a time. The lack of plugs to charge the tablets was a problem because she had 39 learners in her classroom and only 30 learners could complete the weekly exercise of polygon shapes on Green Shoots (MCO) on the day of the observation due to only 30 tablets being charged; the remaining nine learners had to share tablets with other learners.

4.3. Research Question 3: How Do These Teachers' Perceptions Concerning the Use of Educational Technology in Mathematics Compare?

Findings showed that mathematics teachers in South Africa and Germany have different perceptions regarding the integration of educational technology into mathematics.

Only SA_{p1} was of the view that educational technology improves his learners' performance "drastically" because it provides learners with extended opportunities to practise skills, which, in turn, enhances their understanding of mathematics. On the other hand, SA_{p2} doubted whether educational technology had the potential to improve learner performance because of distractions such as "pop-up videos". Another reason for her doubting the potential of educational technology was that she believes that her learners just guessed answers when they were assessed using their tablets. SA_{p2} explained: " ... with the technology during the online assessments, the learners like 'eenie meenie miney mo' [guess answers]". Correspondingly, DEU_{p1} explained that educational technology does not improve the mathematics performance of learners because: " ... in some areas of expertise, they have to do mathematics with their hands. The computer says right or wrong. Learners need to know why it's right or wrong". Similarly, SA_{p3} and DEU_{p3} believed that educational technology just motivated learners and changed their attitudes towards mathematics, as shown in the following comments:

- "They are more interested in working with maths because it's on a device and more willing to [do exercises] ... their attitudes change towards mathematics" (SA_{p3}).
- "The learners get motivated to work with stuff [educational technology]; sometimes they do not understand (mathematics), but they want to learn because it is on a smartphone" (DEU_{p3}).

Interestingly, DEU_{p1} believed that the more educational technology is used during mathematics lessons, the more the learners' motivation decreases. Consequently, if learners are not motivated to do mathematics, they will not perform well in the learning area.

These results show that only SA_{p1} used educational technology because of the potential benefits for teaching and learning. The rest of the participants did not believe that educational technology improved the results of their learners. Furthermore, SA_{p1}, SA_{p3}, and DEU_{p3} thought that educational technology encouraged learners to develop their problem-solving skills in mathematics, while SA_{p2}, DEU_{p1}, and DEU_{p2} disagreed. DEU_{p1} explained that: " ... the computer is not helpful when the children have to learn how to calculate in their head ... mental mathematics. But it can maybe help when they are doing automatising" (DEU_{p1}).

Additionally, SA_{p1} and SA_{p3} believed educational technology is important because it provides learners with images and models that aid concept formation. As SA_{p3} explained: "I think educational technology is quite vital in that sense because there are things that you have access to via the internet that you wouldn't have in your textbook". All South African teachers believed that using technology was more effective than using the traditional way of teaching. Interestingly, DEU_{p3} and DEU_{p2} felt that the traditional method of instruction was more effective than using technology in the classroom, as expressed in the following comments such as:

- "Mathematics is sometimes very complicated if a computer is used" (DEU_{p2}).
- "We need traditional [teaching] methods. Children need to go outside and explore the world, computers only motivate the learners, but it doesn't really help to understand mathematics, because mathematics is not just on your computer, it's all around you" (DEU_{p3}).

4.4. Research Question 4: How Does the Use of Educational Technology Correlate with the Mathematics Achievement of Learners When the Socioeconomic Status of the School Is Controlled for?

Firstly, a null model without any explanatory variables was created for each country using HLM 8.2. The purpose of the null model was to show the variance in mathematics achievement between the schools in South Africa and Germany (see Table 2). The variance of the null model at Level-2/school-level is 4595.67 and 1206.73 for South Africa and Germany, respectively, which represents 4595.67/(4595.67 + 5103.27) × 100 = 47.4% (South Africa) and 1206.73/(1206.73 + 3690.23) × 100 = 24.6% (Germany) of the total variance per country. Moreover, the variance at school-level for both countries is significantly different from zero (p-value < 0.001), indicating that the data is suitable for conducting analysis using multi-level models. The variance at Level-1/learner-level is 5103.27 and 3690.23 for South Africa and Germany, respectively, which represents 5103.27/(4595.67 + 5103.27) × 100 = 52.6% (South Africa) and 3690.23/(1206.73 + 3690.23) × 100 = 75.4% (Germany) of the total variance per country.

Secondly, the full model (for each country) containing school- and learner-level predictors was created to determine the association between the use of educational technology and the mathematics achievement of learners (see Table 3). Gender and SES were included in the model to control for; this is typically done in model building, as much research has shown that gender [46,47] and SES [48–50] are significantly associated with learner achievement, and our aim is to investigate educational technology use in a comparative study between South African and German schools (and not to investigate gender and SES associations with learner achievement); thus, there was a need to control for gender and SES. The variance at Level-2/school-level is 2978.82 and 550.83 for South Africa and Germany, respectively, which represents 2978.82/(2978.82 + 5029.82) × 100 = 37.2% (South Africa) and 550.83/(550.83 + 3523.93) × 100 = 13.5% (Germany) of the total variance per country. Subsequently, the variance at Level-1/learner-level is 5029.82 for South Africa and 3523.93 for Germany, respectively, which represents 5029.82/(2978.82 + 5029.82) = 62.8% (South Africa) and 3523.93/(550.83 + 3523.93) × 100 = 86.5 % (Germany) of the total variance per country. Furthermore, the results show significance at school-level (p < 0.001).

Table 2. Null model of South Africa and Germany.

	South Africa				Germany			
Level	**Standard Deviation**	**Variance Component**	**Chi-Square**	***p*-Value**	**Standard Deviation**	**Variance Component**	**Chi-Square**	***p*-Value**
Level-2	67.80	4595.67	12,055.50	<0.001 *	34.73	1206.73	1310.59	<0.001 *
Level-1	71.44	5103.27			60.74	3690.23		

* Significant at a 5% level of significance.

Table 3. Full model of South Africa and Germany.

	South Africa				Germany			
Level	**Standard Deviation**	**Variance Component**	**Chi-Square**	***p*-Value**	**Standard Deviation**	**Variance Component**	**Chi-Square**	***p*-Value**
Level-2	54.58	2978.82	8226.76	<0.001 *	23.46	550.83	805.81	<0.001 *
Level-1	70.92	5029.82			59.36	3523.93		

* Significant at a 5% level of significance.

Next, the results of the full model, which highlights the coefficients, standard errors, and significance levels, are illustrated (see Table 4). Only the statistically significant findings of each country will be discussed.

Table 4. The association between using educational technology at school- and learner-level and the mathematics achievement of learners.

	South Africa			Germany		
	Coefficient	**Standard Error**	***p*-Value**	**Coefficient**	**Standard Error**	***p*-Value**
School-level predictors (Level-2)						
Socioeconomic status of the school	27.72	11.23	0.014 *	22.78	3.69	<0.001 *
Mathematics teachers' gender	39.95	15.90	0.013 *	−3.28	8.95	0.715
The extent to which the mathematics teacher is doing activities on computers during mathematics lessons to support learning for the whole class	5.49	36.42	0.880	−11.23	5.23	0.033 *
The extent to which the mathematics teacher is doing activities on computers during mathematics lessons to support learning for low-performing learners	61.50	56.77	0.280	−0.64	11.74	0.957
The extent to which the mathematics teacher is doing activities on computers during mathematics lessons to support learning for high-performing learners	−22.99	47.46	0.628	4.57	5.67	0.422
The extent to which the mathematics teacher is doing activities on computers during mathematics lessons to support learning for learners with special needs	−46.10	57.23	0.421	−8.67	9.87	0.381
Learners' complete mathematics test on computers or tablets	−2.95	4.88	0.545	3.08	2.90	0.290
Shortage or inadequacy of technological competent staff	6.70	8.37	0.424	7.67	2.98	0.011 *
Shortage or inadequacy of computer technology for teaching and learning	9.15	6.96	0.189	−4.58	3.39	0.178

Table 4. *Cont.*

	South Africa			Germany		
	Coefficient	**Standard Error**	***p*-Value**	**Coefficient**	**Standard Error**	***p*-Value**
Computer software/applications for mathematics instruction	8.85	6.33	0.163	1.29	3.46	0.711
Learner-level predictors (Level-1)						
The learners' gender	16.93	2.26	<0.001 *	−13.09	2.64	<0.001 *
Availability of a computer/tablet at home	−2.07	2.46	0.399	38.28	5.27	<0.001 *
Availability of an internet connection at home	−1.35	2.65	0.617	21.76	4.89	<0.001 *

* Significant at a 5% level of significance.

4.4.1. School-Level Predictors

Learners taught by teachers from Germany who reported that they do activities "every or almost every day" on computers during mathematics lessons to support learning for the whole class were outperformed [with 11.23 points on average for mathematics] by their counterparts who were taught by teachers who "never or almost never" use computers during mathematic lessons to support learning for the whole class. This predictor was not significant in South Africa.

Furthermore, learners from Germany achieved higher mathematics scores (on average 7.67 points) than their peers where the school's capacity to provide instruction was "a little or not at all" affected by a shortage or inadequacy of technologically competent staff.

4.4.2. Learner-Level Predictors

Findings also showed that learners from Germany who had a computer at home, as well as those with an internet connection available at home, outperformed learners without a computer and an internet connection at home on average, with 38.28 and 21.76 points in mathematics, respectively. These predictors had no influence on the mathematics achievement of South African learners.

5. Discussions and Conclusions

This study firstly compared the use of educational technology in mathematics education in South African and German primary schools. The teachers' and principals' perceptions of educational technology and the barriers hindering the integration of educational technology were also compared. Thereafter, multi-level models were used to determine whether there is an association between the use of educational technology and learner achievement in mathematics in these countries.

The findings showed more differences than similarities between South African and German teachers regarding their use of educational technology in mathematics education. For instance, findings show that teachers from both countries use educational technology as a presentation-, reinforcement-, supplement teaching, and problem-solving tool as well as to stimulate the learning environment. Some South African teachers used educational technology as an engagement and assessment tool, an online portfolio, and to explore concepts. On the other hand, some teachers in Germany reported using educational technology as a motivational tool, to do additional activities, and for demonstration purposes. A supporting finding emerged from Xiang [6], who found that teachers in China use technology to explain mathematical knowledge to learners and teachers from England use technology for demonstration purposes and as a problem-solving tool. The latter author further found that the teachers from China and England used educational technology, such as computers, as presentation tools to explain and justify concepts. A contrasting finding was observed in Turkey, where Birgin et al. [12] found that teachers mostly used educational technology as a communication tool rather than an instructional tool. Similarly, Umugiraneza [13] found that mathematics teachers in South Africa (KwaZulu-Natal province) mostly used computers for administration rather than for instructional purposes.

In line with previous studies, this study found that barriers, such as the lack of educational technology [39–42], lack of support for integrating educational technology [39], and lack of continuous professional development [42] hindered the mathematics teachers' actual use of educational technology in mathematics. For instance, findings revealed that teachers from both countries could not successfully use educational technology due to the inadequacy of computers and/or tablets, lack of technical support, long waiting periods for technical support, and lack of continuous professional development. Similar to previous research [46–48], all the participants explained that the lack of support, in particular, technical support, hindered the use of educational technology in mathematics instruction. None of the German participants mentioned internet connection as a barrier to the integration of educational technology. This could be because the country is a first-world country, or because schools could receive budgets for WiFi connection (as one of the participants mentioned). However, findings revealed a different picture in South Africa. All the South African participants mentioned that their schools require a reliable WiFi connection. In line with previous studies [48], this study found that the current professional development was perceived as irrelevant. Teachers from both countries expressed the need for continuous professional development focusing on using educational technology specifically for mathematics, since the professional development that they attended focused on mathematics content instead of how to teach the content with the use of technology. The literature links the lack of skills and knowledge to a lack of continuous professional development [51,52]. Previous studies also showed that teachers could not use technology effectively in mathematics instruction due to insufficient technology knowledge and skills [53].

As expected, teachers from both countries had different perceptions regarding the use of educational technology. However, two interesting perceptions will be highlighted in this section. Previous studies found that the perception of usefulness influenced teachers' attitudes towards using educational technology for teaching and learning [27,28]. Surprisingly, only one participant was of the view that educational technology improves learner performance. All the remaining mathematics teachers were not of the opinion that using educational technology could improve the mathematics scores of learners. Most German teachers were of the opinion that the traditional way of teaching mathematics is more effective than using computers. On the other hand, most South African teachers believed that educational technology is important since they could access content that was not available in the textbook.

Furthermore, differences and similarities were also observed regarding the association between the use of educational technology and learner achievement. More statistically significant relationships were observed in Germany than in South Africa.

Findings also showed that the frequent (every or almost every day) use of computers for the whole class negatively influenced the mathematics achievement of German learners. This finding supports that of Namome and Moodley [10], who found that mathematics teachers in Africa who participated in TIMSS 2015 had the opinion that the use of computers for the whole class negatively influenced learner achievement scores. A possible reason for lower achievement scores in mathematics could be that the learners who are using computers frequently in mathematics rely too much on the computer to perform calculations, and when it is time for assessment, they are not able to perform similar calculations without the assistance of a computer. Another explanation could be that the learners need individualised lessons on the computer, which could explain the lower scores when the teacher uses computers to teach the whole class. This predictor did not influence the mathematics scores of South African learners. This could be because very few mathematics teachers in South Africa have access to computers, or are not optimally integrating computers in teaching and learning [54]. In Germany, a positive relationship was also observed when learners who attended schools that were "a little or not at all" disrupted by shortages of technically competent staff achieved higher mathematics scores. Teachers who use educational technology in their classes might experience technical issues at some point, which is beyond their control. In some instances, learning is interrupted for long periods if the school does not have technically competent staff readily available to assist teachers. In the case of Germany, learning could have continued due to readily available technical staff. Again, this predictor did not influence the results of South African learners.

The literature on learners' access to educational technology at home shows mixed results. For instance, the findings from Geesa et al. [55] showed negative relationships when learners from South Korea and Turkey owned a computer at home. On the other hand, and in support of the results of Geesa et al. [55], Kim [21] found that access to ICT correlated positively with immigrant learner achievement in the United States. We found that German learners scored higher marks in mathematics when they had a computer at home. These learners might have used the computer under the supervision of their parents. Furthermore, evidence shows that an internet connection positively correlates with learners' mathematics performance [55–57]. Similarly, German learners scored higher marks in mathematics when they had a computer and an internet connection at home. A justification for this result is that these learners with a computer, as well as those with an internet connection, could search for additional activities and/or tutorials which might have expanded their mathematical knowledge. The use of a computer and an internet connection at home had no influence on the mathematics scores of South African learners. This could be because few learners in South Africa have access to educational technology, especially those in economically disadvantaged areas [36].

The qualitative phase of this study was limited to two primary schools in South Africa and Germany, with educational technology available during mathematics lessons. We also acknowledge that the sample size is small, but this was due to the limited number of schools (using educational technology in mathematics) in South Africa and Germany and the researchers' limited time in Germany. The quantitative phase of this study was based on secondary cross-sectional data from TIMSS 2019. Consequently, this study could not determine cause-and-effect impacts. Future researchers could use an experimental research design to determine cause-and-effect impacts of educational technology on learner achievement. Future studies could also include more schools in different regions of these countries to investigate the integration of educational technology in mathematics.

This study contributes to the literature on integrating educational technology into mathematics education. Findings derived from the study suggest that policymakers must provide teachers with continuous professional development on technology integration in mathematics education. Moreover, training sessions need to be personalised according to the teachers' knowledge and skills and the school's needs in terms of digital infrastructure. Furthermore, policymakers need to ensure that teachers receive continuous, adequate onsite technical support at school. This recommendation is based on the findings of this study and is also supported by the recent literature showing a lack of technical support in both countries; see, for example, ref. [58] for Germany and [59] for South Africa. Due to unfavourable experiences, such as technical breakdowns and lengthy wait times for technical assistance, it is vital that both nations have access to technical support. In addition, it is crucial for policymakers in both nations to ensure that there are sufficient technical personnel at schools to shorten the waiting time for teachers. This could lead to more favourable experiences with educational technology, which could enhance the usage of these tools in mathematics instruction.

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References

1. Mullis, I.V.S.; Martin, M.O.; Foy, P.; Kelly, D.L.; Fishbein, B. TIMSS 2019 International Results in Mathematics and Science; International Association for the Evaluation of Educational Achievement. 2020. Available online: https://timssandpirls.bc.edu/timss2019/international-results/ (accessed on 24 September 2021).
2. Gigaba, M. Budget Speech. 2018. Available online: www.treasury.gov.za (accessed on 16 June 2019).
3. Scholz, O. Draft 2019 Budget and Financial Plan to 2022: Forward-Looking, Fair and Responsible. 2018. Available online: https://www.bundesfinanzministerium.de/Content/EN/Pressemitteilungen/2018/2018-07-27-2019-budget.html (accessed on 11 May 2019).
4. Levin, T.; Wadmany, R. Changes in educational beliefs and classroom practices of teachers and students in rich technology-based classrooms. *Technol. Pedagog. Educ.* **2008**, *14*, 281–307. [CrossRef]
5. Jones, A. *A Review of the Research Literature on Barriers to the Uptake of ICT by Teachers*; British Educational Communications and Technology Agency: Coventry, UK, 2004. Available online: https://dera.ioe.ac.uk//id/eprint/1603 (accessed on 1 April 2022).
6. Xiang, K. An Investigation and Comparison on Chinese and English Teachers' Use of Technology in Teaching Mathematics. Ph.D. Thesis, University of Southampton, Southampton, UK, 2018. Available online: https://www.semanticscholar.org/paper/An-investigation-and-comparison-on-Chinese-and-use-Xiang/7294c5f298089b0bb81976c58830b011957adea2 (accessed on 1 November 2022).
7. McCulloch, A.W.; Hollebrands, K.; Lee, H.; Harrison, T.; Mutlu, A. Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Comput. Educ.* **2018**, *123*, 26–40. [CrossRef]
8. OECD. *PISA 2015 Results (Volume I): Excellence and Equity in Education*; OECD Publishing: Paris, France, 2016; p. 1. Available online: https://read.oecd-ilibrary.org/education/pisa-2015-results-volume-i_9789264266490-en (accessed on 1 November 2022).
9. Shute, V.J.; Rahimi, S. Review of computer-based assessment for learning in elementary and secondary education. *J. Comput. Assist. Learn.* **2017**, *33*, 1–19. [CrossRef]
10. Namome, C.; Moodley, M. ICT in mathematics education: An HLM analysis of achievement, access to and use of ICT by African Middle School Students. *SN Soc. Sci.* **2021**, *1*, 1–21. [CrossRef]
11. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User acceptance of information technology: Toward a unified view. *MIS Q.* **2003**, *27*, 425–478. [CrossRef]
12. Birgin, O.; Uzun, K.; Akar, S.G.M. Investigation of Turkish mathematics teachers' proficiency perceptions in using information and communication technologies in teaching. *Educ. Inf. Technol.* **2019**, *25*, 487–507. [CrossRef]
13. Umugiraneza, O.; Bansilal, S.; North, D. Exploring teachers' use of technology in teaching and learning mathematics in KwaZulu-Natal schools. *Pythagoras* **2018**, *39*, 342. [CrossRef]
14. Pajares, M.F. Teachers' beliefs and educational research: Cleaning up a messy construct. *Rev. Educ. Res.* **1992**, *62*, 307–332. [CrossRef]
15. Tezci, E. Factors that influence pre-service teachers' ICT usage in education. *Eur. J. Teach. Educ.* **2011**, *34*, 483–499. [CrossRef]
16. Admiraal, W.; Louws, M.; Lockhorst, D.; Paas, T.; Buynsters, M.; Cviko, A.; van der Ven, F. Teachers in school-based technology innovations: A typology of their beliefs on teaching and technology. *Comput. Educ.* **2017**, *114*, 57–68. [CrossRef]
17. Bas, G.; Kubiatko, M.; Murat, A. Teachers' perceptions towards ICTs in teaching-learning process: Scale validity and reliability study. *Comput. Hum. Behav.* **2016**, *61*, 176–185. [CrossRef]
18. Khlaif, Z. Teachers' perceptions of factors affecting their adoption and acceptance of mobile technology in K-12 settings. *Comput. Sch.* **2018**, *35*, 49–67. [CrossRef]
19. Pierce, R.; Ball, L. Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. *Educ. Stud. Math.* **2009**, *71*, 299–317. [CrossRef]
20. Hermans, R.; Tondeur, J.; van Braak, J.; Valcke, M. The impact of primary school teachers' educational beliefs on the classroom use of computers. *Comput. Educ.* **2008**, *51*, 1499–1509. [CrossRef]

21. Kim, C.; Kim, M.K.; Lee, C.; Spector, J.M.; DeMeester, K. Teacher beliefs and technology integration. *Teach. Teach. Educ.* **2013**, *29*, 76–85. [CrossRef]
22. Tondeur, J.; Van Braak, J.; Ertmer, P.A.; Ottenbreit-Leftwich, A. Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educ. Technol. Res. Dev.* **2017**, *65*, 555–575. [CrossRef]
23. Farjon, D.; Smits, A.; Voogt, J.; Knezek, G.; Christensen, R.; Petko, D.; van Braak, J. Factors affecting pre- and in-service use of technology in teaching: Implications for research and practice—Part 1. In Proceedings of the EdMedia: World Conference on Educational Media and Technology, Amsterdam, The Netherlands, 25 June 2018; pp. 604–607.
24. Moila, M.M. The Use of Educational Technology in Mathematics Teaching and Learning: An Investigation of a South African Rural Secondary School. Masters' Thesis, University of Pretoria, Pretoria, South Africa, 2006. Available online: https://repository.up.ac.za/bitstream/handle/2263/23899/dissertation.pdf?sequence=1 (accessed on 14 November 2022).
25. Bardakcı, S.; Alkan, M.F. Investigation of Turkish preservice teachers' intentions to use IWB in terms of technological and pedagogical aspects. *Educ. Inf. Technol.* **2019**, *24*, 2887–2907. [CrossRef]
26. Stols, G.; Ferreira, a.; Pelser, A.; Olivier, W.; Van der Merwe, A.; De Villiers, C.; Venter, S. Perceptions and needs of South African Mathematics teachers concerning their use of technology for instruction. *S. Afr. J. Educ.* **2015**, *35*, 1–13. Available online: https://www.ajol.info/index.php/saje/article/view/127070 (accessed on 17 January 2023). [CrossRef]
27. Akar, S.G.M. Does it matter being innovative: Teachers' technology acceptance. *Educ. Inf. Technol.* **2019**, *24*, 3415–3432. [CrossRef]
28. van Deursen, A.J.; Ben Allouch, S.; Ruijter, L.P. Tablet use in primary education: Adoption hurdles and attitude determinants. *Educ. Inf. Technol.* **2016**, *21*, 971–990. [CrossRef]
29. Christensen, L.; Johnson, R.; Turner, L. *Research Methods, Design, and Analysis (12. Baskı)*; Pearson Education Limited: London, UK, 2014.
30. Creswell, J.W.; Clark, V.L.P. *Designing and Conducting Mixed Methods Research*; SAGE: Thousand Oaks, CA, USA, 2011.
31. Yin, R. *Case Study Research: Design and Methods*; Sage: Thousand Oaks, CA, USA, 1994.
32. Luciani, M.; Campbell, K.; Tschirhart, H.; Ausili, D.; Jack, S.M. How to design a qualitative health research study. Part 1: Design and purposeful sampling considerations. *Prof. Inferm.* **2019**, *72*, 152–161.
33. Clarke, V.; Braun, V. *Successful Qualitative Research: A Practical Guide for Beginners*; Sage: Thousand Oaks, CA, USA, 2013; pp. 1–400.
34. LaRoche, S.; Foy, P. Sample Implementation in TIMSS 2019. International Association for the Evaluation of Educational Achievement. 2020. Available online: https://timssandpirls.bc.edu/timss2019/methods/chapter-9.html (accessed on 22 September 2022).
35. Reddy, V.; Winnaar, L.; Juan, A.; Arends, F.; Harvey, J.; Hannan, S.; Namome, C.; Sekhejane, P.; Zulu, N. *TIMSS 2019: Highlights of South African Grade 9 Results in Mathematics and Science*; Achievement and Achievement Gaps; Department of Basic Education: Pretoria, South Africa, 2020. Available online: https://www.timss-sa.org/publication/timss-2019-highlights-of-south-african-grade-9-results-in-mathematics-and-science (accessed on 23 September 2022).
36. LaRoche, S.; Joncas, M.; Foy, P. *Sample Design in TIMSS 2019*; International Association for the Evaluation of Educational Achievement: Paris, France, 2020. Available online: https://timssandpirls.bc.edu/timss2019/methods/chapter-3.html (accessed on 12 September 2022).
37. Hsieh, H.-F.; Shannon, S.E. Three approaches to qualitative content analysis. *Qual. Health Res.* **2005**, *15*, 1277–1288. [CrossRef]
38. Cotter, K.E.; Centurino, V.A.; Mullis, I.V. *Developing the TIMSS 2019 Mathematics and Science Achievement Instruments*; International Association for the Evaluation of Educational Achievement: Paris, France, 2019.Available online: https://timssandpirls.bc.edu/timss2019/methods/chapter-1.html (accessed on 23 September 2022).
39. Martin, M.O.; von Davier, M.; Mullis, I.V. *Methods and Procedures: TIMSS 2019 Technical Report*; International Association for the Evaluation of Educational Achievement: Paris, France, 2019. Available online: https://timssandpirls.bc.edu/timss2019/methods (accessed on 23 September 2022).
40. Johansone, I. *Survey Operations Procedures for TIMSS 2019*; International Association for the Evaluation of Educational Achievement: Paris, France, 2019. Available online: https://timssandpirls.bc.edu/timss2019/methods/chapter-6.html (accessed on 23 September 2022).
41. Raudenbush, S.; Bryk, A.; Congdon, R. *HLM 7.01 for Windows [Hierarchical Linear and Nonlinear Modeling Software]*; Multivariate Software: Los Angeles, CA, USA, 2013.
42. Korstjens, I.; Moser, A. Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *Eur. J. Gen. Pract.* **2018**, *24*, 120–124. [CrossRef]
43. Shenton, A.K. Strategies for ensuring trustworthiness in qualitative research projects. *Educ. Inf.* **2004**, *22*, 63–75. [CrossRef]
44. Maree, K. *First Steps in Research*, 3rd ed.; Van schaik: Pretoria, South Africa, 2019.
45. Paul, D.; Leedy, O.J.E. *Practical Research: Planning and Design*; Pearson Educational International: Upper Saddle River, NJ, USA, 2010.
46. Moon, C.Y.; Larke, P.J.; James, M.C. Examining Mathematics Achievement: An Analysis of Fourth and Eighth Grade TIMSS US Data by Ethnicity, Gender, and Sociocultural Variables. *J. Ethn. Cult. Stud.* **2022**, *9*, 226–243. [CrossRef] [PubMed]
47. Muttaqin, S.; Chuang, H.-H. Variables affecting English-medium instruction students' achievement: Results of a multiple regression analysis. *Int. J. Educ. Res. Open* **2022**, *3*, 100–152. [CrossRef]
48. Abenawe, C. Social Economic Status in Selected Secondary Schools in Ibanda District Uganda. *IAA J. Educ.* **2022**, *8*, 73–89.

49. Amel, B. Cyber Bullying and its Relationship to Academic Success According to a Sample of High School Students During the Corona Pandemic (COVID-19). *J. Hum. Sci.* **2022**, *9*, 451–475.
50. Guo, H.; Yuan, W.; Fung, C.V.; Chen, F.; Li, Y. The relationship between extracurricular music activity participation and music and Chinese language academic achievements of primary school students in China. *Psychol. Music* **2022**, *50*, 742–755. [CrossRef]
51. Şahin, M.G.; Öztürk, N.B. How Classroom Assessment Affects Science and Mathematics Achievement? Findings from TIMSS 2015. *Int. Electron. J. Elem. Educ.* **2018**, *10*, 559–569. [CrossRef]
52. Wachira, P.; Keengwe, J. Technology integration barriers: Urban school mathematics teachers perspectives. *J. Sci. Educ. Technol.* **2011**, *20*, 17–25. [CrossRef]
53. Şahin, H.; Göçer, G. Investigation of the Primary School Teachers' Computer Usage Self-Efficacy. *Ahi Evran Üniv. Kırşehir Eğit. Fak. Derg.* **2013**, *14*, 131–146.
54. Graham, M.A.; Stols, G.; Kapp, R. Teacher Practice and Integration of ICT: Why Are or Aren't South African Teachers Using ICTs in Their Classrooms. *Int. J. Instr.* **2020**, *13*, 749–766. [CrossRef]
55. Geesa, R.L.; Izci, B.; Song, H.; Chen, S. Exploring factors of home resources and attitudes towards mathematics in mathematics achievement in South Korea, Turkey, and the United States. *EURASIA J. Math. Sci. Technol. Educ.* **2019**, *15*, 9. [CrossRef]
56. Saal, P.E.; van Ryneveld, L.; Graham, M.A. The Relationship between Using Information and Communication Technology in Education and the Mathematics Achievement of Students. *Int. J. Instr.* **2019**, *12*, 405–424. [CrossRef]
57. Kruger, G.M. The Relationship between Investment in ICT and Mathematics Achievement. Ph.D. Thesis, University of Pretoria, Pretoria, South Africa, 2018. Available online: https://repository.up.ac.za/bitstream/handle/2263/67752/Kruger_Relationship_2018.pdf?sequence=1&isAllowed=y (accessed on 11 September 2022).
58. Becker, D. On the Use of Commercial Video Games in the EFL Classroom in North Rhine-Westphalia—An Empirical Perspective. *Anglistik* **2022**, *33*, 59–79. [CrossRef]
59. Kimanzi, M. Integration of ICT in teaching and learning of economics and management sciences: Student teachers' perspectives in South Africa. In *Social Sciences International Research Conference*; Van der Merwe, Surujlal, H.J., Van den Berg, L., Eds.; North West University: Potchefstroom, South Africa, 2021; pp. 592–604.